In order to dispense with the use of a reflector I arrange the carbons + above, as described in the "Journal of the Franklin Institute" for May and June, 1878.

The peculiar cup-shaped appearance of the positive carbon helps to concentrate the light on the condenser. It is understood that any lamp in which the carbons are arranged end to end can be used with electrodes prepared as above. Such a lamp can be easily substituted in a lantern made for use with oxy-hydro-lime light. I use constantly such a lamp with one of Edgerton's physical lanterns originally made for the lime light. I am inclined to think a kaolin paste would be better than plaster for coating the carbons. The electric force used in all the experiments has been furnished by the Gramme machine, described in the "Journal of the Franklin Institute" already cited.

The use of projections for illustration in lectures on Chemistry and Physics has become so general that I hope the suggestions in this Paper may prove of some benefit.—*American Journal of Science and Arts.*

V. SEED-BREEDING.

By E. Lewis Sturtevant, M.D., So. Framingham, Mass.

We sow wheat in order to reap wheat, and rye in order to reap rye, and corn in order to harvest corn ; and were the wheat to turn out rye, and the corn-field to yield barley, we should suffer even a greater bewilderment than did the heroes of ancient fable when they became intimate with those enchanters and sorcerers who caused fishes to indulge in conversation and mankind to become changed into beast-like forms. For the world is so subject to law that its recognition on a large scale is part of each man's daily experience ; and living amid the triumphs of modern science, even the every-day labourer is educated unconsciously within the sequences of a more and more correct philosophy, so that in general terms he recognises that as he sows he must reap, and that thorns do not bear figs, nor thistles grapes. In this aspect of the case it would seem to be unreasonable to talk about heredity in plants, because the statement of the fact in general is uncalled for, being universally known and universally recognised as known. Yet we purpose to give a few thoughts on the subject, despite the apparent clearness of the claim that seeds have a heredity inherent in their nature and structure, because we recognise that the *application* of the well-known fact of heredity in these cases has not received a proper attention from the public, and that while the fact may be well apprehended, yet too few are willing to carry reasoning based on the correct premise to a logical and practical conclusion.

We certainly have no reason to believe that there is one law for vegetable and another for animal life; rather, we have firm grounds for asserting that all life is subject to the same laws of Nature, and that apparent differences are to be ascribed but to the individual under observation, being subject to forces under a greater or less antagonism, or from the simplicity or complexity of its structure and functions which render it amenable to one law rather than to another. Thus, to illustrate our proposition, we can say that a plant and an animal are subject to the action of the great natural forces which affect life and its development, such as gravity, heat, light, &c.; yet the application of a stimulus which will produce no apparent movement in the one may excite muscular action in the other; or, to make a more mechanical suggestion, a falling stream of water may serve to move a saw which shall convert a log into boards, or shall act on a more complicated series of machinery to turn a lathe which shall convert the same log into spools, or the irregular gunstock. In either case the same moving force has acted, but the work accomplished has been modified into different results through the action of another force, the mind of man, which has intervened to produce oppositions, and through the reaction of these varied oppositions has contributed to the concrete effect of the force derived from gravity upon the shaping of the log. Thus, in Nature, we have the *life*, distinguished from mineral matter by the possession of motion, and the power of adding to itself, through the force which this motion implies, from the surrounding world, of matter suited to its own structure and function, and imparting to it of its motion. Once stop this motion, destroy this mysterious force, and the life becomes subject to other conditions, and dissolves its structure, the function being lost as well, into the matter which is incapable of acting on itself to produce this added power which we call life and organism. We, however, may say that mineral is one phase of matter which is subject to one set of laws and conditions, and that life is this same matter, with added force which renders it subject to an additional set of laws and forces, which are more or less greater or less powerful, according to the complexity of the life upon which they can act. The true view of Nature is, then, according to our view, that laws are continually in action and are universal, and that it is the province of the existent life or matter to use these laws according as the structure and function affect their relations; and that hence the mind of man, which recognises and adapts existing relations to his own benefit, by modifying through law, structure, and function, can arrange relations to other laws, and produce diversity of result.

The law of inertia, which is defined as being that condition of matter by which its existing state is retained, if at rest, rest, if in motion, the continuance of that motion until other forces in action shall produce a change, serves as well for the consideration of the problem of life. A perfect likeness between parent and offspring would presuppose the parents being from all time in a state of *inertia*,—a supposition which nullifies the proposition, as the act of having offspring would be a departure from that state. Yet when we define the science of breeding, and state that "like produces like," we recognise the fallacy of the proposition as applied with exactness to individuals, and modify it immediately by limitations, which if they serve to weaken the statement, yet serve to make it not contradictory to our experience. Rather the law of variation should be the key-word for breeding, although the proposition that "like produces like" as a mental conception is as true and as applicable as is the proposition that *inertia* is a definition of a law of Nature. Like does produce like when every condition is removed which would produce difference, which only can be done as a mental act: a body is considered as continuing in its present state when every condition involving a change is removed by a mental act. Hence the "law of likeness" is of the most importance to that breeder who desires to so modify surroundings as to restrain his animals from being improved in their progeny; and the "law of variation" is deserving of the more attention from that breeder who would desire to improve his animals in their progeny.

