POPPER AND PIAGET ON THOUGHT AND ACTION: A PROBLEM IN EVOLUTIONARY EPISTEMOLOGY

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by

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ABSTRACT

The initial problem is 'Compton's problem', as formulated by Popper: 'how does the universe of abstract meanings influence actions?' Popper solves this problem on the level of 'knowing that' by embedding his theory of the evolution of functions of language within a general theory of evolution. It is in virtue of the evolution of functions of language, from animal to human functions, that 'the universe of meanings' - linguistically formulated theories - exerts a 'plastic control' upon actions. This is a control with freedom and feedback, as opposed to a 'cast-iron' or deterministic control. Within Popper's general evolutionary theory, this solution to Compton's problem 'bridges' animal and human evolution. Through it, both the 'trials' and the method of 'error-elimination' undergo a transition from animal to human evolution; respectively, genetically based 'expectations' or dispositions to react become linguistically formulated theories and error-elimination through 'natural selection' becomes error-elimination through criticism and refutation.

But there is a 'gap' in this bridge. The human use of language presupposes that 'expectations' have become separate from biological organization. The central problem in this thesis is accounting for the emergence of the plastic control of theories upon actions through an account of the separation of 'expectations' from biological organizations.

Piaget's theory of child intellectual development was employed to close this gap. This theory was interpreted by Piaget, through the postulate 'ontogeny recapitulates phylogeny', as providing an account of the intellectual evolution of prehistoric man. It provided a solution to Compton's problem on the level of 'knowing how' by demonstrating that the separation of expectations from biological organization occurs in various stages. These stages represent the attainment of subjective structures which simultaneously represent the 'form' of a series of actions taking place successively. Through these subjective structures, 'expectations' influence a plastic control upon action by enabling controlled experimentation and the linguistic formulation of experimental

results. Piaget interpreted this theory through the postulate 'ontogeny recapitulates phylogeny' in order to demonstrate a merger of the contexts of discovery and justification; while, for Popper, any such merger is erroneous. Hence, the implications of the closure of the 'gap' with respect to the roles of these two contexts in the growth of knowledge are considered.

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INTRODUCTION

By way of introduction, I believe, I ought to explain how it was that my topic developed. Originally I had intended to concentrate on the philosophy of mathematics. In particular, the problem of the applicability of mathematics to the world - the problem of how it is that mathematical structures, developed completely independently of empirical considerations, are often successfully interpreted as providing an account of the physical world - struck me as both an extremely important one within the philosophy of mathematics and one which, for one reason or another, had not seemed to occupy a central position within most traditional philosophies of mathematics.

In this connection, I became interested in the work of Jean Piaget, child psychologist cum philosopher, who in the book Mathematical Epistemology and Psychology (1966), co-authored with the logician, mathematician and philosopher, Evert Beth, proposed a solution to the problem of the applicability of mathematics based upon his conception of genetic epistemology. This solution based the applicability of mathematics upon an evolutionary approach in which the development of intelligence in man was viewed to be the result of a series of progressive adjustments to the environment. Primitive mathematical structures were seen as emerging as a product of these adjustments. In addition, the dynamics of these successive adjustments provided, for Piaget, the possibility of extending these primitive structures and thereby developing pure mathematics. Thus, the applicability of mathematics to the world or, in Piaget's terms, its "intrinsic objectivity", stemmed from its basis within the interaction between the subject and the environment.

Piaget's approach in arriving at such startling conclusions was, of course, biological (evolutionary) and psychological in its orientation. He looked upon the child's intellectual development as a source of information about the development of prehistoric man. This was, in effect, an application of commonly accepted evolutionary postulates, namely the postulates that an organism's ontogenetic development (the development of the individual organism) partially recapitulates its phylogenetic development (the development of the phylum of which the organism is a member); and that the single organism, after mutations, is a 'spearhead' of its phylum in which is telescoped the evolutionary development of that phylum and upon which the future development of the phylum depends.[1] The innovative aspect of Piaget's approach was his application of these evolutionary models to the realm of mind.[2]

With such an orientation, Piaget has explicitly embedded the realm of intelligence within an evolutionary framework. The intelligence, for Piaget, is both a product of evolutionary adaptation and an organ for adaption. In Piaget's words:

> It (the intelligence) is the most highly developed form of mental adaptation, that is to say, the indispensible instrument for interaction between the subject and the environment when the scope of this interaction goes beyond immediate and momentary contacts to achieve far reaching and stable relations. But, on the other hand, this use of the term precludes our determining where intelligence starts; it is an ultimate goal and its origins are indistinguishable from those of sensori-motor adaptation in general or even from those of biological adaptation itself.[3]

With this perspective Piaget developed his genetic epistemology through the application to intelligence of the evolutionary postulates mentioned above. Hence, Piaget looks upon child intellectual development as a kind of "mental embryology". It is from this standpoint that he was able to integrate his psychological studies of child development within an evolutionary epistemology. Child development becomes, for Piaget, a scientific means to study man's pre-history. Through it, Piaget hopes to solve important epistemological problems, such as, the applicability of mathematics to the world by indicating the psycho-genetic origins of mathematics.

Hence, my interest in the problem of the applicability of mathematics, led me, through Piaget into evolutionary epistemology. In this context, I became interested in the work of Karl Popper, who, in the words of Donald T. Campbell, is "the modern founder and leading advocate of a natural-selection epistemology".[4]

Of course, since I was approaching Popper from the perspective of evolutionary epistemology, the work of his which was my central concern was the collection of papers entitled Objective Knowledge (1972). In this collection, Popper makes explicit the evolutionary basis of his epistemological interests. In particular, within one of the papers, "Of Clouds and Clocks", he develops a general theory of evolution embracing both animal and human evolution within one common Darwinian framework.

This general theory of evolution was formulated by generalizing an account of the development of four functions of language: the expressive, the signalling, the descriptive and the argumentative.[5] This account of the development of functions of language was in turn, formulated to provide a solution to what Popper refers to as 'Compton's problem': "how does the 'universe of abstract meanings' influence human behaviour (and thereby influence the physical world)?"[6]

Popper's solution to this problem hinged upon his notion of the emergence of 'plastic controls'. The later functions of language emerged from its predecessors and exercised a plastic control – a control with freedom and feedback – upon them.[7] Thus, since the descriptive and argumentative use of language in which is contained the 'universe of abstract meanings' emerged from the expressive and signalling uses of language, they exercise a 'plastic control' over these lower functions. Moreover, since the expressive and signalling functions involve behaviour or actions, the descriptive and argumentative functions of language exercise a 'plastic control' over behaviour or actions. Thus the 'universe of meanings' exercise a plastic control over action, for Popper, in virtue of the development of the functions of language.[8]

Once Popper had formulated this solution to Compton's problem, he generalized this account of the development of the functions of language to form his general theory of evolution. Specifically, he generalized the notion of the emergence of plastic controls through a trial and error process. Thus Popper viewed animal evolution as a trial and error process in which the organism and its inherited "expectations" along with mutations constituted the 'trials' while 'natural selection' was the form of error-elimination. Plastic controls emerged during this process and were incorporated in the genetic structure of the organism so that the biologically incorporated "expectations" of the organism could be passed on to its progeny. On the other hand, Popper viewed human evolution as also a trial and error process. Within human evolution, expectations were incorporated in human language and thus the 'trials' were linguistically formulated theories - human expectations. The method of error-elimination was through criticism and refutation, through the descriptive and argumentative use of language. The plastic controls incorporated within human evolution were the regulative ideas of truth and validity generated through the descriptive and argumentative use of language.[9]

Popper's formulation of his general theory of evolution brought out the significance within it of his account of the development of the functions of language: it provided an account of the evolutionary transition from animal to human evolution. It is through the development of the specifically human functions of language, the descriptive and argumentative functions, that human evolution becomes possible for Popper.[10]

In this context, I could more clearly understand Popper's solution to 'Compton's problem'. For now it became clear that the 'universe of meanings' exercised a plastic control upon human behaviour, for Popper, in virtue of the plastic control upon linguistically formulated theories or expectations built into the descriptive and argumentative use of language. That is, through the regulative ideas of truth and validity built into the human use of language, we could exercise a plastic control upon our theories. Thus, we could exercise a plastic control upon our actions based upon those theories.

However, I noticed a "gap" within Popper's account of the transition from animal to human evolution through this theory of the development of functions of language. This "gap" was that Popper had assumed, without accounting for, a separation of "expectations" from biological organization in his account of the transition from animal to human language. Thus, although Popper had shown us that human language contained plastic controls built into its use, he did not account for <u>how</u> they may have emerged through a process of the separation of expectations from biological organization.

I postulated that a closure of this "gap" may be important. First of all, I noticed that, in order to close this "gap", a solution to Compton's problem on the level of 'knowing how' as opposed to Popper's solution on the level of 'knowing that' was required. Thus, since Popper had attributed such importance to Compton's problem in that he saw its solution as providing a bridge between animal and human evolution, I contended that a solution to this problem on the level of 'knowing how' may be significant. For if I could provide a solution to Compton's problem on the level of 'knowing how' I might then be in a better position to understand the process of human evolution. For, in that case, I would have provided an account of how the transition between animal and human evolution may have occurred. Thus, I might be in a better position as far as understanding the subsequent growth of knowledge - human evolution - made possible as a result of this transition is concerned.

In this regard, I noted that, for Popper, since the growth of knowledge was characterized by a trial and error process with error-elimination of theories (trials) through criticism and refutation, the contexts of discovery and justification remained separate. That is, for Popper, the question of the origin, of the formation, of a theory remains irrelevant as far as the truth of the theory is concerned. I postulated that perhaps our solution to Compton's problem on the level of 'knowing how' may have some effect on Popper's position with respect to the relation between these two contexts.

The reason for this postulate is tied to the fact that the recognition of the "gap" returned me to Piaget's theory of child intellectual development. Piaget, in formulating his theory of child intellectual development had applied the postulate 'ontogeny recapitulates phylogeny' and had thereby viewed the intellectual development of the child as a "mental embryology". Now the fact that in order to close the "gap" in Popper's solution to Compton's problem we would have to provide an account of how the transition from animal to human evolution may have occurred and the fact that Piaget saw his theory of child intellectual development as partially recapitulating the history of prehistoric man led me to expect that I could apply Piaget's theory of child intellectual development to the problem of the "gap".

But now we can see the reason why it was postulated that, by closing this "gap" and hence moving Popper's solution to Compton's problem from the level of 'knowing that' to 'knowing how', we may affect Popper's position with respect to the role of the contexts of discovery and justification in the growth of knowledge. The reason was simply that Piaget in formulating his genetic epistemology upon the basis of his application of the postulate 'ontogeny recapitulates phylogeny' had intended to demonstrate a certain merger between these two contexts in the growth of knowledge. That is, it was Piaget's contention that there was a parallelism between the process of the formation of knowledge and the process of the evaluation of knowledge. Moreover, it was Piaget's intention of demonstrating this merger between these two contexts within the early evolution of knowledge in prehistoric man. Thus, I maintained that, if our application of Piaget's theory resulting from his application of the postulate 'ontogeny recapitulates phylogeny' demonstrated a merger between these contexts in the early evolution of knowledge, then this may have some implications for the understanding of the role of these two contexts in the subsequent evolution of knowledge.

I received some encouragement for applying this postulate, 'ontogeny recapitulates phylogeny' for closing this "gap" from an examination of Popper's general theory of evolution. That is, I noted that Popper's general theory of evolution also contained this postulate as a part of one of its theses. However, Popper's statement of his postulate appeared to restrict its applicability to animal evolution. Popper had incorporated this postulate within his general evolutionary theory in order to account for the continuation of species through evolutionary change by 'natural selection'. Thus he had limited its applicability to the recapitulation of phylogenetic evolution by an <u>organism</u> in its individual development.[11]

However, it was clear that Popper had employed this postulate to expect within ontogenetic (individual) development a partial recapitulation of the development of plastic controls within phylogenetic evolution. Popper stressed in his statement of this postulate that the organism "telescopes" within its body the <u>controls</u> developed during its phylogenetic evolution. It was because of this "telescoping" of phylogenetically developed controls that Popper expected the individual development of an organism to recapitulate its phylogenetic evolution - after all, the individual organism is not thrown up in the world in a fully developed form. But, at this point, I realized that even on Popper's terms we could expect to apply this postulate to the individual development of a child. For it was Popper's general theory of evolution which had stressed the importance of the development of the plastic controls built into human language for the continuation of human evolution.[12] Thus, I had been reassured by Popper's general theory of evolution that Piaget's theory of child intellectual development might be employed to close the "gap" we had discerned within this general theory of evolution.

Hence my problem became that of filling in the "gap" within Popper's solution to Compton's problem and, hence, within his general theory of evolution as well as considering what implications this closure of the "gap" may have with respect to the role of the contexts of discovery and justification in the growth of knowledge. My approach to this problem became that of accounting for the separation between expectations and biological organization and the development of the plastic controls enabling human evolution by an examination of Piaget's theory of the intellectual development of the child.

The scheme of my argument will be as follows. In the first chapter, I shall introduce Compton's problem by discussing its background. I shall provide an exposition of Popper's solution to Compton's problem as well as indicate the "gap" within it. In the second chapter, I shall examine Popper's general theory of evolution in order to see the significance of this "gap" with respect to the role of Popper's solution to Compton's problem within this general theory. Also, I shall indicate the presence of a methodological principle - ontogeny recapitulates phylogeny - for the closure of this "gap" within Popper's general evolutionary theory. Finally, I shall discuss Popper's position with respect to the role of the contexts of discovery and justification in the growth of knowledge and discuss the potential implications of the closure of the "gap" for this position. In the third chapter, I shall introduce Piaget by briefly discussing his epistemological position including his view of the role of the contexts of discovery and justification in the growth of knowledge. This later aspect of Piaget's epistemological position will be brought out through an examination of his application of the methodological principle - ontogeny recapitulates phylogeny - for the closure of the "gap". Finally, I shall examine Piaget's works resulting from his application of this principle indicating, throughout, how this work can close the "gap" within Popper's solution to Compton's problem.

Of course, the final chapter, the summary and conclusion will tie the thesis up by reviewing the argument and summarizing our Piagetian augmentation to Popper's solution of Compton's problem. In addition, it will include a brief consideration of the implications or our closure of the "gap" with respect to the roles of the contexts of discovery and justification in the growth of knowledge.

CHAPTER I

THE "GAP" IN POPPER'S SOLUTION TO COMPTON'S PROBLEM

I What is Compton's problem?

The great advance in scientific achievement since the seventeenth century brought with it an unheralded change in man's understanding of his role in the cosmos. The development of the idea of a mechanistic universe - the idea that the world is a system of objects governed by mechanical laws - was the cornerstone upon which the impressive edifice of scientific achievement was based. This idea appeared strange against the traditional religious and mythical conceptions which subscribed to some form of animism or purpose, divine or otherwise, in nature. But its strangeness aside, the idea showed itself to bear great fruit and the course of history took a dramatic turn.

With the demonstration of the power of this idea through the success of the sciences, man began to change his conception of himself vis à vis nature. Rather than view himself as an integral part of nature, guaranteed a destiny by its purpose, he began to see himself as nature's ruling monarch capable of controlling his own and nature's destiny. For if the secrets of nature could be unveiled by learning its laws - laws of mechanical causation - man saw the possibility of gaining power over nature. Once man had revealed nature's secrets, he, rather than God, could pull the "strings" controlling nature's course. Such was the dream which accompanied the success of man's initial conquests of nature through the application of this idea of a mechanistic universe.

But this dream was threatening to become a nightmare. For although man began to consider himself nature's ruling monarch, he could not forget that he also was a part of the kingdom of nature. If he was to realize his dream of a mechanistic universe, then he would have to come to grips with a view of himself as governed by the same sort of physically deterministic laws which he believed were operative everywhere in nature.

This meant, however, that he had to view himself as a complex machine. If he discovered the laws operative within human nature, he could in principle predict the course of his own destiny. But now he had lost control of that destiny. For in viewing himself as governed by the same sort of physically deterministic laws which he believed operative elsewhere in nature, he could no longer believe that it was he who controlled his actions. The secrets of his subsequent actions were as indelibly stamped with his physiological make-up as were the motions of the planets stamped into their physical circumstances.

Thus the dream of gaining power over nature was a dream based upon a view of the world as a physically determined, closed, system. The world was considered to be a system of entities which interact with each other - and only with each other - in accordance with definite laws which characterize the system down to its most precise details and allow for no influence from anything outside. This dream, however, was threatening to become a nightmare because man, and his values, were contained within that system. Man in pursuing the dream of a physically deterministic world was threatening to destroy all of his values.

The realization, then, of the nightmare which resulted from the pursuit of this dream was the "crisis" of the natural sciences which began to ferment in the early twentieth century. Man had for too long, on the one hand, accepted the great theoretical and practical advances associated with the pursuit of science while, on the other hand, in the realm of values, he continued to accept his traditional role vis à vis nature provided him by the great religious systems.

Slowly man came to realize that he could not simply accept the guarantee of values in human life provided by the great religious systems. He came to realize that his conception of a physically deterministic world implied that his values, his intentions, were epiphenomena and did not influence his actions. Man's impression of controlling his destiny, of values in human life, of influencing his actions through his thought and intentions, were an illusion from the perspective of physical determinism.

Men like Arthur Holly Compton, the physicist responsible for the discovery of X-rays and the 'Compton effect' in quantum mechanics, who came to realize these consequences of the physical determinist's perspective were understandably bothered. As a first step towards overcoming the tension between man's conception of knowledge based on the idea of physical determinism and his conception of values based on the purpose in nature inherent in the great religious systems, they began to wonder if they could account for the influence of thought or intentions on actions without violating any physical laws.[2]

This, then, is 'Compton's problem', as Popper refers to it. It is the problem of accounting for the influence of thought on action while, at the same time, enabling man to gain knowledge about the world. That is, it is the problem of viewing thought not as an epiphenomenon or illusionary as the physical determinist much do[3] but as actually influencing action and, at the same time, still maintaining that the world is sufficiently deterministic to allow men knowledge of it.

We can see these assumptions expressed in Popper's formulation of the problem; "How does the 'universe of abstract meanings' influence human behaviour (and thereby influence the physical world)?"[4] Here, Popper is assuming that human beings are free, that the 'universe of abstract meanings', the realm of human intentions does influence action. Secondly, it is assumed that the world is such that knowledge of it is possible. For we have a problem of accounting for the influence of thought on action only after, through the success of the physical determinist's perspective in the realm of knowledge, it has been demonstrated that this may be illusion. That is, without the demonstration of the physical determinist's apparent success in providing us with knowledge of the world, we would not have a problem of accounting for the influence of thought on action.

II. Why indeterminism is not enough

The revolution in the physical sciences in the early twentieth century with the development of quantum mechanics and the theory of relativity provided new hope for those within the sciences who, like Compton, had recognized the nightmare of physical determinism. It appeared that the physical world in its microscopic and cosmic dimensions may not be governed by strict physically deterministic laws. At these levels, it appeared plausible that there was a "principle of uncertainty". We may not, in principle, be able to predict, given knowledge of the state of affairs within the sub-atomic world, its subsequent states. (The dispute about the ontological significance of this principle of uncertainty shall not concern us here, that is, we shall not examine the question of whether or not this uncertainty is only an experimental necessity - because in "observing" sub-atomic states of affairs our measuring devices interact with the system observed - or an expression of ontological significance. Rather our concern is with this principle, insofar as it was employed to escape from the nightmare of physical determinism.)

Thus, once it is assumed, through quantum theory, that the physical world may not be such that it is a closed deterministic system, then the possibility of solving Compton's problem in terms of the indeterminism inherent in quantum mechanics was opened up. In fact, Compton took this line of thought.[5]

One could view the brain as consisting of complicated neural relay mechanisms. These mechanisms would be, presumably, electrochemical reactions on a small scale. Since these reactions occur on such a small scale they would be subject to the indeterminacies of quantum mechanics. Moreover, the living organism, on this model, may be viewed an an amplifying device. Thus the result of deliberative processes may be viewed as dependent upon which particular neural relay circuit is fired within the brain. Since this depends upon processes subject to the principle of uncertainty, it may be concluded that the outcome of a deliberation process is not determined by the physical events in the brain.[6]

However, an objection to this model of deliberate decision processes and thus to the influence of meanings upon actions is readily available, as Compton indicates.[7] This is the fact that such a model does not account for the choice by the organism (man) of his action. Although this model does demonstrate the physical indeterminateness of the action, it does not allow the organism to choose. His "choice" depends upon the outcome of an indeterminate (unpredictable) event and thus never becomes <u>his</u> choice.

