ent in all (or nearly all) classes in quantitative analysis and there is nothing to be gained by closing our eyes to this fact. We have only to consider how we may minimize these practices, so destructive to all scientific ideals, in the most effective way. In this connection I should like to mention one thing which we should not do and this is to preach to the students about it. No one ever pays much attention to preaching, in church or out of it. We have, it is true, certain reports of sinners brought to repentance by the fiery eloquence of the preaching evangelist but this is mostly an appeal through the emotions and, while some few may possibly yield permanently to this appeal, unfortunately too many others relapse into former chicken-stealing habits the night after the meeting closes. No one pays any attention to preaching except to indulge in the pious hope that this or that acquaintance may profit by it. As teachers we may solemnly warn our students that if they once begin the use of beauty-shop methods for preparing reports they will never be able to do honest, accurate work after graduation (which is absolutely true) but, at the time we are saying this, each student, instead of experiencing any remorse for his own possible infraction of the rules, is feeling in his heart that several others whom he could mention would do well to take home the advice and to profit by it. I have tried this sort of procedure on occasion, and I have no reason for believing that it ever did any good whatever. The real truth is (and our reformers, preachers and teachers of every description would do well to consider this) that one's conscience can be made to approve anything whatsoever that one desires very much to do.

Falsification of analytical records is encouraged chiefly in three ways. These are:

(1) By assigning for analysis materials the composition of which is obvious to the student, so that if pressed for time or if accident has ruined a determination he is too strongly tempted to report data that were not obtained experimentally but calculated from known values. This is the case when pure salts, rather than mixtures or commercial products, are employed for student analyses.

(2) By requiring impossible accuracy in the results of students' analyses. Rather, we should carefully explain at the outset that skill is to be attained only by long and careful practice, that a kind of work that is worthy of the best efforts of men and women of college age and serious purpose can not be done with the highest degree of accuracy when one is trying for the first time and that, while we do not tolerate careless, slip-shod work, neither do we expect from a novice analytical work of a character worthy of an expert. This is a policy of simple fair play with the students.

(3) By creating an attitude of hostility on the part of the student. This applies to all teaching. We well know that even our best students are not likely to do good or honest work in any class in which the teacher is disliked or considered unfair or oppressive in his methods or requirements. Any instructor who assumes an attitude of frowning aloofness—of a taskmaster who is intent only upon getting work done—will very likely be unable to keep in his students the state of mind which is a prerequisite for work of character. On the other hand, if they understand that he desires to be sympathetically helpful, using his experience and more extensive knowledge in assisting his students to a better perception of the possibilities of good work, I am convinced that he has thereby taken a most important step in the direction of reducing the cheating nuisance to a minimum.

In conclusion, let me restate my conviction that the study of quantitative analysis, pursued under proper guidance and in correct atmosphere, may be made of the greatest possible value in the acquisition of an appreciation of chemistry as a quantitative science and of all science as the study of rigid, quantitative principles of nature. And surely it can not be doubted that if all serious minded people could catch something of this sort of appreciation, our progress toward a more orderly, and therefore a more happy, state of civilization would be very much accelerated.

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THE YIELD OF WHEAT IN ENGLAND DURING SEVEN CENTURIES

POLITICAL economists agree that the inclosure of open-field farms in the sixteenth and seventeenth centuries was one of the most important economic events of England. It is said that over a thousand books and essays have been written on this subject in an attempt to reach an understanding of the causes which led up to the medieval system of villages and of communal open farms and the principles that underlay the breaking up of the open fields into inclosed fields where individual effort was possible. Quite recently four very interesting articles have appeared on this subject.[1]

[1] V. G. Simkhovitch, "Hay and history," *Political Science Quarterly*, September, 1913; Harriet Bradley, "The enclosures in England: and economic reconstruction," Columbia Studies in History, Economics and Public Law, Vol. LXXX, No. 2, 1918: Lord Ernle, "The enclosure of open field farms," *Journal* of the Ministry of Agriculture of Great Britain, December, 1920, and January, 1921; Reginald Lennard, "The alleged exhaustion of the soil in medieval England," *The Economic Journal*, March, 1922.

