INDUCTION IN ARISTOTLE'S SYSTEM OF SCIENTIFIC KNOWLEDGE

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There are many disputes about induction in the logic and philosophy of science. One of the problem is that we often use the term „induction" in different meanings. This is precisely the point of Aristotle, the first thinker who analyzed induction systematically. The aim of the paper is to show that we are confronted with at least four different meanings of induction (epagoge) in Aristotle's writings, to analyze them and to show the role of induction in acquiring scientific knowing and the consequences for the structure and characteristics of Aristotle's system of scientific knowledge.

Preliminary remarks

Some years ago I attended a lecture given by Ladislav Kováč, Slovak biochemist and author of so called *cognitive biology,* which is an attempt to reformulate the fundamental problems of epistemology into the language of empirical (biological, chemical and physical) sciences and is very closed to *evolutionary epistemology* as proposed by Konrad Lorenz, Gerhard Vollmer, Donald T. Campbell, Rupert Riedl, Franz Wuketits and others. In his lecture Ladislav Kováč wondered about the disproportion of citation index of Aristotle's and that of Konrad Lorenz's works in philosophy and social sciences, which was, from his point of view, in the indirect proportion of the importance of their ideas for the development of contemporary philosophy and social sciences. His words were the first impuls for me to study the possible influence of Aristotle's ideas in the development of modern science and philosophy of science.

Another impuls came from biology and philosophy of biology. There was a discussion in biology and philosophy of biology in 70-ties about the striking similarity between Aristotle's *eidos* and *genetic program* in modern biology (Delbrück 1971, Mayr 1976), where some authors claimed Aristotle to be almost the discoverer of DNA[1], and also a discussion on teleology in evolutionary biology. Finally, I had a discussion with Pe-

[1] Max Delbrück gave even an address with the ambiguous title „How Aristotle discovered DNA".

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ter Sýkora about his attempt to revive Aristotle's essences (*to-ti-en-einai*) in an evolutionary framework few years ago (Sýkora 1995, 1997; Gálik 1997, 1998).

All these ideas and problems have led me to study Aristotle's philosophy of science and to reconstruct the possible pathways of Aristotle's ideas in modern and contemporary science and philosophy of science.

Introduction

A number of analyses in philosophy of science, especially when describing the birth of science, starts with modern science and modern philosophy of science in the 16th and 17th centuries. But it seems the situation is changing and many philosophers become aware of the importance of the Greek legacy for the development both of science and philosophy of science. And when we are talking about the Greek legacy, we must mention Aristotle. Though he was not the first to define some fundamental problems in scientific knowledge, there can be only a little doubt he was the first who had analyzed scientific knowledge *systematically* and created the first *theory of science*, the first philosophical fundaments and justification of scientific knowledge. The broad scope of Aristotle's work shows that his aim was to build a *complete* system of scientific knowledge – a system that would contain both the theories describing the world (i.e. scientific theories) and basic principles of building such system (i.e. logic and philosophy of science).

The importance and the influence of Aristotle's analysis of what science is and how to reach the true scientific knowledge are greater than the scientists and many philosophers of science are ready to acknowledge. In fact, many ideas which seem to develop long after Aristotle may be found in Aristotle's works. Unfortunately, we find them in those Aristotle's works that are not as popular and widely read and discussed as his *Physics* or *Metaphysics*. The other reason may be that modern science and modern philosophy of science in the 16th and 17th centuries originated and was (and is) articulated as an anti-Aristotelian approach to scientific knowledge. But if modern science stands at the opposite pole than Aristotelian science, why do we turn back to Aristotle? Is it only for the sake of completing the historical studies to have the more accurate picture of the development of science in different historical stages? Or

is it because there is something in Aristotle that survives in modern and even in contemporary science and philosophy of science?

There is no other way to find the answers to these questions than to read Aristotle's works, try to interprete his ideas, and to find where he was wrong and where his ideas are still fruitful. The aim of this paper is to give a short introduction only to one of the fundamental problems of philosophy of science, to the problem of induction (*epagoge*) in Aristotle and to sketch some traces of it in modern science.

Scientific knowledge

Aristotle was the first (or probably the first) who had analyzed scientific knowledge systematically. Although he was not the first who distinguished scientific knowledge (*episteme*) from opinion or common knowledge (*doxa*), he defined scientific knowledge, described its essential features and analyzed the ways (methods) how to reach the real scientific knowledge.

According to Aristotle scientific knowledge (or scientific knowing) is the knowledge of those properties of things that are *universal* and *necessary*. These are immutable *essential properties* of things that lie behind their manifested changing properties. Aristotle continues here the tradition of his predecessors who divided the world into two parts – the manifested changing world of chance and the hidden immutable world of necessity, with corresponding kinds of knowledge – *opinion* and *scientific knowledge*.