Nevertheless, Compton argues, we may be able to account for man's actions in terms of chance. The brain may be just such an amplification device of quantum events as outlined above. However, within this model of the brain, we may add consciousness. Consciousness may work by selecting, among the possible neural relays, which one would lead to a desirable action.

In order to illustrate this possibility, consider the case of the imaginary experiment in quantum mechanics of the daemon-operated shutter. In this experiment, a beam of light is directed at a box with a shutter. The beam will be diffracted upon entering the hole in the box. This hole can be adjusted so small and the shutter may move so quickly that only a single photon may be allowed to enter the box. At the rear of the box are two amplification devices. If device A is operated an explosion will result, if device B is operated a bell will sound.

The principles of quantum mechanics do not allow us to predict which of the two events will occur because any measuring device we employ to determine the path of a photon approaching the shutter-opening will result in the alteration of that path. However, we may add in this experiment, the assumption that a daemon capable of determining the course of the photon through non-physical means and hence without disturbing its path operates the shutter. Thus the daemon is capable of discriminating between "good photons" - those which result in the bell ringing - and "bad photons" - those which result in the explosion. In this case, the daemon may allow only good photons to enter the box and thus the explosion never will occur.

Does this constitute a violation of the principle of uncertainty? Compton says 'No'. The principle of uncertainty provided only for a statistical prediction of which event would occur and this principle has not been violated since the choice of the daemon is only a single event - it does not affect the probabilities of the emission of the photons by the light-emitting atoms. Thus, the photons are still emitted in accordance with the principle of uncertainty. The daemon, because he is conscious of the qualities of particular photons, merely selects favourable ones. The choice by the daemon is, however, only a single event and hence does not affect the probabilities associated with the emission of photons. Moreover, this choice is a single event even if the daemon so chooses to operate the shutter in a similar manner for a thousand times - in that case, the single event is the choice to operate the shutter similarly for a thousand trials.

Compton applies this thought experiment to deliberate decision-making processes and considers consciousness capable of operating in a manner analogous to the daemon. A deliberate decision is a single event and, as such, does not affect the uncertainties associated with quantum mechanics and is not predictable from the probabilities of quantum mechanics. The physiology of the brain and the acquired habits of the individual determine a "spectrum of possibilities", withih which consciousness can choose any favourable action.[8] (How consciousness could perform this operation of selection is not considered by Compton; he only wishes to show that it is possible to select one of a number of possible actions without violating physical laws (i.e. the uncertainty laws of physics).)[9]

But such an account of deliberate decision making, it seems, begs the question. It is not enough to indicate that the selection by consciousness of a course of action is possible without violating physical laws. We want to know how such a selection can be rational. That is, we want to know how the "spectrum of possibilities" can be delimited, rationally, by the agent. If, as it appears Compton is suggesting, consciousness is capable of weighing the probable outcomes of each of the possible courses of action, and thereby able to actualize that possibility containing the most likely favourable consequences, then we do have to account for this mechanism in order to understand the influence of meanings and intentions upon actions.

Compton says that each deliberate choice is a single event which alters the state of the organism in that it contributes to the acquisition of a habit. This habit, then, in the course of future deliberation will enter into the process of determining the outcome of those deliberations. Thus the "spectrum of possibilities" is restricted through the acquisition of habits. But, our problem is to understand how meanings and intentions can influence actions. It is of no use to account for this influence through the determining factor of habits, for habits are simply the outcome of the influence of meanings upon actions in our previous individual development, that is, habits are simply the outcome of previous deliberation processes and, hence, we cannot use them in accounting for the possibility of deliberation processes.

Thus it appears that the indeterminateness of physical systems is a prerequisite for solving Compton's problem since we must have some element of non-determinateness in order that meanings and intentions influence action. But this indeterminateness cannot simply be chance - indeterminism is not enough.[10] If pure chance is the only form of indeterminateness operative in the influencing of our action, then responsibility, morality and values are not permitted to control our decisions. Our decisions become simply "snap decisions" - merely the "amplification" of chance-like events.

If consciousness can select, deliberately, which amongst a number of chance generated events is amplified, then we must account for this selection if it is to become 'our selection'. Compton, in stressing the selectivity of consciousness, has not solved the problem; he has merely portrayed the limits in which a solution may be found. For this process of selection, if it is going to solve Compton's problem, requires, in addition to accounting for the possibility of indeterminism, accounting for the possibility of deliberation. And, in order to account for deliberation, one must account for a control of meanings upon actions with freedom and responsibility. Thus, we require an intermediate ground between perfect determinism and perfect chance.[11]

III What is Popper's 'Intermediate Ground'?

We have seen that neither perfect determinism nor perfect indeterminism can provide us with a model for solving 'Compton's problem'. Popper turns to biology and the theory of evolution with the hope of finding an intermediate ground between perfect determinism and perfect indeterminism upon which to base a solution to Compton's problem.

Popper's idea of such an intermediate ground is expressed in his notion of a 'plastic control'. A plastic control is a control with feedback and freedom as opposed to a 'cast-iron' or strictly deterministic control.[12] It involves the notion of the evolution of hierarchies of integrated levels or systems. A 'higher level' evolves from a 'lower level' but is autonomous with respect to the 'lower level' if the interaction of entities belonging to the 'higher level' involves operations not belonging to the 'lower level'. However, since the 'higher level' evolves from the 'lower level', the interaction of entities on the 'higher level' presupposes the interaction and operation of entities on the 'lower level'. Moreover, since the 'higher level' is autonomous with respect to the 'lower level' but an evolutionary product of it, the operation of the 'higher level' exercises an influence or control over the 'lower level' without determining the content of the interactions at the 'lower level'. That is, since the 'lower level' is able to operate independently of the 'higher level', the 'higher level' does not exercise a 'cast-iron' or completely deterministic control over the 'lower level', but a control with feedback and freedom. Thus, the 'lower level' may indirectly influence the 'higher level' through the feedback which the operation of the 'lower level' may provide for the further influence of the 'higher level' over the 'lower level'.

With respect to Compton's problem, a plastic control of thought or intentions upon actions would enable thought to control actions but without thought or intentions determining actions. Thus, if our thought exercised a plastic control over our actions, we would have the freedom to determine exactly how this influence would be realized.

Thus, for example, if I have promised to meet someone at a restaurant for lunch, then, he, quite rightly, will expect that I will meet my engagement. My intentions will 'determine' that I will be at this particular restaurant at this particular time. But this control is 'plastic' - I have the freedom to travel to the restaurant by car, taxi, or walk. Moreover, I can exercise some 'feedback' upon my intentions - under various extenuating circumstances, I may change my intentions and cancel my luncheon engagement.

Of course, if Popper intends to solve Compton's problem in terms of a plastic control of the 'universe of meanings' upon actions, then, in general, he must provide an evolutionary theory accounting for the emergence of plastic controls and, in particular, he must account for the emergence of the plastic control of a 'universe of meanings' upon action.

Before considering Popper's general theory of evolution and the particular case of the evolution of a plastic control of 'meanings' on action we ought to briefly consider the mechanism by means of which Popper intends to account for evolutionary emergence. Popper points out that the process of deliberation seemed to characterize the type of influence which the 'universe of meanings' has upon action. He says that deliberation is characterized by a trial and error mechanism. When deliberating we tend to weigh various possibilities considering the consequences of each carefully. That is, each possibility represents a trial and the consideration of consequences along with the rejection of those possibilities which do not appear adequate represents a method of error-elimination.[13]

Thus, Popper indicates that this trial and error-elimination characteristic of deliberation may provide us with a clue for the formulation of an evolutionary theory. However, Popper first intends to provide us with an example both of plastic controls and of the evolution of plastic controls through a trial and error mechanism. This example will involve an analysis of the evolution of various functions of language - from animal to human functions of language. Moreover, Popper intends this analysis of the evolution of functions of languages to be a particular case of his general evolutionary theory. That is, Popper intends this example to provide an account of the emergence of the plastic control of the 'universe of meanings' upon actions. It is the particular case which we saw Popper must deal with in providing a solution to Compton's problem in terms of plastic controls.

Following Bühler, Popper distinguishes between three functions of language and adds a fourth function. The first two of these, the expressive and signalling functions are common to all languages, animal and human, while the latter two, the descriptive and argumentative functions, are peculiar to the human use of language. This reflects, for

Popper, the evolutionary primacy of the animal functions. The human functions of language have evolved from the animal functions and hence the animal functions are present whenever the human functions of language are present, but not vice versa. (This fact, Popper claims, has led some philosophers, in seeking the most general aspects of language, to overlook the importance and distinction between the animal and human functions of language.)[14]

The expressive function refers to the use of some linguistic sign by an organism to express its internal state. Thus, an organism in making some symptomatic expression of its internal state is employing the expressive function of language. This symptomatic expression of the internal state of an organism may trigger or evoke some symptomatic expression of the internal state of another organism, thereby turning the original expression into a signal. This use of language by an organism to respond to the symptomatic expression of the internal state of another organism by a symptomatic expression of its own state, Popper refers to as the signalling function of language.[15]

Although these two functions are necessary for communication to occur, they are distinct because the expressive function can occur without the signalling function. An organism can express its state without receiving any response from another organism. Moreover, the signalling function is "higher" than the expressive function since it depends upon the prior use of the expressive function. Clearly, if there were no expressive use of language, the signalling function could not arise.

For example, a dog may be alarmed and express this by barking loudly. This expression may trigger the response of barking loudly by another dog in the neighbourhood and, as a consequence, it too may be alarmed. Soon, much to the chagrin of those people in the area attempting to sleep, the feedback between the expressive and signalling functions of the dogs' language may result in all of the neighbourhood's dogs barking loudly in a state of alarm.

Human language, however, is much richer and has many more dimensions than animal language. With the descriptive function, language is employed to describe states of affairs. A description of a state of affairs may be true or false. The use of the descriptive function of language results, says Popper, in the rise of a new standard of control, the regulative idea of truth. Once we employ language to describe a state of affairs, the idea that our description ought to be true arises. That is, once we attempt to describe states of affairs, the idea emerges that our description ought to correspond to the state of affairs described. It provides an ideal standard of control - we can "regulate" our descriptions by employing the notion of a true description as a correspondence to the facts described.[16]

Moreover, the descriptive function is distinct from the expressive and signalling functions. Whenever I speak, I can't help but evoke some response in my listeners - the expressive and signalling functions are always present. But I can speak without describing. I can express anxiety - say, about whether my readers will endure this discussion - but I need not describe anything. As G.G. Simpson so succinctly put it, the difference between the animal and the descriptive functions of language is the difference between saying 'ouch!' and 'fire is hot.'[17]

In addition, there is a plastic control by the descriptive use of language over the signalling and expressive functions of language. If, in England, during my luncheon engagement I describe my soup to the proprietor as unfit for human consumption, I am likely to evoke in him an expression of apology and regret. While, if my engagement occurred in Italy, say, the same description might evoke quite a different expression on the part of the proprietor - he may, for example, flay his arms about and express astonishment and indignation at my lack of appreciation of his culinary skills. Thus, in both cases, it was my description which influenced or controlled the expressive response of the proprietors.

But this control was plastic, it did not determine the content of those expressions.

Finally, the descriptive use of language leads to the highest function, the argumentative function. Once we begin to describe states of affairs and become aware of the regulative idea of truth, we may begin to argue about the relative merits with respect to their truth of two or more descriptions of some state of affairs. Thus, the argumentative function refers to the use of language to argue for or against some description. Its use, according to Popper, will lead to the regulative ideas of validity and verisimilitude or truthlikeness.[18] We learn to employ the idea of a valid, as opposed to an invalid argument, as an ideal standard of control of the argumentative function. We control the argumentative use of language by arguing about what Popper refers to as the truth content or truthlikeness of our descriptions. Thus, we regulate our arguments through these notions.

Again, the fact that we can describe without arguing testifies to the distinctness of these functions. And, the fact that all arguments are about descriptions, either for or against some description, indicates the control which they may have over the descriptive function. For we can control our descriptions by arguing about their truthlikeness, compatibility with other descriptions, and so on.

For example, consider the summation speech of a brilliant defense lawyer. He may express sympathy with the defendant; he may even evoke similar expressions from the jurors. Yet these expressions and responses will, at least to a point, be controlled by the content of the lawyer's speech, by his descriptions of the defendant's action, and, more importantly, his arguments for the truth of those descriptions. Unless he has argued well, unless the arguments at least appear to be valid, the jurors may well express sympathy while handing down a decision of guilty as charged.

Thus, for Popper, the four functions of language form a hierarchical system of levels with each function exerting a plastic control over the next lowest function. None of the functions can be reduced to a lower function; each function adds a new dimension to language. The operation of a lower function can occur independently of the operation of a higher function; but the operation of the higher function presupposes the operation of functions lower than it. Each of the higher functions evolved from the use of the immediately lower function and it is through this emergence that it exercises a "plastic control" over its evolutionary predecessor.

Popper's solution to Compton's problem follows immediately, as it were, from his analysis of the development of the functions of language. For, with the rise of the descriptive function of language we learn to abstract from the formulation of a description to its invariant content or meaning. Thus, when we use language to describe a state of affairs, we learn to abstract from the various modes of formulation of that description to its content - the state of affairs which is being described.

For example, if we are given the descriptions: 'John throws the ball to Mary' and 'The ball is thrown by John to Mary', we can abstract the invariant content - the throwing of the ball from John to Mary - from these two formulations of the description of that content.

In addition, the descriptive and argumentative functions of language provide us with new means of controlling our meanings and contents - we can discuss them and criticize them from the viewpoint of their truth, validity or verisimilitude. Thus the emergence of the higher functions of language is the emergence of new means of problem-solving by permitting new types of trials with new means of controlling those trials.[19]

Hence the solution to Compton's problem - the problem of the influence of meanings upon actions - follows, for Popper: for part and parcel of meanings and contents is the function of control.[20]

IV What is the "gap" in Popper's solution to Compton's problem?

But is this control a control of actions? We have only seen that, with the descriptive and argumentative functions of language, we develop meanings, contents, which can be controlled through the regulative ideas associated with these functions. Thus, the control which is part and parcel of meanings is a control over our contents and meanings - a control over our descriptions and arguments. How does this constitute a control over our actions?

Our question here is that of the relationship between descriptions and actions. Only if descriptions influence actions can a control over descriptions be a control over actions.

In order to answer this question we shall have to consider the nature of an action. An action may be considered to be a response, by an organism, to a particular situation. Thus, the familiar behaviourist scheme describes an action as a response to a given environmental stimulus - the S-R model of behaviour. But this scheme overlooks the fact that a response to a stimulus is possible only if that stimulus is interpreted by the organism. A stimulus can only function as a stimulus - that is, trigger a response - only if the organism interprets that stimulus as significant. Moreover, the stimulus can only be significant if, through it, the organism can anticipate a state of affairs yet to come in the environment. That is, in order for a stimulus to trigger a response, in order for it to be interpreted as significant, it must be incorporated within the organism's expectations or dispositions to react. For only if a stimulus is incorporated within an organism's expectations - dispositions to react - can it enable the organism to anticipate a state of affairs yet to come.

In other words, incorporated within the biological organization of an organism are certain expectations or dispositions to react. It is only because a stimulus is assimilated within these dispositions to react that it is significant and triggers a response. If a stimulus could not be assimilated within an organism's disposition to react - his 'horizon of possible reactions' - then, quite simply, it would not be a stimulus for that organism. The importance of an organism's expectations or dispositions to react is reflected in the fact that physically identical stimuli may, at different times, produce different reactions and, conversely, physically different stimuli may provide identical reactions.[21]

Hence what the stimulus-response model of behaviour or action overlooks is the fact that prior to the response, the action, the stimulus must be incorporated within the organism's dispositions to react. That is, all actions are responses based upon the expectations - the dispositions to react - of the responding organism. It is only because a stimulus is significant or enables the organisms to anticipate a subsequent state of affairs that it responds to that stimulus. And the stimulus can only enable an organism to anticipate a subsequent state of affairs if it is assimilated within its 'horizon of expectations' - its dispositions to react.[22]

For example, consider the case of Pavlov's famous dogs. The dogs were "conditioned" to respond to the ringing of a bell, the stimulus, by salivating. But this response was possible only because the stimulus had been assimilated within the dogs' expectations - it lead the dogs to 'anticipate' the presentation of food. Moreover, the "natural response" of salivation to the presentation of food cannot be understood within the S-R scheme. For the dog would not respond to the presentation of food by salivating unless he anticipated the ingestion of that food. Food acts as a stimulus for the dog only because it assimilates the food within his expectations of satisfying the physiological processes responsible for creating the need to incorporate foreign substances (food) within his biological organization. If the foreign substance presented to the dog as food is not interpreted by the dog as capable of satisfying his physiological need for food then he will not salivate - he will not respond to the "food" - for he will not anticipate that substance as capable of fulfilling his expectations. In that case, the substance simply is not food for the dog and it is not a stimulus leading to a response because it is not assimilated by the dog within his horizon of expectations.[23]

Thus, at the biological level, the 'expectations' of an organism are incorporated within its biological organization. Even in the case of a "pure" reflex action, the S-R model of behaviour breaks down. For the reflex is possible only because of the nature of the "expectations" incorporated with the biologically inherited nervous structure and physiological constitution of an organism. Hence an action is never simply a response; it is always a response based upon an 'expectation' or disposition to react.

Now, however, we can see how descriptions influence actions. A description is a linguistically formulated expectation.[24] When we describe states of affairs, especially when these are formulated in terms of theories or explanations, we are embodying our expectations in language. Thus, our control over our descriptions, our expectations, through the descriptive and argumentative functions of language, is a control over actions. By controlling our expectations we are exercising control over actions based upon our expectations.

But Popper's solution to Compton's problem contains a rather large "gap". Popper accounts for the influence of meanings upon actions by describing meanings or contents as linguistically formulated expectations. Thus, once the development of meanings is viewed, through Popper's analysis of the higher functions of language, to bring with it new means of continually controlling these contents a solution to Compton's problem follows. But what this solution does not explain is how the communication and the control of expectations - their embodiment in language containing a descriptive and argumentative function - becomes possible. This is the "gap" in Popper's solution to Compton's problem.

But why is this "gap" important? As long as expectations do become incorporated in language containing a descriptive and argumentative function then we can solve

Compton's problem: part and parcel of the development of 'meanings' is the function of control over linguistically formulated expectations and thereby over actions. Why, then, make a point of some "gap"?

The "gap" is important because without closing it we cannot understand how the communication of expectations in language is possible, and consequently how the controls available with the descriptive and argumentative functions of language arise. In brief, without filling in this "gap" we cannot understand how Popper's solution to Compton's problem works. Without closing this "gap", we can only understand a sketch of a solution to Compton's problem. That is, without filling in this "gap", our solution to Compton's problem would remain on the level of 'knowing that' - knowing that expectations become embodied in language and knowing that built into this language are the plastic controls available through the descriptive and argumentative functions. By closing this "gap" we hope to find a solution to Compton's problem on the level of 'knowing how' - knowing how expectations can become separated from biological organization and incorporated into human language and knowing how the plastic controls built into human language develop during this process of separation.

But the persistent objector may ask 'why is it important to find a solution to Compton's problem on the level of 'knowing how'; isn't 'knowing that' enough from a philosophical point of view?

In order to answer this question, in order to see why there may be some philosophical significance to understanding the details required to move our solution to Compton's problem onto the level of 'knowing how', we are going to have to examine the role of Popper's analysis of the evolution of functions of language within his general theory of evolution. For otherwise, if we stick to the role of Popper's analysis of the development of language with respect to Compton's problem, then the significance of the "gap" in Popper's solution is limited merely to details, to attaining more depth on a scientific plane as it were. However, even this attainment of more depth may be of philosophical significance in its own right. For Compton's problem is, in fact, a philosophical problem. Thus even if we were merely to add some details to Popper's solution and thereby move it onto the plane of 'knowing how' this may be of philosophical significance given the significance which Popper attributes to Compton's problem.

CHAPTER II

POPPER'S GENERAL THEORY OF EVOLUTION: A METHODOLOGICAL PRINCIPLE FOR CLOSING THE "GAP"

I What is the role of the analysis of the functions of language within Popper's general theory of evolution?

In accordance with our desire to discover what the philosophical significance of the 'gap' within Popper's analysis of the development of language, we shall turn now to an examination of the role of his analysis within Popper's general theory of evolution. Moreover, we shall see that, despite the existence of this 'gap' within this analysis, its role within Popper's general theory of evolution will not preclude us from employing an element of this general theory to initiate the closure of the 'gap'.

