

The Method of Multiple Working Hypotheses

With this method the dangers of parental affection for a favorite theory can be circumvented.

by T. C. Chamberlin

As methods of study constitute the leading theme of our session, I have chosen as a subject in measurable consonance the method of multiple working hypothesis in its application to investigation, instruction, and citizenship.

There are two fundamental classes of study. The one consists in attempting to follow by close imitation the processes of previous thinkers, or to acquire by memorizing the results of their investigations. It is merely secondary, imitative, or acquisitive study. The other class is primary or creative study. In it the effort is to think independently, or at least individually, in the endeavor to discover new truth, or to make new combinations of truth, or at least to develop an individualized aggregation of truth. The endeavor is to think for one's self, whether the thinking lies wholly in the fields of previous thought or not. It is not necessary to this habit of study that the subject-material should be new; but the process of thought and its results must be individual and independent, not the mere following of previous lines of thought ending in predetermined results. The demonstration of a problem in Euclid precisely as laid down is an illustration of the former; the demonstration of the same proposition by a method of one's own or in a manner distinctively individual is an illustration of the latter; both lying entirely within the realm of the known and the old.

Creative study, however, finds its largest application in those subjects in which, while much is known, more remains to be known. Such are the fields which we, as naturalists, cultivate; and we are gathered for the purpose of developing improved methods lying largely in the creative phase of study, though not wholly so.

Intellectual methods have taken three phases in the history of progress thus far. What may be the evolutions of the future it may not be prudent to forecast. Naturally the methods we now urge seem the highest attainable. These three methods may be designated, first, the method of ruling theory; second, the method of working hypothesis; and, third, the method of multiple working hypothesis.

In the earlier days of intellectual development the sphere of knowledge was limited, and was more nearly within the compass of a single individual; and those who assumed to be wise men, or aspired to be thought so, felt the need of knowing, or at least seemingly to know, all that was known as a justification of their claims. So, also, there grew up an expectancy on the part of the multitude that the wise and the learned would explain whatever new thing presented itself. Thus pride and ambition on the one hand, and expectancy on the other, developed the putative wise man whose knowledge boxed the compass, and whose acumen found an explanation for every new puzzle which presented itself. This disposition has propagated itself, and has come down to our time as an intellectual predilection, though the compassing of the entire horizon of knowledge has long since been an abandoned affectation. As in the earlier days, so still, it is the habit of some to hastily conjure up an explanation for every new phenomenon that presents itself. Interpretation rushes to the forefront as the chief obligation pressing upon the putative wise man. Laudable as the effort at explanation is in itself, it is to be condemned when it runs before a serious inquiry into the phenomenon itself. A dominant disposition to find out what is, should precede and crowd aside the question, commendable at a later stage, "How came this so?" First full facts, then interpretations.

Premature Theories

The habit of precipitate explanation leads rapidly on to the development of tentative theories. The explanation offered for a given phenomenon is naturally, under the impulse of self-consistency, offered for like phenomena as they present themselves, and there is soon developed a general theory explanatory of a large class of phenomena similar to the original one. This general theory may not be supported by any further considerations than those which were involved in the first hasty inspection. For a time it is likely to be held in a tentative way with a measure of candor.

With this tentative spirit and measurable candor, the mind satisfies its moral sense, and deceives itself with the thought that it is proceeding cautiously and impartially toward the goal of ultimate truth. It fails to recognize that an amount of provisional holding of a theory, so long as the view is limited and the investigation partial, justifies an ultimate conviction. It is not the slowness with which conclusions are arrived at that should give satisfaction to the moral sense, but the thoroughness, the completeness, the all-sidedness, the impartiality, of the investigation.

