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THE SURVIVAL OF THE UNLIKE[1]

SOME years ago, studying the agaves or century plants of the West Indies, I found that they represent not only many species but numerous rather distinct groups, and that the aggregates of individuals that we call species, and of species in these larger groups, resemble and differ from one another in a sort of proportion to the depth of water between the islands on which they are found, which was translated into differences somewhat proportionate to the length of time that their habitats have been separated by water barriers.

Those of near-by and apparently rather recently separated islands were not found to differ progressively and adaptatively in a single character such as flower-shape or size of seed-vessels nor was there a correlated difference in these respects, but sometimes one and sometimes another such character was different, while no indication was evident that the plants were not living under essentially identical conditions so far as pollination and dissemination are concerned.

When the idea of organic evolution was presented before the Linnean Society in 1858 in a convincing way, by Darwin and Wallace, the latter spoke of the process as a survival of the fittest, and the former, as the result of natural selection, in the struggle for existence which effects kinds or species as well as individuals of living things.

The dissociation of parts of the ancestral stock of these West Indian agaves without any marked climatic difference in their homes appeared to me to have left each final island with a stock essentially in harmony with its environment and capable of deviating considerably in flower and fruit proportions from

[1] Address of the president before the Illinois Chapter of the Society of the Sigma Xi, May 19, 1920.

the parent type without derangement of this harmony. I was unable to see that either flower or fruit change within the observable limits rendered its possessor either better or less fitted to survive. Deviation from the type appeared to have followed some innate tendency and to have been possible in quite different directions within rather wide limits without rendering its possessor either more or less fit to survive. Within such limits, the changes of form seemed to have been free to wander at will along a number of differentiating paths.

These plants apparently illustrate the survival of the equally fit, though unlike, rather than of the fittest whether alike or dissimilar, under the operation of Darwin's selective process which would weed out promptly those not really fit to meet the general conditions of life, while permitting secondary differences to appear and persist for a very long time.

This is a rather self-evident presentation of one of the physiologist's exasperating troubles, the controlling existence of a harmonious optimum as he calls it, in conformity with which his cultures succeed best under conditions that sometimes differ annoyingly from those that he has reason to believe are the optima for the individual functions that he wishes to investigate experimentally one by one. It recalls forcibly, though not paralleling, the dominance of certain features in unskilfully made composite photographs. It parallels the transformation of that peculiar function, productive investigation, to the promotion of which the society of the Sigma Xi devotes its efforts. Conditions being collectively favorable, many differences that appear, whether fluctuating or mutant, represent variation rather than real evolution.

Apt in aphorisms, Bailey once hit on the expression survival of the unlike for that outcome of natural selection or the survival of the fittest to which the name evolution usually is applied. It calls up the picture of a changing or changed environment which eliminates the harmoniously fit of the past and allows their successors of the present to fight it out among themselves for the final perpetuation or disappearance of individual idiosyncrasies that they may have inherited or acquired.

The organic change may or may not be abrupt because the change in environment may or may not have been sudden: very commonly it appears to have been gradual. Its product may or may not please us. Except through the artificial selection that we apply in the broad field of agriculture, we have not intentionally changed the controlling conditions. The great response of organic nature is not conformed to our wishes or ideals but to that innate law of living matter that compels it to perpetuate itself and the forms through which it may best do this. The product is as varied in effectiveness as in form, but it tends to efficiency in peopling the earth and in making use of by-products and waste as well as of the raw materials offered by inorganic nature.

The lesson of organic evolution is at once discouraging and hopeful: discouraging as showing that the individual or the kind that can not keep to the gait must fall out of the procession; encouraging as showing that keeping the pace is not necessarily keeping in step; and hopeful in that as the world of dead matter changes, the world of living matter effectively shifts its life processes and vital machinery toward ultimate conformity to the great opportunity that is its own for the moment—a conformity which if perfect would eliminate finally disharmonies, and realize a perfect teleology of self-contained adaptation.