We might amplify this proposition to almost any extent did we deem it desirable to encumber our essay with metaphysics, but we think that the careful reader or hearer will understand us in our statement that progress comes through variation, and not through likeness; that whether we breed the vegetable or the animal, it is the laws of variation which we must study and apply in order to produce progressive results: and that the law of likeness, the "like produces like" of our books, however true as an expression which must be and is followed by numberless limitations, is but of secondary importance to the practical dabbler or expert in the art of breeding, to that much more important law which embraces the variations and fixing of structures and functions which have been obtained. The pendulum swings to the right hand and to the left with a uniform motion. Any pendulum of the same length of rod and same weight of bulb, under given conditions, vibrates through the same arc. This statement may illustrate the breeder's proposition that "like produces like." Yet let any two of us make a pendulum of equal length of rod and weight of bulb at our own homes, and we would find that practically they would not move over the same arc, because we would use rods of different character or diversity, or bulbs of different centres of gravity, or would hang them differently, or would calculate the arc traversed under temperatures which were different. It is only as we understood these causes of variation that it would be possible to produce two pendulums whose oscillations would compare. This may liken the "law of variation" which is the "application law" for breeders, as distinct from the "like produces like," which is a true, yet a "theoretical law," which does not admit of practical application without the use of the "application law" as here defined. Heretofore, the tail has wagged the dog; we do not propose to stop the wag, but to have the dog wag the tail. Unless this point be understood breeding as a science will cease to progress, and, indeed, the triumphs of the art have come from the unconscious application of these facts rather than from the course which theorists have laid down:—"Variation and likeness," not "Likeness and variation." This is the new and correct method for the study of the laws of breeding as practised. Just as cultivated vegetables have in a large degree been removed from the wild vegetation, and their different status been apprehended, must their breeding science leave wild nature, and come to a cultivated application.

These remarks must be understood to have a close and practical bearing on the breeding of seed, for a plant, as being individually confined to one locality, has a limit placed by its structure and position in respect to its environment which the animal does not have, and is subject to a different order of variation. The animal progeny comes from a distinct act of the father, and the offspring following this act have characteristics determined by this and other limited systems of parentage; but the ovules of the plant receive fertilisation in general from a large number of parentages, and the seed represents, as in animals, both maternal and paternal influences. The litter of a sow are brothers and sisters; the kernels of the corn plant are not necessarily brothers and sisters, but bear the same maternal influences and different paternal influences, and hence have a variation in their growth and seeding which is dependent on a different species of relationship than in the animal. To illustrate these effects we may mention that while in carefully bred cattle the variations in the progeny are seldom, if ever, sufficient to constitute a new variety, yet Colonel Le Conteur relates that in a field of his own wheat, which he considered at least as pure as that of any of his neighbours, Professor La Gasca, found twenty-three sorts; and he goes on to state the variations in the kernels which occupy each head, and which implied such variation in growth as to necessitate the selection by single kernels in order to perpetuate a variety. In our own cornfield, with certainly no other field cultivated with a different variety nearer than a mile, on the same ear corn-grains of different colour and structure occasionally appear, and there is always a certain percentage of ears of ten and twelve rows amongst the eight-rowed normal ears of the variety. We have in our collection ears of corn with kernels of white corn, yellow corn, and sweet corn in juxtaposition, the male element so overpowering the ovule as to give to it this diverse development, and, as we must assume, chemically unlike as well.

We may next remark how much more quickly the influence of moisture, of dryness, and of heat, avail to change the aspect of the growth and the produce of vegetable life over animal life. We do know that the character of soil has an influence on the cattle grazed thereon, but this influence is seldom of a character which admits of ready definition; on the contrary, the size and shape of the plant, and even the nature of the product, may be completely changed. Thus the hemp plant in India furnishes a resin known as churras, which is stimulant and intoxicating, but does not produce it when the plant is grown in a temperate clime. The ragweed of our fields will mature its seeds and show a perfect growth on a gravel-bank, the plant being but 2 or 3 inches tall; and the same plant in fertile soil will attain the height, accompanied by a corresponding degree of development otherwise, of as many feet.

Thus we might go on and illustrate from facts which come under the observation of every one, the extreme variability of the plant nature, a variability which is to our advantage, as rendering the plant available to man according as art is exercised by him in developing these variations according to the laws of their structure, in the line of his desires. Every plant with which we are acquainted possesses this power of variation in a marked degree, and the amount of this variation can be artificially determined for it through the processes of hybridisation and of culture as applied to the plant which furnishes the seed from which the individual is derived; and it is this fact which gives to man much power. Each seed possesses its own attributes and its own powers, and its own individuality, so that the conditions for germination and growth being uniform for all, a dozen kernels of corn planted will develop a different germinative power, a different rate of growth, and a different amount of product for each.

Thus in an experiment of ours, kernels of corn were selected of the same size and from the same ear, and were planted, on land made fertile in excess, at the same time and the same depth, and on one plot no cultivation at all, but the weeds pulled by hand; on another plot, the same conditions, but the land kept clean by the hoe. It was observed that there was a different rate of germination for each kernel in the hill, and between the kernels of the adjoining hills; there was a difference in the rate of daily growth between the plants from kernels in the same hill, and that on some day the rate of growth would be reversed as between these hills—one day one plant growing in excess of the others, and other days being the most backward, &c. When the crop was harvested, we found the following for the maximum and minimum product from hills of three kernels planted:—

	Plot 1, Unhoed.		Plot 2, Hoed.	
	Corn (in ear). Lbs.	Stover. Lbs.	Corn (in ear). Lbs.	Stover. Lbs.
Greatest yield per hill	3	5½	3½	6¾
Least yield per hill ...	¾	6¾	1¼	5¼
Average	1·8	4½	2·3	5
No. of ears, all qualities:—				
Largest number ...	9 ears		9 ears	
Least number ...	2 "		3 "	

In experiments with single hills under different treatment, in another plot, the ears varied from three to ten in number, the weight of corn from 1 lb. to $3\frac{1}{4}$ lbs. in the ear, the weight of stover from $1\frac{1}{2}$ to $6\frac{1}{4}$ lbs., and the total weight of hills as harvested from 3 lbs. to $9\frac{1}{2}$ lbs. harvested.

