hypothetical and imperceptible forces or entities to account for the perceptible facts, is essentially a question of scientific convenience. The presumption, surely, is in favor of the positivistic method, which is content to correlate the observable data without going behind them. Yet it must be confessed that it is not by such avoidance of hypotheses concerning imperceptible causes or substances that physics and chemistry have achieved their best results. And the precedent of those sciences might be plausibly (though, I think, unwisely) made, by one convinced of the truth of the vitalistic answer to one or the other of the first two questions, an excuse for not taking his vitalism positivistically or pragmatically. In any case, these hypothetical "forces" or causes would constitute elaborations or embellishments of his doctrine; they would not constitute the basis or the irreducible minimum of it.

A word in conclusion about the position of Bergson, of which Professor Ritter speaks with cordial approval. Bergson holds the doctrine of organic autonomy in a special and a somewhat extreme form. Inorganic and organic processes manifest, in his opinion, radically dissimilar modes of causality. "The present state of an inanimate body depends exclusively upon what took place at the preceding instant. The position of the material points of a system is determined by the position of the same points at the immediately antecedent moment. In other words, the laws which control unorganized matter can be expressed in differential equations in which *time* (in the mathematician's sense) plays the part of an independent variable." This, Bergson insists, is not true of living bodies; their present state does *not* "find its complete explanation in the immediately anterior state." We must absolutely give up "the idea that the living body could be subjected by some superhuman calculator to the same mathematical treatment as that which is applied to our solar system." The "creative" efficacy of organic evolution is shown, for Bergson, precisely in the impossibility of deriving from even the most complete knowledge of the configuration of the components of an organism at a given moment, and of all the "laws" which have been disclosed up to that moment, any absolutely complete and certain knowledge of the future condition and action of that organism. Bergson, moreover, does not stop with this anti-mechanistic view of the actual behavior of organisms; he suggests an explanation for what he conceives to be the facts. And his explanation, though rather elusive, approximates that given by the psycho-vitalists. The neo-Lamarckians, he declares, are right in referring organic evolution to "a cause of the psychological order," though they apprehend this too narrowly. The conception of "effort should be taken in a sense more profound, a sense even more psychological, than any neo-Lamarckian has supposed." It is true that Bergson does not seem to call his doctrine vitalism, and that he speaks in criticism of the vitalism of certain other writers. But it seems to me that any dogmatic (*i. e.*, not merely provisional or agnostic) anti-mechanism in biology should be called vitalism. In other words, the doctrine which it appears to me to be linguistically most convenient to designate by that name is the doctrine of organic autonomy in its biological application, the assertion of an essential logical discontinuity between the "laws" or modes of action of matter dealt with by biology and the "laws" of all the sciences of the inorganic. And in this sense, of course, Bergson is an unmistakable and a radical vitalist. It would certainly be paradoxical to withhold the name from a writer who does not hesitate to say that the "parts of an organized machine do not correspond to parts of the work of organization, since *the materiality of this machine does not represent a sum of means employed, but a sum of obstacles avoided*" by the *élan vital* in its form-creating activity.

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PRODUCTIVITY OF SOILS

The discussion of the "Secular Maintenance of Soils" by Professor Chamberlin before the Geological Club of the University of Chicago aimed at so fundamental and comprehensive a presentation of the subject and the report of it by himself in SCIENCE, February 10, p. 225, is cast with such pedagogic effect that it is much to be regretted that a goodly part of the discussion was not incorporated with the report, as without this some statements are likely to be interpreted in a way widely at variance with authentic data and hence in a way to be misleading.

Although most that is said is undisputed, this presentation in fifty-three terse statements of somewhat unusual form is certain to convey to younger students of the subject the impression that each and all of these phases of the great problem of soil productivity have been brought into the clear light of science and are here set out in proper order. This is, of course, not true and not intended to be so understood but the great confidence accorded to the author's utterances is in danger of leading to the acceptance of his suggestions and beliefs as established knowledge, and to assigning to minor factors an importance far too great.