Even inert matter is coming more and more to evolutionary recognition, as its heavier elements are found to be older and more complex, their unaided combinations to tend into an instable complexity that approaches the surpassingly labile living matter, and their dissociated particles to gather through unmeasured space into solar systems perhaps all at some time as capable of supporting life as our own is known to be at present. The greatest law of nature seems to be that of spontaneous aggregation of matter into complex forms and of the shaping of these into efficient forms.

We are given now to naming our chosen activity—whether in science, literature, history or art—research, and the dictionaries permit each of us who cultivates it productively, to be spoken of as a researcher. I do not like the words: the second is not euphonious to my ear; and the first is too suggestive of the cyaniding of the tailings of an abandoned mine or of the sifting of what may be called variously a dust-bin or an ashpile. Unfortunately it is true that neither mining nor furnace management nor refuse collection is exhaustive, and re-search of their refuse must be made over and over again as values change or methods are improved. But I like to think of our profession as that of investigation and of our colleagues as investigators —trailing the truth wherever it must be sought—through the débris left by our predecessors when necessary, but by preference in the virgin field of nature.

This profession in its history parallels in many ways that of a phylum of plants or of animals. It has had its days of fruitless aimlessness; some of its products appear grotesque to us of to-day; some of its branchlets, like those of a cottonwood or an elm in autumn, have been cast off, perhaps to the benefit of the whole, when they did not continue to produce in proportion to their early promise or in comparison with others more favorably enviroined. Some, too favorably circumstanced, may even have been pruned out as unfruitful or destructive of a collectively effective balanced symmetry because of their rank vegetation. Natural and artificial selection have worked on it since its beginning, and there is little reason to suppose that they will not continue operative until its end.

The parallel may be carried somewhat further than one would carry it at first thought.

Long before man began to find the products of organic nature profitable—indeed long before his appearance on the scene—plants had developed the power of making food and of applying it to their needs; and animals had acquired the habit of carrying its use into a much more dynamic field. The greatest tilth of this field is by man, the present culmination of the family tree of our living world; and what the struggle for existence among his more lowly relatives had produced, that he could use, he has selected and favored and modified to his greater benefit.

The strife between purposeful intelligence and productive capability, in which within limits the former is fore-ordained to dominate the latter, is not peculiar to human civilization and to the dominance of man over man: it reaches far into his relations with his fellow-creatures of lesser endowment. He has shaped them to his needs or fancies, very often in opposition to the selective law of nature; he has multiplied, at the expense of others, those that he fancied, and thereby has increased the power of the earth to support human life and human activity far beyond its unaided capacity; he has become a potent factor in natural selection, and will continue operative as long as he does not kill the goose that lays the golden egg. It is significant that what he does not use, directly or indirectly, he commonly permits to exist through indolence or impotence rather than tolerance.

He knows that what he calls vermin are troublesome if not injurious. He protects himself and what he considers his property against them more or less consistently and completely; but in proportion to their power to evolve helpfully in harmony with conditions of life in the chinks and crannies of the world into which he can not or does not follow them, they escape and thrive not only despite him but at his expense and literally on him. The rat is his uninvited guest the world over, and the gray rat, if he were worshipful and learned, would render daily thanks to the patron who has made him the rat of rats, transporting, housing and feeding him to an almost unbelievable extent. Rust, smut, mildew, and fermentative germ thrive under his régime; the world population of codling moth and chinch bug has enlarged a myriadfold through the ability of these self-seeking creatures to get forward as riders on man's own self-seeking progress.

Perhaps in this survival and increase of parasites and other vermin lies the token that

the earth and the fulness thereof are not to man; for if the Nature whose product he is permits his enemies to thrive and multiply notwithstanding his effort to protect himself, she gives in this permission a strong suggestion that his power is only an expression of her own power, and that while he sleeps and relaxes effort her activity continues unabated along the line of peopling the earth toward its full capacity with a million forms of creatures to each one of which she offers the same fundamental problem as his own—perpetuation of the individual and of its kind, or restriction and disappearance, according to its fitness and adaptability under the conditions of the moment.

