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# THE PHASES OF SCIENTIFIC INQUIRY

## 1. INTRODUCTORY REMARKS. THE EMERGENCE OF THE PROBLEM

Solving a problem cannot be done in a wholesale manner but its particular components must be arranged into some order of tackling, thus eventually producing the final solution in its entirety.[1] When we take up the problem of the methods applied in scientific research we have to start with defining the precise meaning of method. This question has been answered by Tadeusz Kotarbiński, who started with the general definition of method as a systematically applied manner. This preliminary definition calls for some specification. It can be asked what manner actually means. "Any manner", writes Professor Kotarbiński, "is a manner of some action, while the manner of action is a deliberate procedure, that is, a composition and arrangement of the stages of action. The stage of action can be defined as a segment of that action in time."[2]

Thus we arrive at the concept of method as a complex manner of action, which is composed of a number of stages of action. The author of the *Treatise on Efficient Action* supplies a generalized concept of method, which applies not only to scientific research but to all human activity, that is a manner which bears definite characteristics of deliberateness and is applied repeatedly. He has worked out the foundation of general methodology as a theory of all action which also comprises the methodology of sciences as a special field. Thus conceived of, general methodology, or praxiology, can have recourse to the results supplied by the methodology of sciences to generalize them onto other domains of human action and to check if they apply to a more comprehensive field of action.

The *Treatise* furnishes the following definition of method "Method, that is,

[1] Cf. T. Kotarbiński, *Sprzeczność i błąd* [*Contradiction and Error*], Warsaw 1956, p. 3.
[2] Cf. T. Kotarbiński, *O pojęciu metody* [*On the Notion of Method*], Warsaw 1957, p. 3.

a system of procedures, is a manner of carrying out a composite act by a definite selection and arrangement of the constituent activities which is moreover planned out and suitable for multiple application."[3]

What this definition emphasizes is the selection and arrangement of particular activities constituting the whole method. When applied to the analysis of the method of scientific inquiry, this points to the need of considering the stages, or phases, of scientific research out of which the entire body of research work arises. This problem was underlined by J. Zieleniewski in his definition of the method of research, which refers to Kotarbiński's definition. In the essay on the prospects of praxiological studies Zieleniewski wrote: "By method of research we shall mean here the manner of inquiry used deliberately in conviction that it can be efficiently applied to the given research and to other researches of the same kind, with a distinction between the successive stages of research that are characteristic of the given manner and with realisation of the mutual relations between those stages."[4]

This description of method in general and of the method of scientific inquiry is in line with the inclination of many students of the problem who try to identify the phases of the cycle of organized action and, in scientific inquiry, to distinguish the phases of scientific inquiry and explain their mutual relationships.

The methods of scientific inquiry have attracted the interest of numerous philosophers and scientists since the ancient times. Aristotle, the Epicureans and the Stoics reflected on the process of inquiry. In the Middle Ages Roger Bacon tried to establish research procedures through experience. In modern times, Coperincus, Francis Bacon, Kepler, Zabarella, Galileo, Descartes, Leibniz and Newton all searched the best procedures for scientific inquiry.

However, it was not before the 19th century that a wide discussion on the method of scientific inquiry and its specific phases set in. In 1830 the astronomer John Frederick William Herschel published *A Preliminary Discourse on the Natural Philosophy*, in which he listed nine rules for the study of causative relationships. On the ground of those rules J. S. Mill phrased his canons of induction.[5] Her regarded his canons as descriptions of the actual processes of inquiry which researchers actually apply in discovering and justifying scientific laws.

This view was challenged by Whewell, the author of the renowned *History of the Inductive Sciences*. He cited numerous examples to show

[3] T. Kotarbiński, *Traktat o dobrej robocie* [*A Treatise on Efficient Action*], Wrocław–Warsaw 1959, 2nd ed., p. 88.

[4] J. Zieleniewski, "*O stanie i potrzebie badań prakseologicznych*" [„*On the State and Need of Praxiological Research*"], *Nauka Polska*, vol. 8, No. 2/26, 1956, p. 109.