It is in the tentative stage that the affectations enter with their blinding influence. Love was long since represented as blind, and what is true in the personal realm is measurably true in the intellectual realm. Important as the intellectual affectations are as stimuli and as rewards, they are nevertheless dangerous factors, which menace the integrity of the intellectual processes. The moment one has offered an original explanation for a phenomenon which seems satisfactory, that moment affection for his intellectual child springs into existence; and as the explanation grows into a definite theory, his parental affectations cluster about his intellectual offspring, and it grows more and more dear to him, so that, while he holds it seemingly tentative, it is still lovingly tentative, and not impartially tentative. So soon as this parental affection takes possession of the mind, there is a rapid passage to the adoption of theory. There is an unconscious selection and magnifying of the phenomena that fall into harmony with the theory and support it, and an unconscious neglect of those that fail of coincidence. The mind lingers with pleasure upon the facts that fall happily into the embrace of the theory, and feels a natural coldness toward those that seem refractory. Instinctively there is a special searching-out phenomena that support it, for the mind is led by its desires. There springs up, also, an unconscious pressing of the theory to make it fit the facts to make them fit the theory. When these biasing tendencies set in, the mind rapidly degenerates into the partiality of paternalism. The search for facts, the observation of phenomena and their interpretation, are all dominated by affection for the favored theory until it appears to it author or its advocate to have been overwhelmingly established. The theory then rapidly rises to the ruling position, and investigation, observation, and interpretation are controlled and directed by it. From an unduly favored child, it readily becomes master, and leads its author whithersoever it will. The subsequent history of that mind in respect to that theme is but the progressive dominance of a ruling idea.

Briefly summed up, the evolution is this: a premature explanation passes into tentative theory, then into an adopted theory, and then into ruling theory.

When the last stage has been reached, unless the theory happens, perchance, to be the true one, all hope of the best results is gone. To be sure, truth may be brought forth by an investigator dominated by a false ruling idea. His very errors may indeed stimulate investigation on the part of others. But the condition is an unfortunate one. Dust and chaff are mingled with the grain in what should be a winnowing process.

Ruling Theories Linger

As previously implied, the method of the ruling theory occupied a chief place during the infancy of investigation. It is an expression of the natural infantile tendencies of the mind, though in this case applied to its higher activities, for in the earlier stages of development the feelings are relatively greater than in later stages.

Unfortunately it did not wholly pass away with the infancy of investigation, but has lingered along in individual instances to the present day, and finds illustration in universally learned men and pseudo-scientists of our time.

The defects of the method are obvious, and its errors great. If I were to name the central psychological fault, I should say that it was the admission of intellectual affection to the place that should be dominated by impartial intellectual rectitude.

So long as intellectual interest dealt chiefly with the intangible, so long it was possible for this habit of thought to survive, and to maintain its dominance, because the phenomena themselves, being largely subjective, were plastic in the hands of the ruling idea; but so soon as investigation turned itself earnestly to an inquiry into natural phenomena, whose manifestations are tangible, whose properties are rigid, whose laws are rigorous, the defects of the method became manifest, and an effort at reformation ensued. The first great endeavor was repressive. The advocates of reform insisted that theorizing should be restrained, and efforts directed to the simple determination of facts. The effort was to make scientific study factitious instead of causal. Because theorizing in narrow lines had led to manifest evils, theorizing was to be condemned. The reformation urged was not the proper control and utilization of theoretical effort, but its suppression. We do not need to go backward more than twenty years to find ourselves in the midst of this attempted reformation. Its weakness lay in its narrowness and its restrictiveness. There is no nobler aspiration of the human intellect than desire to compass the cause of things. The disposition to find explanations and to develop

theories is laudable in itself. It is only its ill use that is reprehensible. The vitality of study quickly disappears when the object sought is a mere collocation of dead unmeaning facts.

The inefficiency of this simply repressive reformation becoming apparent, improvement was sought in the method of the working hypothesis. This is affirmed to be *the* scientific method of the day, but to this I take exception. The working hypothesis differs from the ruling theory in that it is used as a means of determining facts, and has for its chief function the suggestion of lines of inquiry; the inquiry being made, not for the sake of facts. Under the method of the ruling theory, the stimulus was directed to the finding of facts for the support of the theory. Under the working hypothesis, the facts are sought for the purpose of ultimate induction and demonstration, the hypothesis being but a means for the ready development of facts and of their relations, and the arrangement and preservation of material for the final induction.

It will be observed that the distinction is not a sharp one, and that a working hypothesis may with the utmost ease degenerate into a ruling theory. Affection may as easily cling about an hypothesis as about a theory, and the demonstration of the one may become a ruling passion as much as of the other.