In those plants which have been subjected to culture for the longest time we find variation, as a rule, more marked than in those in a state of nature. It is a curious and valuable reflection that those plants whose origin in their present form antedates the history of civilisation are at the furthest remove from the wild condition, and have become modified to such an extent as to be unable to hold their present forms without the assistance of man. We also find that wherever the part of the plant modified into use admits of a variety of forms as connected with its uses, there such exist. There is, as a rule, but slight variations between the growths of our most ancient cereals, as attention has been paid more to the grain produced than to the plant which produced it: in the cabbage family, however, where the plant rather than the seed is used, we find variation into cauliflowers, broccoli, borecoles, Brussels sprouts, savoys, cabbage, collards, or coleworts, &c., and these varieties all reproduce themselves by seed.

The art of breeding seeds is therefore to produce and select such variations as are found desirable, and then to establish these variations so that they shall be transmissible either in their present or in an improved condition, by seed. The means of breeding is through the act of selection carried on for successive generations under well-considered conditions of environment, by which the heredity of the seed in the desired direction shall be strengthened. This heredity of the seed brings us more closely to our subject.

There are many degrees of heredity, so far as the breeder is concerned. There are some plants in which the tendency of the seedling to grow into a plant but slightly varying from the parent is very strong, and such are usually wild plants which include in their ancestry countless generations of somewhat similar environment, and a uniform natural selection in action which has selected and continuously propagated the type of plant best fitted to exist amidst the dangers and difficulties of the surroundings. With such a plant the first effort of the breeder is to produce a variation, to overcome the tenacity which leads the seed to propagate in the manner of its ancestry. This tenacity is a heredity neither stronger nor weaker than that which is to be found in plants of a more sportive nature, but is the outcome of a set of conditions which have been of a similar character for a long period. The same kind of heredity, neither necessarily stronger nor weaker, leads the cultivated plant to vary. Hence we may say that fixity or unfixity of type is no proof of heredity, and that it is but in the conditions which have availed in the past that the heredity which produces likeness is to be sought.

This tendency that exists throughout Nature for one life to produce in its offspring the characteristics of its past, as well as the modifications which have availed in its near ancestry, is the law of heredity. It is a true law, which cannot be said to be manifested by exact likeness of an offspring to its progenitor, because we have instances of alternate generation which shows this not to be so; but it is a genealogical expression which is to be interpreted that the life transmits itself in its modifications; and to know what these are, in order to use this law to our advantage, we must have the history of the preceding lives,—that is, a genealogical record. Now, in the case of a seed, we desire to act upon this knowledge of what the law of heredity as applied to breeding is, and not saying that the like seed produces a like seed, must realise that the total seed of a plant may produce some good, some bad seed,—some good plants, some poor plants,—some plants better, some worse than itself; and that it is heredity which produces these variations, and that we can through the process of selection modify the heredity of the future, so as to influence future seedings. It is this gradual gain, through the influencing the heredity of the seed, that concerns the seed-breeder. This would seem to imply that the tendency of the seed is to reproduce the plant from which it was grown. This is indeed so, because, speaking of the plant as a whole, it may be said to have in its structure a species of *inertia*,—that is, it tends to keep the form and condition it already has, except as diverted therefrom by cause. We cannot think of a change happening to a life without some cause to produce it; and in just so far, and in just that direction that causes have acted, and continue to act, must this *inertia* of the plant life be overcome, and the change which is adequate to the cause take place. So far from reasoning to prove that continuation of a form in a species does exist, we prefer to say that it must be so from the law of Nature, and challenge others to show the contrary, the burden of proof being with them. Hence, from our point of view, the variations we produce in a plant must be transmitted through the seed, unless they are nullified by some opposing or counterbalancing variation which shall disguise their effect. Let us illustrate this fact:—Prof. Buckman, experimenting with the *Vicia sativa*, or vetch, by a series of five selections, so accumulated the variations that occurred, from a plant but a few inches in height, gained plants more than 3 feet in height, and increased the weight of the seeds from half a grain in the original to 1 grain, and then to 1½ grains in weight. Mr. Hallett selected his original pedigree wheat in 1857, the ear being 4⅜ inches long, and containing 47 grains; in 1861 his finest ears were 8¾ inches long, and contained 123 grains. The second year he obtained ten ears to a stool, and the fifth year fifty-two ears to a stool. This was brought about through the selection of variations, and the continued selection, whereby the effects accumulated in the heredity of the plant. In 1848 Prof. Buckman sowed seeds of the wild parsnep and wild carrot, and, by careful selection, in 1851 the plants of the parsnep presented the stems and foliage of cultivated examples, and approached them in the character of the roots. The change effected in the carrots was not nearly so great as that observed in the parsnep, the Professor observes; but still the progress was quite sufficient to show that it is within anyone's power to renew both of these plants in a cultivated form from wild specimens. It is probable that in the Concord grape, and in our fine varieties of cultivated strawberries, we have the action of selected variation to thank for the result, and none of us can fail to have noticed how soon the varieties of any fruit are offered to the public after a break in the wild species or cultivated species has occurred. Indeed, through this power of heredity, this breaking in upon the *inertia* of the wild plant by mankind—this falling back again upon a trained heredity by art—we have accomplished these wonderful results upon the nature of plants, so that now, once cause a wild plant to sport and the way is immediately opened for the breaking up of the original species into numberless varieties, which shall add to the comfort, to the necessities, or to the gratification of mankind.

If such is our power,—if heredity in life cannot be escaped from,—and if it is the causing of variation, and the fixing of the changes induced which concerns us as agriculturists, what practical lesson can we derive therefrom? We will take up the corn plant, and show what capabilities are offered to energetic and skilful effort to improve this plant through the heredity of the seed, because few species are subject to greater or more valuable variations, and hence it is especially fitted to respond to any wise effort of ours.

