LOGIC AND SCIENTIFIC METHOD

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PREFACE

"Reason and Science, man's very *highest* power", as the great German poet Goethe viewed, should be cultivated by all means. Education could have no task more important than to inculcate rational attitude. Towards this end, constant development of reason, logic and scientific methods is necessary. Europe and America have gone through the mill of critical thinking and rigorous methodology. Developing lands still do not care to distinguish between truth and fiction, between fact and fantasy or between science and irrationality. Here we tend to accept or reject, understate or exaggerate, go all out for or against something without a reasonable enquiry or analysis.

Reason and method have to be developed by systematic training. They are by no means a gift of nature as Schopenhauer assumed when he said, "Of inference, all are capable; of judgement, only a few." False inferences were the rule of the day in ancient times. Mythology, magic, superstition, rituals etc. were rampant. Aristotle introduced the logic, a system of arguments and valid inference. Francis Bacon gave the methods of experimental enquiry and J.S. Mill formalised them. George Boole in the nineteenth century laid the foundations of the symbolic or mathematical logic which was in keeping with the progress of the new scientific age.

Modern science and technology have made remarkable progress in India recently. Yet, rationalism and scientific temper have not gained substantial ground. Systematic training in logic and other scientific methods is of fundamental importance for creating a scientific temper in the society.

No doubt, logic has been taught in our universities for a very long time but it has been appended, or at least oriented, to the traditional philosophy. The wider significance of logic was not recognised. Only recently some universities have shown interest in this respect. In Maharashtra, Gujarat etc. many universities have introduced 'Logic and Scientific Methods', besides 'Science,

Technology and Society', as a foundation course in B.A. and B.Com. (the *foundation* courses could as well be taught to science students). Certainly this is a laudable and commendable step. In the I.A.S. etc. Exams., too, questions are now asked on the logical force of statements, consistency of arguments etc. in the General English paper.

The present book has been written keeping the educated beginner in view. It covers the curriculum of the foundation course. But it offers more to the general reader. Many a time our thinking is foggy and expressions are muddled. There is hardly a 'method' in our working. The arguments are not clear : they 'confuse', because they are 'intermixed'. As such quite often there is erroneous interpretation and wrong inference. This book might help the reader to rationalise his thoughts and statements and activities leading to clear communication, logical force, methodical working and worthwhile impression.

All basic features of logic and scientific method have been covered. Numerous examples have been given by way of illustration. Exercises have been given to test the comprehension of the reader. All exercises have been carefully constructed. Wherever desirable, hints and answers have been indicated. Many of the examples and exercises have been taken from great writings. They would be found interesting and educative. Symbolic logic is a powerful system without a knowledge of which the study of logic would be incomplete. A long chapter of the book has been devoted to the elementary symbolic logic. Logical analysis is the final goal of logic as indicated in the book. In the early chapters only sentences (propositions) have been analysed. In the last chapter on logic a whole bunch of statements in paragraphs has to be analysed logically. To show how this is done, a number of examples have been worked out. The chapters on scientific method explain the nature and working of science and its methods, deductive, inductive and others.

A word of advice to the reader. "Begin at the beginning" or at the second chapter (the first chapter may be read last). Read intensively. A cursory reading will be useless. Write down the new terms or whatever you learn anew. Stop at intervals to review that you have understood everything that you have read. Do *all* the exercises before passing on to the next chapter. You

must do the exercises of Chapter VII which is the target of logic. If you can do it well, then you can easily go on your own. It would be certainly most useful if two friends could read the book simultaneously and discuss the issues together. You should try to frame interesting examples and questions yourself. Read Lewis Carroll's books 'Alice in Wonderland' and 'Through the Looking Glass' for the fun of arguments and logic.

If you have any comments or you have any new ideas, you are welcome to write to me.

Saryoo Prasad Gupta

May, 1978

1

WHAT IS LOGIC ?

Logic is the science concerned with making generalizations, and ultimately abstractions, by a process of orderly thinking. It is a study of the quality of reasoning, of the weight of evidence, of the validity of inference based on the implication of statements.