A Family of Hypotheses

Conscientiously followed, the method of working hypothesis is a marked improvement upon the method of the ruling theory; but it has its defects--defects which are perhaps best expressed by the ease with which the hypothesis becomes a controlling idea. To guard against this, the method of multiple working hypotheses is urged. It differs from the former method in the multiple character of its genetic conceptions and of its tentative interpretations. It is directed against the radical defect of the two other methods; namely, the partiality of intellectual parentage. The effort is to bring up into view every rational explanation of new phenomena, and to develop every tenable hypothesis respecting their cause and history. The investigator thus becomes the parent of a family of hypotheses: and, by his parental relation to all, he is forbidden to fasten his affections unduly upon any one. In the nature of the case, the danger that springs from affection is counteracted, and therein is a radical difference between this method and the two preceding. The investigator at the outset puts himself in cordial sympathy and in parental relations (of adoption, if not authorship) with every hypothesis that is at all applicable to the case under investigation. Having thus neutralized the partialities of his emotional nature, he proceeds with a certain natural and enforced erectness of mental attitude to the investigation, knowing well that some of his intellectual children will die before maturity, yet feeling several of them may survive the results of final investigation, since it is often the outcome of inquiry that several causes are found to be involved instead of a single one. In following a single hypothesis, the mind is presumably led to a single explanatory conception. But an adequate explanation often involves the co-ordination of several agencies, which enter into the combined result in varying proportions. The true explanation is therefore necessarily complex. Such complex explanations of phenomena are specially encouraged by the method of multiple hypotheses, and constitute one of its chief merits. We are so prone to attribute a phenomenon to a single cause, that, when we find an agency present, we are liable to rest satisfied therewith, and fail to recognize that it is but one factor, and perchance a minor factor, in the accomplishment of the total result. Take for illustration the mooted question of the origin of the Great Lake basins. We have this, that, and the other hypothesis urged by different students as the cause of these great excavations; and all of these are urged with force and with fact, urged justly to a certain degree. It is practically demonstrable that these basins were river-valleys antecedent to the glacial incision, and that they owe their origin in part to the pre-existence of those valleys and to the blocking up of their outlets. And so this view of their origin is urged with a certain truthfulness. So, again, it is demonstrable that they were occupied by great lobes of ice, which excavated them to a marked degree, and therefore the theory of glacial excavation finds support in fact. I think it is furthermore demonstrable that the earth's crust beneath these basins was flexed downward, and that they owe a part of their origin to crust deformation. But to my judgment neither the one or the other, nor the third, constitutes an adequate explanation to the phenomena. All these must be taken together, and possibly they must be supplemented by other agencies. The problem, therefore, is the determination not only of the participation, but of the measure and the extent, of each of the agencies in production of the complex result. This is not likely to be accomplished by one whose working hypothesis is pre-glacial erosion, or glacial erosion, or crust deformation, but by one whose staff of working hypotheses embraces all of these and any other agency which can be rationally conceived to have taken part in the phenomena.

A special merit of the method is, that by its very nature it promotes thoroughness. The value of a working hypothesis lies largely in its suggestiveness of lines of inquiry that might otherwise be overlooked. Facts that are trivial in themselves are brought into significance by their bearings upon the hypothesis, and by their casual indications. As an illustration, it is necessary to cite the phenomenal influence which the Darwinian hypothesis has exerted upon the investigations of the past two decades. But a single working hypothesis may lead investigations along a given line to

the neglect of others equally important; and thus, while inquiry is promoted in certain quarters, the investigation lacks completeness. But if all rational hypotheses relating to a subject are worked co-equally, thoroughness is the presumptive result, in the very nature of the case.

In the use of the multiple method, the re-action of one hypothesis upon another tends to amplify the recognized scope of each, and their mutual conflicts whet the discriminative edge of each. The analytic process, the development and demonstration of criteria, and sharpening of discrimination, receive powerful impulse from the co-ordinate working of several hypotheses.

Fertility in processes is also the natural outcome of the method. Each hypothesis suggests its own criteria, its own means of proof, its own methods of developing the truth; and if a group of hypotheses encompass the subject on all sides, the total outcome of means and of methods is full and rich.