[5] Cf. W. Biegański, *Teoria logiki* [*A Theory of Logic*], Warsaw 1912, p. 506; and M. Wallis' foreward to the Polish edition of J. F. W. Herschel's *Introduction to Natural Sciences*, Warsaw 1955.

that preconceived ideas in the form of hypotheses that had been phrased before the inductive researches started might strongly affect the discovery of the laws of Nature. Without a creative idea the laws of Nature could not be formulated. What is necessary are conceptual additions which, when imposed on the knowledge of facts, permit introducing some order and harmony into the chaotic world of facts. Thus Whewell views the procedure of scientific inquiry differently: first we conceive new ideas and hypotheses, and subsequently we judge their validity against the facts. The canons of induction are artificial constructs that have no application in conceiving ideas, as they are conceptual additions to facts, nor in verifying hypotheses, as their agreement with facts alone suffices.[6] Mill defended himself against these charges by pointing out that even if his methods of induction were not a way of discovering new hypotheses they were nevertheless fundamental methods of experimental verification of existing hypotheses. He even thought that the canons of induction have the additional advantage of being capable of demonstrating the truth or falsity of a generalization.[7]

The Whewell–Mill dispute revealed that the inductive methods of inquiry are of no comprehensive significance in the discovery of new scientific ideas or hypotheses. Whewell's stand was supported by the well-known chemicist Justus Liebig, who submitted Bacon's method of discovery of the laws of Nature to a critical analysis.[8]

Claude Bernard, the great physiologist, also pointed to the significance of hypothesis as a precondition for starting experimental research. An idea, or hypothesis, phrased beforehand is an indispensable point of departure for any experiment. No research can be put through without it; all that could be done would be collecting futile observations. Experimenting without a pre-adopted hypothesis would be tantamount to groping in the dark, because experiments merely verify the preconceived idea or hypothesis.[9]

To Calude Bernard, scientific inquiry proceeds in two phases: in the first phase the hypothesis is formulated, while in the second the hypothesis is submitted to experimental verification. He did not analyse closely the way of working out the hypothesis but remarked that sometimes an accidental observation or inference from theory resulted in formulating one.

S. Jevons and Ch. Sigwart, the authors of the inverse theory of induction, furnished an original interpretation of that phase of scientific inquiry. They argued that on the ground of observed facts we seek some general hypothesis. This is the phase of discovery. Next, with a general hypothesis at hand, we deduce definite conclusions from it and compare them to the

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[6] Cf. W. Biegański, *op. cit.*, p. 512–6.

[7] Cf. J. S. Mill, A System of Logic Raciocinative and Inductive, Book III, Chapter IX.

[8] Cf. J. Liebig, *Über Frăncis Bacon von Verulam und die Methode der Naturforschung*, Berlin 1863.

[9] Cf. C. Bernard, *Introduction à l'étude de la médecine experimentale*, 1st ed., Paris 1865, pp. 57ff.

available facts. This is the phase of verification. Deduction plays an important role there, for we are thus able to draw conclusions from a general hypothesis which is either confirmed or invalidated on the ground of the facts. Deduction checks the results of induction, just as multiplication checks the results of division. Just as division is inverse to multiplication, induction is an operation inverse to deduction that cannot be justified without the latter. The generalizations revealed must be justified by deductive reasoning and by confronting the conclusions drawn from experience.

In Poland, the inverse induction theory found its proponent in Jan Łukasiewicz. He interpreted induction as picking the reasons for given consequences.[10] To him induction was a reductive reasoning from consequences to reasons marked specifically by the passage from ascertained consequences to an uncertain general reason. Łukasiewicz called this procedure explanation.[11]

The inverse induction theory emphasized the deductive member in scientific reasoning. It was to deduction that the fundamental justificatory significance was attributed. This led to a four-phase concept of the process of scientific inquiry, namely (1) the recognition of facts, (2) the formulation of a general hypothesis, (3) the deductive derivation of conclusions from the hypothesis, and (4) the confrontation of the conclusions with the facts. In this theory, the selection of a general hypothesis did not have the value of justification. Induction was regarded as merely a specific trial, which acquired its actual significance only owing to the deductive reasoning. This deflated the significance of Mills' canons which then ceased to be regarded as a way of experimental verification of hypotheses concerning causative relations; they were then attributed only some heuristic value (Sigwart).

The description of the process of scientific inquiry in the inverse theory had clearly some advantages, but some flaws as well. The former include the introduction of the well-developed member of deduction from the hypothesis, of the recognition of the role of deduction in inquiry. A further merit of that theory was its distinction between the heuristic and the justificatory phases of the process of inquiry. What can be regarded as a flaw was that this theory underrated the justificatory role of induction through simple enumeration, statistical confirmation or elimination, which enable the student to choose and justify the likeliest hypothesis from several competitive ones. The inverse induction theory reduced the importance of studies of causative relationships whose rules were furnished in the canons of induction. Nor did it furnish room for experimental research which, according to Claude Bernard, can verify experimentally a preconceived hypothesis. It failed to explain how to conduct experimental research. The deductive derivation

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[10] Cf. J. Łukasiewicz, „*O indukcji jako inwersji dedukcji*" ["On Induction as Inverse Deduction"], *Przegląd Filozoficzny*, vol. VI, 1903.