We owe the privilege of wearing the key of the Sigma Xi to the fact that at some time or other each one of us has been recognized by investigators as something of a zealot in their own field, giving promise or bearing the first fruits of his own investigation. In our turn, we welcome to companionship the brothers of a newer day.

Most of us enter this fellowship from the novitiate of university life under guidance and supervision. The founders of the society, themselves, had achieved in college or professional school the qualifications that they prescribe for membership. Their forerunners in investigation through the centuries, for the most part had traveled the same route. Our organization is represented in laboratories rather than in the halls of classic learning.

Those of us who have been connected with the society very long have no difficulty in calling to mind a number of men of our own or an earlier or a later generation, whose lot has not been cast in with the university or the college, but who in purposeful prying into science have shown the zeal that our society stimulates and who in productive and stimulating accomplishments may have surpassed us of seemingly greater opportunity. Those who initiated the inquiry into nature out of which such enormous knowledge and utility have poured into the lives of men within the last few generations, trained themselves or founded the schools in which others have been trained. Their zeal and industry and wisdom were the attributes of the highest human mentality: often, but unfortunately not always, infectious; exceptionally, and this happily, of such quality as to confer immunization on those who came into closest contact with them.

Like other forms of human social development, the specialization of investigators offers many parallels to the specialization of organs and of organisms in nature. Its beginnings were very individualistic and sporadic. Its spread was limited by the natural barriers of sea and mountain, and the quite human obstacles of differing race and language. Investigation usually has meant not a road leading to a successful career—as the animal success of man is measured, but a bypath more often leading to poverty and misunderstanding, and usually at best a way that could not be traveled safely very far from the beaten path of approved and utilized learning. My own university mentor, Farlow, like his great leader, Asa Gray, studied in the practical field of medicine so that he might be assured of the privilege of wandering—nobody could tell how far—into investigation apart from its immediate application in a necessary art.

No doubt it is true that to some investigators the thought that no practical application could be made of their discoveries has lent added fascination to their work. No doubt to others an investigation undertaken with the purpose of securing the answer to an economic question still lacks in attractiveness. The greatest incentive to such work has been an innate thirst for knowledge for its own sake and a love of its pursuit.

Even with the multiplication and broadening and deepening of universities that the last generation has witnessed, the privilege of adding to knowledge, of shaping something up by one's own effort, has resided very largely in the opportunity offered by a university chair for stealing a little time and a little effort from the first and paramount duty of the professor, teaching what is known already and training adaptable minds to meet life's needs.

Even to-day and among our own friends are to be found men who fail to see that the university that we know not only watches with some care over teaching schedules so that the man who wishes to follow productive lines in his scholarship may not find that he has no time left for this after completing his prescribed task as a teacher, and who fail to comprehend that one is misplaced in a true university if he can merely retail what others have made known.

As yet, most of us who have been judged worthy of membership in the society of the Sigma Xi have acquired our status as investigators as a byproduct of our opportunity as teachers; for what are called research professors are few and far between, and organizations for investigation only are none too common. We find encouragement in the stimulating fraternal association. We touch at a tangent the productive activities of colleagues in our own department or in related departments. We lay our little offerings before local or state or national gathering of our confreres, and come home with suggestions for bettering and amplifying our own activities. We get what we may out of an undigested and heterogeneous program, and give little thought to the assimilability in it of what we contribute to it.

We are individualistic to a surprisingly large degree. As a rule we are generous to a fault with what we have to offer to others and as a rule we are not greedy in seizing on such help as they offer to give to us; above all we are not markedly seekers after advice or direction. We enjoy the prerogatives of the present, but cling to the methods of the past.