The use of the method leads to certain peculiar habits of mind which deserve passing notice, since as a factor of education its disciplinary value is one of importance. When faithfully pursued for a period of years, it develops a habit of thought analogous to the method itself, which may be designated a habit paralleled or complex thought. Instead of a simple succession of thoughts in linear order, the procedure is complex, and the mind appears to become possessed of the power of simultaneous vision from different standpoints. Phenomena appear to become capable of being viewed analytically and synthetically at once. It is not altogether unlike the study of landscape, for which there comes into the mind myriads of lines of intelligence, which are received and co-ordinated simultaneously, producing a complex impression which is recorded and studied directly in its complexity. My description of this process is confessedly inadequate, and the affirmation of it as a fact would doubtless challenge dispute at the hands of psychologists of the old school; but I address myself to naturalists who I think can respond to its verity from their own experience.

Drawbacks of the Method

The method has, however, its disadvantages. No good thing is without its drawbacks; and this very habit of mind, while an invaluable acquisition for purposes of investigation, introduces difficulties in expression. It is obvious, upon consideration, that this method of thought is impossible of verbal expression. We cannot put into words more than a single line of thought at the same time; and even in that the order of expression must be conformed to the idiosyncrasies of the language, and the rate must be relatively slow. When the habit of complex thought is not highly developed, there is usually a leading line to which others are subordinate, and the difficulty of expression does not rise to serious proportions; but when the method of simultaneous vision along different lines is developed so that the thoughts running in different channels are nearly equivalent, there is an obvious embarrassment in selection and a disinclination to make the attempt. Furthermore, the impossibility of expressing the mental operation in words leads to their disuse in the silent process of thought, and hence words and thoughts lose that close association which they are accustomed to maintain with those whose silent as well as spoken thoughts run in linear verbal courses. There is therefore a certain predisposition on the part of the practitioner of this method to taciturnity.

We encounter an analogous difficulty in the use of the method with young students. It is far easier, and I think in general more interesting, for them to argue a theory or accept a simple interpretation than to recognize and evaluate the several factors which the true elucidation may require. To illustrate: it is more to their taste to be taught that the Great Lake basins were scooped out by glaciers than to be urged to conceive of three or more great agencies working successively or simultaneously, and to estimate how much was accomplished by each of these agencies. The complex and the quantitative do not fascinate the young student as they do the veteran investigator.

Multiple Hypotheses and Practical Affairs

It has not been our custom to think of the method of working hypotheses as applicable to instruction or to the practical affairs of life. We have usually regarded it as but a method of science. But I believe its application to practical affairs has a value coordinate with the importance of the affairs themselves. I refer especially to those inquiries and inspections that precede the coming-out of an enterprise rather than to its actual execution. The methods that are superior in scientific investigation should likewise be superior in those investigations that are the necessary antecedents to an intelligent conduct of affairs. But I can dwell only briefly on this phase of the subject.

In education, as in investigation, it has been much the practice to work a theory. The search for instructional methods has often been proceeded on the presumption that there is a definite patent process through which all students might

be put and come out with results of maximum excellence; and hence pedagogical inquiry in the past has very largely concerned itself with the inquiry 'What is the best method?' rather than with the inquiry, 'What are the special values of different methods, and what are their several advantageous applicabilities in the various work of instruction?' The past doctrine has been largely the doctrine of pedagogical uniformitarianism. But the faculties and functions of the mind are almost, if not quite, as varied as the properties and functions of matter: and it is perhaps no less absurd to assume that any specific method of instructional procedure is more effective than all others, under any and all circumstances, than to assume that on principle of interpretation is equally applicable to all the phenomena of nature. As there is an endless variety of mental processes and combinations and an indefinite number of orders of procedure, the advantage of different methods under different conditions is almost axiomatic. This being granted, there is presented to the teacher the problem of selection and of adaptation to meet the needs of any specific issue that may present itself. It is important, therefore, that the teacher shall have in mind a full array of possible conditions and states of mind which may be presented, in order that, when any one of these shall become an actual case, he may recognize it, and be ready for the emergency.

Just as the investigator armed with many working hypotheses is more likely to see the true nature and significance of phenomena when they present themselves, so the instructor equipped with a full panoply of hypotheses ready for application more readily recognizes the actuality of the situation, more accurately measures its significance, and more appropriately applies the methods which the case calls for.