*Z*ea maize, Indian corn, or simply corn, occurs within a wide range of climate, and is modified accordingly in the growth of the plant and the structure of the grain. There is a vast range between the pop-corn, whose normal length of ear is 1½ to 2 inches, and the field corn of from 9 to 12 inches, or even 15 inches; or in the number of rows of corn on the cob, which varies nominally from eight rows to twenty-four or thirty-six rows, as the "Canada 8-rowed" and the "Virginia white gourd" illustrate, and exceptionally even more or less. We find some varieties wherein the arrangement of the kernels on the cob is uniformly 8-rowed; other varieties where the rows may be either eight, or ten, or twelve; others still uniformly 12-rowed, or 16- to 22-rowed, or from 24- to 36-rowed. Some varieties bear the crop near the ground, from the lower nodes of the stalk; others, high up, on the upper nodes; and this feature of the plant is, so far as our observation extends, a true and uniform characteristic of varieties. In shape the ears may be blunt, or pointed after a manner, at the extremities; or may be of a long oval, tapering from a swollen centre towards the butt and tip ends; or may form a true taper from butt to tip; or may be cylindrical throughout. The kernel, again, may be arranged in lines wherein there is a distinct evidence of arrangement in pairs, or without any distinction or manifest separation into pairs of rows. The shape of the kernel may be nearly globular, or oval, or elongated; it may possess a flat point, or a dented extremity, or be furnished with a sharp tooth, either straight or recurved: it may be shaped like a horse's tooth, or be flattened; be longer than broad, or broader than long; may be smooth, or wrinkled, &c. In colour the kernel may be white, pale yellow, translucent, dark yellow, orange-yellow, reddish yellow, red, violet, purple, blue, slate, black, or variegated; in texture may be hard and brittle, softer and granular, and in some varieties almost gummy. Its specific gravity varies greatly—some 8-rowed, yellow, like the "Waushakum," weighing 64 lbs. to the struck bushel; others, like the Tuscarora, weighing seldom 56 lbs. to the bushel. The kernels differ in the structure of their contents: in the pop-corns the oils being distributed nearly universally throughout the kernels; in the varieties of the Canada corn the oily appearance being external to the chit and starchy portions, and forming the periphery from the hilum as a centre; in the dents, the apex being free from this oily showing ; in the true Tuscarora, no oil to be recognised, &c. This arrangement, which furnishes the basis for a practical classification of varieties, seems thus far to have been unused. In the cob we find also differences between varieties which are general for each variety—the large cob and small cob, the tapering cob, the cylindrical cob, the bulging cob, the white cob, the red cob, &c. In habit of ripening, one variety may mature in from 90 to 100 days, while another variety may require from 180 to 200 days. These variations we have mentioned are not in the nature of monstrosities, or exceptional in their nature, but are general, and peculiar to varieties. They are hence strongly inherited, and transmissible by the seed in all cases when other conditions than those which have availed in the past are not brought into interference.

Hence, if sweet-corn seed be planted, sweet-corn is harvested ; if a pop-corn, then the pop-corn harvest is obtained ; if a red corn, then red ears are gathered ; if an 8-rowed corn, an 8-rowed crop, &c., throughout the whole list. As an undoubted fact—a fact which is the explanation of our general practice of planting the seed of the crop which we would gather—each seed has a heredity which causes it to develop the plant in the line of the past growth ; and whenever, through natural or artificial agency, the character of the heredity has been determined for the seed, through any process by which like forces are accumulated and stored, we find the corresponding development in the offspring. That law of inheritance whereby we say "like produces like," meaning thereby the great law of continuance of development in the line in which forces compel, is hence so evident that as breeders of seed, or of animals, we can assume it as an axiom, and drop it from our discussion as too well known, too fully realised by the educated and trained mind, to require explanation or illustration. What is of practical concern is the defining of certain kinds of heredity, the accumulation in line of desired tendencies, knowing that the law of likeness is uniform and universal, and acting always within the lines of its application. To mark out these lines, to compel the action in the direction for our profit, is the true art for practical study, use, and endeavour.

If this position be the correct one, as we firmly believe, we may pass to the consideration of "variations," knowing full well that variations in all cases have a tendency, more or less strong, to be continued in the offspring, and that, if we can retain desirable variations for a sufficient number of generations, that these will become established as permanent.

The production of variations in a plant is easily acccomplished. Any interference with the normal condition will cause them—a change of climate; a little more or less heat or moisture; the influence of crossing with the pollen of another variety; or an interference with the growth of the plant; or abundant or scant nutrition: all these, of the more evident causes, are effectual. A small eared, 8-rowed Canada corn, removed to a more genial clime than where it has been grown, increases in height of plant and in length of ear; a little greater change, and the tendency to increase of rows of grain on the cob becomes manifest. An 8-rowed flint-corn, removed and cultivated in Ohio, in one instance, became, from seven years' use, closely allied to gourd seed, being much dented, and the number of rows on the cob had increased to twelve and twenty. In Louisiana, the continued cultivation of soft gourd seed-corn from the West produced a hard flint-corn with a larger cob, in twelve years. This change, which is too well recognised to require further illustration, is also accompanied by a change in the habit of growth of the plant, which is not confined to the shape, and structure, and composition of the seed, but also to the habits of maturity,—the seed from northern localities, the first year after removal, ripening earlier than the varieties native to the region, but shortly approximating the periods common to the locality. It is this fact which enables the extension of culture into localities whose temperature will not admit of the immediate transference from southern sources, but which can be entered through the gradual cultivation through intermediate stations. Thus the potatoes, which require five months for their development in Germany, are cultivated, according to Leopold von Buch, in Lyngen, two degrees beyond the polar circle, and attaining their full development in little less than three months. The feature to be noted in these cases is, that these variations, brought about through means at the control of man, become fixed in the variety.

The effects of temperature and moisture are of great avail towards changing the habits of the plant, yet from the nature of the case cannot be well separated and defined. We have observed a difference in the transpiration of water from different plants, a variation which is of extreme importance as leading to the selection of that variety which requires the least water for the processes of growth, for planting in drouthy localities, and *vice versâ*. Heat alone, moisture in sufficient quantity being present, tends to an elongation of the internode of the plant, while a diminution of temperature tends to shorten the nodes, and is suggestive of other changes in the character of the plant and its fruitage. As a general rule, for varieties of corn which are quite similar, elongation of the internodes means an influence on the ear; but there seems to be many exceptions, and the matter is worthy of further study.