[11] Cf. J. Łukasiewicz, *O nauce. Poradnik dla samouków* [*On Science. A Guide to Autodidacts*], vol. I, Warsaw, 1915, pp. XXIII–XXIV.

of conclusions from a general hypothesis is but an ancillary operation. What is necessary are rules and methods of verifying the conclusions by experiment or observation. After the work of Herschel and Mill the inverse induction theory put emphasis on the opposite methodological pole—the significance of deduction and its indispensability in the process of scientific inquiry. Both trends, that is inductionism and deductionism, came up very strongly in the discussion on the methods and phases of scientific inquiry. Both illuminated the research process, though from different angles, and both emphasized, but onesidedly, certain important aspects of this process.

Władysław Biegański, the Polish methodologist, made the attempt to reconcile these two approaches. Following Claude Bernard and the inverse theory, he divided the process of inquiry into a heuristic and a justificatory phases. He concentrated especially on the former. He analysed the heuristic forms of inductive reasoning,[12] and pointed to the significance of inference through analogy in the discovery of new hypotheses. He described the four main types of inference on the ground of analogy of relations.[13] Biegański thought that scientific discoveries are made in a rational manner while intuition is a form of abbreviated reasoning. General hypotheses are arrived at through observation in conjunction with induction or with inference by analogy.

The second main phase, the verification of the hypothesis, is to Biegański based on the elimination of a number of possible hypotheses in order to arrive at the one right hypothesis that expresses the relation of necessity. It furnishes the ground for the formulation of a law. In scientific inquiry, most often in experimental research, facts are selected in such a way that not only should the given hypothesis be confirmed by its agreement with the facts but that all competitive hypotheses should be ruled out.

The deductive derivation of conclusions from a hypothesis and their comparison with facts do not suffice to justify the relations of necessity implied in a scientific law. What must also be applied are methods close to Mill's canons of induction. Biegański attributed great significance to the canons of induction, as these are to demonstrate the existence of relations of necessity that express scientific laws. Biegański emphasized his allegiance to the ancient Greek belief (Aristotle) that relations of necessity can be disclosed in Nature. In its development, modern science tended to shift its point of emphasis toward the disclosure of probable relations. Probabilistic laws are sought more frequently than absolute laws. Relations of necessity are neither unequivocal nor easy to discover. Apart from the development of research in statistical induction, scientists also develop the theory of induction by elimination, another tool of the modern methodology of

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[12] Cf. W. Biegański, *Wnioskowanie z analogii* [*Inference from Analogy*], Lwów 1909.

[13] W. Biegański, *Czwarta postać wnioskowania z analogii* [*The Fourth Pattern of Inference from Analogy*], Warsaw 1913.

science. The effort made by methodologists since the Epicurean philosophers through Francis Bacon, Herschel, Mill or Biegański down to the recent works by Łoś, Greniewski or von Wright constitutes a valuable line of development of induction by elimination as one of the methods science needs. The other types of induction are supplementary to that classical method of studying relations of necessity, and extend it. Simple induction, also referred to as induction by simple enumeration, intuitive induction (Johnson), and statistical inductions are further useful tools of scientific thought and practical research.

## 2. SOME RECENT PRESENTATIONS OF PHASE PATTERNS OF SCIENTIFIC INQUIRY

In a paper on "The Problems of the Phases of Scientific Inquiry" (in Polish, *Kultura i Społeczeństwo*, 1973, No. 4) I made a critical survey of several recent concepts of the phases of the process of scientific inquiry. In the present paper, which is intended to furnish normative models of the phase pattern of scientific inquiry for various types of research, I wish to analyse a few examples of representative models worked out by different authors to indicate their limitations as well as the ways in which they have contributed to the general methodological knowledge of the course of scientific inquiry.

Le Chatelier, the outstanding French specialist on organized action, scientific method and phases of inquiry, describes scientific research thus:

1. Above all, science demands faith in itself, that is, in the necessity of its laws, which is referred to as determinism.

2. The next level, or stage to go through, is the accurate specification of all conditions that any phenomenon depends on, that is, of its causes of conducive factors. Such a complete specification of the parts of a whole is simply a practical application of the main principle of division indicated in the Cartesian method.

3. Next we must take account of the degree of importance of any factor, that is, of its major or minor influence on the effect sought for, or, to use Taine's term, of the degree of its "beneficiality". This is indispensable if we are to succeed in prolonged and necessarily incomplete studies, for science can never be sounded right to the bottom.

4. Finally, through measurements one arrives at accurate quantitative relations, at algebraic formulas, which link the phenomena studied with their factors, that is, with laws.

The modern psychologist R. Hyman distinguishes in his book on *The Nature of Psychological Inquiry* between phases of scientific inquiry and stages of research. Phases are individual stages of the researcher's activities in a given process of inquiry. Stages, on the other hand, depend on the improvement of scientific notions, on the development of an increasingly adequate notional apparatus that is verified in various researches.