The application of the method of multiple hypotheses to the varied affairs of life is almost as protean as the phases of that life itself, but certain general aspects may be taken as typical of the whole. What I have just said respecting the application of the method of instruction may apply, with a simple change of terms, to almost any other endeavor which we are called upon to undertake. We enter upon an enterprise in most cases without full knowledge of all the factors that will enter into it, or all of the possible phases which it may develop. It is therefore of the utmost importance to be prepared to rightly comprehend the nature, bearings, and influence of such unforeseen elements when they shall definitely present themselves as actualities. If our vision is narrowed by preconceived theory as to what will happen, we are almost certain to misinterpret the facts and to misjudge the issue. If, on the other hand, we have in mind hypothetical forecasts of the various contingencies that may arise, we shall be the more likely to recognize the true facts when they do present themselves. Instead of being biased by the anticipation of a given phase, the mind is rendered open and alert by the anticipation of any one of many phases, and is free not only, but is predisposed, to recognize correctly the one which does appear. The method has a further good effect. The mind, having anticipated the possible phases which may arise, has prepared itself for action under any one that may come up, and it is therefore ready-armed, and is pre-disposed to act in the line appropriate to the event. It has not set itself rigidly in a fixed purpose, which it is pre-disposed to follow without regard to run a specific course, whether rocks lie in the path or not; but, with the helm in hand, it is ready to veer the ship according as danger or advantage discovers itself.

It is true, there are often advantages in pursuing a fixed determined course without regard to obstacles or adverse conditions. Simple dogged resolution is sometimes salvation of an enterprise; but, while glorious successes have been thus snatched from the very brink of disaster, overwhelming calamity has in other cases followed upon this course, when a reasonable regard for the unanticipated elements would have led to success. So there is to be set over against the great achievements that follow on dogged adherence great disasters which are equally its result.

Danger of Vacillation

The tendency of the mind, accustomed to work through multiple hypotheses, is to sway to one line of policy or another, according as the balance of evidence shall incline. This is the soul and essence of the method. It is in general the true method. Nevertheless there is a danger that this yielding to evidence may degenerate into unwarranted vacillation. It is not always possible for the mind to balance evidence with exact equipoise, and to determine, in the midst of the execution of enterprise, what is the measure of probability on the one side or the other: and as difficulties present danger of being biased by them and of swerving from the course that was really the true one. Certain limitations are therefore to be placed upon the application of the method, for it must be remembered that a poorer line of policy consistently adhered to may bring better results than a vacillation between better policies.

There is another and closely allied danger in the application of the method. In its highest development it presumes a mind supremely sensitive to every grain of evidence. Like a pair of delicately poised scales, every added particle on the one side or the other produces its effect in oscillation. But such a pair of scales may be altogether too sensitive to be of practical value in the rough affairs of life. The balances of the exact chemist are too delicate for the weighing-out of coarse commodities. Dispatch may be more important than accuracy. So it is possible for the mind to be too

much concerned with the nice balancings of evidence, and to oscillate too much and too long in the endeavor to reach exact results. It may be better, in the gross affairs of life, to be less precise and more prompt. Quick decisions though they may contain a grain of error, are oftentimes better than precise decisions at the expense of time.

The method has a special beneficent application to our social and civic relations. Into these relations there enter, as great factors, our judgment of others, our discernment of the nature of their acts, and our interpretation of their motives and purposes. The method of multiple hypotheses, in this application here, stands in decided contrast to the method of the ruling theory or of the simple working hypothesis. The primitive habit is to interpret the acts of others on the basis of theory. Childhood's unconscious theory is that the good are good, and the bad are bad. From the good the child expects nothing but the good; from the bad, nothing but the bad. To expect a good act from the bad, or a bad act from the good, is radically at variance with childhood's mental methods. Unfortunately in our social and civic affairs too many of our fellow citizens have never outgrown the ruling theory of their childhood.

Many advanced a step farther, and employ a method analogous to that of the working hypothesis. A certain presumption is made to attach to the acts of their fellow-beings, and that which they see is seen in the light of that presumption. They do not go to the lengths of childhood's method by assuming positively that the good are wholly good, and the bad wholly bad; but there is a strong presumption in their minds that he concerning whom they have an ill opinion will act from corresponding motives. It requires positive evidence to overthrow the influence of the working hypothesis.