The property of making abstractions, i.e. going to the essence of things, is the very core of intelligence. Intelligent action always involves the ability to relate parts to the whole or individuals to a group, to generalise, to classify and to abstract the essence. Suppose the following characteristics are observed : rectangular cube, material of paper, printed pages, some form of binding, meaningful communication. These characteristics are partly found in many things like a magazine, packaging, chocolate box, book etc. One however abstracts 'book' from all these objects because a book has all the characteristics mentioned above. Similarly one can generalise from the following list of characteristics :

Head, foot, feet at the corner, base frame, and get a mammal, staircase, bed etc. which share one or more of the above characteristics. But abstracting from these items, one recognises 'bed' as the only item which contains all these characteristics. While a precise definition of logic cannot be given, its function is to study the conditions under which a proposition necessarily follows or may be deduced from one or more (other) propositions. Logic is also said to be the study of the laws of thought.

'Logos', a Greek word, suggests (i) 'Word' which is the substance of semantics (the science of the meaning of words) (ii) 'reasoned discourse', the system of orderly thinking, which is

the substance of logic. But logic is more than orderly thinking ; it makes the 'orderly thinking' subject to the guidance of a 'method'—often the scientific method or the method of scientific inference. It is the control of logic through its role of reasoning etc. that enables man to grapple intelligently with problems. Aristotle, the great Greek philosopher, defined man as a rational being beeause man can think and apply reason to his thinking. Thinking involves the ability to comprehend concepts and words.

A 'concept' is an idea. It is an idea of an individual object, or of a group or of abstract qualities built up by experience. It is the sum of our knowledge of a particular type of objects, generalized and abstracted from a range of similar objects. It is thus a unified idea based on percepts or sense-data. It is experessed in words or symbols so that the concept can be discussed and manipulated in place of the object itself. Concepts are building blocks of knowledge. Psychology is interested in the formation of concepts and the nature of concepts. Semantics is concerned with the labels and signs which are applied to concepts. Logic is concerned with the use of concepts in the erection of structures, and with the rules and criteria as to the correct use of concepts.

The use of Logic

A concept recalls from percepts i.e. sense-data that the object is like this or that or of a certain form. Also one has to abstract the particular object from all other similar objects until the particular concept is isolated by a process of classification. Classification is the process of grouping individual objects on the basis of a common property or likeness. So when we have the concept, we build a structure for giving a form to the concept by expressing it in symbols, words and sentences. Then we apply logic to make the structure stable and useful. This is the practical aspect of logic. According to the great mathematician and philosopher A.N. Whitehead, logic has two aspects : practical and theoretical. The theoretical aspect seeks to promote understanding. Our knowledge of the world depends on observation, on percepts and sense-data. We extract from

the sense-data what we need and draw inferences to build concepts and account for the relationships between them. The range of our knowledge, depends on the synthesis of observations, on the assessment of relationships between them and the validity of inferences. The theoretical aspects of logic belong to the world of ideas. It is a 'normative' science dealing with things as we believe they ought to be. It is also concerned to make aesthetic or ethical judgements about the value of concepts and the 'truth' of statements. In this sense it is a kind of philosophy. As a practical science is the study of a thing as it is, so logic is a positivist science. It assists in checking the validity of inference by which a thinker passes from one concept to another, along a chain of relationships which seem to justify the inference. In this sense it is a scientific method.

Every science attempts to predict the future on the basis of the study of the past and present ; for example physics, meteorology, economics, political science etc. make predictions. What is the method by which this is attempted ? The method is a curious mix of various processes : Observation, analysis, experimentation, inference, testing etc. In any case the method involves the use of the principles of logical inference. Any precise work must involve the use of mathematics. And mathematics, its basis and process, is outright logical although the relation of the theory of logical inference to the kind of deductive reasoning used in mathematics may not be apparent. Even in empirical studies logic plays an important role. Consider for example the statement made by the World Health Organisation "while Yoga and meditation may temporarily lower blood pressure, there is no evidence of consistent results", or the statement of a doctor on a new drug, "Although it had not yet been tested on human beings, experiments on mice had been conclusive", or the statement from economics, "There may be a few cases where industrialization and economic growth have been achieved under conditions of inflation, but there is no causal relationship as such." All these statements show how logic permeates through the empirical sciences as well. Evidence, consistency, conclusion, causal relationship, testing of hypothesis etc. are important components of logic and science, and we shall learn about them later in this book.