In the discussion there is a considerable amount of information bearing upon the subject of soil exhaustion which probably has not come very generally to the attention of our soil scientists because of the character of the journals in which the papers have appeared. Simkhovitch ascribes the principal reason for the change from the open field to the inclosed field system to the deterioration of the soils and ascribes the change and the subsequent improvement of agriculture to the introduction of hay grasses, of the clovers and of alfalfa. He says:

> The introduction of grass seed and clovers marked the end of the Dark Ages of Agriculture. It is the greatest of revolutions, the revolution against the supreme law, the law of the land, the law of diminishing returns and of soil exhaustion.

Miss Bradley appears to agree that the exhaustion of the soil below profitable returns was the cause of the revolution. She does not place much credence on the statements made by other writers that the Black Death was the principal cause nor that it was due to the increased price of wool and to the cupidity of farmers who insisted that the raising of sheep, which was incompatible with open-field agriculture, was the principal cause, nor does she think it was due primarily to the growth of industries.

Lord Ernle in his first paper gives a very interesting account of the general methods of medieval agriculture, of the open-field system, and the historical development of the inclosure of open-field farms. In his second paper he expresses a very decided opinion that soil exhaustion was the main cause of the inclosures. He accepts a statement supposed to have been made by Walter of Henley that in the thirteenth century a yield of 10 bushels per acre of wheat could be expected and then shows by numerous records of yields obtained from the old manuscripts that the yields of wheat in the fourteenth century were around six and a half to seven and a half bushels per acre. He accepts this as conclusive evidence of the exhaustion of soils in the one hundred-year period, due to the loss of plant food from soils which were insufficiently fertilized. He says:

> It was not till the period 1485 to 1560 that the inclosing movement, long in progress, reached a height which alarmed the country. . . . tempted by the high prices of wool, so ran the charge, the land owners, and especially the new ones, evicted the open field farmers from the arable land, meadows and common pastures of the village farms and turned the whole into sheep walks. . . . The evidence collected by the commissions of the sixteenth and seventeenth centuries goes to show that inclosures of whole townships were rare. The period coincides with the breaking up of feudal households, the dissolution of the monasteries, and industrial reconstruction. . . . Between 1577 and 1689 most of the changes which have revolutionized British farming in the nineteenth century were discussed and foreshadowed in agricultural literature. We have, for example, the field cultivation of rape, of trefoil or Burgundian grass and of turnips suggested in 1577. Lucerne followed early in the next century and potatoes in 1664.

In addition, he has to say:

> With arable lands of open fields subject to common rights while fallow, or from corn harvest to seed time, it was impossible to introduce new crops. Rotations were limited and fixed by immemorial usage. No individual could use hand or foot to effect improvements without the unanimous agreement of the whole body of joint occupiers. If one man sowed turnips it would be the live stock of the community that would profit. Better stock breeding was impossible when all the grazing was in common. The difficulties of drainage were enormously increased by the necessity of securing cooperation. . . . What was wanted was a lead, and in the eighteenth century it was given by the land owners. They initiated experiments; and poured their money into the land. Farms were at great cost adapted to modern methods by new buildings, roads, fences and drainage. Much of the land was literally made during the period. A wave of agricultural enthusiasm rose with each decade of the period until at last it swept over the country. The introduction of roots, clover and artificial grasses solved the problem of winter keep. It enabled farmers to carry a larger head of stock; more stock yielded more manure; more manure raised larger crops; larger crops supported larger flocks and herds; which were both better bred and better fed. . . . Inclosure was no longer a question only of social or agricultural advantage; it had become one of economic necessity. The pressure steadily increased in severity. It culminated during the Napoleonic Wars when every pound of food became of national value. At the declaration of peace in 1815 the old system of common cultivation had practically disappeared and the newer system of individual occupation was almost universally installed in its place.

Lennard takes exception to Lord Ernle's view of the exhaustion of soils. He calls attention to the fact that it was not Walter of Henley who made the statement accepted by Lord Ernle that the yield of wheat in England during the thirteenth century was 10 bushels per acre, but that the statement was made in an anonymous paper evidently published about the same time and that the statement evidently referred to what should be and not as to what was. He then gives the yields from 45 estates in the thirteenth century and from 35 estates in the fourteenth century. He admits some doubt as to the statistical correctness of the yields given, as it appears uncertain whether the acreage used was of the year before or of the year of the harvest, that is, the seeded acreage for the following crop. He also says that there is doubt as to whether the yields were reported before or after the tithe was extracted. He thinks the probabilities are that the measure is the measure that came to the farmer and therefore the tenth part that was given

for tithe was not included. Making allowance for the tithe, he estimates the yield in the thirteenth century at six and a fourth to six and a half bushels per acre and for the fourteenth century at seven and a half to seven and three fourths bushels per acre.