Popper formulates his general theory by generalizing to the "whole of evolution what we learned when we analysed the evolution from animal language to human language."[1] The main aspect of this analysis which is generalized is the notion of plastic controls. Popper views evolution, both animal and human, as a growing system of plastic controls. The second aspect of Popper's analysis of linguistic evolution which is generalized is the notion that plastic controls may emerge as a result of a process of trial and error-elimination.

Thus Popper describes the fundamental evolutionary sequence of events as follows:

$$P_1 \rightarrow TS \rightarrow EE \rightarrow P_2$$

A problem P_1 leads to a tentative solution, TS, which in turn leads to the attempt to eliminate errors, EE. The result of this sequence is the emergence of a new problem, P_2, which, in turn, will lead to a new evolutionary sequence with the attempt to solve this problem. Moreover, there may be a number of tentative solutions to a particular problem. This multiplicity of tentative solutions will constitute the background of the problem-situation (along with the whole chain of problem-situations preceding the one under consideration). Error-elimination will consist of the selection of some amongst these tentative solutions as most adequate. But this process of selection through error-elimination will result in new problems; problems which have arisen from the new situation constituted by the attempt to eliminate errors amongst the various tentative solutions to the original problem. In this manner a chain of evolutionary sequences arises; these sequences do not form a cycle because each problem arises from a new situation.[2]

The application of this notion of a chain of problem-situations to animal evolution results in a new emphasis on the Neo-Darwinian theory of evolution. The traditional explanation of Darwin's theory, due to Herbert Spencer,[3] of the "survival of the fittest" has a near tautologous character. The only criterion of fitness is survival, so that the slogan becomes reduced to "those that survive are those that survive". Popper, in applying the notion of a chain of problem-situations hopes to make this thesis a little less vague. He interprets genetic mutations as trials, tentative solutions, to a problem-situation; and 'natural selection', as a method of error-elimination.

Within animal evolution, as we have seen, expectations - the biological equivalent of theories - are incorporated within the physiological structure of the organism. It is the genetic structure which transmits these expectations from one organism to another. Popper maintains that within the genetic structure plastic controls may be incorporated. New trials, new expectations arise through mutations within the genetic structure. Moreover, since the genetic structure may incorporate hierarchical levels exerting a plastic control over each other, mutations may occur within any one of a number of levels. Thus a mutation on one level may tend to favour certain mutations on a lower level due to the plastic control of the higher level over the lower level. Popper formulates this hypothesis of a genetic structure incorporating plastic controls and hence a genetic pluralism[4] because, firstly, it is consistent with the importance of plastic controls within the evolution of the functions of language. Secondly, it enables him to account for apparently "goal-directed" evolution.[5]

Thus, for example, the evolution of complex organs like the eye has been a traditional problem within Darwin's evolutionary theory. The eye is an organ which has evolved, it appears, to fulfill a certain purpose or function. The complicated structure of the eye, involving an inter-relationship between various physiological structures is extremely difficult to account for in terms of a long series of independent mutations fortuitously resulting in a functioning eye. Popper hopes that he can account for such apparently goal-directed evolutionary developments by maintaining a genetic pluralism. Thus, within the genetic structure, Popper distinguishes between different levels each capable of exerting a plastic control over its predecessor: (1) the level of aims or preferences, (2) the level of skills, (3) the level of anatomical executive tools.

"In this way, interest in seeing may be successfully fixed genetically and may become the leading element in the orthogenetic evolution of the eye; even the smallest improvements in its anatomy may be selectively valuable if the aim-structure and the skill-structure of the organism make sufficient use of it."[6]

'Natural selection' is the form of error-elimination within animal evolution. Once an organism confronts his environment with his biologically inherited expectations, his survival will depend upon the adequacy of these expectations to enable the organism to adapt to his environment. If these expectations are radically in error, the organism may be eliminated; and with his death, the expectations programmed within his genetic structure will not be transmitted to other organisms. Or, less drastically, the conditions of the environment may exert selective pressure on certain mutations of the organism's genetic structure within its progeny. In this manner, 'natural selection' or biological error-elimination will result in the modification of organs within the progeny of an organism.

Thus, Popper views animal evolution as an evolution of sequences of problem-situation. Organisms are constantly engaged in problem-solving. They attempt to solve their problems, which initially may be sheer survival problems but which can and usually are sub-divided into subsidiary problems such as reproduction, the spreading and caring for offspring, the acquisition of food supplies, etc. by a trial and error method.[7]

But is Popper being anthropomorphic here? Can we really say that all organisms are constantly involved in problem-solving? Popper is quite willing to admit that organisms are not aware of the problems they are solving. But the important point is that we can understand their behaviour (and, indeed, their evolution) in terms of problem-solving situations. That is, with hindsight, we can reconstruct animal behaviour and animal evolution in terms of a sequence of problem-solving situations. In fact, in cases of human problem-solving it is often only with hindsight that we become aware of the problem which we are actually solving. Thus, for example, Kepler thought that the problem he was solving was the problem of the discovery of the harmony of world order; while, we know, with hindsight, that the problem he actually solved was the problem of the mathematical description of motion in a two-body planetary system. Thus, the validity of employing hindsight in the case of understanding human problem-solving situations, Popper agrees, should not make it inappropriate when attempting to understand animal problem-solving.[8]

However, the fact that animals or organisms are not aware of the problems they solve - and, more importantly, that it is we who reconstruct their problem-solving situations - does reflect an important difference between animal and human problem-solving situations. This difference is a difference of attitude. The organism, at the risk of being anthropomorphic, is, at best, annoyed by error, while humans are, at best, intrigued by it. That is, human beings may approach their own solutions critically and, when they discover errors they may learn from them by abandoning them. The organism, on the other hand, "dislikes" to err. Its expectations, its tentative solutions, are incorporated within his physiological organization, and hence, he cannot consciously try his best to eliminate errors within those tentative solutions.

Thus, this difference of attitude is made possible by the separation, apparent with the descriptive use of language, of expectations from biological organization. As we have seen, the higher functions of language permit new types of trials and new means of error-elimination.

Human evolution becomes exosomatic - outside the body. We formulate theories and through criticism and refutation attempt to eliminate errors within our theories. The fundamental evolutionary scheme, $P_1 \rightarrow TS \rightarrow EE \rightarrow P_2$, becomes, within human evolution, applied to the growth of knowledge not to the evolution of our biological organization. Thus, ultimately, it is our hypotheses which die in our stead.[9]

Now we are in a position to see another important function which Popper's analysis of the development of the higher functions of language has for the formulation of his general theory of evolution. As we have seen, it is Popper's contention that the development of the higher function of language is the development of new trials - linguistically formulated expectations - and new means of controlling those trials - criticism and refutation. Moreover, it is precisely these types of trials and error-elimination which characterize human evolution. Thus, the evolution of the higher functions of language bridges, for Popper, animal evolution and human evolution.[10]

Hence, when Popper formulates his general theory of evolution by generalizing what we learned from the analysis of the functions of language, he employs this analysis for two distinct purposes: (1) firstly, he generalizes the notion of a plastic control and finds within animal evolution plastic controls incorporated within the biological structure of an organism as well as within the language embodying human, exosomatic evolution. Moreover, the emergence of plastic controls within both types of evolution is seen as a product of the same type of fundamental sequence of problem-situations, $P_1 \rightarrow TS \rightarrow EE \rightarrow P_2$; (2) secondly, this same analysis bridges these two types of evolutionary sequence. Their essential differences are that animal evolution is endosomatic, within biological organization, while human evolution is exosomatic; within animal evolution organisms are not consciously aware of their problem-situations, while, within human evolution, man tries, at best, to be as conscious as possible of his problem-situations. These differences are bridged, by Popper, through this analysis of the development of the language - with the higher functions we develop new trials, which are exosomatic, linguistically formulated expectations, and new means of error-elimination, which is characterized by a conscious critical attitude towards tentative solutions of problems - expectations.

II. The importance of the 'gap' within Popper's General Theory

Having seen the importance of Popper's analysis of the higher functions of language within his general theory of evolution, we are in a position to understand the importance of the "gap" we discerned within that analysis. For unless that "gap" is closed, we cannot understand how Popper can bridge animal and human evolution. We saw that the development of the higher functions of language depends upon the separation between expectations and biological organization. Also we saw that the transition between animal and human evolution depends precisely upon the development of this separation. Thus, we cannot employ Popper's analysis of the development of the higher functions of language to bridge animal and human evolution since this analysis contains the same "gap" which must be accounted for in the transition between animal and human evolution.

This does not mean, however, that we must totally reject Popper's analysis of the development of the higher functions of language. Rather, this analysis has indicated an important aspect of the evolution both between and within animal evolution and human evolution, namely, the existence of plastic controls. In particular, this analysis has indicated the importance of the emergence of the new types of plastic control permitted through the development of the higher functions of language. That is, through this analysis, Popper has indicated that we can understand the transition between biological evolution and the growth of knowledge as a transition in which these new types of plastic control emerge. Popper, thus, has indicated 'that' these new types of plastic control emerge in this transition. Our problem, the problem of the gap, is a problem of understanding 'how' these new types of plastic control emerge. That is, the problem of the "gap" is the problem of understanding 'how' in the process of the separation of expectation from biological organization these new types of control emerge. For these new types of control - the control of the descriptive and argumentative functions of language - enable both the communication of expectations and the increased control of expectations over actions.

It may be still contended that this problem of 'how' is unimportant. Popper is interested in formulating a general theory of evolution in which our understanding of both animal evolution and the growth of knowledge can become unified within one common (Darwinian) framework. This he has done through his stress on the importance of sequences of trial and error-elimination and the emergence of plastic controls through these sequences. Popper can and, indeed, does appear to claim that as a theory of biological evolution does not have to explain how life emerged but only the evolution of life given its emergence; his general evolutionary theory does not have to explain how human evolution emerged from animal evolution but only the similarity (and the differences) between animal and human evolution given what we know from the fact that it so emerged.[11]

But this analogy breaks down. The problem of the origin of life can, indeed, be considered outside the scope of an evolutionary theory. Clearly, an evolutionary theory can arise only after life itself has emerged. The explanation of the evolution of life starting from its most primitive manifestations may be all that we can expect from an evolutionary theory. Even here, however, it may be hoped than an account of how life itself emerged from physical and chemical processes will provide a key with which to unlock some mysteries within the process of evolution itself. Nevertheless, the problem of the emergence of human evolution from its origins within animal evolution is not on the same level as the problem of the origin of animal evolution from its origins in physical and chemical processes. For the problem of the emergence of human evolution is a problem which is posed within an evolutionary context. It is not a problem which demands a solution reaching beyond the context of an evolutionary theory.

Moreover, if one attempts to preserve the parallel between the problem of the emergence of life from inanimate matter and of human evolution from animal evolution by asserting that the problem of the emergence of human evolution demands a solution that reaches beyond the "givens" of human evolution then one is simply denying the possibility of formulating a general theory of evolution. For, in that case, one is preserving the parallel between these two problems by asserting that, just as the problem of the emergence of life requires a solution that reaches beyond the "givens" of a situation involving life, so the problem of the emergence of human evolution requires a solution which reaches beyond the "givens" of the human situation. But, if there is this parallel between these problems then, _ipso facto_, one could not construct a general theory of evolution, that is, a theory which embraced both animal and human evolution within one common framework.

Hence, although it is not clear whether Popper in fact takes this approach to the analogy between these two problems, it is clear that, if he does, he is caught in a logical bind. For it is not good enough, on the one hand to formulate a general theory of evolution from what we know given the fact 'that' human evolution emerged from animal evolution, while, on the other hand, to argue that 'how' this evolutionary transition occurred demands a solution that is somehow, logically, beyond its scope.

Thus, perhaps Popper is quite willing to concede that the analogy between these two problems does not involve a strict parallel in the above sense. Nevertheless, he can attempt to preserve some analogy between these two problems by asserting that 'how' human evolution evolved from animal evolution involved the occurrence of a unique event which prior to its actualisation was of extremely low probability. In an analogous manner, the emergence of life from inanimate matter may be viewed as a unique event which was of low probability prior to its actualisation. Thus the analogy between our two problems may be viewed as a consequence of the uniqueness of these two events. For, precisely because of this uniqueness, all attempts at explaining their occurrence may be frustrated.

Now it appears that while Popper may not be attempting to draw the first parallel between these two problems, he, at least, would assert this second, somewhat weaker, analogy between them.[12] Thus, if this analogy holds between these problems, it would amount to an assertion that the problem of 'how' human evolution emerged from animal evolution is methodologically beyond the scope of a general evolutionary theory. For, in that case, we could not account for this transition because of the uniqueness of this evolutionary transition. Hence, the best that we could do would be to formulate a general evolutionary theory based upon the fact 'that' this evolutionary transition has occurred.

However, even this analogy between these two problems breaks down. For while it may be the case that this evolutionary transition was unique, it is not the case that this transition involved a single event. We have noted two major occurrences during this transition: the separation between expectations and biological organization and the emergence of plastic controls embedded in the descriptive and argumentative use of language as a result of this separation. Moreover, it will be our contention that these two occurrences are not simply two unique but related events but are a product of some evolutionary process.

Thus, if this transition involves an evolutionary process in which through a separation of expectations from biological organization the plastic controls of expectations upon actions develops enabling the human use of language, it would be an error to insist upon this "uniqueness analogy" between the problem of the emergence of life from inanimate matter and the problem of the emergence of human evolution from animal evolution. For, in that case, we would have provided an account of how the controls built into descriptive and argumentative language emerged as a product of some developmental process occurring with pre-historic man enabling him to emerge from animal evolution and to begin human evolution. In other words, even if this complete evolutionary sequence is unique in the sense that this transition occurred only once, it is not a 'single step'. Hence what we are asserting is that Popper's remark that 'from the amoeba to Einstein is just one step,'[13] is a somewhat dramatic overstatement which runs the risk of overlooking the importance of analyzing what is involved in this "single" step. We are saying that this step can be seen to involve a gradual process - a process of the separation of expectations from biological organization - involving the development of the plastic control of expectations upon actions embodied in human language. Thus, if we succeed in demonstrating the likelihood of such a gradual process and, by providing some developmental account of how it may have occurred then, <u>ipso facto</u>, we would have denied Popper's "uniqueness analogy".

Our problem now, in the following section of this chapter, will be to indicate why we think that it will be plausible to provide an account of how this evolutionary transition occurred. We shall do this by discerning within Popper's general theory of evolution a methodological principle upon which we can expect to construct an account of this transition from animal to human evolution.

III A methodological principle for at least the partial closure of the "gap".

Now we again turn to Popper's general theory of evolution, this time with the intention of discerning within it a methodological principle which may be employed to help close the 'gap' within Popper's analysis of the evolution of the functions of language. Our problem, we saw, was to account for the emergence of the controls embodied in the descriptive and argumentative functions of language through an account of the transition between animal and human evolution.

We have seen that an important aspect of Popper's general theory of evolution, unifying his conception of both animal and human evolution, is the incorporation of plastic controls. These are incorporated within the biological organization of organisms in the case of animal evolution and within language within human evolution. Our problem will be to understand how it is that in the transition of the incorporation of expectations in biological organization to their incorporation in human language the controls embedded in language emerge, enabling both the communication of the content of expectations at the same time as enabling the increased influence of expectations on actions.

However, we may get some direction for handling this problem by examining the biological aspects of the incorporation of plastic controls. Thus, the fact that organisms incorporate plastic controls within their evolution brings us to an important point within Popper's general theory. For in order for an organism to retain the characteristics of its species, the controls developed by the species must be inherited within the organism. Unless this condition were met an organism would, as it were, become lost and the species of which it is a member would become extinct. Thus, the structure of an organism must contain the sum of the many inherited modifications through which the species has passed.[14] Hence, Popper states in his general theory, a single organism "telescopes" within one body, the controls developed during the evolution of its phylum.[15]

This "telescoping" further implies that an organism is a kind of "spearhead" of the evolutionary sequence of organisms to which it belongs - its phylum. The organism is a kind of trial thrown up by its phylum yet carrying with it the fate of the phylum to which it belongs. An organism is related to its phylum as the actions of the organism are related to this organism: the organism and its behaviour are both trials which may be eliminated through error-elimination.[16]

The fact that within biological evolution the continuation of a species entails the telescoping within an organism of the controls developed by its phylum contains, for the biologist, an important methodological principle: ontogenesis recapitulates phylogenesis. That is, since an organism telescopes its phylum within its organization, we should expect that the individual development of the organism (ontogenesis) should partially recapitulate that of its phylum (phylogenesis).

Of course, such a recapitulation can only be partial. For, it would be a logical impossibility that every single organism belonging to a phylum should recapitulate, in its entirety, the development of the phylum. In that case, the organism would have to live as long as the entire course of its phylogenetic evolution repeating it in every detail. Moreover, its progeny would have to, in repeating its phylogenetic evolution, repeat all that its parents repeated plus the repetition of its parents' repetition. Clearly such a hypothesis could hardly account for evolution since it virtually entails the termination of any evolution.

Secondly, the organism, since it is a spearhead of its evolutionary sequence, can hardly reflect entirely the evolution of that sequence. For the organism inherits the controls and structures developed through that sequence. Thus in its ontogenetic development, it begins, not where its evolutionary ancestors began, but with a modified physiological structure which is precisely the product of the evolution of its ancestors. That is, an organism, since it begins its ontogenetic development at the "top" of its phylogenetic development can hardly be expected to repeat that phylogenetic development.

Nevertheless, the fact that it must telescope within it, the controls developed during its phylogenetic development does entail that this organism ought to recapitulate at least partially its phylogenetic evolution. The organism may be a "spearhead" of its phylogenetic evolution but this spearhead is not thrown up within the organism in a complete form. The organism as an individual must develop from its beginnings in the embryo to a mature organism which, then, represents a spearhead of its phylum. Thus, to expect within this individual development a partial recapitulation of that phylogenetic development which must be telescoped within the (mature) organism appears to be a sound, evolutionary postulate. In fact, the application of this postulate to the development of organisms within the embryo forms the cornerstone of the study of embryology from which much has been learned about the phylogenetic evolution of the organisms concerned.

Popper, of course, recognizes this postulate and so includes it within his general evolutionary theory.

However, he seems to have restricted its applicability to animal evolution or, perhaps, to the biological aspects of human evolution.[17] The question which we shall raise is whether we can apply this postulate to human beings in order to discover something about the evolution from animal to human evolution. That is, can we apply this postulate to the study of the development of the child with the intention of discerning something about the separation of expectations from biological organization? More specifically, can we apply this postulate to the study of the development of the child with the intention of discerning something about the phylogenetic emergence of controls which enabled the increased influence of expectations upon action and the communication of expectations in language?

It appears that there is no reason why we should not expect such a study to be feasible. We have seen that the evolution of the higher functions of language is the evolution of new types of trials with new means of control for those trials. In addition, these new means of control were precisely those controls which enabled specifically human evolution to occur. Therefore, since these controls were developed in our phylogenetic evolution and since their development was of such importance for our evolution, we should expect that within ontogenetic evolution (the development of the child) some recapitulation of this phylogenetic evolution.

Is such an hypothesis naive? It has been objected by G.G. Simpson that we cannot expect to apply this hypothesis to the study of the acquisition of language in the child with the intention of discovering the acquisition of human language from animal language.[18] This objection rested on two grounds. Firstly, the child in acquiring his use of human language is not acquiring a primitive human language but a complete, sophisticated modern language unrecognizably different from any possible primitive language. Secondly, the child is doing this with a modern brain already genetically constructed (through natural selection) for the use of a complete, wholly non-primitive, language.

Such objections, however, do not mitigate against our application of this hypothesis. For our concern is not with the actual phylogenetic acquisition of language. Rather our concern is with discerning how controls emerged in our phylogenetic evolution enabling the human use of language. To put it in other words, our concern is not with discerning the actual route through which human beings acquired language, but is with discerning something about the human capacity for (human) language. That is, we have seen that the transition from animal to human evolution involved the embodiment of expectations in language rather than in biological organization and, moreover, that linguistically formulated expectations carried with them new types of control enabling specifically human evolution to occur. Thus, this transition involved the acquisition of a capacity to communicate and to control expectations. To expect this capacity for communication and, most importantly, for the control of that communication to be inherited and to be reflected, albeit partially, in the individual development of the child seems to be in perfect agreement with the general postulates of evolutionary theory given its importance as far as human evolution is concerned.