The importance of capillarity in supplying potassium and phosphorus to crops, emphasized by the figures which are cited, will be understood as being much greater than can be the case. Indeed, instead of the "capillary cycle" and the "plant cycle" tending on the whole to the concentration of potassium and phosphorus toward the surface of the soil contributing to "secular maintenance," as is implied, quite the reverse tendency is the case, as may be seen from a comparison of the composition of soils and of rocks. We cite the complete analyses of 27 soils given by Hopkins[1] in the form of mean values for three depths.

In this series 74 per cent. of the cases in the second depth have the potassium higher than in the surface soil, and 59 per cent. of the cases in the third depth have the content higher than in the surface sample. The larger amount of phosphorus compounds in the surface soil is not a case of concentration due to the action of either or both cycles named, but has occurred in spite of them and is less than it would have been because of their action. The most pronounced effect of both "cycles" is to leave soluble ingredients upon or above the surface of the soil whence they are transported to the sea by both surface drainage and wind action, the loss in this way being materially greater than the supply by capillarity to the root zone.

Depth	Phosphorus (P) lbs. per million	Potassium (K) lbs. per million
0 to 6⅔ inches	581	16,376
6⅔ to 20 inches	485	16,649
20 to 40 inches	488	16,936

	Igneous Rock	Sedimentary rock Shale	Sand-stone	Lime-stone
	Pounds per million			
Potassium	24,400	26,981	10,959	2,740
Phosphorus	1,100	7,426	3,494	1,747

The phosphorus content[2] of all rocks is seen to be higher than that of soils, and the higher content of sediminetary rocks will not be ascribed to either capillary or plant action, but to other processes named in the article. It must of course require a positive addition of plant food elements to cultivated soils, in amounts equal to or greater than all removals, to perpetuate indefinitely uniform or increasing productivity.

Studies like those of Professor Whitson[3] of phosphorus in cultivated and virgin soils indicate, in the case cited, an average loss of P_2O_5 during about sixty years, of 1,255 pounds per acre, from the cultivated soil, and in but three of the nine comparisons was the loss less than that which would be assigned to removal by crops. It may fairly be questioned whether this difference is due entirely to greater loss from the cropped soils, but it

[1] "Soil Fertility and Permanent Agriculture," pp. 82–87.

[2] "Data of Geochemistry," Bull. No. 330, U. S. Geol. Survey, pp. 26–27.

[3] Research Bulletin No. 2, University of Wisconsin Agr. Expt. Station.

will hardly be urged that it is even chiefly due to capillary and plant concentration such as might prevail over large areas like the United States. At least the projection of such a rate of concentration through any material period forward or backward would point to very unusual if not impossible conditions.

If it be true that 1,200,000 tons of PO_4 are lost annually from the soil of the whole United States by drainage into the sea and that capillary water is carrying toward the surface 18,000,000 to 40,000,000 tons, there would be a total mean movement of 30,200,000 tons of PO_4 or 9,800,000 tons of phosphorus. A yearly removal at this rate maintained for 10,000 years would require more phosphorus than is carried in 10.5 feet of igneous rock, assuming 200 pounds as the weight of a cubic foot and Clark's value cited above; and all of the phosphorus carried in 40 feet of soil weighing 4,000,000 pounds per acre-foot, containing 581 parts per million of phosphorus. A combined chemical and mechanical erosion which would remove 40 feet in 10,000 years, from the United States, would have to exceed one inch in 21 years.