He then asks the pertinent question that if, according to Lord Ernle, the yield had dropped from ten bushels in the thirteenth century to between six and seven bushels in the fourteenth century what would the yields have been at the time of the Norman conquest? In conclusion, he says:

> In regard to the problem as a whole I wish to emphasize the fact that I do not profess that the evidence I have brought forward is adequate to prove or even to make probable any positive conclusion. I am not prepared to maintain that the yield of corn improved or even remains steady in the later Middle Ages.

The quotations given above carry sufficient information about the open-field culture that was dominant in England during the Middle Ages and shows how difficult it would have been to have introduced any modifications. The system was rigid and inelastic to an extreme. However or whenever the system of open-field cultivation was started, an attempt was made by the military, monastic and political forces to maintain it for its social advantages long after its economic failure had been realized.

It must be remembered that in medieval times the object was for the people themselves to be satisfied to gain a living from their farms. There was not a large urban population in England at the time. There were few industrial workers at that period who had to be fed. The transportation facilities were execrable, and it was a period and a system under which the least possible crop was removed from the farm. Therefore, soil exhaustion due to the removal of plant food from the soil would have been at its lowest ebb.

It is admitted by every one who has looked into the matter that the system and methods of agriculture in England during the medieval period were very crude and very poor, and that they finally broke down towards the beginning of the seventeenth century when the open-field method gave way to the inclosures and that this period was coincident with the end of the baronial and monastic periods. It is admitted further that from the beginning of the seventeenth century methods of agriculture began to improve with a consequent increase in the yield per acre of wheat.

It is highly desirable that, through diligent research into old manuscripts, reports and commissions' investigations, the yields per acre for each of the centuries be as accurately determined as possible to establish the level of agriculture under the medieval system and the rate of increase under the more intelligent methods used since then.

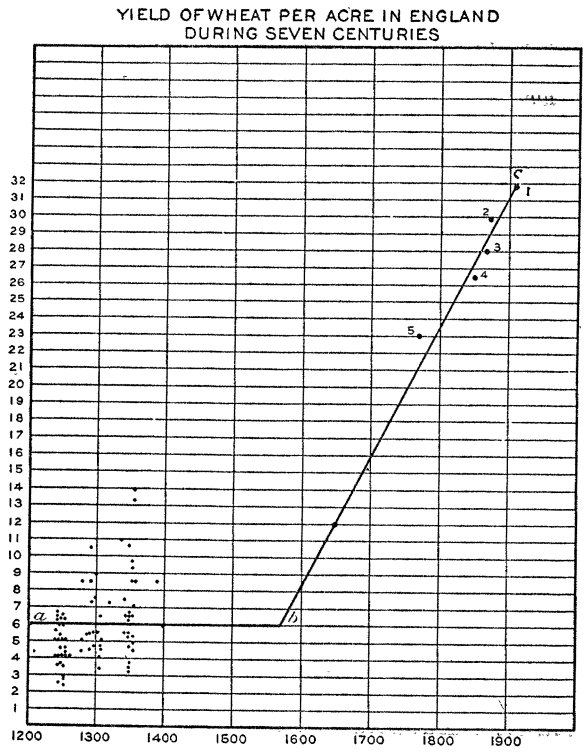
The political economists have given a great deal of attention to the yields in the thirteenth and fourteenth centuries, which marked the beginning practically of written records. They have succeeded in establishing a number of more or less accurate figures for these two centuries, but they have not given us yields in the fifteenth, sixteenth and seventeenth centuries. It is admitted by them that there is probably a wealth of information to be obtained by any one who will take the trouble to search the records of those three centuries, and this should by all means be done, preferably by some one in England who can obtain access to these old figures through the libraries and through baronial and monastic records and Parliamentary reports of many inquiries that have been made from time to time into the state of agriculture.

In the following figure I have drawn a line a—b—c which appears to me to furnish a reasonably satisfactory basis to represent in a crude way the yield of wheat per acre during these seven centuries.

