THE DEVELOPMENT OF UNDERSTANDING OF SOCIAL SYSTEMS

by

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ABSTRACT

The child's understanding of open systems, as exemplified by an eco-system and a socio-economic system, was assessed in a Piagetian type interview with 8 males and 8 females in each of grades 3, 5, 7, 9, 11 and first year post-secondary (n=96). Since Piagetian theory has been based on tasks using mainly inanimate, physical content, the generalizability of Piagetian stages and sequences to the two open systems content domains was tested. Tasks assessing the four concrete operations examined were repeated in each of the physical, the bio-ecological and the societal domains. Typical stage and sequence patterns were observed in all three domains. Post-concrete operations were represented by three formal operations in the physical domain and four systemic operations in each of the open systems domains. Logical and philosophical arguments for the qualitative difference between formal and systemic logic were presented. Three blind judges reached spontaneous agreement on 84.6% of the scores assigned for the systemic task protocols. A scalogram analysis and comparisons of the differences between pass/fail proportions indicated that the systemic operations of systems synthesis and transitive recycling were more difficult than the formal operational tasks by a Guttman step of the same size as that between the formal and concrete stages. A cluster analysis showed those most difficult systemic tasks to be grouped as if they were a part of a separate structure d'ensemble. Further analyses indicated that the greater difficulty of these two systemic operations could not be attributed to the greater unfamiliarity of the task contents. Systemic task success rates were zero for respondents below grade 9 (14 years) and consistently fell far below
formal task success rates for same aged peers'. The most difficult systemic operations satisfied the criteria for membership in a fifth stage as well as any other Piagetian operations do for their imputed stage membership. Nevertheless, an alternative interpretation construing systemic operations as post-concrete developments parallel and complementary to formal operations could not be ruled out. The implications of the findings for the areas of cognitive development, social development and social psychology were discussed.
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The purpose of this research was to chart the development of the child's understanding of certain distinguishing features of social organization and to relate this sequence to other structurally analogous changes in cognitive development. This research was somewhat exploratory because the understanding of social organizations appears to require cognitive structures that have received little attention to date. These are the structures, introduced herein, which deal with the understanding of open systems. Thus this research came to examine the development of systemic cognitive structures in the course of examining the development of understanding of social organization.

In very brief detail, an attempt was made to compare the cognitive structure evident in children's thinking as they attempted to reason about physical, bio-ecological and social systems. Parallels in the course of development across these three domains were sought and special attention was focused upon those cognitive structures necessary to adequately understand the open systems features characteristic of bio-ecological and social systems. This process led to the postulation and later assessment of two novel cognitive structures dubbed "cyclic transitivity" and "cyclic integration."

1. In this research a system is defined as: A set of elements in some ordered relationship such that information and/or material flows, either directly or indirectly, from every element (or class of elements) to every other element in ways which affect the functioning of all elements. A closed system is subject to entropy. An open system, by contrast, is characterized by periods of increasingly organized complexity. The tendency to become more organized and complex, rather than less, has been called "negentropy" (Brillouin, 1961). Open systems are negentropic, partially because they can, at least temporarily, export entropy. Overton (1975) distinguishes open from closed systems as follows: "A closed system is one which is functionally isolated from its environment or, at most, exchanges only energy with its environment. Open systems are those which are characterized by import and export of material as well as energy". (See Appendix E for a further discussion.)
2. These concepts and their relationship to one another and to other better understood aspects of cognitive development structures became the pinion point around which this study revolved. Because of their novelty and complexity a good deal of groundwork needed to be laid in order to make these concepts meaningful and in order to justify what was seen to be their importance relative to other better understood aspects of cognitive development. An attempt is made to lay out that groundwork in Chapter II.

The approach taken from the outset in this work was one wherein the structure of "the things being thought about" is described along with the structure of the thinking itself. In other words, "the known" has a structure just as "the knower" does. A more explicit and formal statement of this general approach is contained in the following three assumptions which oriented this research: 1) that persons, in the course of their ontogenetic development, progress through a regular sequence of different modes of cognitive organizations; 2) that important organizational aspects of the social environment are themselves arranged as systems according to definable rules and regularities, and, somewhat less routinely, 3) that the same logico-mathematical principles which have been used to describe the various structures of cognitive organization can also be usefully applied to characterize the structure of certain social organizations. These assumptions, taken as a group, lead to the suggestion, to be tested in this

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2: Following Piaget (1970), the rules and methods by means of which intrapsychic elements are coordinated and otherwise processed are herein referred to as "cognitive structures". In parallel fashion, the rules and methods by means of which the elements of a socio-economic organization are coordinated and integrated are called, "societal structures". For the sake of simplicity, the various cognitive and social structures, and the logico-mathematical principles used to describe them will all be assigned parallel labels.
research, that a child's ability to comprehend various sorts of social organizations will prove to be a predictable function of his or her current level of cognitive maturity.