In fact, such an expectation appears to agree with the positions of both Simpson and Popper. Simpson tells us that it is "not language per se but the capacity for language which is an inherited genetic function of the human brain,"[19] while Popper states that "language is about the only exosomatic tool whose use is inborn or, rather, genetically based, in man" and that, "the human mind ... [is] ... the producer of human language for which our basic aptitudes are inborn" (brackets mine).[20]

Hence if the ability to use language is genetically based in man, then, according to the postulate of Popper's general theory of evolution which views organisms as "telescopes" of their phylogenetic evolution, we ought to expect a partial recapitulation of the development of this ability in the development of the child. In applying this postulate it is freely admitted that the child acquires language with a modern brain genetically constructed through natural selection. In fact it is partly for this reason that we expect the recapitulation of phylogenetic evolution to be partial. For it is clear that the child begins his individual development at the "top" of its phylogenetic evolution. Nevertheless, as we have pointed out, the child is not thrown up in the world in its adult state, it must develop individually. And, since the product of this development, barring any unfortunate genetic defects, will be a normal adult possessing the controls developed during human phylogenetic evolution, we ought to expect a partial recapitulation of this evolution during individual development.

IV Why 'knowing that' may not be enough

So far we have been concerned in this chapter with examining the role of Popper's analysis of language development within his general theory of evolution and with discerning within this general theory a methodological principle for closing the 'gap' within this analysis. We have seen that Popper's analysis of language development bridges animal and human evolution. Therefore, we saw that the 'gap' in this analysis was precisely the 'gap' between animal and human evolution.

On a "scientific plane" this aroused an immediate interest in moving our understanding of Compton's problem from the level of 'knowing that' to 'knowing how'. If we could succeed in closing this 'gap' we could have a more complete understanding of how this evolutionary transition from animal to human evolution may have occurred.

We saw that this understanding would be more complete because in order to close the 'gap' we would have to account for a process involving the separation of expectations from biological organization enabling the acquisition of the plastic control of expectations upon action and the embedding of this plastic control into human language.

But, is this likely to have some philosophical significance? It is my suspicion that the answer to this question is 'yes'. Firstly, it is reasonable to expect that a more complete understanding of the process enabling human evolution may provide us with a more complete understanding of the process of human evolution itself. Clearly, if we understand not only 'that' new trials and new types of control emerge in the transition from animal to human evolution but 'how' this process occurs, then we will be in a better position to understand the process generated through these new types of trials and controls. To understand this process on the level of 'knowing how' may even shed some light upon the limits of the process of human evolution generated through these new types of trials and controls as well as suggesting the possibility of the subsequent evolution of as yet unknown or unrealized trials and controls.

However, as a precautionary note, even if this understanding of Compton's problem on the level of 'knowing how' does carry with it these suggestions, it by no means implies that this solution will carry with it a method of predicting subsequent evolution. That is, if we understand the transition from animal to human evolution on the level of 'knowing how', the fact that we would then understand how new types of trials and controls emerged in our pre-history may suggest the possibility of the emergence of unknown or unrealized controls in our subsequent evolution. But this clearly does not suggest that such an understanding of this transition on the level of 'knowing how' is likely to be capable of predicting the emergence of presently unknown types of trial and controls. Such a suggestion would be clearly absurd since it would require that an evolutionary theory - a theory which is intended to account for the emergence of higher level structures from lower level structures - be capable of predicting the 'path' of unrealized products of evolutionary emergence. Clearly any such 'path' of the subsequent evolution of higher stages could not be predicted from the standpoint of the lower stage. Rather, after the event, an evolutionary theory may enable us to understand what occurred during this particular evolutionary transition. And, by so doing, it may suggest possibilities for subsequent evolution without being able to predict this subsequent evolution.

However, it will be beyond the scope of this thesis to speculate upon all of the possible ramifications of the closure of the 'gap' for understanding the growth of knowledge - human evolution. I merely suggest here that it is plausible that there are a number of ramifications for understanding the growth of knowledge through the closure of this 'gap'.

Nevertheless, it will be my intention to speculate upon at least one such possible ramification of this study as far as the growth of knowledge is concerned. The issue which will be my concern in this regard is the controversy concerning the roles of the contexts of discovery and justification in the growth of knowledge.

For Popper, these two contexts remain separate. Since he views the growth of knowledge to be a process generated by a trial and error mechanism with the trials being linguistically formulated theories and the method of error-elimination being criticism and refutation, he maintains that these two contexts are separate from each other. For Popper, the context of discovery, of the process of the formation of theories, is unimportant as far as understanding the context of justification, of the evaluation of theories and the elimination of errors within theories is concerned. That is, for Popper, the growth of knowledge is entirely within the context of justification - the realm of the evaluation of theories, the elimination of errors within theories. Since this realm is not dependent upon how those theories were formulated but is only concerned with their evaluation after their formulation, the contexts of discovery and justification remain separated. The question of how theories are formulated may be of empirical interest, for Popper, but he maintains that it is irrelevant from an epistemological viewpoint. Thus, Popper writes:

> The question of how it happens that a new idea occurs to a man - whether it is a musical theme, a dramatic conflict, or a scientific theory - may be of great interest to empirical psychology; but it is irrelevant to the logical analysis of scientific knowledge. This latter is concerned not with 'questions of fact' (Kant's

> *quid facti?*) but only with questions of 'justification or validity' (Kant's *quid juris?*) Its questions are of the following kind. Can a statement be justified? And if so, how? Is it testable? Is it logically dependent upon certain other statements? Or, does it, perhaps, contradict them? In order that a statement may be logically examined in this way, it must already have been presented to us. Someone must have formulated it, and submitted it to logical examination.[21]

It should be noted here as a matter of clarification that, although Popper has mentioned that one of the questions involved with the evaluation of theories is whether they can be justified, it is his position that no theory can ever be finally justified. That is, it is his position that theories can only be shown to be falsified and that positive evidence in favour of theory corroborates without justifying it.[22] In brief, it is Popper's position that the best theories are those which survive the continuous struggle engendered by the elimination of errors regulated through the idea of truth.[23]

Popper sees any confusion in epistemology between the contexts of discovery and the contexts of justification to be an outgrowth of the idea that there are absolutely reliable sources of knowledge which may, as it were, justify knowledge by pedigree. That is, it is Popper's view that the belief in absolutely reliable sources of knowledge through which "untainted, pure, knowledge" may be attained is responsible for the confusion of the controls of discovery and justification in epistemology.

Once Popper rejects the notion that such reliable sources of knowledge exist, he maintains that he has broken the logical link between the contexts of discovery and justification.[24]

The question which shall concern us after our examination and closure of the "gap" in Popper's solution to Compton's problem and hence within his general evolutionary theory is whether or not this will have any bearing on Popper's position with respect to the roles of the contexts of discovery and justification in the growth of knowledge.

We shall see that in considering the implications of the closure of this "gap" for the understanding of the role of these two contexts in the growth of knowledge, we shall be following up a lead suggested by Piaget's application of the methodological principle 'ontogeny recapitulates phylogeny'.

CHAPTER III

HOW PIAGET CAN BE UNDERSTOOD AS CLOSING THE "GAP"

I Piaget's application of the principle 'ontogeny recapitulates phylogeny'

Piaget's interest in epistemology became fully developed only after a long involvement in the sciences, particularly biology and child psychology. When he turned to epistemology it was with a marked suspicion of the traditional methods of philosophy. Piaget saw the traditional epistemological question as, 'How is knowledge possible?'[1] This question, Piaget claims, was both too broad and too vague. Moreover, its major problem, for Piaget, was that it viewed knowledge as, at least in principle, static - a state to be obtained.

That is, Piaget claims that the traditional approach to epistemology was in error in that it assumed that, ultimately, knowledge was a fixed and absolutely true description and explanation of reality. This conception, claims Piaget, led philosophers to seek an elusive 'basis' upon which this final account of reality could be constructed.[2]

Against this perspective, Piaget contrasts those modern trends in epistemology which view knowledge as a process, not a state.[3] Piaget claims that it is with the 'fact' of knowledge as continually changing and evolving that we ought to begin epistemology.[4] By doing so, Piaget claims that we can delimit epistemological problems to manageable areas and ask as the central problem, 'How is knowledge increased?[5]

Here we can see a certain affinity between the approaches to epistemology of Piaget and Popper. For, as we have seen, Popper also disagrees with those approaches to epistemology which seek to erect a firm foundation for knowledge upon which the absolute truth might be constructed. Popper sees this type of approach, however, to be a result of the view that the sources (origins) of knowledge might justify the validity of knowledge by pedigree, as it were. Since Popper rejects the notion of absolutely reliable sources of knowledge, he also rejects such questions as 'how is knowledge possible?' and rather asks, 'how do we detect error?'[6] or 'how does knowledge progress?'[7]

Piaget further specifies his central problem for epistemology, he asks:

> By what process does a science pass from a specific knowledge, later judged insufficient, to another specific knowledge, later judged superior by the common consciousness of adepts of this discipline?[8]

This question, Piaget points out, has both normative and factual aspects. Firstly, the normative aspect is the judgement that one state of knowledge is superior, more valid, than its predecessor. Secondly, the factual aspect is the problem of the nature of the mechanism of transition from a 'lower' to a 'higher' state of knowledge. Thus, Piaget views his "genetic epistemology" to be essentially collaborative. Psychologists must study the nature of the transition from one state of knowledge to another; logicians must formalize the states of knowledge obtained so as to determine the value of these states and the characteristics of progress; scientific specialists in the field of study concerned must determine the interest obtained within the newly acquired state of knowledge.[9]

This characterization of the central problem of epistemology would not upset Popper. He, too, would find interest in such a collaboration. However, Popper would caution that the psychological aspect of this collaboration is not, strictly speaking, epistemological. That is, without wishing to enter into a controversy over words, Popper would be quite willing, and even interested, in participating in such a collaboration: the context of discovery - the study of the psychological (and even sociological processes) involved in a transition from one state of knowledge to another would provide, for Popper an interesting empirical addition to an epistemological study. However, for Popper, it would be the roles of the logician and scientific specialist as described here by Piaget which would constitute the epistemological or evaluative aspect of this collaboration. That is, for Popper, the logician and scientific specialist concerned with epistemology would describe as clearly as possible how science should develop in order to be rational, in order that the elimination of errors within the present state of knowledge would be as effective as possible.[10]

However, it is clear that Piaget's interpretation of this collaboration would not be in accord with this Popperian characterization of it. Piaget does distinguish between the contexts of discovery and justification as is clear from the above quotation, but nevertheless, he also insists upon a merger between these two contexts.

To be more precise, it is Piaget's contention that in order for this collaboration to function the contexts of discovery and justification must be separated to the extent that psychologists, logicians, and scientific specialists are given specific domains in which to work.[11] However, it is also Piaget's claim that, although the work of each of these specialists must be primarily in one of these two contexts, the "meaning" of this collaboration is that the acquisition of norms by means of which the evaluation of the truth of knowledge is possible is dependent upon, and parallels, the psychological processes involved in the formation of knowledge.[12]

Piaget gives an explicit statement of this hypothesis:

> The fundamental hypothesis of genetic epistemology is that there is a parallelism between progress made in the logical and rational organization of knowledge and the corresponding formative psychological processes. Well, now, if that is our hypothesis, what will be our field of study? Of course, the most fruitful and most obvious field would be reconstituting human history - the history of human thinking in prehistoric man. Unfortunately, we are not very well informed about the psychology of Neanderthal man or about the psychology of Homo siniensis of Teilhard de Chardin. Since this field of biogenesis is not available to us, we shall do as biologists do and turn to ontogenesis. Nothing could be more accessible to study than the ontogenesis of these notions. There are children all around us. It is with children that we have the best chance of studying the development of logical knowledge, mathematical knowledge, physical knowledge, and so forth. [13]

We can see here that Piaget applies the same methodological principle which we discussed within Popper's general theory of evolution. Piaget's purpose in applying this principle is, however, not to close a "gap" in Popper's general theory of evolution. Rather, Piaget's purpose is to demonstrate his hypothesis of a merger, a parallelism, between the contexts of discovery and justification.

This brings us to a crucial point as far as the potential implications of our closure of the "gap is concerned. It will be our intention to apply Piaget's work resulting from his application of this methodological principle 'ontogeny recapitulates phylogeny' to close a "gap" we discerned within Popper's solution to Compton's problem and thereby within his general theory of evolution. But the fact that Piaget views his application of this principle as a means of demonstrating his hypothesis of a merger between the contexts of discovery and justification should alert us to the possible ramifications of this study as far as the issue of the role of these contexts in the growth of knowledge is concerned.

In fact, we can see a certain similarity in our application of Piaget's work and his application of this postulate to demonstrate a merger between these two contexts. For our problem of the "gap" is the problem of accounting for the process of the separation of expectations from biological organization resulting in the development of the plastic control of thought upon action and the embodiment of this control in human language. That is, our problem of the 'gap' deals with the context of discovery - the process of the separation of expectations from biological organization - in order to discern something about the context of justification - the possibility of the plastic control of expectations upon actions embodied in the product of this process of separation, linguistically formulated expectations.

Hence, if we succeed in demonstrating, through Piaget's application of this principle 'ontogeny recapitulates phylogeny', that the controls embodied in the descriptive and argumentative use of language arise due to the separation of expectations from biological organization, then we may be in a better position than heretofore to discuss the broader issue concerned with the roles of the contexts of discovery and justification in the evolution of knowledge. For then, it would appear that at least as far as the early evolution of knowledge is concerned there does exist some parallel between these two contexts. That is, there would be a parallel between these two contexts insofar as the contexts through which the 'justification' of theories is regulated would be viewed as dependent upon their process of formation through the separation of expectations from biological organization. But this merger of these two contexts during the transition from animal to human evolution is quite different from a merger of these two contexts in the subsequent growth of knowledge. In the subsequent growth of knowledge, a merger of these contexts would have to demonstrate that an understanding of the process of the formation of <u>theories</u> is relevant to the 'justification' of <u>theories</u> through the controls available. Thus, our problem, at that point, would be to consider what, if any, are the implications of this merger of these two contexts during the transition from animal to human evolution for the understanding of the role of these two contexts in the subsequent evolution of knowledge.

Before going on to our application of Piaget's work I ought to reiterate my remarks concerning the similarity between Piaget's application of the principle 'ontogeny recapitulates phylogeny' and our application of Piaget's work in order to avoid a possible misunderstanding. That is, I do not mean to suggest by this that Piaget 'really' is concerned with our problem - the problem of the 'gap' - when he applies this principle. All I am suggesting is that we can understand Piaget's application of this principle in terms of our problem. That is, we can employ Piaget's work resulting from this application to see if we can discover something of importance as far as our problem is concerned. I am in no way suggesting that Piaget was motivated in his application of this principle by discerning a problem within Popper's general theory of evolution - a suggestion which would be quite absurd considering the chronology of Piaget's application of this principle and Popper's formulation of his general theory of evolution.

That is, we can employ Piaget's work resulting from his application of this principle to our problem of the 'gap' because we saw that Popper's general theory of evolution led us to expect its applicability given the importance which he attributed to the development of the plastic controls built into human language during the transition from animal to human evolution. At the same time, the indicated similarity between Piaget's motivation for applying this principle and our motivation in attempting to close the 'gap', has led us to expect the results of our application of this principle to be of some importance for arriving at some decision concerning the roles of the contexts of discovery and justification in the growth of knowledge.

II Piaget's theory of intellectual development - how the controls embodied in human language arise through a process of the separation of expectations from biological organization.

Central to Piaget's analysis of the intellectual development of the child is the notion of a structure. A structure, for Piaget, is a system of entities, properties or 'things' inter-connected by laws of interaction. More specifically, a structure is a system governed by laws which apply to the whole system and not merely to individual elements within the system. That is, the laws which govern a Piagetian structure are transformation laws - they apply to elements of the system and transform one element into another. Finally, a structure is closed with respect to its transformation laws - when the laws of the system are applied to elements of the system, the result is also an element of the system.[14]

Piaget maintains that the intellectual development of the child is characterized by an interaction between subjective structures available to the child for ordering and making intelligible the environment which confronts him and the structures which the child confronts in the environment. The first aspect of this interaction Piaget refers to as assimilation and involves the imposition by the child of his subjective structures upon the environment. The second aspect of this interaction Piaget refers to as accommodation and involves the alteration of subjective structures as a result of feedback or resistance from the environment.[15]

These two processes, Piaget stresses, are complementary to each other. Neither occurs in total isolation from the other. Rather, each process refers to the two poles involved in any interaction between the subject and the environment.[16] However, when attempting to understand the nature of the interaction between the subject and the environment, it is useful to employ the concepts of assimilation and accommodation in order to focus upon what may be, at any particular time, the document aspect of this interaction. In other words, the concepts of assimilation and accommodation are abstractions from a situation in which the subject and the environment are constantly interacting with each other. But, these abstractions are useful for understanding this interaction to the extent that this interaction may be described, at various times, by one or the other of the complementary processes. Thus, for example, consider a young baby who is presented with a rattle for the first time. He attempts to assimilate it to his structures. Previously he may have learned to grasp objects presented to him. So he attempts to assimilate the rattle to the grasping scheme. But he must also, at the same time, accommodate his structures or schemes to the rattle. He must accommodate his visual activities in order to perceive the spatial position of the rattle well enough to enable him to grasp it. He must also accommodate and co-ordinate the muscular activities of his arms to his visual activities and the rattle. In grasping the rattle his fingers must accommodate themselves to the shape of the rattle. In short, the grasping of the rattle involves a series of interactions between assimilation and accommodations.[17]

The fact that these processes represent two poles of an interaction between the subject and the environment leads to another essential point of Piaget's concept of this interaction: equilibration.[18] This refers to the continual attempt by the subject to obtain a state of equilibrium between assimilation and accommodation. That is, the subject attempts to obtain subjective structures which are so fitted or accommodated to those of the environment that there is a stability in their interaction so that no alteration occurs within the subject's structures.[19]

Although it might appear that, if such a point of absolute equilibrium or adaptivity were obtained then henceforth there could only be assimilations during the subject's interaction with the environment, strictly speaking, this is not the case. For to assert that only assimilations occur from this point on is to overlook the fact that such a state of absolute equilibrium would be, itself, a product of many assimilations and accommodations during the subject's interactions with the environment. Thus, since this state of absolute equilibrium would be such a product, then any assimilations henceforth would involve accommodations to the extent that stability has been reached only in virtue of these previous accommodations. Hence, assimilations from the standpoint of a structure in absolute equilibrium would still involve accommodations to the extent that the absolute adaptivity of the structures would presuppose previous accommodations.

However, such a state of absolute equilibrium or adaptivity is never actually obtained. Rather, any actually realized equilibrium occurs only for a limited period of time because the subjective structures involved will always have some restrictions and limitations eventually resulting in a need for accommodations.[20] Thus, Piaget characterizes child intellectual development in terms of several periods of "relative equilibrium" in which for 'reasonably' lengthy periods of interactions between the subject and the environment little alteration of the subject's structures occurs.[21] The four main stages of "relative equilibrium" characteristic of child development, for Piaget, are the sensori-motor stage (approximately ages 0-2 years), the pre-operational stage (age 2-7 years), the operational stage (age 7-12 years) and the hypothetico-deductive stage (age 12-15 years).[22]

It is important to note that, for Piaget, these classifications are not nominal but reflect the actual acquisition of different subjective structures. This is demonstrated, claims Piaget, by the fact, as we shall see, that the acquisition of structures is not simply a cumulative process but involves the reconstruction or reorganization of previous structures within a newly acquired structure.[23] Moreover, since any particular structure is characterized by its closure, the final acquisition of a particular structure is marked by a kind of acceleration during which this closure property is being obtained. Thus, the acquisition of a structure is marked by what Piaget refers to as a "relative discontinuity" which reflects the completion of the construction of that structure through the realisation of its closure with respect to its transformation laws.[24]

Thus Piaget views child intellectual development as a continuous, but not linear, process of interaction between the subject and the environment. It is continuous in the sense that the complementary processes of assimilation and accommodation always occur. But not linear in the sense that stages of relative equilibrium between assimilation and accommodation are progressively obtained Perhaps, a better characterization of this process may be to refer to it as "stepwise continuous".

But what are the beginnings of this developmental process? If child intellectual development may be characterized as a "stepwise continuous" process of assimilation and accommodation resulting in periods of relative equilibrium, then what are the first subjective "givens" which permit this interactionary process to begin?

Piaget maintains that we cannot know what these initial structures might be. For at the earliest level of child development, the sensori-motor stage, the subjective structures through which the child interacts with his environment are hereditary. That is, the child at this level, simply acts in his environment upon the basis of various "schemes of action" which are the behavioural counterparts of inherited physiological and neurological structures.[25]

The sensori-motor child's actions, that is, exhibit certain general patterns, such as grasping, looking, sucking, etc. Piaget refers to these as "schemes of action" which he defines as the generalized form of a repeatable action.[26] By this he means that a scheme of action is the behavioural manifestation of certain physiological and neurological structures which permit certain types of action to be repeated or applied to new situations.[27] Thus, at this level, there is no separation of "expectation" from biological organization. Rather, as within animal evolution, the sensori-motor child's expectations are incorporated within his biological organization.