Scientific knowledge as knowledge of that what is universal, immutable and necessary is necessary true, it can not be false. Opinion, on the other hand, may be true or false, and if it is true then mainly by chance. Second, we can claim to posses scientific knowledge of a thing, that is to claim to have necessary true knowledge of it, if we are acquainted with its primary conditions, first principles, first causes (see *Physics*, *Metaphysics*, *Posterior Analytics* etc.). Third, it is not sufficient to assert something about the nature of things, we have to explain the cause of it, and to explain the cause of thing does not mean to make „*mere assumption or to lay down any gratuitous axiom*". We have to prove or justify our assertion or, in Aristotle's words, „*to employ either inductive or demonstrative reasoning*" (*Phys.* VIII 1; similarly *Anal. Post.* II 19). This is an important point. Aris-

totle postulates here fundamental norm for every science – a need of justifying every assertion, every claim we make in science.

Here also one kind of induction finds its role as a method of justifying assertions, one of the methods that guarantees a scientific nature of knowledge. But there are different kinds of induction in Aristotle's system which play different roles in scientific knowledge.

Induction as learning

Aristotle was not the first to use induction as a method of scientific reasoning. In *Metaphysics* he wrote: „*two things may be fairly ascribed to Socrates – inductive arguments and universal definition, both of which are concerned with the starting-point of science*" (*Met.* XIII 4). But Aristotle was obviously the first who had analyzed induction systematically.

We can distinguish at least four different kinds of induction in Aristotle. These kinds of induction may be divided into two groups according to their different relation to universal properties, principles, elements:

1. induction as a process of grasping unknown universals;
2. induction as a process of understanding known universals.

While induction (or inductions) in the first group may be characterized as a step-by-step approaching from particular things to universal properties, that is as an element of method of discovering universal properties, as a method of acquiring scientific knowledge, induction in the second group represents, in a sense, a process directed from universals to particulars. This type of induction is a method of learning and understanding scientific knowledge with the help of perception. It is a way how to familiarize a pupil with the universals through examples. For Aristotle induction in this sense plays a crucial role in learning – it is even the only way the pupil can understand universals, abstractions: „*...it is possible to familiarize the pupil with even the so-called mathematical abstractions only through induction...*" (*Anal. Post.* I 18). There is no other way „*...to grasp universals except through induction*" (*Anal. Post.* I 18).

That means we learn about properties of particular things through perception and we understand universals through induction. Rather to be a process of inference induction as learning is a process of *taking a pu-*

pil to universals.[2] But this also means „*that the loss of any one of the senses* (that is of any of the source of perceptual knowledge) *entails the loss of a corresponding portion of knowledge, and that this knowledge cannot be acquired*" (*Anal. Post.* I 18).

Induction as a syllogism

In the second sense there is an induction as a kind of syllogism. We can describe it as a bottom-up syllogism. Induction in this sense means finding out an appropriate middle term where both extreme terms are given, i.e. „*if B is the middle term between A and C, it consists in proving through C that A belongs to B. For this is the manner in which we make inductions...*"; „*in a way induction is opposed to syllogism: for the latter proves the major term to belong to the third term by means of the middle, the former proves the major to belong to the middle by means of the third. In the order of nature, syllogism through the middle term is prior and better known, but syllogism through induction is clearer to us*" (*Anal. Pr.* II 23).

This kind of induction is in fact a process of creating hypotheses that can serve as premisses of a valid deductive argument where some empirical data and some theoretical (universal) premisses are given.[3] Although this kind of induction can play some important role in scientific knowledge, the next two kinds of induction have a crucial position in building the very fundament of the system of scientific knowledge.

Induction and sense-perception

Induction is for Aristotle not only a tool for learning about universals or a method of acquiring a lower premise from higher premise and conclusion. First of all, it is a method of grasping universal properties of parti-

[2] There is a discussion about translating *epagoge* as *induction*. For some authors this could lead to confusion of Aristotle's concept of induction with that of John S. Mill. Therefore they propose to translate *epagoge* as *taking to* (as an opposite to *apagoge, taking from*), see for example (von Fritz 1975). It is possible to avoid this confusion if we are aware about different meanings of *epagoge* in Aristotle, and also about different meanings of *induction* even in contemporary philosophy of science.