Here we are going to tackle the former of the two issues, namely we shall try to define what are the phases that scientific inquiry goes through. Hyman distinguishes between the following five research activities: (a) the formulation of the problem, (b) collecting information, (c) processing information, (d) interpreting information, (e) communicating it. A research team may divide its task in such a way that its members deal with some phases of the research only. The joint effort of several researchers affords the full cycle of the research work that is composed of those phases.[14]

This concise pattern of the cycle of scientific inquiry has its flaws, though. It does not explain how the problem is being formulated, or in what way one arrives at posing it. Nor does it take account of heuristic problems—that is, how one takes the first steps in a research project. Further, Hyman slips by the problem of the hypothesis, that is, how one arrives at a fertile scientific hypothesis. Next, regarding item *b*, the collection of information applies to all research techniques employed in the empirical sciences and to the methods of verfication of hypotheses. But there is still the open question of how information is interpreted, an issue discussed in detail by E. Betti in his great work,[15] or the problem of communicating the results, which is of great significance in the sociology of science. All that Hyman has done, then, is pointing out some problems of the course of scientific inquiry, while the issue itself must be submitted to further systematic analysis and methodological assessment.

Another pattern has heen proposed by the methodologist F. Northrop who starts with distinguishing between the following phases of scientific inquiry:

1. The analysis of the problem on the basis of fundamental theories.
2. The selection of the simplest possible phenomena comprising the factors the problem involves.
3. The inductive study of those significant factors.
4. The formulation of hypotheses suggested by those significant factors.
5. The inductive derivation of conclusions from the hypotheses postulating the experimental verification of the conclusions.
6. The explanation of the problem in the light of the verified hypotheses.
7. The generalization of the solution *via* the extension of the logical conclusions from the new hypotheses, concepts and theories, in connection with other domains and their applications there.[16]

Northrop begins with the formulation of the problem on theoretical grounds, and only afterwards proceeds to the phase of observation of facts in which the factors involved in the problem occur. Next he derives the

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[14] Cf. R. Hyman, *The Nature of Psychological Inquiry*, Englewood Cliffs, N.J., p. 9.

[15] Cf. E. Betti, *Allgemeine Auslegungslehre*, Tübingen 1967, p. 771.

[16] Cf. F. S. C. Northrop, *The Logic of the Sciences and the Humanities*, New York 1960, p. 28.

way of inductive inference from the available hypotheses with a view to verifying them for their agreement or disagreement with experiment. Further generalization is provided for under item *7.* which concerns the meaning of the verified hypotheses to other domains of science. In Northop's pattern, the course of scientific inquiry integrates the methods of generalizing induction with the hypothetical-deductive method of deriving conclusions from general hypotheses. But Northrop is not precise enough in distinguishing between those two methods: item *5* should properly read: deductive derivation of conclusions from hypotheses, while the "inductive study of significant factors" in item *3* is not clear enough, either. What can be inductively generalized are significant factors discovered before. To arrive at them we need methods close to diagnosis. Hence item *3* should be more adequately phrased as the "diagnostic study of significant factors".

Next Northrop analyses the three main stages of scientific inguiry: (1) the analysis of the problem that initiates the research, (2) Bacon-type induction, (3) the theoretical extension of conclusions from experiment.

In the first stage of research, according to Northrop, we employ the method of analysis which consists in reducing the problem to significant factors of the factual situation. In the second stage the author introduces the Bacon-type induction as a method of discovering and generalizing hypothetical empiric relations.[17] Northrop seems to succumb to the illusion of some early nineteenth-century logicians and methodologists, such as Herschel or Mill, who believed that Bacon's induction is the method of discovery. Later critics (Whewell, Liebig, Bernard, Jevons, Sigwart) demonstrated that this view was groundless. The old view concerning the heuristic significance of induction should now be replaced by the insistence on the significance of a deepened analysis of individual facts illuminating the paths of further study.

James K. Feiblman, too, views scientific inquiry as a multi-phase process. He distinguishes the following stages of scientific research: observation, induction, hypothesis, experiment, calculation, anticipation, and decision regarding the procedure of control.

In this pattern, it is observation that is the starting-point and which leads to the disclosure of thought-provoking facts. This is a purely descriptive stage of the cognitive process. Inductions are derived from provocative facts in order to discover general hypotheses worth studying. To obtain hypotheses we need inventive insights into the reality studied. Next, those general hypotheses are studied in a triple manner. The first way of study consists in verifying the hypotheses by way of experiment, the second in verifying hypotheses by confronting them with theories by way of mathematical analysis; in this stage, too, it is shown that quantitative laws are logical consequences of a certain small number of axioms or postulates. The

[17] Cf. F. S. C. Northrop, op. cit., p. 30.

third way consists in deriving forecasts from the hypotheses to use them subsequently as an instrument for influencing the actual practice. Hypotheses that pass all the three ways of verification are recognized as scientific laws.