The influence of hybridisation in corn is very peculiar, but always results in a change of character in the kernel. Thus we have before us an ear of a pale yellow field-variety which contains sweet-corn kernels, wrinkled, sweet, and of their proper shape. In this case the pollen has determined the development of the ovule of another variety so as to disguise completely the natural order of its development. We have another ear of a deep red corn, whereon the influence of the foreign pollen has been to modify the shape and the colour of the few kernels affected in such a manner that they seem intermediate in character between the two parentages, and in other kernels the influence of the pollination seems to be confined to distinct localities of the kernel. In these variations, these departures from the variety, we have the means at hand for further progress in an intermediate or diverse direction from either parent, because, as is too well known for argument, or even statement, the produce from these kernels would show effects resulting from this departure from the type of either parentage.

The influence of interference with the growth of the plant, in order to produce variation, seems not to have attracted the attention of authors, although of great interest. In some experiments of our own we have found that the obstruction to the flow of sap in the stalk, whether by ligature or by splitting the stalk and injuring the pith in the cross-section, has been in all cases followed by the elongation of the foot-stalk of the ear, and we have thus secured a branching corn-plant. This treatment increased the rate of growth of the plant in height, caused an earlier bloom, and increased the amount of produce over that of adjoining hills not thus treated. The removal of the upper nodes of the plant early in the season has caused a development of ears from the lower nodes, which in the variety experimented upon are universally barren as cultivated in the fields. When the leaves were cut from the ear-wrappings (not the leaf-stalks which form the husk, but the leaf extremities which are formed beyond the ear), the effect on the ear was manifested by irregularity of kernel development; when the leaves were reduced on the plant during growth to a large extent, the growth was little vigorous, the plant was stunted, and, although there was an appearance of earing, there were no ears developed into crop, but all were of the class called pig-ears. When the stalks of the plant were daily twisted until a snap could be heard, the earing was very abundant, far more so than in other plants, but all did not develop into crop. When the lower roots were all removed from a plant, by digging up the seed soon after vegetation had commenced, and cutting off all the roots below the seed (removing the radicle), the plant showed a character of growth different from that of normal plants, throughout the season, and tillered largely; one hill which had the flowering-stalks of the plants broken down at the period of bloom gave a better lot of ears, and a plumper kernel, than did another hill whose plants had the flowering-stalk entirely removed; but the number of plants thus experimented on were too few to offer results to afford data for a reliable conclusion.

We now have indicated, in a general way, how variations may be produced, giving data but from experience. We might add, from theoretical grounds, the planting of seed from peloric ears or tassels, from using mutilated seeds, or seed from mutilated plants, from butt kernels or tip kernels, from ears in abnormal positions on the stalk, or from kernels in irregular positions on the cob.

Had we no other means of arriving at a conclusion of the antiquity of maize as a cultivated plant, this very fact of its pliability towards changed conditions, and the manner of its present sportiveness, would be ample. It is indeed far removed from a wild state, and has become domesticated, if we may use the term in this connection. Its present form, in any given case or variety, has been derived from the accumulation of tendencies which have been impressed on its varied generations by the needs of corn-eating man. In those features which have attracted the attention of its growers it shows this variability. In those other features which have been overlooked, and which, if influenced at all by man, have been through correlations, the plant shows a degree of stability which it is difficult to overcome. For instance, the "Waushakum" corn-plant bears its ears on the fifth node from the first, and developes embryo ears at the five nodes counting from the first which sends forth roots. Through no effort of ours have we been able as yet to change its nature in this respect. We have succeeded in causing the ear to be developed on the fourth, or third, or second, or first, counting downward, but never on the sixth, the seventh, or the eighth. We have not been able, so far as we have observed, to change the plant from a nine-noded one or less, through manure or any other process we have as yet tried. This method of structure has remained constant, because there has been no effort in the past by any one to produce variation, as no variation in this line has promised advantage or been brought to the attention. Yet we have been enabled to vary the grain, the shape of the cob, and the habit of growth, the most readily in those directions in which a practical usefulness could be seen. Indeed the teleological argument is a fitting one as between the plant and man. In other varieties of corn we find a different arrangement of parts, and as strictly defined in the variety as in the case given. Thus a variety grown in Tennessee contains sixteen nodes in all, and the first ear appears on the fifth from the bottom, and on each intervening node up to and including the twelfth. Darling's early sweet corn produces its ears near the ground, as a variety characteristic, as does also the Narragansett, and some pop-corns we have grown. In the Southern white corn, as grown for fodder in New England, the ears develop high up on the stalk.

If we pass to intermediate characteristics, those which probably have been valued as a peculiarity of variety through many generations of culture, we find a fixity which is quite difficult to overcome except through successive efforts, if at all. Colour is perhaps the most prominent. Thus the red corn, occasionally cultivated here and there in New England, and which, although out of general culture, is tenaciously held on to by individuals, presents a fixity of type which overcomes in most instances the effect of hybridisation even in its colour. We know of instances where it is claimed for it that it does not receive hybridisation from other varieties of corn, because the colour continues, but a careful examination of those ears we have seen, and which have been grown among other corn, has shown an influence in the shape and quality of the kernel; and if in a few cases the colour has changed, or become modified, this fact but proves by its exceptional occurrence the fixity of the colour peculiarity. The red cob is another instance in point. We know that some growers place a value on this peculiarity, just as certain features of little real consequence have become valued in poultry by fanciers. We have known of instances where through hybridisation the colour of a kernel and the shape have become changed, while the cob has retained, apparently, its variety characteristic of a red colour. In the arrangement of the kernels we have a feature wherein there has been little effort to fix the number, as the benefit of a fixity of type here has not been generally recognised. Hence we find in this respect a great variability, and there are but few varieties wherein a good percentage of other numbered rows than the normal number do not appear. Scarcely a field of eight-rowed corn but what will show ten- or twelve-rowed ears to the searcher after them. Scarcely a twelve-rowed corn wherein eight-, or fourteen-, or sixteen-rowed specimens do not exist.