It appears to be overlooked, in making the estimates, that capillary sweeping is very often and strongly downward as well as upward, and also that a large proportion, probably more than three-fourths of the rainfall, not removed in the runoff, never penetrates the soil beyond a depth of two feet and should not, therefore, be used as a measure of surfaceward movement of plant food below that depth. We have measured the combined capillary and internal-evaporation-movement out of the 5- to 10-foot depth into the 0- to 5-foot depth in four instances, two of which were a clay loam and two a sandy loam soil. The measurement was continuous through 314 days under a summer temperature. Under the most favorable conditions for upward movement water was carried from the 5- to 10-foot zone into the 0- to 5-foot zone at the rate of three pounds per square foot during the 314 days, where the surface was continuously firm, while under a 2-inch earth mulch the movement was 2.2 pounds. In the sandy loam the movement out of the 5- to 10-foot zone into the 0- to 5-foot zone was less than .8 pounds in 314 days. The annual combined upward movement from the 5- to 10-foot zone into the 0- to 5-foot zone, at the most rapid rate, was .7 inch in the clay loam and .17 inch in the sandy loam.

Assuming a soil solution containing 20 parts per million of PO_4, the total phosphorus which might thus be added to the surface five feet from the five feet below, would be but 1 to .25 pound per acre annually and even these values we regard materially too high for average conditions, although they show a rate less than one fifth that of the estimate cited by Chamberlin. It is true that the capillary and plant "cycles" are agencies which, at the time, assist in the utilization of plant food substances, but they primarily accelerate their waste and should not therefore be reckoned as "efficient factors" of secular maintenance of soil productivity.

We quite agree that the Mongolian races have "demonstrated one mode of effective secular maintenance of the soil productivity," but we fail to see that it is "closely analogous to the natural method of the geologic ages." Our observations bring the conviction that they return to their fields, year by year, a full measure of all potassium and phosphorus removed with their crops; that their cultural methods very largely reduce losses by both physical and chemical erosion; and that they secure a very high efficiency for the plant food used by the crops. All human and animal excreta and all fuel ashes of country and city are universally applied to the cultivated fields. Enormous quantities of bean, rape seed, cotton seed and peanut oil cake are used as fertilizers annually and an enormous tonnage of canal, reservoir and river mud is also applied, even to the extent of 70 to 100 tons per acre in some instances, as single dressings which must carry to the fields not less than 100 to 150 pounds of phosphorus. Then their very extensive practise of irrigation adds, with the silt and soluble plant food carried in the water, quite as much fertility as is removed by leaching, and all irrigated areas are placed under conditions which practically eliminate surface erosion. Both canal and reservoir mud, together with soil and subsoil, are fermented with organic matter to be used as fertilizers to an extent which would appear to western nations impossible. Indeed it appears probable that as much labor and time are spent in specific fertilization of the fields as in seeding and harvesting the crops.

While these people, so far as we can learn, have never used rock phosphates or potash salts taken from mines, as western nations are doing in recent years, they have in effect done so to a remarkable extent through their home manufacture with their compost methods. So far as we could discover they have nowhere developed or applied systems of tillage looking specifically toward physical amelioration, as such, for their soils but they have practised the culture of legumes as a source of nitrogen very systematically, persistently and extensively. Feed and water the crops is written on every field in China and Japan. Japan is now beginning to import notable amounts of commercial fertilizers and during the years 1906 to 1908 the total import of all kinds aggregated 1,427,658 tons, with a cash value of $55,423,394 and all applied to about 21,000 square miles of tilled land, constituting a tax of more than a dollar per capita for the entire population, and this is paying for an addition to an already enormously large yearly fertilization.

But the one factor which is probably equal in importance to all others is the extreme personal attention and care bestowed upon the crops, made possible and necessitated by the dense population and increasingly smaller holdings. But this has not and can not supplant their supplemental irrigation and their plant feeding except through a smaller annual output. It must be this factor coupled with the increasing larger return to the fields of plant food which has given rise to the increase in yield during recent years in this country and in Europe, to which attention has been called. It is clear that such increase may well be coincident with a decreasing plant-food content in soils of the stronger type and for the simple reason that great care may augment the rate of production of the plant-food content of film moisture for a time, with a decreasing content of the basal food elements. That the oldest and most densely settled countries should show marked increase in yield is to be expected, for here is where better care pays best, where it is compelled and where it is more readily made possible because of the denser population. But it should not be ignored that the countries named are those which are largely importing feeding stuffs and fertilizers which immediately or ultimately find place in the soil, and that those who purchase and apply these have faith that they are indispensable adjuncts to better cultural methods, improved varieties and more sanitary conditions.