Feiblman views that multi-phase process of inquiry as the foundation of the general scientific method. Though it has a consistent logical structure it does admit the role of induction and is an aid to it rather that its substitute. We would have no scientific method without admitting induction in each of its phases.[18]

We must appreciate Feiblman's insistence on the role of observation in disclosing hypotheses. Observation should distinguish significant facts which subsequently become the foundation of induction and of the derivation of general hypotheses. Feiblman of course assumes that the researcher's attention has already been directed to some difinite problem for otherwise he would not be able to make fertile observations. From the didactic point of view, one must not overlook the first stage, that of the formulation of the problem, which precedes the observations and diagnoses explaining the recorded facts.

Feiblman deprecates the emphasis on induction as a creative method, for it constitutes but a methodologically developed way of generalizing what the researcher has already noticed to be significant in the studied facts. It is precisely the diagnosis explaining certain facts that constitutes the first creative link of the work that suggests the hypothesis. Without a good diagnosis of concrete facts, generalizing induction will not bring the researcher to fruitful hypotheses.

Yet Feiblman's method is limited in that it provides but a physical pattern of verification of hypotheses by experiment and mathematical analysis. Not all sciences have to, or can, employ experiment. For instance the human sciences or some social sciences such as anthropology, sociology or pedagogics, need not do that to verify their respective interpretative hypotheses. This restricts the field of application of Feiblman's physicalist method above all to the physico-chemical sciences.

To arrive at a rational phase division, which is important to at least those empirical sciences that employ observation, and which Feiblman himself posed as his task, we must look for a more comprehensive explanation of scientific method and of the stages of inquiry.

Mario Bunge, another outstanding methodologist, lists eight phases of scientific inquiry:

1. The formulation of well-phrased and similarly fruitful questions.
2. The formulation of justified and verified hypotheses furnishing answers to the questions.
3. The derivation of logical conclusions from hypotheses and other assumptions.

[18] Cf. J. K. Feiblman, *Scientific Method*, The Hague 1972, pp. 7ff.

4. The design of techniques for the verification of hypotheses.

5. The study of the designed techniques for their significance and credibility.

6. The completion of researches and the interpretation of the results obtained.

7. The evaluation of validity of the assumptions and the reliability of the techniques.

8. The identification of domains to which the assumptions and techniques apply and the formulation of new problems posed by those researches.[19]

Bunge, in his pattern of phases of scientific inquiry, distinguishes sharply between the formulation of the problem and the subsequent step, that is, the formulation of hypotheses. At this point let us only point to the heuristic methods that are most fruitful in the formulation of good hypotheses. Bunge's model applies both to diagnostic and generalizing researches in which there are inductions of different degrees of generality.

A more extensive pattern was given by Bunge in his earlier study on metascientific queries, where he distinguished five groups of problems in scientific inquiry:

I. Approach to the problem.

1. A survey of facts: the study of a given group of facts, their preliminary classification and selection of those significant in any given respect.

2. The recognition of the problem: an assessment of the whole situation within the available domain of scientific knowledge.

3. Posing the problem, formulating the question that has a chance of being right; this is tantamount to reducing the problem to its fruitful core by utilizing the available knowledge.

II. Constructing a theoretical model.

1. Selecting the significant factors: formulating the likely assumptions regarding the variables that may turn out to be significant.

2. Formulating the central hypotheses and auxiliary assumptions: suggesting a set of assumptions regarding the relations between the significant variables—the formulation of propositions in laws that are likely to account for the facts observed.

3. The mathematical presentation and putting the constituent terms of the hypotheses into mathematical formulas.

III. The derivation of specific consequences.

1. The search for rational explanations: deducing specific consequences that may be verified in the given or related fields.

2. The search for empirical foundations: the derivation— in virtue of the theoretical model and of empirical data — forecasts providing for the application of practicable and sufficient verification techniques.

IV. The verification of hypotneses.

1. Scheduling the verification: working out the ways of verification

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[19] Cf. M. Bunge, *Scientific Research*, vol. 1, Berlin–Heidelberg–New York 1967, p. 9.

through observations, measurements, experiments and all other instrumental activities.