Because of the central role which they have played in the framing of this study, each of these orienting assumptions needs further elaboration. The first, which asserts that cognitive development unfolds according to an organized and ordered sequence, is a commonplace following from the work of Piaget and many others. That work, however, has emphasized the development of understanding of the impersonal, non-social world. The systematic study of the development of understanding in the interpersonal and societal domains is much more recent and in much shorter supply (e.g., Selman & Jaquette, 1977; Furth, 1977; Jahoda, 1979). The second assumption states that the social environment can be seen as organized according to logico-mathematical principles and, parenthetically, that certain of those principles may be different from the ones hitherto emphasized in the study of cognitive development. In particular, the structure of social organizations may be best represented in logico-mathematical principles that deal with the organization of systems. The third assumption, which brings together the first and second, presumes that society and the mind are organized according to some of the same abstract principles. This premise, which can be justified partially on logical grounds, is presented in greater detail in sections A and B of chapter II. Section A of chapter II is devoted to showing how the societal structures examined in this study are adequately described by corresponding logico-mathematical principles. In section B of chapter II it is argued that the developmentally successive thought structures considered herein are described by these same logico-mathematical principles. Together, sections
A and B argue that these principles form a bridge between the societal structures and the cognitive structures that are presumably necessary for comprehending the societal organizations.

Some societal structures embody, and can be understood by the use of, cognitive structures of the sort made familiar by Piaget's theory. More commonly, however, social organizations, and society in general, are best characterized as open systems. Children's understanding of such open systems consequently was taken as the central focus of this study. Historically the work of Piaget and his collaborators has emphasized children's understanding of inanimate, physical phenomena (e.g., chemical reactions, pendulums)\(^3\). Society, social organizations and even ecosystems, because they attain a high state of organized complexity, are strikingly open systems (Overton, 1975). In order to study children's understanding of social structures one must shift therefore from a traditional emphasis on physical systems to a more novel emphasis on animate, open systems. This refocusing upon the comprehension of social organization, with its consequent shift in emphasis to more open systems, leaves open the question of the extent to which the work of Piaget and his colleagues also applies to these new content areas. It was necessary, therefore, to verify the generalizability of Piagetian theory to the new content domains in which open systems are typically found. This preparatory step became the first conceptual order of business in this study.

3. "Standard" Piagetian content usually means that the tasks deal with non-social problems in the physical sciences like physics and chemistry. For example, Inhelder and Piaget (1958) combined their study of formal operational thought with the study of children's understanding of physical phenomena like oscillating pendulums, floating bodies, falling bodies on an inclined plane and equilibrium in the hydraulic press.
Having established the generalizability of Piagetian theory and method to the closed aspects of social systems, it was possible to turn attention to the main focus of this study, the child's understanding of the open system aspects of social systems and ecosystems. This focus led to the identification of two hitherto unstudied cognitive structures unique to the understanding of open systems. These are discussed further in section A of this introduction. In sections B of chapter I and C of chapter II there is a discussion of the issues surrounding the preliminary problem of establishing the applicability of Piagetian theory to the content domains where the understanding of open systems can more readily be studied.

A. Two Systemic Cognitive Structures

This section provides a very brief introduction to the open systems structures that were the central focus of this study. Their manifestations as societal structures are described more fully in section A (iii) of chapter II. Section B (ii) of chapter II contains more details about their manifestations as cognitive structures and about the general features of the tasks used to assess mastery of these cognitive structures. The distinction between open versus closed structures in various aspects of the world was reflected in this research by a corresponding distinction regarding the structure of the individual's cognition about those various aspects of the world. Specifically, an analysis of the structural regularities evident in certain familiar and well understood social organizations led to the postulation of two previously undescribed cognitive structures. It was thought that since people do, at least occasionally, understand the structure of
their social organizations, there must be cognitive structures of corresponding complexity by which such understanding is mediated. The attempt to identify and document the developmental presence of these counterpart cognitive structures was one of the original contributions of this research. These two cognitive structures concerned with the understanding of open systems are labeled "cyclic transitivity" and "cyclic integration". For the sake of brevity, the phrase "systemic cognitive structures" (or some variant thereof) is hereafter used to refer to both cyclic transitivity and cyclic integration together.