The means in the power of the seed-grower to improve his seed is now indicated, and their efficacy has been shown. It is not heredity; it is not that the seed will produce a plant and a seed like its parent plant; it is no new and novel proposition which has been untried, but, as shown by all the facts of experience and reasoning, it is in the accumulation of desired qualities so as to determine the character inherited; for, let us repeat, even if charged with tautology, that heredity is general in the poor and the good seed alike, in the desirable as well as the undesirable qualities, and that it is but the character of the qualities which are transmitted which concern us most intimately in our efforts to improve. To accumulate good qualities to be transmitted in the stead of less desirable qualities,—to gain even an advance this year, and again another the next, and so on continuously, is the secret of breeding. It is not the plant like the parent plant that is the most profitable, but the better plant than the parent, and all that is to be done is to cause the individual plant to vary for the better, and then to hold on to the gain by each year, each generation to fix this good quality and to add on to it, so that it shall become a characteristic of the variety or the breed. The art of selection, the practice of selection, the continuous adding and subtracting of qualities from our plant is the secret, as well as the plain common-sense of breeding. So long as law prevails and forces act, we have in our plant, in our seed as representative of the plant, the reproduction of those qualities which have been impressed upon it from the past, and by changing these qualities in the present we can pass them along through the intervention of the seed, to future generations, and thus, through the continuous additions and strengthenings, can form the plant which shall devote itself to the carrying out of our desires, and which shall in a measure eventually overcome even what at first thought we would call the design of Nature.

Thus, through selection, winter and spring wheat, which botanically have been considered distinct species, have been transformed the one into the other. The beet-sugar plant, since its introduction into cultivation for sugar in France, has had its percentage of sugar almost exactly doubled through the agency of most careful selection and testing of roots gathered to be used for the growing of seed. By selection during a course of years the early maturity of peas in Great Britain has been hastened from ten to twenty-one days. Among florists' plants the Canterbury bell was doubled by four generations of selection. The wild cabbage plant has been developed into at least ten distinct varieties through cultivation; the crab has been transformed into the apple; the sloe into the plum; the wild grape into the concord grape; the wild strawberry into the large and fine cultivated species, and each year brings numerous varieties thus gained before the purchasing public. The whole secret of all these triumphs being the production of or the seeking for variation, and then putting into action a rigorous selection.

How rapidly changes may take place in a plant through yearly variation is shown by the results of Metzger's growing of corn in Germany from foreign seed. In the third generation, in one case, nearly all resemblance to the original and very distinct parent form was lost, and in the sixth generation this maize perfectly resembled a European variety. In another case, with a "white-tooth corn," the tooth nearly disappeared in the second generation. In our own experience we find that various features of the corn plant resist acts of selection more strongly than do others. It has seemed to us that three generations of selection have sufficed to change the size of the cob and the shape of the cob; that it has had a strong influence in changing the character of the grain, but has not yet fixed it; and that it has had a less effect on the earing habit of the plant, and yet an effect which is very noticeable and persistent.

Let us now consider the corn plant alone, and see what features we desire to obtain, and what must be the principle of selection which would seem the most efficient to bring us success.

As a rule, the one feature of the plant that concerns the farmer the most is that of prolificacy. There is less difference betweeen the values of different qualities of corn grain, from a sale point of view, than there is between the yield of different varieties. Seventy-five bushels per acre of any variety grown is usually more valuable than forty bushels of another variety, and yet these figures represent actual differences which may prevail in the same neighbourhood. Hence how to increase the corn crop is an important question. This cannot be done by manuring alone, or by culture alone, but through the intervention of seed selection. If we plant a kernel of corn by itself, and dung it and care for it, we are sure to have an ear produced from it; and yet if this same kernel be planted in a field where it has to overcome disadvantages arising from the presence of other plants, and less of individual condition concentrated in itself, we are not as sure. In field culture we always find barren stalks in greater or less number, according to variety; we always find small ears—pig corn as we call them—no matter the amount of fertility; we always find perfectly formed and shapely ears scarce. This fact of non-productive plants can be proven by a calculation of the amount of grain which would be harvested from fields variously planted, *provided* each stalk furnished one first-class ear.

To plant an acre in hills $3\frac{1}{2} \times 3\frac{1}{2}$ feet distance, and four kernels in a hill, requires 14,224 kernels of corn. If each produced one stalk only, and one good ear shelling 7 ounces of corn,—not an impossible amount for a first-class ear,—the yield would be 111 bushels. If the acre be planted in drills, $3\frac{1}{2}$ feet apart, and hills every 28 inches, containing four kernels, the number of hills planted is 5335, the number of kernels 21,340, and the yield in the same supposition of 7 ounces would be 165 bushels. As a matter of fact it is not uncommon to harvest 3 lbs. of ears from a hill of three kernels, and 4 lbs. from a selected hill of four kernels, or 1 lb. of corn in the ear to a kernel planted. If we accept this as a maximum our yield would, on the suppositions above, be 355 bushels of ears (40 lbs.) and 533 bushels of ears per acre.

These calculations are not offered to show the crop that may be grown, but simply to illustrate the difference we find in practice between our ordinary yields and yields from the best hills of our field, in order to make evident the proposition that improvement in our seed-corn is needed, and that each farmer can find in his field the hint for the direction of this improvement. Whatever man can improve his seed so that every plant shall be the equal to the best of his planting has accomplished the difficult and scientific feat of the formation of a variety which is at present beyond aught that we have reached.