[3] This kind of induction is sometimes used as an argument against anti-inductionists as a demonstration of the existence of induction as a logical inference. The problem is that this kind of induction goes far beyond the problem of induction which is, in this case, the problem of justifying induction as a kind of logical inference.

cular things, a method of achieving first principles. Induction in this sense proceeds from particular things, their particular properties to universal properties. The result of induction is a system of universal statements about universal and necessary properties of things, about causes and principles. These statements, with the universal statements about first principles common to all sciences ahead, are for Aristotle the fundaments of the system of scientific knowledge.

Induction as a method of grasping universals is closely tied-up with sense-perception. But this does not mean that it is perception alone which leads to scientific knowledge about universals. Though sense-perception is a necessary gate for acquiring scientific knowledge, scientific knowledge is, according to Aristotle, „*not possible through the act of perception. Even if perception as a faculty is of 'the such' and not merely of a 'this somewhat', yet one must at any rate actually perceive a 'this somewhat', and at a definite present place and time: but that which is commensurately universal and true in all cases one cannot perceive, since it is not 'this' and it is not 'now'; if it were, it would not be commensurately universal – term we apply to what is always and everywhere. Seeing, therefore, that demonstrations are commensurately universal and universals imperceptible, we clearly cannot obtain scientific knowledge by the act of perception: nay, it is obvious that even if it were possible to perceive that a triangle has its angles equal to two right angles, we should still be looking for a demonstration – we should not (as some say) possess knowledge of it; for perception must be of a particular, whereas scientific knowledge involves the recognition of the commensurate universal. So if we were on the moon, and saw the earth shutting out the sun's light, we should not know the cause of the eclipse: we should perceive the present fact of the eclipse, but not the reasoned fact at all, since the act of perception is not of the commensurate universal*“ (*Anal. Post.* I 31).

But as far as induction in this sense is a consequence of sense-perception, if some kind of sense-perception is missing, there is no way how to grasp corresponding universals; such particulars can not be objects of scientific knowledge. More precisely, a person who is lacking of some kind of sense-perception is not capable of scientific knowledge about corresponding kind of things: „*induction is impossible for those who have not sense-perception. For it is sense-perception alone which is adequate for grasping the particulars: they cannot be objects of scientific knowledge, because neither can universals give us knowledge of them without induction, nor can we get it through induction without sense-perception*“ (*Anal. Post.* I 18). This is precisely the same result as in induction as learning – where some kind

of sense-perception is lacking, there is impossible to learn about and to understand universals of corresponding properties of things and also it is impossible to grasp these universals, or in other words, to create appropriate premisses of scientific knowledge.

Induction as generalization

For Aristotle induction as a method of achieving universals is not mere elaboration of data given by perception. It operates upon the sense data, but it is an act of reason. Induction in this sense has two forms – generalization, and rational inference into the necessary and universal properties of things.

A generalization is a logical inference from singular (singular proposition) to universal (universal statement) through the frequently repeated observations of the same event: „*...induction is a passage from individuals to universals...*" (*Top.* I 12); „*...by watching the frequent recurrence of this event we might, after tracking the commensurate universal, possess a demonstration, for the commensurate universal is elicited from the several groups of singulars*" (*Anal. Post.* I 31).

It seems that Aristotle's attitude to induction as generalization was not unambiguous. On one hand, this kind of induction is widely applied method in natural sciences (there are many places in different Aristotle's writings, especially in his scientific ones, where the expression „*this is known by induction*" appears) and may serve as a genuine tool for grasping knowledge of the universal, knowledge that is necessarily true, i.e. for grasping *scientific knowledge.* There is no doubt about the complete induction where we formulate a universal statement upon the observation of all the members of the given class of objects. But even the uncomplete induction may lead to necessary universal statements – we could somehow *elicite* the universal from frequent occurences of the same event.

On the other hand, Aristotle seems to be aware of the limits of inductive generalization. Though this is a method of grasping universals, it cannot serve as a genuine demonstration, because we have no guarantee „*against an unessential addition, or against the omission of the final or of an intermediate determinant of the substantial being...*"; „*...induction, perhaps, is not demonstration any more than is division, yet it does make evident some truth*" (*Anal. Post.* II 5). This skepticism may stem from two different types of

universals – universals that are the expression of those properties which belong to things of the same kind by necessity. Then there are universals that are the expression of those properties that may belong to things of the same kind by chance, and therefore these universals are not genuine universals: „*Some occurrences are universal (for they are, or come-to-be what they are, always and in ever case); others again are not always what they are but only as a general rule*" (*Anal. Post.* II 12). The genuine universals are the source of real scientific knowledge. If induction via generalization is not an appropriate tool for grasping these universals, then we have to apply another method, another kind of inductive inference.