Ultimately, says, Piaget, we may know more about the structure of these schemes of action through more detailed information about neurological and physiological structures. But even in that case, we would not have discovered a "beginning" of intellectual development. For whatever these neurological and physiological structures may be, their structure will depend upon more primitive structures of which they are an evolutionary product and so on.[28]

Thus the question of the origin of these schemes of action becomes, for Piaget, precisely the question of the origin of life from inanimate matter. As we have seen, this question may, to some extent, be legitimately considered outside the scope of an evolutionary theory. The important point as far as our problem is concerned - the problem of accounting for the development of new types of control of expectations upon actions in the process of the separation of expectations from biological organization and their incorporation in human language - is that these schemes of action are nothing more than the behavioural counterparts of inherited neurological and physiological structures.

That is, we can see that the fact that 'biological expectations' or dispositions to react are incorporated within biological organization implies that the organism or the baby cannot separate his expectations from his actions in which some expectation or disposition to react is manifested. We saw that this lack of separation between biological expectations and subsequent actions based upon them reflected in the limitations of the animal use of language. Since the organism's or baby's expectations are incorporated in his biological organization, his use of language - his ability to communicate expectations or dispositions to react - was limited to expressing or manifesting his dispositions to react in his actions.

On the other hand, we saw that with the human use of language, the content of expectations becomes communicated through their linguistic formulation. That is, with the human use of language, the expectations themselves, linguistically formulated theories, were communicated. Thus we saw that expectations were able to exert a plastic control over actions in virtue of the controls over the content of expectations built into the descriptive and argumentative use of language. In other words, we can see that once expectations become separate from biological organization and embedded in language, they become separate from the actions based upon expectations. Unless linguistically formulated expectations - theories - were separate from actions based upon these theories, the descriptive and argumentative use of language could not exert a plastic control upon actions.

This brings us to an important point. The process of the separation of expectation from biological organization involves a process of the separation of expectations from action. For unless human expectations are separate from the actions based upon them, we could not employ the descriptive and argumentative functions of language.

Unless human expectations were separated from action we could not describe statesof affairs; we could merely respond to them based upon some disposition to react. And, even more clearly, unless this separation of expectation from action existed, we could not argue about the validity of a description of some state of affairs. For to be able to argue about a description, this description must be first represented, in language or even simply in thought, independently of actions which may follow based upon this description or linguistically formulated expectation.

Thus, when we continue to examine Piaget's theory of the intellectual development of the child, we ought to see in it a process whereby expectations become separated from the context in which actions realising expectations occur. Through this process we ought to see how these expectations, separated from the actual context in which they are realized, are able to exert an increasing influence upon subsequent actions based upon them. In addition, we ought to see how this process enables these expectations to be formulated in language into which is built the human functions of language.

Now, to return to Piaget's theory of child development, we note that the lack of separation of expectations from biological organization reflected in the sensori-motor child's inability to separate his expectations from his subsequent actions. That is, the sensori-motor child cannot represent the form of a scheme of action on the level of thought. Rather, for the sensori-motor child, a scheme of action can only be manifested in his actions. Thus, prior to his action, the sensori-motor child cannot represent, in his thought, the form of an action and then proceed to carry out that action. In other words, the sensori-motor child cannot first think about his actions and then carry them out. Rather, he simply acts.

Gradually, through a trial and error process involving repeated attempts to assimilate new situations to his schemes of action (and, of course, subsequent accommodations of these schemes to the environment),[29] the sensori-motor child begins to co-ordinate his schemes of action. That is, the sensori-motor child is constantly attempting to assimilate new aspects of the environment within his available schemes of action. This activity results in an increased co-ordination of his schemes of action enabling the child to order his activity according to a certain "logic" of this co-ordination.

Thus, for example, as we have stated, a baby has, amongst others, a sucking scheme, a grasping scheme and a looking scheme. These schemes may become co-ordinated such that the baby first looks at an object, then grasps it, and finally sucks on it. There is, within this co-ordination of schemes, claims Piaget, a certain practical logic of order. In order to achieve the desired end of sucking the object, the baby must order the co-ordination of his available schemes, which he will employ as means towards that end. He could not, for example, attempt to suck the object without first grasping it. Nor could he grasp it without first co-ordinating this with his looking scheme. This practical order of the means-end relationship within the baby's co-ordination of actions, Piaget claims, lays the basis for the later development of a logical structure of order.[30]

But a consequence of the increased co-ordination of the schemes of action is the attainment of a first concept - the notion of the "permanence of an object". This marks the beginning of the separation of expectation from action and, hence, from biological organization. For at this point, the child's expectations are separated from his actions to the extent that his behaviour exhibits a tendency to consider objects as still in existence despite the fact that they have been removed from his field of perception.

That is, prior to the attainment of the notion of object permanence, the child would behave as though an object, which he desires to assimilate to some scheme of action, but which has been removed from his field of perception, say, by playing a screen in front of it, had disappeared. The child, without the notion of object permanence, would no longer attempt to assimilate this object when the screen is placed in front of it. But, the child with the notion of object permanence, would still continue to look for the object, say, by removing the screen or moving around it. Thus, objects, for this child, have a certain permanence and are no longer viewed as disappearing when they leave the perceptual field.[31]

It is interesting to note, at this point, that perhaps we can understand the baby's fascination with the game "peek-a-boo" in terms of Piaget's theory. For, unless the individual playing peek-a-boo with the baby were considered to be disappearing and reappearing during the game we could not understand the point of the game for the baby.[32]

But in order to understand how the process of the separation of expectations from action begins, for Piaget, we have to ask how the attainment of the concept of object permanence is viewed to be a consequence of the increased co-ordination of actions? We have said that gradually the child's schemes of action become more and more interco-ordinated. Our problem, now, is to explain how this increased co-ordination may lead to a first representative concept, that of object permanence.

Piaget accounts for this transition by pointing out that the co-ordination of actions begins to assume a group structure, that is, the co-ordination of actions begins to assume the structure of a 'group of displacements'.

In general, a mathematical group is a system or set of elements together with an operation or transformation law such the following conditions hold:

(i) associativity - the order of operation upon the elements makes no difference as to the final result. For example, $a + (b + c) = (a + b) + c$,

(ii) closure - applying the operation to any two elements results in an element of the set. For example, if a and b are integers then $a + b = c$ is an integer.

(iii) identity - there exists an identity element such that in combination with another element of the set, the operation yields that other element. For example, $a + 0 = a$.

(iv) inverse - for each element of the set there exists an inverse element such that the operation upon these two elements yields the identity element. For example, $a + (-a) = 0$.

The 'group of displacements' involved with the co-ordination of actions is characterized by the set of objects and the operation of displacing or moving them. The child's attempts at assimilating objects within his schemes of action and their subsequent co-ordination gradually leads him to become aware, in his actions, of the group properties of his actions upon objects. That is, although he is not conscious of these properties qua objects of representative thought, in his activity he gradually comes to realize them. Thus he becomes aware of the inverse operation in his understanding that he can "cancel" a movement by returning to its starting point. Again, in his activity, itself, he becomes aware of associativity, when he realizes that he can reach a certain point by several different paths. For example, he can reach the living room from the kitchen either by moving through the dining room or through the hall. Of course, the identity element takes care of itself, as it were, since remaining stationary would constitute it.

But what about closure? In order for the child to become aware of the closure property he must consider objects to be permanent. For, in general, any group must have invariants, the elements upon which it operates. The 'group of displacements' in order to be closed must be viewed as operating upon objects considered as permanent.

For only if objects are viewed as remaining in existence after leaving the perceptual field can operations upon them be still considered to yield objects. For otherwise, if a displacement of an object results in its leaving the child's perceptual field, then its "disappearance" will preclude the closure of the 'group of displacements' in the child's activity.

The attainment of this closure property is, for Piaget, an accommodation on the part of the child. It is, for the child, the simplest "strategy" he can adopt in order to accomandate his structures to the environment available to him from the perspective of the increased co-ordination of his schemes of action.[33] That is, it is the very structure of the co-ordination of actions, a structure which approaches more and more closely to a group, which, as it were, "forces" the concept of object permanence upon the child due to a need to construct an invariant for this group of displacements.

This step marks the beginning of the transition towards a separation of expectation from action and hence biological organization. It involves the attainment of his first representative concept. From the subject's perspective, it involves a "de-centering" of his environment. As we have seen, previous to the acquisition of this concept, the world was, for the child, simply the world-as-it-wasappearing in his immediate surroundings. However, with the attainment of the notion of object permanence, the world becomes a world-as-it-has-appeared-and-will-appear to the child. Thus the child's world becomes "de-centered". There is here a kind of Copernican revolution. The child no longer relates to everything in the world from the perspective of his own body as if it were the centre of the universe - albeit, a centre unaware of itself. Rather, the child begins to see himself as an object amongst others with actions no longer centered on his own body, but in which he remains an integral part of the world to the extent that he acts effectively on it.

But this Copernican revolution remains at the level of actions. The child at this level cannot form a representation of his actions on the level of conceptual thinking. For example, a study by A. Szeminska of children aged four to five years showed that, although they understood perfectly well how to follow, by themselves, a path which led from their house to their school, they were unable to depict it by means of material representing the principal landmarks named along the route.

That is, the Copernican revolution associated with the notion of object permanence, does lead to an initial differentiation between the subject and the object, the environment. But this does not constitute a complete separation between expectation and action and hence biological organization. For, even at this level, and to a certain extent, also at the concrete operational level, the subject's thought is tied to the contents of the present moment.

In fact, Piaget characterizes the process of transition from the sensori-motor level to the subsequent stages of intellectual development as largely a matter or the translation of what is "known" at the level of action to a representation of that knowledge at the level of conceptual structures or representative thought.[36] In other words, this process of transition can largely be entitled a process of translating 'knowing how' - at the level of action - to 'knowing that' - at the level of representation.[37]

This process of translation begins after the attainment of the notion of object permanence and involves a gradual "interiorization" of the schemes of action into representative concepts. This interiorization process is achieved through a series of refinements upon what Piaget refers to as the semiotic function of intelligence. This function refers to the ability of a sign or symbol or another object to represent something else. It arises, claims Piaget, in conjunction with the notion of object permanence and begins the translation from intelligence which is acted out (sensori-motor intelligence) to intelligence which is thought.

This process begins firstly by imitation in actions. The child imitates the behaviour of others, particularly, of course, parents. This imitation in action becomes deferred by being carried out not only in the presence of others but also during their absence. The child's play, Piaget claims, becomes symbolic. He intends his actions to stand for other events. Thus, for example, Piaget cites the case of a young child who saw a piece of frayed cloth which vaguely resembled the edge of her pillow. She seized the cloth, folded its edge, and law down on her side, her thumb in her mouth with her head on the cloth and began to laugh.[39] These processes of imitation, deferred imitation, and symbolic play are viewed by Piaget as reflecting a gradual interiorization of imitation. It is through this process, claims Piaget, that the schemes of action of the sensori-motor period will be gradually interiorized to form conceptual operations.

Most important, in this process, is the acquisition of language. However, although the acquisition of language is important in this transition, Piaget does not consider it to be a sufficient condition for this transition. That is, the acquisition of language is only a part of the semiotic function whose development consists of the interiorization of imitation and is partly dependent upon endogenous or maturational factors resulting in the co-ordination of actions. It is important to note here that this semiotic function is an extremely general function of language which pervades all of the functions discussed previously with reference to Popper, that is, the expressive, signalling, descriptive and argumentative functions of language. Piaget sees its development through the interiorization of imitation to be a necessary condition for the subsequent acquisition of language and influence of social and cultural transmissions.[40]

To support this claim Piaget cites experiments with deaf and dumb children in which these children develop the same logical structures as normal children although at slightly retarded rates of development. This is contrasted with similar experiments with blind children, in which the delay in development is much more significant, although, ultimately, the same structures are developed. Piaget accounts for this difference by pointing out that the blind children are much more hampered in developing the co-ordination of actions in space than normal or deaf and dumb children.[41]

The result of this process of interiorization is the attainment of the concrete operational level. This is attained when the schemes of action of the sensori-motor level have been interiorized to form (definition) operations.[42] This results in the formation of concrete operational structures through the interiorization of the co-ordination of the schemes of action. A concrete operational structure achieves this interiorization by forming systems of operations which have an operational reversibility.

Perhaps an example will help clarify this point. If we present children with a collection of ten sticks each varying in length by small amounts from each other, and ask them to arrange them in order of increasing size, we can observe illuminating differences of approach according to the stages of development of the children. Pre-operational children will either be unable to complete the series only managing to arrange sub-groups of two or three sticks in order or, if they do succeed in ordering the entire series correctly, do so only by a trial and error rather than a systematic procedure. The children of this stage have not formed an operational structure of "seriation". Thus they cannot deduce that, if a stick B is greater than A it will, at the same time, be less than C. Piaget claims that this inability is a reflection of the fact that they do not have an operation of transitivity involved in ordered series. He points out the operational nature of the concept of transitivity by remembering that even if a pre-operational child is shown A < B and B < C, he will not be able to state the relationship between A and C. When asked why he is unable to state this relationship, the pre-operational child will simply respond by saying that he has never seen them together.[43]

In contrast to this the concrete operational child will state immediately that A < C. Moreover, when asked to justify this conclusion, he will simply state that 'it is forced' since A < B and B < C.[44] Piaget accounts for this conviction of necessity in the child's judgement by indicating that he possesses an operational structure which is closed with respect to the transitive relation involved in ordering. The concrete operational child, when asked to arrange the ten sticks in order, reflects the operational nature of this structure in his method. He proceeds systematically. He compares the sticks and selects the shortest one. Then he compares the remaining sticks and selects the shortest remaining stick, placing it next to the first one and so on. His method, Piaget claims, reflects his attainment of the concrete operational structure in that it demonstrates his knowledge that if E > D, C, B, A (already ordered sticks) then, at the same time, E < F, G, H, I, J (remaining sticks).[45]

Thus, we can see in this example that the structures of the concrete operational level have operations or transformations. These operations reflect the same sorts of "cancellations" possible at the level of action with the added novelty that their formation into a structure permits "cancellations" or reverse transformations in thought rather than merely in action. In other words, the attainment of closed, operational structures enables the child to be simultaneously aware of the order relationships amongst the ten sticks rather than to be limited in this awareness by having to carry out these relationships in his actions by directly comparing sticks.

This particular example of the operational structure of seriation represents one of the two types of reversible operations at the concrete operational level. Its mode of reversing transformations through the relationship "bigger than" and "smaller than", Piaget refers to as a reciprocal reversibility. The other type of reversible transformation at the concrete operational level is negation, characteristic of classification structures.

Thus, for example, children at the concrete operational level can consider the class of all birds, B, and subdivide it into sub-classes, A, the class of all ducks and A^1, the class of all birds other than ducks. In addition they understand the relationship between a class and its sub-classes. They know that $A + A^1 = B$ which can be reversed to $B - A^1 = A$.

Younger, pre-operational children, however, do not understand this relationship between the sub-class and class. If asked if there are more birds in the woods or more ducks, they will say they don't know because they haven't counted. At this stage, Piaget claims, the pre-operational child does possess certain aspects of a classification structure. He does distinguish between the class of birds and its sub-classes. Moreover, the child can make comparisons between sub-classes by counting them. But he does not possess the operational structure of classification because he cannot deduce the relationship between a class and sub-class.

Children of a slightly earlier level - an earlier sub-division of the pre-operational stage - Piaget says, also can handle some aspect of classifications. They can, he says, form figural collections. That is, they can arrange, say, a number of squares in a certain figural arrangement and a number of circles in a similar arrangement. But if the configuration of the arrangements of circles or squares is altered, the child will maintain that the size of the classes has also been changed.[46]

These various stages reflect the gradual and progressive character of the transition from the sensori-motor to the concrete operational stages. We see in the refinement and development of the classification structure various levels in which the closure of the operation of class inclusion is gradually attained.

Moreover, we can see in this process a gradual separation of expectation from action and, hence, from biological organization. Thus, the child who is limited to figural classifications, is at the beginning stages of developing a classification structure but this primitive "pre-classification" structure is not sufficiently separated from the actions of the subject to become operational. The child confuses his own actions upon the objects of arranging them in figures with the properties of classes as such. In so doing, the child's actions become, for him, an essential part of his classifications insofar as their results - the figures - are viewed as belonging to the objects themselves - the classes - rather than to the actions of the child relative to the objects.[47]

Again, the slightly more advanced child, who is able to classify objects without viewing their configuration as essential, but who has not attained operational reversibility, has a slightly higher degree of separation of expectation from action. His expectations are more separated from his actions insofar as he no longer confuses the results of his action - the configuration of the classes - with the classes themselves. But, his expectations remain tied to his actions insofar as his perception of the relationship between a class and its sub-classes is tied to his actions of separating the sub-class from the class. Thus if a child of this level is shown a collection of ten cards containing pictures of five ducks and five other birds, he will maintain that these are the same number of ducks as birds. Here the action of collecting the sub-class of ducks results in their separation from the class of birds so that they are compared only with the five remaining birds.[48] Thus, even at this level, the child has not separated his actions upon the objects from the relationships amongst the object themselves.

Moreover, we shall see that even at the concrete operational level itself, there is not a complete separation of expectation from action. For even at this level, it is necessary for the child to be actually in the presence of objects in order to solve problems dealing with them. Thus, he can not solve problems presented to him verbally which he could have solved by actually manipulating objects. In fact, it is for this reason that Piaget refers to these structures as "concrete".

For example, a concrete operational child who has been able to solve the problem of ordering ten sticks mentioned earlier, cannot solve the verbal problem: 'Edith is lighter than Suzanne and Edith is darker than Lily; which is the darkest of the three?'[49] Here it appears that all that is required to solve the problem is an understanding of the same ordinal relationships used in the ten sticks problem. However, the fact that the verbal problem can not be solved while a similar problem involving the actual manipulation of objects can be solved, reflects an essential limitation of the concrete operational level. At this level, the child's thought remains tied to actual situations. He cannot reason hypothetically and consider hypotheses independently of a given empirical situation. That is, the concrete operational child cannot represent relations given to him verbally without actual physical props upon which to support them. His expectations remain linked to his actions insofar as he requires objects which it is possible for him to manipulate in order to successively graft his expectations upon a given problem situation. That is, the concrete operational child can solve problems only by assimilating them to his structures which are limited in that they must be tied to objects which it is possible for him to manipulate.

This functional limitation of the concrete operational level is reflected formally in the structure of this level itself. The structures of the concrete operational level, in being tied to objects which can be manipulated, have certain formal limitations. Thus, for example, the concrete classification structure has two formal properties which structurally reflect its limitations. These are "tautology" and "re-absorption". That is, if A = class of ducks and B = class of birds then tautology is expressed by A + A = A and reabsorption is expressed by A + B = B.

The limited nature of these concrete operational structures is also reflected in the inability of the concrete operational child to combine or integrate his structures. That is, while we saw that the attainment of the notion of object permanence resulted in a certain "decentering" of the sensori-motor child's actions, the concrete operational child's thought remains "centered". We shall see at the hypothetico-deductive level a certain "decentering" in relation to thought which parallels the decentering in relation to action.

Thus, if a concrete operational child is given a "complex" problem, one involving the combination or integration of concrete operational structures, he will not be able to solve it even if he is given objects to manipulate. For example, concrete operational children cannot solve problems of relative motion involving the co-ordination of two frames of reference. If we give the concrete operational child a problem involving the movement of a snail upon a movable board, he will be unable to integrate the two forms of reversibility, reversing the movement of the snail to the right by a movement of the snail to the left and reversing this motion by a movement of the board to the left. With respect to an external frame of reference both of these movements would constitute an inverse of the movement of the snail to the right. However, the concrete operational child's thought remains "centered" upon one frame of reference and he cannot integrate those two forms of reversibility within a single operational system which incorporates both frames of reference.[50]

Thus, we see the limitations of the concrete operational level reflected in three ways: firstly, expectations remain tied to actions insofar as objects are required in order for expectations to be incorporated for the solution of problems; secondly, the structures of the operational level have formal restrictions; and thirdly, the formally restricted structures cannot be integrated for the solution of "complex" problems. But, of course, there is a positive side to the attainment of the concrete operational level with respect to its predecessors, despite these limitations.