From the time when learning awoke after the world's long sleep, when civilization began really to have meaning outside of very restricted circles, the occupation that has become our profession has resembled my Antillean century plants in following its inherent bent. The conditions of its environment have presented an increasingly harmonious optimum for its simple existence, with neither serious competition nor any great obstacle interposed anywhere to its drift along the lines of least resistance—or in this case of greatest attractiveness. That conditions have changed is evident enough, but they have changed gradually and the changes have been in favoring directions.

The aggregate utility of what is called research had led, even, to its sedulous cultivation in a limited way: but even under cultivation it has shown few mutations unfitting it for continued existence if once more thrown over to the unrestricted action of natural selection. It has scarcely become domesticated. Its survival and increase have been of the fit rather than of the fittest, where change about us has been gradual and of degree rather than of kind, and where neglect rather than encouragement have favored it. It has resembled the wayside weed doing too little harm to be worth repression, and more or less useful for fodder or bedding-down when the trouble was taken to harvest its produce.

Almost suddenly we are confronted with totally different environing conditions. The last decade has seen an interest in scientific investigation that was unknown before. The period of the war has brought its real value to recognition. The harmless weed has been seized on as most promising for intensive cultivation. Its natural attributes are being selected and blended with a skill such as the agriculturist uses in bettering his crops and his stock. Its maximum development is favored by a more or less serious effort to remove or reduce disturbing competitors. The stigma that science, the organizer of knowledge, has not organized itself seems about to be removed.

"Tempora mutantur, et nos, in illis." The almost catastrophic changes that the last few years have brought into the human world is placing scientific research on a business basis. It is not too much to expect great things from its effective organization as a means to an end: or to expect it to yield quickly in orderly controlled team play results that individual fatuous effort could bring about slowly and disconnectedly if at all.

Is science capable of transplantation and cultivation under artificial conditions? If so, the product will differ from the original in kind as well as in degree quite as much as the highly specialized animals and plants of the farm do from their undomesticated prototypes. If so, its nature will have shown a plasticity to be looked for in nature hardly elsewhere than in the outgrowth of human intelligence.

Transplantation is actually at work. The investigating manpower of the world is being registered with startling rapidity, preliminary to preferred enrollment or selective conscription. There is scarcely a person here present who will not feel its force within a few years if the signs of the times are to be trusted. To the organizer, it promises new and enlarged opportunity for leadership. To the drudge it holds opportunity for the kind of shoulder-to-shoulder effort before which mountains crumble and the bowels of the earth yield up their secrets; but the drudge by birth is a rara avis among men moved by the real spirit of investigation, and the drudge from necessity is neither a happy nor always a profitable artefact.

That the new order will survive is almost certain. That its survival will be through artificial rather than natural selection is probable. That it will be a survival of the unlike is self-evident.

That waifs and escapes from it will be found outside the cultivated fields is to be expected. Whether these shall profit the gleaner like strays of wheat, or foul the fleece like the carrots of the roadside, or prove all but baneful like the reverting parsnip, remains to be proved. In any event, if not destroyed, they may be counted on through the centuries to furnish vestiges of the old and primitive stock as rudiments for a new start when, if ever, the cultivation of research is abandoned—provided that the present cultivation is not so intensive as to destroy them utterly.

In the primitive desultory gratification of human interest in human environment lies the essence of investigation for investigation's own sake. The amateur in science has entered, occupied uncontested the center, and is passing from the scene.

The largest creel of fish may be secured by seining or dynamiting or drugging the pool; and the largest bag of birds, by the skilful use of a net on a drizzly day. The market, unless glutted, will pay for the haul. But the sportsman does not wish to become a pothunter, and the naturalist knows that game must be protected to a reasonable extent if fishing and hunting are to continue and if sportsmanship is to endure. Forest and mine are most attractively exploited by organized onslaughts that take what it pays to take and sometimes leave a wake of destruction behind. The profit of the day is great, the rapid material progress to which it contributes is held to justify the attack: but what of the future?