Logic and Language

The method of valid reasoning involves construction of logical form to the language and to bring logical precision to the analysis of ideas. But howsoever sharp this tool of logic may be, it cannot enhance the usefulness of language to give a universal description of nature in a single, closed, consistent language. There can be no precise language which is universal. Even a formal language has this serious inherent limitation, because every formal language which is at least as good as arithmetic contains meaningful sentences that cannot be asserted to be either true or false. In 1931 Kurt Goedel proved two remarkable theorems showing that a logical system which has any richness can never be complete nor guaranteed to be consistent.

Language is a means of communication. We generally communicate our feelings and ideas to others. Emotions and sentiments too are expressed in language. Language does not only consist of letters, words and sentences but also of symbols, diagrams and drawings. Some symbols like ;, ? etc. are well known to us as an indispensable part of the everyday language. In addition, mathematics and other sciences use a variety of symbols like=, %, etc. In logic too, symbols are used and that part of logic is called 'symbolic logic'. Diagrams are not only used in sciences but also in logic and arts. A 'circuit diagram' of a radio or an electrical network tells a lot more than the ordinary language. So is the case of a drawing. A drawing of a building gives much more idea of the building than a long description of the building or perhaps the building itself. In fact, it is said that 'drawing is the language of engineers'.

Symbolism

Complex problems cannot be studied without the use of symbols. Inference from complex propositions cannot be drawn if symbols are not used for propositions and operations. Ordinary language becomes too clumsy and unmanageable. It is generally vague and ambiguous. Any subtle analysis of such a language

is not practicable. Hence the necessity for the use of symbols. When symbols are used in logic, they can be studied like mathematics. This part of logic is called symbolic logic or mathematical logic.

The use of symbols makes the language precise and compact. Further it enables the use of laws and operations, for example, the operations of addition, multiplication etc. In a broad sense, every word is a symbol because a word represents a concept. But further symbolisation in addition to words, descriptions and operations is of very great advantage. For example $X(Y+Z)=XY+XZ$ would represent the following description :

"If a number X is multiplied by the sum of a second number Y and of a third number Z, then the result is equal to the sum of the multiples obtained by multiplying X with Y and Z separately."

As in mathematics, one can write the logical operations and arguments in the language of symbols. Any symbol should, however, be meaningful. Many a time one comes across symbols, for example, symbols of certain companies when one cannot make out the head or tail of the symbols. Such symbols are of little use otherwise; they can neither be read nor understood.

The Function of Language

The function of language is to work as a vehicle of communication so that one may express his idea precisely, and others may understand it exactly in the same way as the person had originally thought. Unfortunately ur language, spoken or written, is vague and has a lot of deficiency. But language is not alone to blame. Even our thinking is often muddled. Logic offers a way of thinking, speaking or writing in a clear, orderly and precise manner. It has a theory of correct reasoning or theory of valid inference whose principles are used in every branch of knowledge. In the common language the logical form of argument is not often clear but it is there all the same. Logic takes up a small number of key-words and phrases like 'and', 'not', 'every', 'some' and builds a structure for the play of arguments. Then with the rules of inference it analyzes the

character of arguments and finds a way to test their validity. Arguments are given by all of us, and not only by lawyers, whenever we have to stress a point or in support of a contention.

The most exact science, mathematics, relies heavily on logic. In fact, Bertrand Russell felt that pure mathematics is nothing but logic. Pure mathematics consists entirely of assertions that if such and such a proposition is true of anything then another proposition is true of that thing. It hardly matters whether the proposition is really true or not. What is important is the relation of the two propositions. Mathematics uses only the logic of deductive resoning in proving a theorem or deriving an inference. The theory of inference is of great relevance to all sciences (apart from mathematics), to philosophical analysis, to the proceedings in the courts of law and in fact to every serious deliberation.

The most modern of scientific inventions is the 'computer'. The computer is a machine which performs arithmetical functions surprisingly fast. It has a method of reducing all problems, even the problems of language, into arithmetical terms and thereby solving them. The very basis of the working of the computer is Boolean logic, a logic introduced by George Boole (1815-1864). Thus logic is seen to have affected not only our language but also the machine.

In order to eliminate vagueness one of the methods employed is to isolate a small number of basic concepts and then to define other concepts in terms of the basic ones. Logic gives a method for doing this job in an exact way. Like science logic starts from the fact that certain words have certain meanings. Words may denote things, relation and operations. Logic has a lot of concern with words and general grammar. It helps in the study of the meaning of words since the information conveyed by a word depends on the sense conveyed by sentences. The same word may have different meanings in different sentences. Logic corrects the ambiguity and vagueness of the ordinary language. Logic and the laws of language are precise and they do their job by means of precise definition, laws and symbols as mathematics does.