We can see in the transition from the preoperational to the concrete operational stage the attainment of structures which are representations of transformations. That is, at the concrete operational level transformations, in being represented in thought can be reversed in thought. At the pre-operational level, transformations are not represented in thought but are inseparably linked with action. Thus, since actions occur in space and time, they can only be reversed in space and time - by actually carrying out the reverse transformations in action, which means, of course, that at the sensori-motor level the "reversal" of a transformation is never "perfect" since time is irreversible. Moreover, certain transformations cannot be reversed at all - once some things are done they cannot be undone.

Thus, the attainment of the concrete operational level is the attainment of transformational structures which enables the simultaneous reversal, in thought, of various transformations. Here there is a certain partial separation of expectation from action in that previously the reversal of a transformation had to actually occur in action - a situation which is not always possible. In other words, the attainment of the concrete operational level embeds actions in a system of transformations capable of being conceived simultaneously. Thus, a series of actions which, at earlier levels could only occur successively, can now be represented simultaneously.[51]

This partial separation of expectation from action, despite its limitations, we shall see has a very significant positive aspect: the extension of "reality" by the realm of "what is possible". By this I mean that the concrete operational child can organize a given set of data by embedding it within a system of transformations. This enables him to understand the empirically given situation - the reality - by extending that reality into a system of possibilities - a system of transformations which provides a concept of "what is possible" given some transformations in reality. That is, the concrete operational level, the partial separation of expectation from action, enables, in a sense, the anticipation of actions by expectations.

This "anticipation" is a consequence of the representation of actions in operational structures. For in representing the co-ordination of actions in an operational structure, the concrete operational child can anticipate the form of a possible series of actions before carrying them out. This occurs due to the "extension" of a given actual situation by embedding the actual transformations given into a system of possible transformation. The child at the concrete operational level thus extends and anticipates reality by embedding it within the realm of "what is possible".

For example, if we consider the example of the ordering of ten sticks, the concrete operational child knows after ordering the first five sticks that he can continue to order the remaining five. He does this by extending the actual transformations already carried out on the first five sticks into the realm of "what is possible" by assimilating the possible transformations on the remaining five sticks into the same scheme of expectations which enabled his actual ordering of the first five sticks.[52]

Or, to consider another example, if we show two balls of plasticine to a pre-operational child which he considers to contain the same amount of plasticine, he will deny their "equality of substance" when one of the balls is changed into a sausage shape. He will then maintain that, say, the sausage is bigger or contains more plasticine because it is longer than the ball. The concrete operational child, on the other hand, will assert the "equality of substance". He will claim that they contain the same amount of plasticine and justify this conclusion by one of three arguments: either by reasoning through 'identity' - nothing has been added or taken away during the transformation between states; or by reasoning through transformational reversibility - one ball has been changed into a sausage and hence the sausage is capable of being changed back into a ball; or by reasoning through 'compensation' - the sausage is longer but this is compensated for by decreased height.[53]

In all three arguments we can see an extension and anticipation of "reality" by the realm of "possibility". For the pre-operational child, lacking the partial separation of expectations from action and hence the influence of the "possible" on the "real", could only concentrate on some aspect of the actual states of the plasticine, say, on their length. The pre-operational child could not extend the reality - the various states of the plasticine - into the realm of possibility by considering the transformation between the states of plasticine to be a part of a system of possible transformations upon the states of the plasticine. That is, the pre-operational child cannot "observe" the transformation between the states of the plasticine since he cannot embed them into the concrete operational structures permitting the understanding of these transformations as the actualization of a sector of possible transformations.

But the concrete operational child can embed the transformations occurring in reality into a system of possible transformations. In so doing, he extends and anticipates reality by reasoning on the basis of the structure of these possible transformations. Each of the arguments employed by concrete operational children to justify his assertion of the "equality of substance", reflects this transformational character of their reasoning. The 'identity' argument concentrated on the fact that during the transformation process no change was made in the amount of plasticine. The transformational reversibility argument directly employs the use of the system of possible transformation - the concrete operational child knows that this transformation can be reversed. Finally, the compensation argument, although it appears to be based merely on the immediate empirical reality asserting a compensation for increased length by decreased height, the a priori nature of this argument shows the influence of the realm of possibility. For the child employing this argument makes no attempt at measuring the compensation. Rather, he simply asserts that these different dimensional changes will compensate each other, implicitly appealing to a transformational structure which guarantees compensation due to transformational reversibility.

Thus, in this example, we can see how the concrete operational child can extend and anticipate reality by employing his operational structures to provide him with a concept of the "possible" which is then grafted onto a given reality. In the case cited above, this process enabled the concrete operational child to achieve a concept of the "conservation of substance". We can see another reflection of the partial nature of the separation of expectation from action in the time-lag which occurs between the attainment of this conservation notion and that of the conversion of weight and volume. That is, although one might think that the concrete operational child merely has to generalize his concept of the conservation of substance to weight and volume to achieve a notion of the conservation of these properties, in fact, there is a lag of several years between the acquisition of each of these conservation notions. This time-lag is due, Piaget claims, to the increased difficulty for the child, in separating the properties of weight and volume from his own actions upon objects than in separating the property of substance from actions upon objects. That is, the concept of substance is easier for the child to dissociate from his actions upon objects than are the concepts of weight and volume.[54]

Now we shall turn to an examination of the hypothetico-deductive level. We shall see that this level overcomes the limitations outlined of the concrete operational level. Formally, we shall see in the hypothetico-deductive level, a combinatorial or integrational character. It will overcome the structural limitations of the concrete operational level by combining or integrating in a single structural system operations comprising the two forms of reversibility, negation and reciprocity, which remained isolated in mutually exclusive structures at the concrete operational level.

Functionally, we shall see in the operations of the hypothetico-deductive level an increased separation between expectation and action. That is, we shall see in the operations of the hypothetico-deductive level an ability to reason hypothetically - upon hypothesis, independently of any objects embodying the relationships expressed in hypothetical propositions.

Perhaps the best method of approach for indicating the overcoming of the limitations of the concrete operational level with the attainment of the hypothetico-deductive level is to show how this is a consequence of a more general characteristic of the transition between these levels. This most general characteristic is the reversal of the roles of "reality" and "possibility" in the child's reasoning.

We saw that at the concrete operational level the child is able to solve certain problems by extending the "reality" given to him with these problems into the realm of "possibility" by considering the real, actual transformations given to him to be a sector of a system of possible transformations. At the hypothetico-deductive level, we shall see a reversal of the roles of "reality" and "possibility" in the sense that, the child of this level will not merely extend a given reality by embedding it within a system of possible transformations, but will actually subsume a given reality within a system of possible transformations. That is, the hypothetico-deductive child, will not accept a "given" situation as real, as "facts", until he has subsumed the "given" transformations under a system of possible transformations, the actualization of a sector of which can account for the "givens".

Thus, we shall see that there is a reversal of the roles of "reality" and "possibility" between the concrete operational and the hypothetico-deductive levels in the sense that, while the former "extends" a given reality by embedding it into a system of possible transformations, the latter subordinates "reality" to a system of possibilities. For the hypothetico - deductive child does not accept the "facts" given to him in a problem situation as real until he has succeeded in constructing a system of possible transformations, a sector of which can account for the transformations given to him.[55]

But how does this transition between the concrete operational and the hypothetico-deductive level occur? Piaget sees this as a gradual process of the child's accommodating his structures to the structures he discovers in "complex" problem situations.[56] We saw that concrete operational children tend to structure the reality which confronts them 'factor-by-factor', in which there is often a time-lag between the application of the same structure to different situations. Also, we saw that concrete operational children tend to apply their structure to extend a given reality. That is, their concept of "what is possible" is a direct extension, as it were, of a given reality. Thus concrete operational children tend merely to register the facts which confront them by embedding them into concrete operational structures. They do not, and can not, Piaget points out, take a critical attitude towards problem situations since their structures, their expectations, remain tied to the objects upon which they operate.[57]

However, sooner or later, the concrete operational child will confront a problem situation which he must assimilate to his structures. Thus, when a concrete operational child confronts a problem situation involving several heterogeneous variables, his attempted registration of the results of the experimental manipulation of the objects concerned, by assimilating them to concrete operational structures, will be contradictory and inconsistent. For example, he may find event x nearly always occurs with event y, but, also, he may find situations in which $\bar{x}.y$ and even $x.\bar{y}$ occur (not x and y and x and not y) which may be exceptions to some general rule. That is, the more accurately he analyses the problem situation, the more likely that he will discover results which are a mixture of various regularities and exceptions to those regularities. And, as long as he remains at the concrete operational level, the child will not be able to separate the inter-dependent variables from one another so as to determine the relationships responsible for the observed results.

This is so because the concrete operational structures remain linked with the objects upon which they are imposed. In order to separate out the influence of relevant variables the child must adopt a critical attitude towards the registration of results. But in order for him to succeed, in order for him to separate heterogeneous variables, he will have to reverse the direction of the roles of "possibility" and "reality".

For in order for him to isolate relevant variables he will have to look upon the results of experimentation critically. He will have to suspend his acceptance of given relationships as "facts" and to view them all, temporally, as embodying possibilities. Moreover, once the child begins to view various relationships as embodying certain possible transformations he will have to combine these relationships themselves into certain structures in order to separate factors and test some of the possible relationships against reality.[58]

For example, as we have already seen, a concrete operational child may be faced with two events or properties x and y whose occurrences he has classified to form four possibilities: $x \cdot y + x \cdot \bar{y} + \bar{x} \cdot y + \bar{x} \cdot \bar{y}$. That is, x and y may occur together, x may occur without y, y may occur without x, or neither x nor y may occur at all. But, if he is going to discover which of these possibilities occurs in reality he will have to classify the relations embodied within these possibilities, that is, the child will have to impose a classification structure upon these relationships embodied in the four possibilities by using these as a basis. In other words, in order to reason about possible transformations considered hypothetically the child must impose classification structures upon relations or operations rather than upon objects themselves. This characteristic of employing "second-order" operations - operations upon operations - is one of the distinguishing features of the hypothetico-deductive level.[59]

When the child constructs such second-order operations he combines structures which had been isolated at the concrete operational level into a single operational structure. Thus if we label the four possibilities outlined above as follows: $1 = x.y$; $2 = x.\bar{y}$; $3 = \bar{x}.y$; $4 = \bar{x}.\bar{y}$; then the imposition of a classification structure upon these relationships results in the following possible relationships:

0;

(1), (2), (3), (4);

(1+2), 1+3), (1+4), (2+3), (2+4), (3+4);

(1+2+3), (1+2+4), (1+3+4), (2+3+4); (1+2+3+4).[60]

It is important to note at this point that in any given problem situation, the hypothetico-deductive child may not actually construct such a complete classification of all possibilities given the four base relationships. But, nevertheless, Piaget points out that those classifications which he actually constructs are a product of his hypothetico-deductive structures which enable him, even if he does not actually do so, to construct a complete enumeration of all possibilities, given certain base relations. That is, this complete classification is for the hypothetico-deductive child "structurally possible". His structures enable him to form such a complete list of all combinations with respect to certain base relations.[61]

This structure combines both forms of reversibility, negation and reciprocity, found at the concrete operational level. Thus an inverse of relationship $1 = x.y$ will be relationship $(2+3+4) = x.\overline{y} + \overline{x}.y + \overline{x}.\overline{y}$. This combines the inverse by negation of concrete classification structures, $\overline{x}.\overline{y}$, with the inverse by reciprocity of concrete ordinal structures, $x.\overline{y} + \overline{x}.y$. For $x.\overline{y}$ and $\overline{x}.y$ represent the reciprocal implications $x > y$ and $y > x$, respectively. That is, $x > y$ is true for all truth values of x and y except $x.\overline{y}$ and similarly for $y > x$. By so ordering the relationships $x.y$, $x.\bar{y}$, $\bar{x}.y$ and $\bar{x}.\bar{y}$, the hypothetico-deductive child may test, for example, the compatibility of properties x and y. If $x.y$ holds true in reality then x and y are compatible, while if $x.\bar{y} + \bar{x}.y + \bar{x}.\bar{y}$ holds true, then x and y are incompatible.

Moreover, it is this combinatorial aspect of the hypothetico-deductive level which permits the separation of heterogeneous variables. For the hypothetico-deductive level provides a combinatorial operation which is not a simple classification of objects or properties but which is a generalized classification providing a classification of all possibilities with respect to a set of possible relationships between objects or properties. In so doing, the hypothetico-deductive level permits the choice of certain combinations, which keep one or several variables constant while altering another variable, to be tested against reality. The feedback from this test then permits the hypothetico-deductive child to draw some conclusion as to the influence of the separated variable in conjunction with the other variables.[63]

Speaking (even more) generally, the hypothetico-deductive level achieves its combinatorial aspect by increasing the separation of expectation from action. For the structures of the concrete operational level were limited in that they deal directly with some given reality.

As we have seen, problems which could have been solved by manipulating objects become insolvable for the concrete operational child when stated verbally. We characterized this limitation by indicating that concrete operational structures merely extend the real by a concept of "what is possible" which is a direct continuation of structures given in reality.

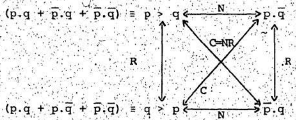
The hypothetico-deductive level, on the other hand, in attempting to go beyond the classification of results and seeking to isolate the influence heteorgeneous variables, must increase the separation between expectation and action by imposing concrete operational structures upon operations themselves. That is, the separation between expectation and action is increased, at the hypothetico-deductive level, by re-applying concrete operational structures to the results of their previous application upon objects.

This involves a reversal of the roles of "reality" and "possibility" in that the hypothetico-deductive child can discover the inter-relationships between heterogeneous factors by viewing transformations in reality as a function of possible transformations. That is, the hypothetico-deductive child, seeking to isolate heterogeneous variables, must, first, embed the relationships in reality within a system of possible relationships. After constructing a system of possible relationships, he can then choose from amongst them those possibilities which he believes to be operative in reality. Then he may proceed to check his beliefs against reality by a systematic testing procedure. That is, he can choose particular combinations of relationships from amongst the combination of possible relationships for testing which will yield the effects of variables isolated from each other.

But, at the same time, the hypothetico-deductive level permits purely verbal reasoning. As we have seen, at the concrete operational level it is sufficient to replace a problem stated verbally but in the presence of objects to manipulate, by the verbally-stated problem only, to make it not solvable. This reflects the type of linkage between propositions at the concrete operational level: they are linked to each other not by virtue of propositional connections but in virtue of the content of the propositions - the actual objects - upon which class and relational structures can be imposed. But as soon as the child can reason hypothetically, in terms of possibilities as such, at the hypothetico-deductive level, he can connect propositions to each other in terms of the combination of possibilities and no longer has to combine them through the actual manipulation of objects.[64]

Thus, a hypothetico-deductive child, given a complex problem to solve may ask himself the nature of the relationship between two events embodied in propositions p and q. He may ask if $p > q$ is true and attempt to answer this by looking for a counter-example embodying $p.\overline{q}$ (inverse by negation). Or, he may wonder if the relationship between p and q is the reciprocal of $p > q$, i.e. $q > p$. In which case, he may attempt to find a counter-example embodying $\overline{p}.q$. Moreover, the hypothetico-deductive child knows if he finds such a counter-example $\overline{p}.q$ that it is compatible with $p > q$ since it is its correlate, the negation of the reciprocal.

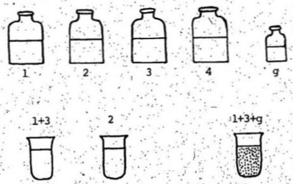
That is, the course of the hypothetico-deductive child's reasoning exhibits a structure which combines the forms of reversibility, negation and reciprocity, found at the concrete operational level. If we label; negation, N; reciprocal, R; correlate, C; and identity, I; we can describe the hypothetico-deductive child's reasoning in terms of the INRC group as follows:[65]



That is, the hypothetico-deductive child combines the reversible transformations of the concrete level to form the INRC group with transformations: NR = C, NC = R, CR = N, and NRC = I. In other words, the combinatorial aspect of hypothetico-deductive thought permits the child of this level to link propositions, implications, conjunctions, etc., with each other by allowing and connecting reasoning about possibilities independently of a direct connection between these possibilities and some actual situation.

Thus, in order to solve problems verbally, by argument through the employment of a propositional logic, the hypothetico-deductive child represents the actual, intra-proportional, content of arguments through inter-propositional connections. That is, the hypothetico-deductive child subordinates the intra-propositional content of propositions embodied in actual situations at the concrete operational level to a system of possible transformations. The inter-connections of the combinations of possible transformations then permits the representation of intra-propositional contents by inter-propositional connections which are the insertion of these combinations into propositional form.[66]

In order to illustrate these points, consider the following experiment (see diagram below). The subject is shown four glasses each containing a colourless, odourless, liquid. Glass 1 contains diluted sulphuric acid; glass 2, water; glass 3, oxygenated water; and glass 4, thiosulphate. In addition, there is a small flask, labelled g, containing potassium iodide. The experimenter presents two more glasses to the subject. One contains liquids 1 + 3, diluted sulphuric acid and oxygenated water, and the other contains liquid 2, water. While the subject watches, the experimenter adds several drops from g, thiosulphate, to each of these glasses. The liquid in the glass containing 1 + 3 turns yellow, while the glass containing water remains clear. The subject is then asked to reproduce the colour using any combination he wishes of the initial four glasses and flask.[67]



Concrete operational subjects proceed by combining 1 x g, 2 x g, 3 x g, 4 x g and 1 x 2 x 3 x 4 x g. This latter combination is formed by adding g after each addition of 1, 2, 3, and 4. Thus it yields a yellow solution after the combination 1 x 2 x 3 x g but a colourless solution after 1 x 2 x 3 x 4 x g.

Unless prompted by the experimenter, concrete operational children will not consider combining two or three liquids with g. Piaget interprets this to be a consequence of the elementary and limited structure of the combinational 'groupings' of this level in which associations and correspondences occur only between one term and all the others. Children of this level, that is, lack the necessary structure to consider all possible combinations spontaneously. When prompted to make some hypothesis as to their results, these children either maintained that too much "water" had been added or that they combined the liquids in the wrong order. In neither case was there a systematic method or explanation. The subjects tended to attribute the property of colour to a single liquid having a "potential" to become coloured and not to the combination of liquids. Even when forming the hypothesis that the order of combination was important for producing a coloured liquid, subjects did not proceed to systematically trying various combinations but merely to changing or reversing already tried combinations such as 4 x 3 x 2 x 1 x g, etc. Piaget again interprets this as reflecting the concrete operational structures of the subjects, that is, first-degree combinations. A structure embracing combinations upon combinations would be necessary before the subjects could try a more systematic approach. This is reflected, claims Piaget, in the failure of these children, even after observing that 1 x 2 x 3 x g yields a yellow liquid on route to forming the combination 1 x 2 x 3 x 4 x g, to consider the possibility of the exclusion of 4 and "colourness". Rather, the subjects merely report that the colour disappears for various reasons, such as "too much water" is added.

Slightly more advanced concrete operational children, Piaget notes, do begin to try combinations of two and three liquids, such as 1 x 4 x g, 2 x 3 x g and even 1 x 3 x g (yellow). But these children do not consider all the possible combinations and, as a result, neither proceed with a systematic method nor formulate any systematic explanations. In fact, their explanations still tend to view the property of "colourness" as a potential quality of one of the liquids and not as a property of their combination as such.

With the attainment of the hypothetico-deductive level, however, children proceed by a systematic method trying out all the combinations involved. Moreover, even after succeeding in producing a yellow liquid with 1 x 3 x g, they proceed with trying out other combinations in order to determine the role of the combination 1 x 3 x g amongst the total number of combinations.

In addition, at the same time that they apply a combinatorial structure in their experimental method, hypothetico-deductive children apply the same structure to their judgements and explanations of their results. That is, the children are able to interpret their experimental results, setting up links of conjunction, implications, and exclusion, etc. using the same combinatorial system which enabled their systematic experimentation. For example, the reciprocal exclusion or incompatibility of liquid 4 with "colourness" is established by the child's ability to conjoin the combinations leading to "colourness" and not 4, no "colourness" and 4, and no "colourness" and not 4. By a similar method, the child establishes the neutrality of liquid 2. He notes that liquid 2 appears with colourness, and without colourness. In addition, there are combinations with colour but without 2 and without colour and without 2.

Finally, the combinatorial character of the child's reasoning, Piaget claims, leads him to attribute the cause of "colourness" not to any potential of one of the liquids but to the combination of liquids themselves. That is, the fact that each of the liquids gives rise to colourness or no colourness, depending upon its combination with others, leads the children at this stage to attribute their properties to the combinations themselves.