2. Carrying out the verifying operation: completing the indispensable operations and collecting the empirical data.

3. Systematizing the data: classification, analysis, evaluation, and elimination of insignificant data.

4. Deriving the conclusions: the interpretation of the data against the theoretical model.

V. The introduction of the conclusions from the empirical data into theory.

1. Comparing the conclusions against the degree of agreement of the results obtained with the theoretical model.

2. Modifying the model: possible alterations or even substituting a new model for the previous one.

3. Suggestions for further work. Looking for gaps or errors in theoretical presentations and empirical procedures if the model has been invalidated, or indicating its extension and its significance to other domains of scientific inquiry if the model has been confirmed.[20]

As regards the phase pattern of scientific inquiry, Bunge distinguishes the following main phases:

1. The formulation of the problem.
2. The formulation of the pertinent hypotheses.
3. The inductive derivation of conclusions and formulation of forecasts.
4. The verification of the hypotheses.
5. The extension of the theory.

The advantages of this procedure include the distinction of the major stages ot scientific method, the indication of the systematic procedure of research work in the formulation and verification of hypotheses, and their introduction into scientific theories.

But Bunge puts too much emphasis on the formulation of the problem on the basis of a survey of facts and the selection of significant facts. This is surely the next phase already, that of formulating hypotheses which are suggested by a detailed analysis of facts. Still, Bunge's model is among the most interesting suggestions for a pattern of the procedure of scientific inquiry. Of course, it applies to generalizing, i.e. only to fundamental research, not to applied or diagnostic studies.

## 3. THE PROPOSED MODELS OF PHASE PATTERNS OF SCIENTIFIC INQUIRY

In proposing models of phase patterns of scientific inquiry, authors generally tend to identify a single optimal model of research applicable to a whole scientific discipline, or to all sciences. In contrast to this approach, let

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[20] Cf. M. Bugne, *Metascientific Queries*, Springfield, vol. III., 1959, pp. 83–6.

us consider a preliminary pluralistic view, which implies the development of several models, each for some type of inquiry. Scientific research may differ greatly from case to case, depending on the aim the researcher pursues, specifically on whether he works on fundamental, i.e. theoretically geared problems, or seeks an applicative purpose such as the design of a construction or a new production technology.

We can now take recourse to the comprehensive multi-aspect typology of scientific inquiry developed before[21] to expand the problem of rationalizing the course of scientific inquiry toward developing possibly rational research models that may raise the efficiency of scientific inquiry in different types of research. Let us first point to certain polarization of different types of research that may result in differing research models. Specifically let us concentrate on the fundamental, applicative and implementative, and diagnostic and generalizing researches. In the first typology, as mentioned before, fundamental research is on the pole opposite to implementative research, whereas applicative research with its topics narrowed down to definite tasks of immediate utility pursues some narrow theoretical purpose concretizing the fundamental research; methodologically it is close to the first type of research.

Diagnostic research is also diametrically opposed to generalizing research; while the former is intended to explain some concrete situation, the latter is to arrive at statements of lower or higher generality. Fundamental research may be either generalizing or diagnostic, as it happens in different disciplines of the social and human sciences, and therefore we must provide for two different models of fundamental research– one generalizing, the other diagnostic.

Model A– Generalizing fundamental research in empirical research.

1. The formulation of the problem on the ground of scientific literature or previous research.

2. Introductory research to distinguish certain important facts significant to the given problem.

3. A diagnosis explaining the meaning of the disclosed significant facts.

4. The formulation of the likeliest hypothesis, as a rule one only, which allows the researcher to establish the path of the empirical research.

5. The derivation of conclusions from the general hypothesis adopted. Confronting the hypothesis with the theories functioning in the given science.

6. Research verifying the conclusions from the general hypothesis.

7. The statistical presentation and interpretation of the results obtained. Possible modifications of the base hypothesis, its restriction, extension or refutation.

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[21] Cf. S. Ziemski, „*Zarys typologii badań naukowych*" ["An Outline of the Typology of Scientific Research"]. *Nauka Polska* 1972, No. 4.

8. A report recapitulating the whole research project and formulating problems for further study.

This model is proposed here on the ground of the method of a single fruitful hypothesis derived from a thorough-going diagnostic study of some significant facts. It was this method that was applied in a number of great scientific discoveries; for details see my papers in *Nauka Polska* 1972, Nos. 3 and 4, and 1973, No. 2.

There is a much more time-consuming method which consists in studying all the possible solutions to the given problem—by this I mean what is referred to as the morphological method developed by the Swiss astronomer Zwicky. The application of that method in industrial research, but also in fundamental research, requires enormous outlays and necessitates the cooperation of a number of specialist teams. It is practicable in big research centres with hundreds of researchers. The method allows to explain all alternative solutions to the problem under study. Research institutions with modest scope would perhaps be well advised to prefer the diagnostic method as more efficient in carrying out deepened and more versatile analyses and explaining certain significant facts to formulate pertinent hypotheses conductive to an efficacious research procedure.