I have indicated on this figure the 45 yields given by Lennard in the thirteenth century and the 35 yields which he gives for the fourteenth century. The average yield of the thirteenth century without allowance for tithe is five and one fourth bushels. The average for the 35 yields in the fourteenth century is six and three fourths bushels. I have considered that under the circumstances this difference of one and one half bushels between the two centuries may be considered as insignificant and I have therefore drawn the line a—b approximately midway between five and one fourth and six and three fourths and have taken an average of six bushels per acre.

Starting with c on the line b—c we have the average of the official British figures for 1909–1913 as given in the year book of the United States Department of Agriculture for 1922. The second dot is the figure determined as the average yield per acre in Great Britain in 1873 by the International Statistical Congress at St. Petersburg which arranged to have the average yields of the principal countries determined. The third dot is an estimate by Sir James Caird of the average yield of wheat in England for 1868. The fourth dot is an estimate of Sir James Caird of the yield in 1850, the fifth dot is the estimate of Arthur Young of the average yield in England in 1770. I have inserted a dot at 1650 indicating a yield of 12 bushels per acre, as it is my impression that the yield of wheat per acre in England at that time was around that figure. From here the line is extended until it meets the line a—b at about the year 1570.

The lines a—b and b—c of course do not meet at the point b at an angle, but the two lines should be connected with a curve, the form or radius of which can not be determined without a sufficient number of figures. As drawn, the line b—c has a slope of about eight bushels per one hundred years, or an increase of one bushel in twelve and one half years.



It seems to me that a horizontal line somewhere around the average yield of six bushels per acre will probably be found to be a very satisfactory basis of the yield of wheat with the method prevailing under medieval conditions and that if we could establish the facts this same level could have been extended back for a period of a thousand years during which time the methods and system of agriculture had not materially changed.

During the whole of the medieval period in England, life was comparatively simple. There were few people whose occupations required them to be fed by labor other than their own; there was a very small proportion of urban population. There was little or no trade in agricultural products within the kingdom or with neighboring states on account of the difficulties of transportation. There was no necessity and little opportunity for the production of large crops. There were a few thoughtful men as there are in all ages who were dissatisfied with conditions, who thought they could be bettered. The early English agricultural writers, such as Tusser and Fitz Hubert, were thundering for reforms, but reforms only came when necessity drove, when in the sixteenth and seventeenth centuries the urban population increased, the industrial age began and the lack of sufficient food for the non-producers caused bread riots and the demand for inclosures where individual effort could be rewarded. Not until then was the old system finally swept away to give place to the new.

As the inclosure system began to prevail over the open-field system, the introduction of grasses, of clovers, of lucerne, of turnips and of potatoes became possible. Drainage began to be installed where needed. The selection of seed, the rotation of crops, the improvement of cattle, sheep and hogs, the improved implements, the improved transportation facilities and above all human and personal desires and aspirations, the use of marls and of guanos and later the introduction of bones and of commercial fertilizers made possible a better system of agriculture which has tended steadily to increase the yield per acre of wheat.

The introduction of these improved methods had little or no effect upon the average yield of the country until the methods had permeated and affected the practice of a large proportion of the farmers. With a million men engaged in agriculture, the combined labor of all making up the average, it was not until the methods had been adopted and intelligently used by a majority of the million farmers that the average yield of the country could be materially increased. So it is reasonable to expect that when we obtain sufficient figures the line b—c down to somewhere near the point b and extended over three centuries will be a nearly straight line with no jogs which could be attributed to the introduction of clover, or to the improvement of livestock, or to the introduction of fertilizers, for these methods spread but slowly through the mass of farmers, the efforts of whom in the mass make up the average.

Let us look at the probabilities of the line a—b at the six bushels level with the methods employed under the medieval system of agriculture. Thorold Rogers, from the records of Merton College, shows that in 1334, 1335 and 1336 the yields on their estate at Gamlingay were respectively, six, seven and one half, and three and one tenth bushels. In the same years the average yields per acre of wheat on their estate at Cuxham were 15.1, 15 and 15.2 bushels per acre. He considers these yields higher than the average, because during this period the price of wheat was lower than the average of the periods before and later, indicating a relative abundance of wheat in these years and consequently a relatively high yield per acre. From the figures furnished by Lennard the yield ranges from about two and one fourth bushels per acre to as much as 14 bushels per acre with an average for the two centuries of somewhere around six bushels per acre or, with an allowance for tithe which may have been deducted, six and one half bushels per acre.