Thus, this example shows the close connection between the mode of organization or the combinatorial structure of the experiment, on the one hand, and the "inter-propositional operations" or arguments interpreting the results, on the other hand. In fact, Piaget argues, this connection is a consequence of their essential identity. The combinatorial organization of both the experiment and the results springs from the combinatorial character of the hypothetico-deductive structures which provide the scaffolding upon which both are erected.[68]

But, we can also see in this example, that more general characteristic of the reversal of the roles of "reality" and "possibility" with the attainment of the hypothetico-deductive level. Moreover, it will be through an examination of this characteristic that we shall see both the increased separation of expectation from action and the increased "anticipation" and influence of expectation upon action.

For the hypothetico-deductive level is attained through combining the structures of the concrete operational level. This is done by re-applying these structures to operations themselves rather than to objects. But this employment of "second-order" operations involves the reversal of the roles of possibility and reality at the concrete operational level. For now, with these "second-order" operations the child subordinates transformations in reality to possible transformations in the sense that he first considers all possible transformations and only subsequently selects from them transformations which may occur in reality.

In our example, the hypothetico-deductive child constructed a scheme of all possible combinations of the liquids in the flask and from this standpoint proceeded to experimentally manipulate the flasks in order to determine which combinations yielded a yellow liquid. Moreover, it was by embedding actual combinations within a system of possible transformations, that the child was able to deduce certain consequences, for example, the incompatibility of colourness and liquid 4. That is, by observing the conjunction of colourness and not 4, no colourness and 4 and no colourness and not 4 ($x.\bar{y} + \bar{x}.y + x.\bar{y}$ of pages 117, 118, 119) and embedding it within the system of possibilities of the combination of two properties (page 118, 119), that the child could deduce this incompatibility.

But at the same time these second-order operations of the hypothetico-deductive level constitute an increased separation of expectation from action. For hypothetico-deductive children can go beyond the framework of transformations bearing directly on some empirical reality (concrete operations) in subordinating them to hypothetico-deductive operations. That is, hypothetico-deductive operations being operations upon operations further increase the separation of expectation from action. For they constitute structural systems which are a system of transformations constructed from concrete operational structures by abstracting from them their immediate links with actual situations through the re-application of concrete operations to concrete operations themselves. Hypothetico-deductive operations, thus, constitute systems of transformations which are tied to possible transformations and not directly tied to actual transformations.[69]

However, this increased separation of expectation from action manifested in the reversal of the roles of "possibility" and "reality", can also account for an increased influence of these expectations upon actions. This is so because the expectations of the hypothetico-deductive level permits the embedding of actual transformations within a system of possible transformations and thereby allows these actual situations to be interpreted in terms of the "structurally possible". That is, the hypothetico-deductive level structures permit the interpretation of actual transformations in terms of a structural system embodying all of the possible transformations with respect to certain base relations.

Thus, in our example, the base relations were provided by the combination of liquids and the presence or absence of colour. The hypothetico-deductive child was able to guide his manipulation of combinations through the second-order operations of his structures. They provided him with an understanding of all possible combinations. Moreover, the observation of colourness or no colourness with certain actual combinations could be interpreted in terms of all the possible combinations. Thus the incompatibility of liquid 4 and colourness could be deduced from the observation of various combinations with respect to all the possible combinations.

Here the hypothetico-deductive child's expectations "anticipated" or influenced actions to the extent that they permitted a wide enough range of possibilities to allow the child to order his subsequent experimentation (his action) such that the influence of liquid 4 upon the property of colourness could be separated from the other variables - liquids 1, 2, 3, and g. And, by the same token, the results of his experimental manipulation could be interpreted in terms of the system of possible combinations allowing the deduction of certain relationships - the incompatibility of liquid 4 and colourness.[70]

Thus, the hypothetico-deductive structures permitted the child to control his interactions with the environment such that he could determine from the results of this interaction the influence of inter-dependent variables. In addition, at the same time as we saw this increased influence of expectation upon action, we saw that these same hypothetico-deductive structures permitted the linguistic formulation of the results of this controlled interaction by allowing inferences to be made concerning these results with respect to the system of possibilities within which they were realized.

Hence, the influence of the child's expectations upon his actions, as well as the ability to argue about the results of this influence, is both a logical and a temporal consequence of their process of formation beginning with the co-ordination of actions. We saw, at the sensori-motor level, a lack of separation between expectation and action. The sensori-motor child simply acted upon the basis of inherited 'expectations' - his schemes of action which were the behavioural counterparts of inherited physiological and neurological structures.

At the concrete operational level, certain aspects of the co-ordination of actions were interiorized. The concrete operational child's expectations became operations which were the translation of some aspects of the structure of the schemes of action of the sensori-motor level into a system with operational reversibility. These expectations in being the representation in thought of the form of a series of actions were partially separated from the actual context in which actions occurred. This enabled them to influence actions by extending actual transformations through a concept of the structure of possible transformations. In other words, the representation of the form of a series of actions within concrete operational structures provided the concrete operational child with a concept of the structure of possible actions. By applying this concept to actual situations, the concrete operational child's expectations influenced his actions by enabling him to understand a present situation through understanding the structure of possible actions or transformations.

But the range of influence of the concrete operational child's expectations was limited, we saw, in that the operations of this level were formed by a direct translation, as it were, from the level of action to representative thought. As a result these operations were limited to directly extending certain actual transformations by embedding these actual transformations within a realm of possible transformations. Thus, the concrete operational child's expectations remained tied to concrete, actual, situations.

A consequence of this limitation of concrete operational structures was that the child at this level could not solve complex problems: problems whose solution demanded a temporary suspension of the acceptance of given transformationsin order to construct a system of possible transformations based on a view of the actual transformations as also embodying the actualization of certain possibilities. In other words, the concrete operational child could not solve problems which required that he suspend his acceptance of certain actual situations and view these actual situations as embodying certain possible situations. In brief, the concrete operational child could not think hypothetically since his expectations remained tied to actual situations.

These limitations of the concrete operational level were overcome at the hypothetico-deductive level. The hypothetico-deductive level is attained when the child combines or integrates the two types of structures of the concrete level, structures characterized by reversible operations of reciprocity and negation, by applying concrete operations to concrete operations rather than to actual situations. The resultant structurally more complex expectations of the hypothetico-deductive level enable the limitations of the concrete operational level to be overcome by permitting hypothetical reasoning through these 'second-order operations'.

At the same time, these hypothetico-deductive structures, in being comprised of 'second-order operations', were more separate from the actual context in which actions occur. That is, it was in virtue of this increased separation between expectation and action that the hypothetico-deductive structures enabled hypothetical reasoning and thereby the increased influence of expectations upon actions.

But it is important to realize that these hypothetico-deductive structures do not constitute a complete separation between expectation and action. That is, the hypothetico-deductive structures, in being comprised of 'second-order operations', remain tied to actions in virtue of the fact that these operations are the 'second-order' interiorization of schemes of action (cf: definition of operation, page 99). In other words, the hypothetico-deductive structures remain tied to actions in that they embody structurally complex representations of possible actions.

Nevertheless, the hypothetico-deductive level is sufficiently separated from actions to permit verbal reasoning and the organization of experimental manipulation in terms of linguistically formulated expectations. For as we saw the hypothetico-deductive child is able to employ his structures to linguistically formulate the results of his experimental manipulations by forming verbal inferences. These are the translation into propositions of the relationships he discovered between the combination of possible transformation and the actualization of a sector of these possible transformations. That is, it is the same hypothetico-deductive structures which in being sufficiently separated from actions to allow the subject to control his interaction with the environment well enough to separate inter-dependent variables, that permit the subsequent formulation of the results of this controlled interaction in language. For the linguistic formulation of expectations requires that the subject connect propositions hypothetically - independently from situations embodying the relationships expressed in those propositions. In order to inter-connect these propositions hypothetically the subject must employ operations upon those relations expressed in the propositions. That is, he must employ the 'second-order operations' of the hypothetico-deductive level.

Hence, in sum, Piaget has accounted for the intellectual development of the child by showing how the interaction between the subject (the child) and the environment results in a gradual separation of expectation from action. Moreover, this process carried with it an account of how, during this process of separation, expectations gained an increasing influence upon actions. In addition, we saw that the final stage of this process contained a sufficient separation between expectation and action to permit verbal reasoning - argument - about the results of the influence of expectation upon action.

SUMMARY - COMPTON'S PROBLEM REVISITED - AND CONCLUSION - THE CONTEXTS OF DISCOVERY AND JUSTIFICATION

Our initial problem was 'Compton's problem' as formulated by Popper: "How does the 'universe of abstract meanings' influence human behaviour?"[1]

We saw that Popper's solution to this problem hinged upon his theory of the evolution of functions of language. Popper viewed languages, both animal and human, as being comprised of a number of different functions. Each function evolved from its predecessor in such a manner that it exerted a plastic control - a control with freedom and feedback - upon it.

We saw that Popper's solution to Compton's problem followed immediately from his theory of the evolution of functions of language. The 'universe of meanings' - the realm of linguistically formulated theories - exerted a plastic control upon actions in virtue of the plastic control of the descriptive and argumentative use of language upon the content of linguistically formulated theories. Since the content of linguistically formulated theories was plastically controlled through the human use of language, then actions based upon these theories were plastically controlled by the human functions of language as well.

In order that this solution to Compton's problem would not be ad hoc, since it hinged upon an example of plastic controls in the evolution of functions of language, Popper formulated a general theory of evolution in which plastic controls emerged in both animal and human evolution through trial and error processes. Within this general theory, the 'trials' of animal evolution were "expectations" incorporated within the biological organization of organisms and the method of 'error elimination' was 'natural selection'. Plastic controls emerged within the genetic structure, and hence within the biological organization, of organisms due to the selective pressure upon gene mutations. On the other hand, the 'trials' of human evolution were linguistically formulated theories with the method of 'error elimination' being the criticism of theories made possible by the descriptive and argumentative functions of language regulated by the idea of truth and validity. The plastic controls of human evolution were those built into the descriptive and argumentative use of language.

This formulation of Popper's general theory of evolution brought out the significance of his solution to Compton's problem: it acted as a "bridge" between animal and human evolution. That is, it is through the evolution of functions of language that Popper provides an account of the evolutionary transition between animal and human evolution. Through it, Popper accounts for the changes between both the type of trials and the methods of error elimination in the transition from animal to human evolution.

But, the significance which Popper had thus attributed to his solution of Compton's problem also provided significance to the "gap" which we discerned within it. We noted that the transition from the animal use of language (the expressive and signalling functions) to the human use of language (the descriptive and argumentative functions) assumed that expectations had become separate from biological organization and that, through this process of separation, the plastic controls of expectations upon actions built into the human functions of language emerged.

We characterized this problem of the "gap" as a problem of finding a solution to Compton's problem on the level of 'knowing how' which would thus augment Popper's solution on the level of 'knowing that'. That is, we saw that Popper's solution to Compton's problem indicated <u>that</u> in the transition from animal to human evolution new types of 'trials' and new types of controls for those trials emerged. It did not indicate <u>how</u> these new types of trials and controls for those trials may have emerged through a process of the separation of expectations from biological organization.

Put in this light, we surmised that our problem of the "gap" may be philosophically significant. Firstly, and most obviously, the significance which Popper attributed to his solution to Compton's problem on the level of 'knowing that' implied our proposal to find a solution on the level of 'knowing how' may be significant. Secondly, we noted that a solution to Compton's problem on the level of 'knowing how' may have broader implications for our understanding of the growth of knowledge since it would require that we understand how the controls enabling human evolution - the growth of knowledge - may have emerged.

Although, for the purposes of this thesis, the emphasis was simply upon revealing and closing the "gap" within Popper's solution to Compton's problem and hence within his general theory of evolution, it also was considered important to at least consider what significance a solution to Compton's problem on the level of 'knowing how' may have with respect to one problem within the growth of knowledge, namely the problem of the roles of the contexts of discovery and justification within the growth of knowledge.

This particular problem was chosen as an area in which to consider any implications of closure of the "gap" for the understanding of the growth of knowledge for several reasons. Firstly, we noted that a closure of the "gap" required that we account for the emergence of the plastic controls of expectations upon actions built into human language - a control through which the context of justification in the growth of knowledge can operate - by an account of the process of the separation of expectations from biological organization - a problem within the context of discovery. Thus, our problem of closing the "gap" through finding a solution to Compton's problem on the level of 'knowing how' required a certain merger of the contexts of discovery and justification. That is, our problem of closing the "gap" required that in attempting to account for the transition from animal to human evolution we had to merge the contexts of discovery and justification to the extent that in the process of the formation of a separation between expectations and biological organization we had to account for how the plastic control of expectations upon actions may have emerged - a plastic control through which 'justification' within the growth of knowledge could be regulated. Hence, although this merger is not equivalent to a merger of the contexts of discovery and justification within the growth of knowledge since, there, a merger between these two contexts requires that the process of the formation of theories is relevant to the process of the evaluation of theories, it did exhibit this above parallel.

Secondly, we noted a difference of opinion with respect to the relation between these two controls between Popper, who formulated a solution to Compton's problem on the level of 'knowing that', and Piaget, whose work we would find could be employed to provide us with a solution on the level of 'knowing how'. Popper maintained that the growth of knowledge consisted of the proposal of theories and the elimination of errors through the criticism and refutation of those theories. Thus, for Popper, the context of discovery, of the formation of theories, was irrelevant as far as the context of justification, of the evaluation of theories with respect to their truth, was concerned. On the other hand, Piaget maintained that the study of the process of the formation of knowledge would reveal information relevant to the evaluation of knowledge. Thus, if we could employ Piaget's work - which was formulated with the intention of demonstrating a merger between these two contexts - to close the "gap" within Popper's solution to Compton's problem, we had reason to believe that there may be implications for understanding the role of these two contexts in the growth of knowledge.

Thus, having assured ourselves of the potential significance of our proposal to find a solution to Compton's problem on the level of 'knowing how', we turned toward finding an approach to solve our problem of the 'gap'. We found that Piaget's theory of child intellectual development could be employed to close this 'gap'. We noted that Popper's general theory of evolution contained a postulate which could be employed to close the "gap" and which Piaget had employed in formulating his position of "genetic epistemology". This postulate was 'ontogeny recapitulates phylogeny': the individual development of an organism partially recapitulates the development of the phylum to which the organism belongs. This postulate was contained within one of the 'thesis' of Popper's general theory of evolution in order to account for the continuation of species through evolutionary change. Popper contended that, since the plastic controls within the biological organization of an organism are passed on to its progeny through genetic transmission, the individual organism is a "telescope" of its phylogenetic evolution. Thus, since this "telescope" within the individual organism is not thrown up in the world in a complete form "spear-heading" the subsequent development of the organism's phylum, Popper, along with most evolutionary theorists, postulated that the organism's individual development partially recapitulated its phylogenetic development.

This postulate of Popper's general evolutionary theory, we have shown, could be employed to fill in the "gap" we had discerned within that theory. Popper had emphasized in his general evolutionary theory the importance of the development of the plastic controls built into human language. Thus, to expect a partial recapitulation of the development of these controls during the transition from animal to human evolution within the intellectual development of the child was in agreement with this postulate of Popper's general theory of evolution.

Hence, we focused our attention upon Piaget's theory of child intellectual development - a theory which Piaget had formulated with the intention of demonstrating a parallelism between the process of the formation of knowledge and the rational organization and evaluation of knowledge through his application of the postulate 'ontogeny recapitulates phylogeny'. And, of course, we were very fortunate we found that this theory of child intellectual development did fulfill our expectations. That is, if we interpreted this theory as partially recapitulating the intellectual development of prehistoric man, then we could see within it an account of how, in the process of the separation of expectations from biological organization, the plastic controls built into human language through which expectations influence actions may have emerged.

We noted that a consequence of the incorporation of expectations within biological organization was that the organism - or, the young baby - could not separate his dispositions to react, his expectations, from his actions corresponding to the actualization of some of those dispositions to react. That is, the incorporation of expectations within biological organization implied that the organism could not separate his expectations from his actions based upon them in which his dispositions to react were manifested. On the other hand, we noted that the separation of expectations from biological organization and their embodiment in human language implied that linguistically formulated expectations were separated from the actions based upon them. That is, the fact that linguistically formulated expectations could exert a plastic control upon actions implied that they were separate from the actual context in which actions based upon them were carried out. In other words, we noted that linguistically formulated expectations do not remain <u>mere</u> dispositions to react. For, if they did, they would not be sufficiently removed from the actions based upon them to enable their representation independently of actually carrying out actions manifesting them. Hence, if expectations remained mere dispositions to react they could not become formulated linguistically and could not exert a plastic control upon actions.

Now, when we examined Piaget's theory of child intellectual development we found within it an account of how expectations, incorporated in the biological organization of the young baby, were gradually separated from the actual context in which actions manifesting the child's expectations occurred. Moreover, we saw within this account of the separation of expectations from actions how the plastic control of expectations upon actions emerged enabling the embodiment of this control in the argumentative use of language.

That is, we saw that, for Piaget, the beginnings of child intellectual development was characterized by the incorporation of expectations within biological organization. The baby inherited certain physiological and neurological structures which provided him with certain expectations or dispositions to react. These were manifested in his actions which were characterized as various 'schemes of action' and were the behavioural counterparts of these inherited physiological and neurological structures.

Gradually, through a continual trial and error process of adaptation to the environment, the young child attempted to attain subjective structures which were in 'equilibrium' with the environment. That is, the young child, in attempting to adapt to his environment, strived to attain subjective structures which were stable during interactions with the environment.

This process began with the attainment of the child's first representative concept: the concept of 'object permanence'. This concept was constructed by the child in order to adapt to the environment available to him through the increased co-ordination of his schemes of action. However, this concept of 'object permanence' provided the child with a broadened horizon. The environment available to him through this concept was no longer simply the immediate 'givens' of his perceptual experience. Rather, the environment now available to him had a certain temporal character - the child's immediate surroundings now possessed a past and a future.

The child attempted to accommodate his expectations to this broadened horizon provided by the concept of object permanence. This involved a process of 'interiorization' in which 'knowing how' at the level of actions was translated into 'knowing that' at the level of representation. The child attempted to interiorize his schemes of action into representative structures in which operations represented the form of his schemes of action.

We saw that the first operational structures available to the child - the concrete operational structures - in representing the structure of a series of actions were characterized by an increased separation between expectation and action over the earlier sensori-motor stage. At the same time, we noted that this increased separation of expectation and action also provided an increased influence of expectation over action. For the concrete operational child could represent simultaneously the structure of a series of action before carrying that series of actions out. By so doing, the concrete operational child was able to influence his actions through his expectations and thereby to deduce various properties of objects through viewing his actions upon objects in the light of his representative, operational structures.

In other words, we saw that at the concrete operational level, the increased influence of expectations upon actions enabled the child to dissociate properties of objects from those of his actions upon objects. We also saw that this influence of concrete operational structures upon actions and the subsequent dissociation of properties of objects from those of actions upon objects was limited by the close ties of concrete operational structures with actual situations. That is, we saw that the construction of concrete operational structures from schemes of action through their interiorization resulted in concrete operational structures remaining linked with the context of actual situations.

We characterized this limitation of concrete operational structures by noting that the influence of expectation upon action which they permitted was characterized by a direct extension of actions - actual transformations - through a concept of possible transformations.

Finally, we saw that the hypothetic-deductive stage overcame the limitations of the concrete operational stage by constructing operational structures based upon transformations upon the operations of the concrete operational level. Through these 'second-order' operations of the hypothetico-deductive level, the child was able to accommodate his structures to complex problem situations by integrating what had been isolated structures at the concrete operational level.

This 'second-order' characteristic of hypothetico-deductive structures, we noted, involved an increased separation between expectation and action. The hypothetico-deductive child could now represent in his thought structurally more complex actions before carrying them out. By so doing, the influence of expectations upon actions had been increased. For the hypothetico-deductive child could now reason about actual transformations by embedding them into a system of possible transformations, the actualization of a sector of which could account for the actual transformations. That is, the hypothetico-deductive child could exert a plastic control upon his actions. For his hypothetico-deductive structures enabled him to control his experimental interaction with the environment by carrying out his experimental manipulations in terms of the system of possible transformation provided to him by his hypothetico-deductive structures. Thus, once the observed, actual transformations were fed back into this system of possible transformations, the hypothetico-deductive child could deduce various relationships. In other words, the hypothetico-deductive child could reason hypothetically by employing a concept of possible transformations through which he could understand various actual transformations. The limitations of the concrete operational level had been overcome by reversing the influence of the "possible" on the "actual" through an increased separation between expectations and actions.