Since the modern researcher should be able to choose from a number of methodological devices for carrying out research projects, let us also have a look at the research procedure based on Zwicky's morphological method.

Model $A_1$—The morphological procedure.

1. The formulation of the problem for study.
2. The examination of the entire field of possible solutions to the problem.
3. The formulation of a variety of hypotheses comprising all possible solutions to the problem.
4. The derivation of theoretical conclusions from the hypotheses.
5. Carrying out a series of verificatory studies to eliminate successively the alternative hypotheses.
6. Recapitulating and interpreting the results of studying the one hypothesis that stood the tests of verification following the phase of verificatory studies.
7. The acceptance of the hypothesis or its modification or refutation. Preparing a report of the research project and the formulation of new problems.

Both models proposed here, $A$ and $A_1$, presuppose continuous research cycles: the first studies put out the problems for subsequent studies whose partial results in turn lead to the design of further research.

But there are significant differences between these methods and between the respective degrees of complexity of research conducted by either of these two methods. In model $A$ elimination is carried out in the phase of diagnosis, which includes the study of the multiple alternative explanations of certain significant individual facts with a view to arriving at the best-

-justified explanatory hypothesis through differentiation, that is, through the elimination of individual hypotheses.

The morphological method, on the other hand, shifts the elimination of hypotheses to the phase of generalizing research when a multiplicity of facts has to be used to decide about the value of various general hypotheses. This method requires less ingenuity on the part of the researcher than the other one; instead, it necessitates numerous verificatory tests to be conducted by several research teams to eliminate and evaluate alternative general hypotheses. It is well practicable in scientific megacentres employing hundreds of research workers.

In organizing a research centre we may follow one of two paths: either to prepare the centres for diagnostic research in the selection of facts and all alternative explanations and hypotheses concerning the significant facts in order to eliminate the hypotheses in the first phase and to follow one research procedure later on, or to create big research centres which will conduct broad empirical and statistical researches in order to eliminate the successive general hypotheses from the entire field of alternative explanatory hypotheses.

Both the former and the latter tendencies are observable in scientific research in the world. In the industrial countries, say in the United States, the latter tendency seems to prevail with its drive toward creating huge research centres capable of launching large-scale studies of multiple alternatives. It was in the United States that Zwicky devised and successfully promoted his morphological method.

Smaller countries tend to employ the other method, which calls for more meticulous labour and ingenuity on the part of the individual researcher, who is a specialist in the given domain. For instance the Swiss tend to think that the morphological method that requires huge expense in money and labour can be replaced by the work of outstanding researchers who are able to formulate fruitful research hypotheses from a restricted field of significant facts.

In Poland we tend to develop the diagnostic methods, which are good ways toward establishing the direction and procedure of efficient action. This praxiological issue of good diagnosis and preparation of activities applies to scientific inquiry, too. We can work out increasingly efficient models for scientific research that would enable us to rationalize and cut the time necessary for scientific inquiry. Apart from the much improved inductive methods of empirical research, the methods of diagnosing concrete events, situations, significant facts may prove very useful in research practice.[22] In fact these latter turn up in any heuristic research project that does not employ the method of studying all possible solutions to the problem. This latter method

[22] Cf. S. Ziemski, „Diagnoza jako metoda nauk empirycznych" ["Diagnosis as a Method of the Empirical Sciences"], *Nauka Polska* 1973, No. 2.

can only be employed by gigantic scientific-research megacentres with hundreds of employees.

Since fundamental research is not always intended to furnish generalizations but also diagnoses of concrete facts, simple or composite objects, we can include in the discussion a model of the other type of fundamental and applied scientific research, namely of diagnostic studies.

Model B—The diagnostic type of fundamental research.

1. The observation and description of the studied object, event or situation.
2. Classing it with a given type.
3. The genetic explanation of a certain sequence of causes generating the given event or state of the objects (possibly explaining the sequence of phases, and its development).
4. The explanation of the significance of the given object or event against the background of a greater whole to which it belongs.
5. The identification if its present phase and of the development trend.
6. Forecasting its further development.
7. The verification of the whole diagnosis depending on the way in which the forecast turns out to have been true, and possibly of the action that may have been taken on account of the diagnosis—a corrective, preventive or optimizing action.

The diagnostic research procedure links fundamental research of a cognitive purpose with practical research—applied, implementary—which also must be based on an accurate knowledge of the situation in which the action will occur. In fundamental research one can content oneself with an accurate diagnosis of the style or properties of a work of art, while in practical research, say in pedagogy, a good diagnosis of the pupil's personality or situation is conducive to an adequate preparation of educative actions. In what has been said so far one may notice a certain narrowness in representing the common research typology, namely that it includes only fundamental, applied and implementary research. This is only adequate in the case of research for industrial purposes. It does not incorporate researches in the domain of practical sciences such as pedagogy, clinical psychology, the psychology of work, educational psychology, sociotechnics, etc. The division of sciences into theoretical and practical is more comprehensive. Under the heading of theoretical research we might include all kinds of cognitive fundamental research whereas practical research would incorporate all kinds of research serving directly practical purposes—pedagogical, sociotechnical and broadly social—as well as contributing to works connected with the development and improvement of production and the development of economic life.