Now manure will not cause prolificacy to an equal extent in corn plants from various seed, as we have shown that under excessive manuring the variation in crop between sixteen hills under like treatment has been as 1 to 3¼ by weight of corn on ear, and as 1½ to 6¾ lbs. of stover per hill. Under ordinary manuring the difference has been nearly or quite as great. Under insufficient manuring the variations appear even greater. We desire to lay stress upon this fact, that manuring does not produce crop by itself, and that increase of manure is not necessarily followed by increase of crop. We know of a field which received thirty-five cords of manure per acre, and yet another field fertilised with six or seven bags of Stockbridge corn manure to the acre gave a larger and fairer yield of corn. On Waushakum farm, one rather poor (as we have considered it) piece of land, which has been heavily cropped by the aid of Stockbridge manures in past years, yielded 66 bushels of corn this year when manured with seven bags of Stockbridge fertiliser; while another field, considered our best land, manured with about 5½ cords of clear cow-dung and six bags of Stockbridge fertiliser, yielded 66 bushels (or exactly 131⅓, and 132 baskets of 41 lbs., respectively, per acre). Hence manure is but an element, an important one, but not sufficient in itself to furnish us large increase of crop.

Will cultivation do it? We can say also the like for our culture, that it is an important factor in the improvement of corn, and yet is not all-sufficient, being but a factor. In an experiment to determine this we took a suitable plot of ground, and manured it most excessively, so as to eliminate by the abundance of fertility the specific effect of the manure in producing differences between the yields (some forty-two cords of cow-dung per acre, besides abundant chemical fertilisation), and planting in hills 4 × 4 feet apart, three kernels to each hill, using selected corn and equivalent conditions of planting: we had three plots, each containing sixteen hills. Plot I. received no culture whatsoever, the weeds being pulled by hand. Plot II. was hoed thoroughly and frequently during the season. Plot III. was weeded by hand, as Plot I., but a knife was run vertically around each hill to the depth of 6 or 7 inches, at various times during growth. The following are the results of harvest;—

TABLE I.

	No. of hills.	Weight of corn in ear.	Weight of fodder.	Proportion of ear-corn to fodder.	No. of ears.	Length of ears.
Plot I.	16	29¼	72	1 ; 2·46 lbs.	86	643¾ ins.
„ II.	16	37¼	81	1 : 2·17 „	92	752 „
„ III.	16	33¾	48¾	1 : 1·44 „	104	774 „

TABLE II.

	Total No. of ears.	No. of good ears.	No. of fair ears.	No. of poor ears.	Ears good as seed.	Merchantable ears.
Plot I.	86	38	6	42	2	44
„ II.	92	57	13	22	5	70
„ III.	104*	47	22	35	26	69

We can study this table with advantage, as there is shown an influenee of cultivation upon the ear and upon the crop, which conforms to the general experience of farmers, and hence is undoubtedly a true and not an exceptional influence.

It is to the selection of the seed that we must look for the important factor, which manure and cultivation shall act upon to give the largest possible result. As a rule, seed has been selected with reference to the grain, and not with reference to the plant. We hence find many varieties of corn with grain of superior quality and ears of fair appearance, but the appearance of the ear gives us but little clue to the prolificacy of the plant. In our own experience we have had the results from seed corn from similar ears vary as 2 to 1, or as an actual result 55 bushels of grain per acre from the one, and 110 bushels from the other, under equivalent conditions of treatment. It is to the corn plant that we must look first in the improving of seed corn through selection, and we must bear in mind continuously the principles of breeding, remembering that by a law of nature the seed *must* transmit the tendencies it has itself inherited and acquired.

If there is one principle of breeding which is more fully and satisfactorily determined than another, it is that of the survival of the fittest. That animal or plant which is best fitted to overcome obstacles is the one which in the long run will succeed in establishing itself and its race. If we desire to modify individuals of either class, animals or plants, we by our interference furnish them advantages which aid them in overcoming, or prevent them from coming into conflict with the competition which they cannot endure. Thus our corn plant is protected during growth from competing for the possession of the ground with weeds; it is aided and encouraged through the furnishing of conditions suited to root-extension by means of the plough, the harrow, and the cultivator, &c. If we study the corn plant with reference to

* Three ears of large size too much affected by smut to count in the harvest. On Plot I. considerable smut, but none to destroy the ears. On Plot II. less smut, but no ears destroyed.

its parts, we find the same rule to apply. If we encourage an excess or produce a deficiency of leaf surface, the grain suffers from our interference. If we examine into the physiological structure of the stalk, we find that nature has provided the embryos of many ears, but that in the ordinary course of events, one ear, usually the upper one, develops, attracts to itself through its superior vitality the nutriment from the stalk, while the lower embryos are apparently unable to struggle against this prepotency of the one, and starve. We can state as facts that in a field where the average productive stalk yields but one ear, and this the upper one, its removal will cause the next lower to develop and form the crop; and thus by our interference we can cause the one to develop which we shall aid by removing its competitors in the struggle to secure the advantage.

What conclusion, then, can be logically derived from what we have stated?

1st. It seems to us clear that our first effort for the improvement of seed corn is to remove the changes which come through the hybridising of the corn by pollen from infertile stalks, as thus confining the heredity each year within the lines of productive parents, and thus bringing the heredity to act stronger and stronger in the way most agreeable to our profits. This is one species of selection, one influencing of variation, the selecting of prolific parents, and the causing thereby of variation in the direction desired. This has now been practised for two years with the "Waushakum thoroughbred corn," and the effects are strongly evidenced already, while the show for a still greater improvement is very promising. The inheritance or transmissal of qualities is always present in a seed, but we are securing the transmissal of good qualities, and eliminating the bad qualities—meaning good and bad in their relations to man—by this most influential and important method of selection.