This ability of the hypothetico-deductive child to reason hypothetically and thereby to control his interaction with the environment in the light of his structurally complex representation of possible transformations was reflected in his ability to linguistically formulate the results of this controlled interaction. The linguistic formulation of the results of this experimental manipulation was made possible by translating into propositional form the inter-connections deduced between the actual transformations and the system of possible transformations. That is, expectations could be formulated linguistically by forming inter-propositional connections which reflected the relationship deduced from the feedback of the observed actual transformations upon the system of possible transformations. In other words, the linguistic formulation of expectations was made possible by erecting inter-propositional connections upon the same scaffolding - the 'second-order operations' of the hypothetico-deductive structure - which make possible the plastic control of expectations upon actions; reflected in the ability to control experimental interactions with the environment in terms of a system of possible transformations.

Thus Piaget's theory of child intellectual development has fulfilled the expectations which we had for it. It has closed the 'gap' which we had discerned within Popper's solution to 'Compton's problem'. We have seen within it an account of the separation of expectations from actions within actual situations and of the development of the plastic controls built into human language through this process of separation. The influence of the hypothetico-deductive structures upon actions, we have seen, was characterized by an ability to control experimentation and to linguistically formulate the results of this experimentation. Moreover, this influence was a plastic control - a control with freedom and feedback.

It was the feedback from experimentation which enabled the hypothetico-deductive child to deduce the role of actual transformations. Hence, once the results of this experimental manipulation become embodied in language by applying these same hypothetico-deductive structures to propositions, argumentation as to the validity of the results is possible. Moreover, this argumentation exerts a plastic control upon actions in virtue of the fact that it depends upon an interaction between hypothetico-deductive level subjects.

However, it may be objected that Piaget has not fulfilled our expectations. It may be objected that Piaget has not provided a solution to Compton's problem on the level of 'knowing how'. For we have seen in Piaget's theory of child intellectual development that the child passes from one stage of development to another during the process of the separation of expectations from actions. We have not provided an account of how these transitions were made.

Nevertheless, it is my view that this problem of 'how' - the problem of how these transitions were made - is on a deeper level than our problem of 'how' associated with the 'gap'. That is, our problem of 'how' was the problem of accounting for the separation of expectations from actions and the development of the plastic control of expectations upon actions. The Piagetian solution to this problem formulated here did answer this problem of 'how'. It did so by indicating that this process of separation occurs through the various stages outlined and that this process enables us to understand the development of the plastic control of expectations upon actions as well as the embodiment of these controls in human language. Thus, if we now ask the question, 'how does the transition occur between these various stages?', we are asking a somewhat different, deeper level, 'how' question.

Moreover, Piaget has attempted to answer this deeper level 'how' question. He has formulated his hypothesis that the subject is able to alter his subjective structures through a "mechanism" he labels "reflective abstraction". In general, this "mechanism" refers to the ability of the subject to integrate lower subjective structures within higher ones by reconstructing the lower ones through the use of new operations upon those of the lower ones.

However, although Piaget has attempted to answer this deeper level 'how' question it has not been examined in this thesis because, without answering it, we can close the "gap" and thereby move Popper's solution to Compton's problem from the level of 'knowing that' to the level of 'knowing how' and, as Piaget himself acknowledges, his account of "reflective abstraction" needs a great deal of work in order to be clarified.[2]

The question which remains to be examined is whether or not this Piagetian solution to Compton's problem on the level of 'knowing how' is merely an augmentation to Popper's solution on the level of 'knowing that'. That is, does this Piagetian solution to Compton's problem merely close a gap within Popper's solution or does it imply anything further as to the validity of Popper's theory of human evolution? In particular, does it imply anything with respect to Popper's position on the roles of the contexts of discovery and justification in the growth of knowledge?

We noted that, for Popper, the question of the growth of knowledge was characterized by the question 'How do we detect error?' This implied that, for Popper, the context of discovery was to remain separated from the context of justification. It does not matter, where the truth of a theory is concerned, how a theory arose. What does concern the growth of knowledge, for Popper, is how to eliminate errors through the criticism and refutation of theories once they have been formulated in response to problems.

We can see that Popper's position here reflects his belief that a theory is a system of propositions which, once formulated, can be criticized with respect to its truth, its correspondence with the facts. The formation of a theory, in this context, is irrelevant for Popper. Criticism begins after a theory has been formulated and the standards which regulate criticism are validity and truth - the regulative ideas build into the human use of language. Thus, since criticism and the regulative ideas by means of which criticism is directed are independent of the origin of a theory, the contexts of discovery and justification remain independent for Popper.

Now we have seen that our Piagetian solution to Compton's problem has demonstrated a certain merger between the contexts of discovery and justification within the transition between animal and human evolution. We have seen that the emergence of the plastic control of expectations upon actions is dependent upon it's process of formation through the separation between expectations and actions. That is, it was the process of separation of expectations from actions in which the subject acquired structures which represented the form of more and more complex series of actions that enabled the plastic control of expectations upon actions. At the same time, this process of separation enabled the linguistic formulation of expectations by embedding the results of this influence of expectations upon actions into propositional form. Thus, we can see in this Piagetian solution to Compton's problem a merger of the contexts of discovery and justification to the extent that the emergence of the controls by means of which 'justification' is regulated is seen as dependent upon its process of formation.

But, of course, the context of justification with respect to controls and the context of justification with respect to theories are different matters. That is, even if it is admitted that this Piagetian solution to Compton's problem has demonstrated a merger of the contexts of discovery and justification with respect to the emergence of the controls by means of which the subsequent growth of knowledge can be regulated, this does not imply, automatically, that there is a merger of these two contexts in this subsequent growth of knowledge. The subsequent growth of knowledge, that is, may well proceed along Popperian lines with the context of the discovery of theories remaining separate from the context of the justification of theories by means of the controls available.

Nevertheless, in this case, the subsequent growth of knowledge will indirectly, as it were, involve a merger of the contexts of discovery and justification. Since we have shown a merger of these two contexts with respect to the emergence of the controls available to 'justification', the subsequent growth of knowledge by means of these controls will at least indirectly involve this merger.

However, if this is the only sense in which the growth of knowledge involves a merger between these two contexts, then, as we have seen, the Popperian position with respect to these two contexts remains intact.

Moreover, without going beyond the bounds of this thesis, this will remain the concluding note as far as this issue of the contexts of discovery and justification is concerned. I will, however, add a few remarks which might at least indicate the direction which further research generated through this thesis may pursue.

First of all, it is my suspicion that further work - that is, more detailed work in closing the "gap" by providing an answer to the deeper level 'how question' above - may reveal information relevant to the issue of the contexts of discovery and justification, as well as to other broader issues, in the growth of knowledge. As I have mentioned, in the introduction, Piaget sees the mechanism by means of which the transition between subjective structures is made as providing a means whereby the growth of mathematics is possible. Thus, once this issue of the "psychological possibility of pure mathematics"[3] is clarified along with a clarification of the role of the growth of mathematics with respect to the growth of scientific knowledge, then I believe we will be in a better position to examine the consequences of this

Piagetian solution to Compton's problem.

Secondly, I believe that this Piagetian solution to Compton's problem may have indicated the importance of another regulative idea in the growth of knowledge besides those of truth and validity, namely the idea of adaptivity. That is, I maintain that the closure of the "gap" in Popper's solution to Compton's problem through this analysis of the process of the separation of expectations from actions - a process in which the subject attempted to adapt his structures to those of the environment - may indicate, even a theoretical significance to the idea of adaptivity as a regulative idea. Now, although Popper warns us of attributing to the idea of adaptivity a significance as a regulative idea in the growth of knowledge,[4] I maintain that our Piagetian solution to Compton's problem may indicate some theoretical significance to this idea as long as the idea of mere survival is not equated with adaptivity. That is, it is my contention that the idea of adaptivity, in addition to the ideas of truth and validity, may have been shown, through our study of Piaget, to have some significance as a regulative idea in the growth of knowledge.

REFERENCES AND FOOTNOTES

INTRODUCTION

1) Popper, K. Objective Knowledge. "Of Clouds and Clocks". Oxford University Press, London; third ed. 1975, first published 1972; p. 243 - 'theses' 5 & 6. (Hereafter referred to as O.K.)

2) I am indebted to Dr. C. Preston of the M.U.N. Psychology Department for pointing out to me that other psychologists, one of the earliest being the American, G. Stanley Hall, have applied this postulate within psychology, albeit somewhat more naively.

3) Piaget, J. Psychology and Intelligence. Littlefield, Adams & Co., Patterson; 1960, p. 7.

4) Campbell, D.T. Library of Living Philosophers. Vol. XIV; ed. P.A. Schilpp; "Evolutionary Epistemology". Open Court, Illinois; 1974, p. 450. (Hereafter referred to as Lib. of Liv. Phil.).

5) Popper, O.K. p. 242

6) Ibid, p. 230

7) Ibid, p. 232

8) Ibid, p. 240

9) Ibid, p. 242-244

10) Popper, Liv. of Liv. Phil. "Karl Popper, Autobiography" p. 135, p. 151.

11) Popper, O.K. p. 243 - theses 5 & 6 - Note that Popper's statement of these theses mentions only organisms, and hence is restricted to animal evolution. Also note

that the "telescope" refers to the recapitulation of plastic controls.

12) Ibid, p. 243

CHAPTER I

1) Popper, O.K. p. 219

2) Compton, Arthur Holly. The Freedom of Man. Greenwood Press, New York, 1969 - first printing Yale University Press 1935, p. 60.

3) Popper, O.K. p. 217

4) Popper, O.K. p. 230

5) Compton, The Freedom of Man, p. 60-65.

6) Ibid, p. 50-52

7) Ibid, p. 53

8) Ibid, p. 60-65

9) Ibid, p. 64

10) Popper, O.K. p. 226

11) Ibid, p. 228

12) Ibid, p. 239

13) Ibid, p. 234

14) Ibid, p. 238

15) Ibid, p. 235

16) Ibid, p. 120, p. 236

17) Simpson, G.G. Biology and Man. Harcourt, Brace & World, Inc., New York; fourth ed., 1969; first published 1964, p. 112.

18) Popper, O.K. p. 120, p. 237.

19) Ibid, p. 240

20) Ibid, p. 240

21) Ibid, p. 343-4 & Piaget, J. Biology and Knowledge, translated by B. Walsh, University of Chicago Press, Chicago; third ed. 1975, first published 1971, p. 8-10; p. 219-221.

22) Ibid, p. 343

23) Piaget, Biology and Knowledge, p. 179-180.

24) Popper, O.K. p. 345

CHAPTER II

1) Popper, O.K. p. 242

2) Ibid, p. 243, theses 7 & 8

3) Ibid, p. 241

4) Ibid, p. 281

5) Ibid, p. 278

6) Ibid, p. 283

7) Ibid, p. 244 & B. Lutz, Evolution, 2, 1948, p. 29

8) Popper, O.K. p. 246

9) Ibid, p. 244

10) Popper, Lib. of Liv. Phil., "Autobiography", p. 135 & Popper, K. "Scientific Reduction and the Essential Incompleteness of All Science"; Studies in the Philosophy of Biology; (ed.) F.J. Ayala and T. Dobzhansky; University of California Press, Berkeley and Los Angeles; 1974, p. 274.

11) Lib. of Liv. Phil., "Autobiography", p. 134-135.

12) Popper, Lib. of Liv. Phil., "Autobiography", p. 135 &

Popper, O.K. p. 270 - Note that Popper describes evolutionary theories as providing explanations of typical, i.e. non-unique, events. This remark combined with those on p. 135 of Lib. of Liv. Phil. seem to suggest that Popper sees this second, somewhat weaker 'uniqueness analogy' between the problem of the emergence of life from inanimate matter and the problem of the emergence of human from animal evolution.

13) Popper, O.K., p. 246

14) Darwin, The Origin of Species, New American Library - Mentor Books, New York, 1958, p. 189.

15) Popper, O.K. p. 243 - 'thesis' 5

16) Ibid, p. 243 - 'thesis' 6

17) Ibid, p. 243 - see note to reference 10 of Introduction.

18) Simpson, Biology and Man, p. 116 & Simpson, "The Biological Nature of Man", Science, Vol. 152, 1966, p. 477.

19) Simpson, Biology and Man, p. 117

20) Popper, K. Lib. of Liv. Phil. "Autobiography", p. 151.

21) Popper, K. The Logic of Scientific Discovery. Harper and Row, New York and Evanston, second Harper ed. 1968, first publication in English 1959, p. 31. (Hereafter referred to as L. Sc. D.)

22) Popper, K. Conjectures and Refutations. Harper and Row, New York and Evanston, first Harper ed. 1968, first

published 1962, p. 225. (Hereafter referred to as C & R) & O.K. p. 29.

23) Popper, O.K. p. 264

24) Popper, C & R, p. 21, 24, 25.

CHAPTER III

1) Piaget, J. Psychology and Epistemology, translated by A. Rosin, The Viking Press, New York, third ed. 1974, first ed. 1971, p. 1. (Hereafter referred to as Psych. & Epis.

2) Piaget, Psych. & Epis., p. 2, p. 16, & Piaget, J. Genetic Epistemology, translated by E. Duckworth. W.W. Norton, Inc., New York, first Norton ed. 1971, first ed. 1970, p. 2. (Hereafter referred to as Gen. Ep.)

3) Psych. & Epis., p. 2 - Piaget refers specifically to Couvnot, Brunschvieg and Netorp and Kuhn, here, as four examples of the tendency to view knowledge as continually evolving. However, within Biology and Knowledge, p. 184, we can find a bracketed remark in which Piaget refers to falsification in the growth of knowledge. Thus, this suggests that Piaget is also, at least, aware of Popper's view of the growth of knowledge as a process of continuous revolution through criticism and refutation.

4) Gen. Ep., p. 2

5) *Psych. & Epis.*, p. 26, p. 98

6) Popper, *C & R*, p. 25

7) Popper, *O.K.*, p. 35

8) *Psych. & Epis.*, p. 26

9) Ibid, p. 8-10

10) Popper, *L. Sc. D.*, p. 31

11) *Psych. & Epis.*, p. 8

12) Ibid, p. 8-10

13) *Gen. Ep.*, p. 13

14) *Gen. Ep.*, p. 22-23 & Piaget, J. *Structuralism*, translated by C. Maschler, Basic Books, Inc., New York, 1970, p. 5-16.

15) Ginsburg, H. and Opper, S. *Piaget's Theory of Intellectual Development*, Prentice-Hall, Englewood Cliffs, New Jersey, 1969, p. 18-19. (Hereafter referred to as *P. Th. of Int. Dev.*)

16) Piaget, J. "Problems of Equilibration", *Piaget and Inhelder on Equilibration* (ed.) C.F. Nodine, J.M. Gallagher, R.H. Humphreys, The Jean Piaget Society, Philadelphia, Pennsylvania, 1972, p. 2. (Hereafter referred to as *Piaget and Inhelder on Equilibration*)

17) Ginsburg & Opper, *P. Th. of Int. Dev.*, p. 19.

18) Piaget, J. *Piaget and Inhelder on Equilibration*, "Problems of Equilibration", p. 2.

19) Ibid, "Problems of Equilibration", p. 18 & Ibid, "Piaget's Reply to Furth, p. 30.

20) Ibid, "Problems of Equilibration, p. 18

21) See Popper, O.K., pp. 256-7 n., where Popper refers to Spencer's formulation of the 'organismic approach to biology'. Popper remarks that his conjecture of a genetic pluralism within the biological organization of an organism are included to solve some 'classical' difficulties in the Darwinian theory of evolution which Spencer was aware of in innovating the 'organismic approach'. The central idea of this approach is that of a 'moving equilibrium' within the biological organization of an organism - the organism is 'an open system in fluent equilibrium', that is, changes in certain organs implicate all the other organs of the organism. Here, it is interesting to note that Piaget's notion of 'equilibration' is that of a moving equilibrium but applied to the realm of mind and no longer restricted to biological organization. That is, we can see here a further tendency of Piaget's to carry over postulates applied within animal evolution to human evolution - such as, we have already seen, with his application of the postulate 'ontogeny recapitulates phylogeny'.

22) Beth, E.W. and Piaget, J. Mathematical Epistemology and Psychology, translated by W. Mays. D. Riedel

Publishing Company, Dordrecht, Holland, 1966, p. 157, p. 159-60. (Hereafter referred to as Math. Epis. & Psych.)

23) Ibid, p. 159

24) Ibid, p. 193

25) Ibid, p. 198, p. 204, p. 238, p. 248-250, p. 284

26) Piaget, Gen. Ep., p. 42

27) Piaget and Beth, Math. Epis. and Psych., p. 235

28) Ibid, p. 198, p. 238, p. 248-50, p. 284

29) Ginsburg and Opper, P.Th. of Int. Dev., p. 46

30) Piaget, Gen. Ep., p. 42-43.

31) Ibid, p. 43

32) Elkind, D. Children and adolescents. Oxford University Press, London, Toronto, 1970, p. 13.

33) Piaget, Math. Epis. and Psych., p. 214, p. 197, p. 297.

34) Piaget, J. The Principles of Genetic Epistemology, translated by W. Mays. Routledge and Kegan Paul, London, 1972, pp. 20-22. (Hereafter referred to as Prin. of Gen. Ep.)

35) Ibid, p. 26

36) Piaget, J. and Beth, E.W. Math. Epis. and Psych., p. 156-7 and Piaget, Psych. and Epis., p. 15-18.

37) Mays, W. "The Epistemology of Professor Piaget", Proceedings of the Aristotelian Society, New Series, Vol. LIV, Harrisons & Sons Ltd., London, 1953-54, p. 50

38) Piaget, Gen. Ep., p. 45 and Piaget, Psych. and Epis., p. 35.

39) Piaget, J. Plays, Dreams and Imitation in Childhood, translated by G. Gatteguo and F.M. Hodgson, W.W. Norton & Co., Inc., New York, 1951, 1962, p. 76.

40) Piaget, Gen. Ep., p. 47 & Piaget, Prin. of Gen. Ep., p. 27

41) Piaget, Gen. Ep., p. 46

42) Piaget, Math. Epis. and Psych., p. 156

43) Piaget, Gen. Ep., p. 30

44) Piaget, Math. Epis. and Psych., p. 158

45) Piaget, Prin. of Gen. Ep., p. 35

46) Ibid, p. 27-28

47) Piaget, Prin. of Gen. Ep., p. 29

48) Piaget, Math. Epis. and Psych., p. 221-222

49) Inhelder, B. and Piaget, J. The Growth of Logical Thinking from Childhood to Adolescence, translated by A. Parsons and S. Milgram, Basic Books, Inc., New York, 1958, p. 252. (Hereafter referred to as The Growth of Log. Th.)

50) Piaget, Gen. Ep., p. 40 & Piaget, Math. Epis. and Psych., p. 157

51) Piaget, Psych. & Epis., p. 36 & Piaget, Math. Epis. and Psych., p. 237.

52) Inhelder and Piaget, The Growth of Log. Th., p. 249

53) Piaget, Psych. & Epis., p. 32-37 & Piaget, Math. Epis. and Psych., p. 196.

54) Inhelder and Piaget, The Growth of Log. Th., p. 249-250.

55) Ibid, p. 253-255

56) Ibid, p. 280, p. 282

57) Ibid, p. 283

58) Ibid, p. 256, p. 288

59) Ibid, p. 290

60) Ibid, p. 290-291

61) Ibid, p. 263

62) Ibid, p. 290-291

63) Ibid, p. 288

64) Ibid, p. 292

65) Piaget, Math. Epis. and Psych., p. 181-182

66) Inhelder and Piaget, The Growth of Log. Th., p. 252-253

67) Ibid, p. 108

68) Ibid, p. 111-222

69) Ibid, p. 254

70) Ibid, p. 288

CONCLUSIONS

1) Popper, O.K., p. 230

2) Piaget, Gen. Ep., p. 78

3) Piaget, Math. Epis. and Psych. See pp. 244-247 where Piaget cites the psychological reasons for the possibility of pure mathetatics.

(1) 'autonomy of operational development' - we have seen that the development of subjective structures progress through 3 stages by 'equilibration' starting from the co-ordination of actions. Piaget extends this idea of autonomous development of (math.) structures through reflective abstraction.

(2) 'the freeing of form from content - in our terms this is the separation of expectations from actions. Piaget, likewise, sees this process as continuing indefinitely beyond the hypothetico-deductive level with the development of mathematical structures.

(3) 'hierarchical overlapping of form and content - in our terms this is the plastic control which occurs between any successive evolutionary structures.

4) Popper, O.K., p. 264.