The method of multiple hypotheses assumes broadly that the acts of a fellow-being may be diverse in their nature, their moves, their purposes, and hence in their whole moral character; that they may be good though the dominant character be bad; that they may be bad though the dominant character be good; that they may be partly good and partly bad, as is the fact in the greater number of the complex activities of a human being. Under the method of multiple hypotheses, it is the first effort of the mind to see truly what the act is, unobscured by the presumption that this or that has been done because it accords with our ruling theory or our working hypothesis. Assuming that acts of similar general aspect may readily take any one of several different phases, the mind is freer to see accurately what has actually been done. So, again, in our interpretations of motives and purposes, the method assumes that these may have been any one of many, and the first duty is to ascertain which of the possible motives and purposes actually prompted this individual action. Going with this effort there is a predisposition to balance all evidence fairly, and to accept that interpretation to which the weight of evidence inclines, not that which simply fits our working hypothesis or our dominant theory. The outcome, therefore, is better and truer observation and juster and more righteous interpretation.

Imperfections of Knowledge

There is a third result of great importance. The imperfections of our knowledge are more likely to be detected, for there will be less confidence in its completeness in proportion as there is a broad comprehension of the possibilities of varied action, under similar circumstances and with similar appearances. So, also, the imperfections of evidence as to the motives and purposes inspiring the action will become more discernible in proportion to the fullness of our conception of what the evidence should be to distinguish between action from the one or the other of possible motives. The necessary result will be less disposition to reach conclusions upon imperfect grounds. So, also, there will be a less inclination to misapply evidence; for, several constructions being definitely in mind, the indices of the one motive are less liable to be mistaken for the indices of another.

The total outcome is greater care in ascertaining the facts, and greater discrimination and caution in drawing conclusions. I am confident, therefore, that the general application of this method to the affairs of social and civic life would go far to remove those misunderstandings, misjudgments, and misrepresentations which constitute so pervasive an evil in our social and our political atmospheres, the source of immeasurable suffering to the best and most sensitive souls. The misobservations, the misstatements, the misinterpretations, of life may cause less gross suffering than some other evils; but they, being more universal and more subtle, pain. The remedy lies, indeed, partly in charity, but more largely in correct intellectual habits, in a predominant, ever-present disposition to see things as they are, and to judge them in the full light of an unbiased weighing of evidence applied to all possible constructions, accompanied by a withholding of judgment when the evidence is insufficient to justify conclusions.

I believe that one of the greatest moral reforms that lies immediately before us consists in the general introduction into social and civic life of that habit of mental procedure which is known in investigation as the method of multiple working hypotheses.

Biography

Thomas Chamberlin (1843-1928), a geologist, was president of the University of Wisconsin at the time this lecture was written. Later he was a professor and director of the Walker Museum of the University of Chicago. In 1893 he founded the *Journal of Geology*, which he edited until his death. In 1908 he was president of the AAAS. The article is reprinted from *Science* (old series), 15, 92 (1890).

T. C. Chamberlin published two papers under the title of "The method of multiple working hypotheses." One of these papers, first published in the *Journal of Geology* in 1897, was quoted by John R. Platt in his recent article "Strong inference" (*Science*, 16 Oct. 1964). Platt wrote: "This charming paper deserves to be reprinted." Several readers, having had difficulty obtaining copies of Chamberlin's paper, expressed agreement with Platt. One wrote that the article had been reprinted in the *Journal of Geology* in 1931 and in the *Scientific Monthly* in November of 1944. Another sent us a photocopy. Several months later still another wrote that the Institute for Humane Studies (Stanford, CA) had reprinted the article in pamphlet form this year. On consulting the 1897 version, we found a footnote in which Chamberlin has written: "A paper on this subject was read before the Society of Western Naturalists in 1892, and was published in a scientific periodical." Library research revealed that a scientific periodical was *Science* itself, for 7 February 1890, and that Chamberlin had actually read the paper before the Society of Western Naturalists on 25 October 1889. The chief difference between the 1890 text and the 1897 text is that, as Chamberlin wrote in 1897: "The article has been freely altered and abbreviated so as to limit it to aspects related to geological study." The 1890 text, which seems to be the first and most general version of "The method of multiple working hypotheses," is reprinted here. Typographical errors have been corrected, and subheadings have been added.