There were imported into the United Kingdom in 1885, 282,960 tons of oil cakes; 64,387 tons of bones and fish; 25,258 tons of guano, and 238,572 tons of mineral phosphates. In addition, some 300,000 tons of Thomas slag are manufactured annually and largely used at home. During 1861–65 there was a mean annual importation of 1,277,778 tons of grains and beans, besides wheat. During 1901–05 importation had increased to an annual mean of 4,641,204 tons. A mean of these values may be taken, together with the fertilizers named, as a low measure of the annual importation of plant-food substances into the United Kingdom during the past twenty or thirty years.

As a rough approximation, it may be said that 2,000 pounds of the products named will contain:

	N lbs.	P lbs.	K lbs.
Oil cakes	120	18.8	30
Bones and fish	80	170	
Guano	70	170	
Mineral phosphates		250	
Thomas slag		160	
Grains and beans	50	8	12

The arable lands of the United Kingdom aggregate 19,528,000 acres and there are 28,267,000 acres of permanent pasture.

On the basis of the amounts named the

annual importation of the three plant-food elements, including that in 150,000 tons of Thomas slag, would be:

	N tons	P tons	K tons
In oil cakes	16,977	2,660	4,244
In bones and fish	2,575	5,472	
In guano	884	2,147	
In mineral phosphates .		29,821	
In Thomas slag		12,000	
In grains	73,987	11,838	17,757
Total	94,423	63,938	22,001

To these amounts should be added the heavy importations of nitrate of soda and of potash salts.

The phosphorus content of these importations is sufficient to apply 6.54 pounds to each acre of arable land in the United Kingdom and this amount is all that is carried in the grain and straw of 20 bushels of wheat. During the twelve years preceding 1906 there was an importation of potash salts sufficient to carry 99,426 tons of potassium, which, added to the above, aggregates enough for 13 pounds per acre of the arable land. Through more than a century increasingly larger importations of fertilizers and feeding stuffs have been going into all of the countries of western Europe. These annual additions of soluble plant food elements to the film moisture and to the interior of the soil granules can not fail to exert cumulative effects upon both microscopic and higher plant life, which together must react upon yields continuing their increase until available soil moisture and then standing room become the limiting factors.

The increase in yield in the United States to which attention has been called is certainly associated with the importation of feeding stuffs and fertilizers, and while better cultural methods, better seed, better strains and fuller control of fungus diseases are responsible for some of these increases, the addition of plant food must play a large part now in the older states, especially in the North and South Atlantic groups where fertilization has been so long and so extensively practised. In the northern group, $15,641,995 and in the southern, $22,732,670 were paid for fertilizers in 1899 and applied to less than 24,683,365 and 29,194,361 acres, respectively, the amount of land in all crops that year. To give expression to these figures in terms of plant-food elements and crop yields, the mean value and composition of twelve "complete"[4] fertilizers may be used, worth $23 per ton and containing 33 pounds of N and K and 88 pounds of P. On this basis the fertilizer purchased would contain sufficient phosphorus for 2.42 pounds for every acre under crop in the North Atlantic states and for 2.98 pounds in the South Atlantic states. These are the amounts of phosphorus contained in the grain and straw of 7.5 bushels of wheat and 10.5 bushels of corn in the first case and in the second case, 9.31 bushels of wheat and 13.0 bushels of corn. But in the most thickly settled states the amounts of fertilizer used are much above the average, Rhode Island using sufficient to carry 10.2 pounds of phosphorus to each acre in crop; Connecticut, sufficient for 6.5 pounds; New Jersey, for 6.39 pounds; Massachusetts, for 6.37 pounds, while the District of Columbia is credited with fertilizers sufficient for 26 pounds of phosphorus and of 10 pounds of potassium per acre in crop, added to her cultivated soils each year.