Organization of attacks on the secrets of nature differ from organization of attacks on the material products of nature in this very essential respect, that the former do not destroy but rather bring the world's material resources to more effective and economic utilization. But is such purposeful organization likely to hamper or put an end to unorganized though purposeful and intelligent investigation? Is the seiner likely to foul the pool or barricade it against the sportsman?

Organization backed by a probable profit and loss sheet and a program for each enterprise—once called a proposition, and now a project—enlists capital in business. Such organization and reinforcement are enlisting already, for research, capital looking to ultimate return, and also impersonal endowment because of the established repute of science as conducing to the general welfare of man.

To the investigator, investigation may become a renumerative profession when he bears his alloted share in cooperative effort. For the most part, up to the present he has paid amply for the privilege of doing such work; and to enjoy the privilege of doing it even on these terms he has rather gratefully if sometimes complainingly sold his services

as a teacher at a ridiculously low figure when measured by his training and talent.

He has done and is doing this under the spur of that most intangible but most essential trait of man that we call character, and because of those chimæras of the mind of man that we call ideals. Is he sanely enough balanced to conform his ideals to the trend of the times, to the chance for subordinating them to the broader plans of leadership; or are ideals never ideals when his own mind does not shape them, when from sport—which one pays for, they become work—for which one is paid? And if the zealot who can not modify his view still continues in our midst, as he must, is he to be weeded out; or allowed on sufferance to occupy the waste places of research; or to be kept purposefully from extermination, against a day when the nourishing hand of society may be withdrawn, and zeal in research again becomes synonymous with its primal meaning—devotion with all one's character to one's inborn ideal?

As we, the professionals in science who follow the amateur on to the stage, find ourselves marshalled in the ranks or leading the artisans of science, it may be well to remember that a Galileo, a Newton, a Berzelius and a Darwin lived and worked—not in vain—before the day of organization and intensive team work had dawned!

WILLIAM TRELEASE
THE UNIVERSITY OF ILLINOIS

THE STRUCTURE OF THE HELIUM ATOM

ACCORDING to the model which Bohr proposed in 1913, the helium atom consists of two electrons moving in a single circular orbit having the nucleus at its center. The electrons remain at the opposite ends of a diameter and thus rotate in the same direction about the nucleus. The angular momentum of each electron is assumed to be $h/2\pi$, where h is the quantum constant. The ionizing potential of helium calculated by this theory is 28.8 volts. Recent experimental determinations by Franck and Knipping have given 25.4 ± 0.25 volts. Bohr's theory is approximately right but does not give the true structure.

For the hydrogen atom and helium ion, atoms containing but a single electron, Bohr's theory seems to be rigorously correct. For atoms containing more than one electron there are many facts which indicate that modifications or extensions are needed.

The chemical properties of the elements, particularly the periodic relationships and the phenomena of valence, have shown definitely that the electrons are not in general arranged in coplanar orbits. According to the theory which I advanced last year, the electrons in their most stable arrangements move only within certain limited regions about the nucleus, each of these cells containing not more than two electrons. The atoms of the inert gases were found to have their cells arranged symmetrically with respect to an equatorial plane, no electrons however ever lying in this plane. According to this view, the two electrons in the helium atom should not move in the same orbit but in separate orbits symmetrically located with respect to the equatorial plane. The two electrons in the hydrogen molecule (and in every pair of electrons which acts as a chemical bond between atoms) must be related to one another in the same way as those of the helium atom.

The most obvious model of this type is one in which the two electrons move in two circular orbits in parallel planes equidistant from the nucleus. By properly choosing the diameters of the orbits, the force of repulsion between the electrons is compensated by the component of the attractive force of the nucleus perpendicular to the plane. This model however proves impossible as it gives a negative value (-5.8 volts) for the ionizing potential.

A. Landé[1] has recently proposed a model for the eight electrons of an octet in which each electron occupies a cell bounded by octants of a spherical surface. The eight electrons move in such a way that their positions are symmetrically placed with re-

[1] *Verh. d. phys. Ges.*, 21, 653, October, 1919.