The average yield of wheat in the United States forty-odd years ago was around 12 bushels per acre. It is now in the neighborhood of 15 or 16 bushels per acre. There are some six million farmers

at the present time, a large proportion of whom are raising wheat, which affects this average in proportion to what they produce. Is it not safe to assume that a considerable proportion of our farmers are using methods that yield them about the same returns as the farmers of England obtained under medieval systems of agriculture? Have we not, all of us, seen examples of a tenant farmer with insufficient capital, with poor and decrepit livestock, without ambition or adequate training, use methods not unlike the medieval methods and by injudicious cultivation, by inefficient methods, bring down the yields of even our better farms to a level of the yields obtained by the medieval farmers of England?

On the unfertilized wheat plot at Rothamsted the yield of wheat has declined to an average of about 12 bushels per acre. If this plot had been cultivated with insufficient capital, with half-starved animals and if the weeds had not been rigorously subdued by a laborious system of hand-picking, the yield of wheat on this plot would probably have come down to the yield of wheat under medieval conditions and with a much more rapid decline than has actually been experienced. It is safe to say that in a period of five years on most of the soils of the United States the yield of wheat could be brought down to the yields obtained under medieval methods in England if those same methods and conditions were revived now in this country. It does not take centuries to impair the productive power of soils. It requires only a few years of the life and effort of a man to lower the level of productivity to that of the medieval English farmer.

On the other hand, many of the long-time fertilizer and rotation experiments of modern times have shown that in a period of from five to fifteen years through intelligent methods yields equal to the present English yields can be obtained by the individual farmer. They have obtained these larger yields by rotations alone, by the application of fertilizers alone, or with a combination of fertilizers and rotations.

These things are well known and yet with all of our experience and all of our knowledge we must consider that these improved methods must be adopted by a large proportion of our farmers before they sensibly affect the average yield of the country.

So it seems to me that the low average yield in medieval times must be ascribed to the methods, to the system, rather than to any loss of plant food from the farm and that the increased production of England to-day must be ascribed to the methods, system, and to the higher average intelligence of the man who works the soil.

If, by further research of the political economists or the soil experts, the line b–c is found to be substantially correct or if on the average in the past three hundred years the increase in wheat production is shown to have been around one bushel in twelve and one half years the question may well be asked: What are the possibilities of the future and where is the end to the possible production of the soil? To answer this I can only refer to King's statement in his study of the agriculture of China that he himself measured the yield of wheat on a field cultivated by a Chinese farmer and determined that the yield per acre was 117 bushels and that in traveling through the province he saw many fields that yielded as much or more. Whether we can ever attain such yields as these Chinese farmers have secured or whether, if it were possible, it could ever be economically done under the general economic conditions of the world is another question; but so far as I can see the limit of possible production even for the average farmers in England has not yet been reached. While the world can obtain wheat at low cost from countries where the yield is low because of primitive methods but where vast quantities of the grain can be secured for the international markets, the question of increasing our yields is dependent upon economic conditions; but we are concerned here only with the possibilities of wheat production—with the maximum yield that may be obtained, and in weighing the evidence for or against soil exhaustion, as this term is usually understood.

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THE GEOGRAPHICAL DISTRIBUTION OF MEMBERSHIPS IN THE NATIONAL ACADEMY OF SCIENCES

THE geographic distribution of membership in the National Academy of Sciences is a subject which has interested me for several years. At my request Dr. Aitken has prepared for SCIENCE the tabulations of membership distribution in the academy, as set down below, on the basis of states in the Union, and of universities, colleges and research institutions. Three members of the academy are at present residing outside of the continental area of the United States—at Manila, P. I., at Arequipa, Peru, and at Freiburg, Germany; these have been credited respectively to Washintgon, D. C.; Cambridge, Massachusetts, and Chicago, Illinois, in the several tabulations. The number of members assigned to the individual states or institutions may be in error here and there to the extent of one member, because changes of address may be unknown to us; but these possible defects can scarcely affect the significance of the tables.