Scientific design work is a variation of practical research.

Here is an extended model of the phase pattern for this type of research.

Model C—Implementary research.

1. The accurate study and diagnosis of the base situation, e.g. the modes

of production applied so far together with the assessment of their deficiencies and advantages.

2. On the basis of accurate diagnosis of the existing state of things and of new technological knowledge other technological needs are formulated which concern the problem to be solved.

3. The consideration of a number of alternative solutions and the choice of the solution that is optimal under the given conditions.

4. The formulation of a number of design hypotheses regarding the relations between the parameters.

5. The experimental testing of the hypothetical designs and the choice of the best relations between the parameters.

6. Working out the whole design for implementation with its innovation.

7. Forecasting the implementation of the design and assessing its feasibility.

8. The implementation of the design.

9. The assessment of the implementation of the new product and of its practical feasibility. Suggestions for indispensable modifications. Problems for a new research cycle.

In this model we tried to take account of certain significant points of the methodology of empirical research indicating the ways toward the formulation of the technological problem and, next, the passage from the phase of hypotheses to their verification in experimental work. We cannot decide whether to employ the morphological method or the diagnostic method in the phase of formulating the design hypotheses, in delimiting the full field of possibilities of technological solutions to the given problem. Which of them will in fact be applied depends on the scope of the scientific-research possibilities of the given centre. The shortened procedure can be applied when we rely on the skill of outstanding experts in the given domain whose wide experience and preparatory work will enable them to decide correctly on the most fruitful direction of the verificatory experimental work. In the nine phases of implementary research listed here we gave a full cycle of research, also opening possibilities for further research work. The pattern proposed is of course open to discussion: it can be compared to previous experiences and previous work on innovations, with a view to securing the best possible efficiency of scientific research. But one has to work out the first models in order to improve them in subsequent research activities.

The relationships between types and phases of research in research models

| | | |
|---|---|---|
| Theoretical research | | Practical research |
| Generalizing research | Diagnostic research | Design research |
| Models $A$ and $A_1$ | Model $B$ | Model $C$ |
| Fundamental research | Applied research | Implementary research |

This diagram shows the relationships between the four models of phase patterns of scientific inquiry: Models $A$, $A_1$, $B$ and $C$, and some types of research such as generalizing, diagnostic and design research as well as theoretical and practical or fundamental, applied and implementary research. The comparison of the fundamental models with other types of research will be done in a forthcoming study.

In discussing the procedure of scientific research we emphasized the necessity of differentiation the models of scientific investigation as far as the aims of each research type are concerned. But if we endorse a pluralistic approach in research types, the methods applied and the patterns of research procedures, we arrive at the question whether or not the different procedures have any common points. Here is a list of the methodological elements that can be regarded as common to the different types and patterns of research.

1. The formulation of the problem for study.
2. The survey of available facts and the selection of significant facts.
3. The diagnosis explaining the selected significant facts.
4. The formulation of the hypothesis or several hypotheses or of a design for further research.
5. The derivation of theoretical conclusions from the hypothesis or from the design.
6. The collection of new facts on the ground of observations, experiments or tests.
7. The comparison of the conclusions from the hypothesis or design with new facts.
8. The interpretation of the results obtained. The report on the whole research project, the confirmation, refutation or modification of the hypothesis. The formulation of problems for further research.

This model, which can be designated model *W*, integrates the methodological elements common to all the different models *A*, $A_1$, *B* and *C*. However, in the course of work on specialized methodological tools for different types of research there emerges a *unitas multiplex* of scientific method—a commonnes of research steps and methods applied in different sciences and types of research. In particular, that sense of commonness of all research work in the empirical as well as mathematical sciences is suggested by the method of formulating hypotheses as tentative statements channelling further verifying research in the proper directions.

But the inductive method is not common to all empirical sciences, as we used to think before, because scientific inquiry is not always directed to generalization but may also have particular purposes such as the study of certain concrete situations, works and their authors, events and processes. What is common to all empirical researches is diagnosis, the recognition and explanation of individual facts at least in the heuristic phase.

This shift of emphasis of the common methodological link of the empirical sciences from the methods of generalizing induction to the method of diagnosing concrete facts, situations and personalities has to be recognized as a new accomplishment of modern science.