There never has been doubt regarding the truth embodied in the statement, "that therefore there must be some efficient natural process for the maintenance of soils," but because of its association with other statements there is danger that it may be taken explicitly to mean, that therefore there must be some efficient natural process for the maintenance of soil productivity capable of sustaining, in the United States, 2,000 million people with relatively little greater effort at curtailment of waste or of return of essentials to the soil than is now practised here. If all that the Chinese and Japanese farmers are doing, and for centuries have felt compelled to do, are to be included in the "some efficient process," then all danger of misleading will be removed, for there has long been more applied science in the agriculture of "oriental experi-

[4] Hopkins, "Soil Fertility and Permanent Agriculture," p. 157.

ence" than has yet been explained or suggested by "western scientific research."

It never can be too strongly emphasized that, granting suitable climatic and physical soil condition, the fundamental of crop production is crop feeding, and that crop hunger (and thirst) has been the prime condition determining reduced yield oftener than any other. These have been the tenets of practical men through all the past and are likely to remain so to the end. Disease, parasitism, phagocytism, degeneration of seed, toxic substances or what not may at times reduce yields and the advance of knowledge which shall make it possible to diagnose these cases and apply the proper remedy, for each will augment the efficiency of plant food but make the demands for it greater nearly in proportion to increase of yield, and will accelerate soil exhaustion where nature or man makes inadequate return.

It is difficult to see on what basis of knowledge one may contend that the increase in the productivity of soils of western Europe, referred to as occurring in recent years, has been due to improvements along any of these minor lines rather than to better physical soil condition and to the increasing application of the three most essential plant-food elements which have certainly been coincident with these increases of yield; and even more difficult does the case become when referred to the long and high maintenance of soil productivity in China where plant feeding has been the heaviest burden of the people.

F. H. KING

MADISON, WIS.

A KINETIC THEORY OF GRAVITATION

TO THE EDITOR OF SCIENCE:

Imagine a pound-weight of iron raised from the surface of the earth to a point near the moon, the point so chosen that the opposing attraction of the earth and the moon shall exactly balance each other. In the surface of the earth the pound-weight had some so-called "potential energy of position" because it was capable of falling into a pit: but in its new position near the moon this potential energy has disappeared entirely; the pound-weight, left free to move, remains stationary. We can not believe that the whole or any part of it [the energy] has been annihilated: it must, in some form, be resident somewhere. I believe it was absorbed by, and is now resident in, the ether through which the weight was raised. Conversely if this be true, a falling body must acquire its energy from the ether through which it falls."[1]

Since the ether is as yet a hypothetical substance, postulated to explain certain physical phenomena, it may be allowable in discussing some phenomena to postulate its non-existence. We do not know that if the ether were non-existent and only an imaginary substance, that gravitation would also be non-existent. Assuming the non-existence of ether, but gravity acting as usual, would not the pound-weight act just as is described by Dr. Brush?

Consider a simple case. A ball weighing one pound is lifted five feet from the floor, and placed on a shelf. It has a potential energy of five foot-pounds, with reference to the floor, but it can not exert this energy, or convert it into kinetic energy, for it is prevented by the shelf. So if the ball is raised to the point near the moon, it has 20,000,000 foot-pounds of potential energy, referred to the earth, and this energy could be made kinetic, if the body were "free to move," which it is not; it is restrained by the attraction of the moon, just as it was restrained by the shelf. Suppose the ball is of iron, and that on being raised five feet it comes within the field of attraction of an electromagnet which attracts it and prevents it falling to the floor. It has five foot-pounds of potential energy, just as it had on the shelf, but it is for the time being unavailable. Let the current which actuates the electromagnet be interrupted for a fraction of a second, the ball begins to fall and the potential energy becomes kinetic. In neither of these cases has the potential energy "disappeared entirely," it has only been rendered unavailable by the attraction of the moon or the electromagnet, or by the shelf. It has not been annihilated nor is it "resident in the ether."

[1] Extracts from an article, "Kinetic Theory of Gravitation," by Charles B. Brush, SCIENCE, March 10, 1911.