Induction as rational inference into the principles

Aristotle believed that real scientific knowledge must proceed through the demonstration. That means that every claim we make in science must fit into some demonstration, it must be shown to follow from premisses of a valid demonstrative syllogism. If the system of scientific knowledge is a system of hierarchically organized statements where every statement at a lower level is (and must be) deducible from the primary premisses of corresponding science, and these, again, must follow from the highest premisses of all scientific knowledge, then there is a problem how to reach the primary and immediate premisses of scientific knowledge and how to guarantee they are necessary true - „*scientific knowledge through demonstration is impossible unless a man knows the primary immediate premisses*" (*Anal. Post.* II 19).

Here, again, induction as a method of grasping universals plays a crucial role - „*it is clear that we must get to know the primary premisses by induction; for the method by which even sense-perception implants the universal is inductive*" (*Anal. Post.* II 19). It is not induction as a mere generalization but as a rational inference into the necessary and universal properties of things. This induction is a step-by-step process of analyzing different properties of things of the same and of the different kind, finding out universal properties and formulating statements on species level, genus level etc. This is „*the right method of investigation: We must start by observing a set of similar – i.e. specifically identical – individuals, and consider what element they have in common. We must then apply the same process to another set of individuals which belong to one species and are generically but not specifically identical with the former set. When we have established what the common element is in all members of this second species, and likewise in mem-*

bers of further species, we should again consider whether the results established possess any identity, and persevere until we reach a single formula, since this will be the definition of the thing." (*Anal. Post.* II 13)

But the other problem still remains. In order to have a complete system of scientific knowledge, we need the first premisses, the knowledge of the first principles. The problem is we cannot grasp the highest premisses of the system of scientific knowledge via scientific knowledge – induction is not enough. The only way how to reach them is the intuition: „*Now of the thinking states by which we grasp truth, some are unfailingly true, others admit of error – opinion, for instance, and calculation, whereas scientific knowing and intuition are always true: further, no other kind of thought except intuition is more accurate than scientific knowledge, whereas primary premisses are more knowable than demonstrations, and all scientific knowledge is discursive. From these considerations it follows that there will be no scientific knowledge of the primary premisses, and since except intuition nothing can be truer than scientific knowledge, it will be intuition that apprehends the primary premisses - a result which also follows from the fact that demonstration cannot be the originative source of demonstration, nor, consequently, scientific knowledge of scientific knowledge. If, therefore, it is the only other kind of true thinking except scientific knowing, intuition will be the originative source of scientific knowledge. And the originative source of science grasps the original basic premiss, while science as a whole is similarly related as originative source to the whole body of fact.*" (*Anal. Post.* II 19)

Intuition is an act of reason, a rational insight into the very essence of the thing. As such it cannot be false, it *must* be true. It is the last step from inductively infered universal properties to the first and immediate causes, principles, to the first and immediate premisses, to the fundament of the system of scientific knowledge.

Conclusion

Aristotle's system of scientific knowledge is in fact an attempt to build it as an axiomatic-deductive system. The base of the system consists of axioms (immediate premisses as a knowledge of the first principles) and definitions (formulas about the essence of things) which we get through the induction and intuition. From axioms and definitions basic theorems may be infered. Now we can deduce all the knowledge (or prove all assertions through the deduction from the first premisses, or show how all

other sentences of the system follow from its premisses) as consequences of these primary premisses.

Aristotle was the first who had not only built a complete system of scientific knowledge as an axiomatic-deductive system, but also had accomplished its theoretical analysis. His ideas had an enormous impact, although not direct, often hidden and intermediated, on the further development of science. Many authors who had tried to build system of scientific knowledge on similar principles, were not aware of the inspiration by Aristotle's system (in fact, many of them would deny it). Let us take for example Newton's physics (or natural philosophy, as he calls it). Newton's physics, though created as an anti-Aristotelian system, shares similar structure and follows similar rules as Aristotle's system: „*In experimental philosophy we are to look, upon propositions inferred by general induction from phenomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phenomena occur, by which they may either be made more accurate, or liable to exceptions. This rule we must follow, that the argument of induction may not be evaded by hypotheses*" (Newton 1968). My point is that although Newton's physics stands in opposition to Aristotle's physics in describing and explaining natural phenomena, and in fact differs in some important features from Aristotle's philosophy of science, it resemblances the same logical and epistemological structure. But this is the question of another investigation.

It is true that Aristotle did not and could not see many problems that have been postulated in the following centuries. But leaving this aside I would like to stress the fundamental idea of the axiomatic-deductive structure of scientific knowledge which is, first, the guarantee of necessary truth of scientific knowledge that lies in a method though which we have reached it, and second and more important, the necessity to prove or justify all assertions we make in science. Though we may and should have doubts about the first thesis, we should rely on the second one if we want science to be science.

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