2nd. The next direction for selection, as taught by these principles we have referred to, is of the ear. It is of advantage to select seed from plants which develop twin ears, but as the influence of cross-fertilisation as usually allowed by the grower, is to introduce a tendency to barrenness, this way of improving our yields of corn is slow in practice, and possesses an element of uncertainty which should be eliminated. In using seed of a strong tendency towards developing two ears to a stalk, we obtain perhaps the two ears, but the kernels on these two ears, perhaps, are fertilised by pollen from a plant which does not develop any ear at all; the seed thus grown has a divided quality; it inherits from the mother plant a tendency towards fruitfulness, and from the father plant the tendency to barrenness, and according to the prepotency of either must the result be. While there is therefore a usefulness in the taking of seed corn from a twin-eared plant, this method of selection must be secondary to the first, so long as barren stalks abound in our fields and furnish pollen.

3rd. There is another method of selection which has a relationship to the 2nd, and which has not in practice, so far as we have observed, received the attention which its theoretical importance would seem to warrant. This is the influence of the position of the ear. The upper ear of the stalk, in many of our New England field varieties certainly, and doubtless in the majority, has a prepotency which enables it to develop normally at the expense of the lower embryo ears. Under moderate or poor manuring, this ear (if any) always, so far as we have critically observed, develops, and none others; under better manuring, a second ear, and always, so far as our observation extends, the one immediately below the upper one may develop, but it is probable will not be the equal to the first: under heavy manuring, a third, or even a fourth, may develop, but the quality is apt to deteriorate as we proceed from the top. This series of facts, if facts they are, indicate that the prepotency of the ears decreases as they occupy positions nearer to the ground. In the selection of seed-corn, therefore, we should endeavour to secure the lowest ear on the stock for seed purposes, as we thus are using seed which by overcoming the difficulties of position has proved itself to have great prepotency and vigour, and as the prepotency increases as we go upward, the selection of the lowest ear gives us the advantage of, as well as selecting, a prepotency of position which shall affect the development of all the ears which grow above it, or a plant prepotency, with reference to its seed bearing qualities, as well as the one prepotency we have selected for continuance.

We thus have indicated the three guiding selections which should be the careful concern of the seed-breeder. How long it shall take to secure the fixity of these qualities by continuous selection we cannot say with certainty for any given case, but for limits we have slight reasons for supposing seven and sixteen years. We know from experience that three years only are productive of recognised benefits.

The character of the grain and its arrangements on the cob, the length of cob, &c., are minor objects for the breeder's care, as requiring less time to fix, as being most readily apprehended, and as showing results so quickly as to encourage continued efforts. These minor characters can usually be fixed by three years of selection, if any variety of ordinary culture be worked on, and if the changes desired are not outside of the fixed characters of the variety. If we shall attempt to change a field corn into a sweet corn through other selections than those influenced by hybridisation between the two, or *vice versâ*, we shall have difficulty, perhaps shall fail, most probably shall not succeed. We can always place our efforts most successfully where the plant experimented on indicates by the nature of its variation the direction for us to act. Do we wish to change an 8-rowed corn into a 12-rowed corn? We shall do it more readily with a variety that presents frequent variations from the 8-rowed form, than with another where this variation seldom occurs. Do we wish to diminish the proportion of the cob to the grain? We can do this more readily with a variety where the proportion already existing is far from uniform, than with another variety where the proportion is quite uniform. Do we wish to lenghthen our ears? We can do this the more readily with a variety which varies greatly in the number of ovaries in line on the cob, than with another which presents a more uniform number, &c.

We believe that by the proper selection of varieties to be used as a beginning to work from, that we can so far offset the influences of climate as to grow a flint corn into a dent corn, or *vice versa*; a pop-corn into a field corn; a yellow corn into a white corn; a flat corn kernel into a rounded kernel; a deep-kerneled corn into a shallow-kerneled corn; an 8-rowed corn into a 10, 12, 16, or more, rowed corn; a large cob into a small cob; a short cob into a long cob; an ordinary variety of corn into a branching variety, &c. We believe that the corn ear can be removed, through selection, from the upper node to an intermediate one; can be borne on branches either terminal or axillary; can be transferred to the tassel, &c. In a word, that under the axiomatic law of inheritance, or the transmissal of forces, the process of selection will produce these changes we have indicated.

What kind of corn should the New England farmer seek to develop? First and last, one possessing prolificacy, as being the most important quality and the most difficult to be attained. Then smallness of cob, as being a correlative with the stalk (to be used and found exceedingly valuable as a forage plant if small and thus easily cured) and as having a direct bearing on the storage of the crop. A small-cobbed corn can be binned in larger piles and earlier in the season than a coarse-cobbed corn, with less danger from mould, and is earlier to be husked and earlier to be binned, and earlier to be shelled and marketed, on account of the small cob drying out its moisture more readily and quickly. Then length of ear, as diminishing the labour of husking. Then depth of kernel and closeness of packing on the cob, a most evident economy. Then uniformity of kernel, as adapting the grain to more varied uses. Then colour, as having a relation to ease in marketing, because if one coloured corn sells more readily than another coloured corn, it is more desirable to be grown.

We would also call attention to the importance of securing adaptability to climate, and to the farm. This can be obtained by closely watching the corn of the farm, and using the evident changes produced by the locality to influence our selection. If there is a difficulty in keeping a 12-rowed variety from changing to an 8-rowed variety; that is to say, that if the 8-rowed ears are constantly appearing in the crop planted from a 12-rowed seed, then it is probable that your selection had better be towards the 8-rowed variation, rather than attempting to retain the 12-rowed.

The improvement of seed corn through systematic effort, guided by careful study of what facts we possess, has scarcely yet attracted the attention it deserves. Success, it seems to us, can be hoped for, and he who undertakes it understandingly must win some degree of success, sufficient at least to amply repay for the trouble and care, besides the satisfaction which shall attend the effort. It is for farmers to assist such an effort by demanding good seed, and by paying for good seed a price sufficient to remunerate the grower.—*From the Report of the Secretary of Conn. Board of Agriculture*, 1878.