As Patrick Suppes said, "Logic in a narrow sense is the

theory of valid arguments, or the theory of deductive inference. A slightly broader sense includes the theory of definition. A still broader sense includes the general theory of sets and the axiomatic method." By further broadening the sense one may say that logic is a science concerned with making generalizations and ultimately abstractions, by a system of orderly thinking.

Conclusion

In the search for reality we are all groping in darkness. Without logic we would be lost from the very start. We would fare no better then the blind men, who went to 'see' an elephant but ended in drawing funny inferences, that the animal was like a wall or spear, and so on, as depicted beautifully by John Godfrey Saxe in his poem "The blind men and the elephant" given below :

There were six men of Hindustan,
To learning much inclined,
Who went to see the elephant
(Though all of them were blind)
That each by observation
Might satisfy his mind.
The first approached the elephant,
And, happening to fall
Against his broad and sturdy side,
At once began to bawl :
"God bless me ! but the elephant
Is very like a wall."
The second, feeling at the tusk
Cried : "Ho ! what have we here
So very round and smooth and sharp ?
To me 'tis mighty clear
This wonder of an elephant
Is very like a spear !"
The third approached the animal,
And happening to take
The squirming trunk within his hands,
Thus boldly up and spake :

"I see", quoth he, "the elephant
Is very like a snake !"
The fourth reached out his eager hand,
And felt about the knee;
"What most this wonderous beast is like
Is mighty plain", quoth he;
"Tis clear enough the elephant
Is very like a tree !"
The fifth, who chanced to touch the ear
Said : "E'en the blindest man
Can tell what this resembles
Deny the fact who can,
This marvel of an elephant
Is very like a fan !"
The sixth no sooner had begun
About the beast to grope,
Than seizing on the swinging tail
That fell within his scope,
"I see", quoth he, "the elephant
Is very like a rope !"
And so these men of Hindustan
Disputed loud and long,
Each in his opinion
Exceeding stiff and strong,
For each was partly in the right
And all were in the wrong !

Exercises

1. Explain what do you understand by the term 'logic'. How would you define it ?
2. What are the various definitions of logic? Examine them.
3. (i) How do you know that you are an Indian ? Is it on the basis of sense-perception (i.e. immediate, direct knowledge) or on evidence ?
   (ii) How do you know that you are alive ? Isn't it on the basis of sense-perception ?
   (iii) How do yon know that you exist ? Are there other

things in existence besides yourself ? On what evidence can you assert that ?

4. What are the uses of logic ? Is it useful in everyday life ?
5. How does logic affect the common language ? What is the quality of the language of logic ? Can there be a language of symbols only ?
6. What is a 'concept' ? How are concepts represented and communicated ?
7. Explain 'classification' and 'abstraction'.
8. Discuss how logic is related to a language ? How does logic affect the language ?
9. Explain the uses of symbolism .

2

TERMS AND PROPOSITIONS

Terms are words or symbols which are commonly used to represent concepts. For example, we have a concept of a book : that a book is generally of rectangular shape, contains a number of printed pages, it has an attractive cover, the cover has the title of the book and the author's name printed in bold letters as well as the publisher's etc. etc. All these ideas and sense-data are contained in the concept of the book and the concept is symbolised by the word 'book'. The concept is symbolised by different languages. The symbolisation may also be done by a picture of book (as in the pictorial languages like Chinese) or by a letter 'b'. But the symbol has to be accepted by people otherwise it may not be understood. The symbol for representing a concept is called 'term' in logic.

There is a lack of general consensus of opinion about the precise meaning of 'term'. The 'term' is the basic building block of logic in the same way as a 'word' is the basic building block of grammar. There is always a natural difficulty in giving a precise meaning of a basic object since a definition. explanation or interpretation of a term inevitably involves the use of other terms. Then these other terms must be defined in the first instance. As we proceed like this to more and more basic terms, we come to a term from which we cannot go further basic. The 'most basic' term cannot be defined or explained precisely, even though we have a concept of the object which the term represents. Such a term is called a 'primitive' term. The 'term' of logic, which we are trying to understand now, is a primitive term.

Interpretation of a term comprises 'denotation' and 'connota-