A thorough description of these systemic cognitive structures is presented later. For now it is sufficient to note that cyclic transitivity relates to structures known as negative feedback loops and cyclic integration is related to hierarchical structures where the supraordinate and the subordinate levels mutually influence each other. The logico-mathematical principles exhibited by these systemic structures can be discerned in open systems throughout nature (including human societies). Since traditional

4. From this perspective, the social environment may be seen as a relationship between social systems (e.g., organizations) and psychological systems (i.e., individuals). Psychological systems are component parts of social systems and as such must adapt to an environment that is significantly influenced by the social system. By the same token, psychological systems are an influential force in the maintenance, restructuring, and dissolution of social systems (Payne, 1968). Psychological systems are, in a manner of speaking, the internal environment of social systems. Different individuals will often respond in different ways to the same social system depending upon their diverse conceptualizations of that social system and their individual roles within it. Before these mutual influences can be studied we must have some understanding of how the individual conceptualizes such social systems. In the present research, social organization and the individual's understanding of it are depicted in common structural terms. Several social psychologists (e.g., Smelser and Smelser, 1970; DiRenzo, 1977; Maines, 1977) have for some time been calling for just such a model, a model that would provide a single framework for analyzing both person systems and social systems.
Piagetian theory has not focused attention upon the child's ability to apprehend systems of any sort, it follows that cyclic transitivity and cyclic integration have yet to appear in the standard pantheon of Piagetian cognitive structures.

Beyond the attempt to define and document these systemic cognitive structures, an effort was also made to compare them in various ways to other more well documented and thoroughly studied structures. Consequently, four of the six cognitive structures assessed in this research have already been studied by numerous investigators working within a Piagetian tradition (i.e., seriation, linear transitivity, logical multiplication, class inclusion).

These four are commonly classified as achievements of the concrete operational stage. That classification, however, is based upon the child's use of these cognitive structures to understand inanimate, physical reality only. The ages at which these four cognitive structures can be applied in efforts to understand animate and/or societal reality remains unknown. Neither is it known in what order these structures would be mastered in the open systems domains.

B. Parallel Development Across Domains

Learning something about ages and orders of mastery in the bio-ecological and the societal domains entailed determining the extent to which cognitive development unfolds in a parallel or yoked fashion across the various content domains. If cognitive structures are mastered at different ages in

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5. This issue, too, is dealt with more extensively later. See Appendix E for a discussion of the difference between formal logic and systemic logic.
different content domains then it is also possible that they may be mastered in a different order. This would attenuate the generalizability of Piagetian theory to the bio-ecological and the societal domains. Questions of generalizability, of course, are questions of degree. There are at least two degrees of detail at which evidence of generalizability could be sought. At what shall be called the "macroscopic" level, evidence could be sought for across domain replication of the major stages. If, in the open systems domains, there is no discontinuity between the most advanced concrete stage cognitive structure and the simplest formal stage cognitive structure, then the legitimacy of applying a Piagetian analysis to children's understanding of such ecosystems or social systems would be cast into serious doubt. If, by contrast, children who were found to be at Piaget's concrete or formal operational levels in the traditional impersonal or physical domain were shown to evidence equivalent structures when reasoning about the bio-ecological or societal domains, then parallelism would be demonstrated at this "macro" level.

At what shall be called the "microscopic" level, however, there is more room for error. The microscopic level of analysis is a more fine grained, detailed version of the macroscopic level. Here the criteria for across domain parallelism in cognitive development are set at their highest. What is sought at this level of analysis is evidence that there is a uniform progression of mastery of logico-mathematical principles regardless of the content used to illustrate those principles. If this stringent criterion were not met owning to some misordering of cognitive structures within stages, there would be no need to question the whole of Piagetian theory as inaplicable. Misordering of cognitive structures across stages, however, would
raise significant doubts.

The whole issue of determining the legitimacy of applying a Piagetian approach to children's understanding in the bio-ecological and societal domain receives more attention in section E. There the issues surrounding the search for parallel patterns of development across domains are discussed more fully. Two of those issues, however, must be briefly introduced at this point in order to facilitate the detailed discussion of societal and cognitive structures in section A and B of chapter II. The first of these concerns the reasons underlying the decision to include the bio-ecological domain (subsection B (i), chapter I). The second issue (subsection B (ii), chapter I), concerns the problem of unequal levels of familiarity with the materials used in the various content domains.

(i) **The Bio-ecological Domain**

Because the focus of this research is upon an extension of Piaget's research in the domain of physical phenomena to the societal domain, it might appear that this study could have been performed using only content sampled from these two domains. The child's understanding of the physical domain is relatively well documented while relatively little is known about cognitive structures relating to the understanding of society. Given an intention to proceed from the known to the unknown, it would seem reasonable to attempt a direct comparison of performance in the physical domain with performance in the societal domain. There were, however, two reasons for deciding to include materials drawn from a third domain representing bio-ecological systems. First, the physical domain of standard Piagetian tasks differs from the societal domain on at least two dimensions. They include a) the physical versus non-physical, and b) the inanimate versus
animate. It was thought that comparisons of the physical domain with the societal domain would be facilitated by the inclusion of a third domain, the bio-ecological, having one characteristic in common with each of the other two. Ecosystems, like social systems, are animate, but also contain physical elements (e.g., birds, insects) which are just as palpable as the physical objects used in standard Piagetian tasks. Second, as mentioned earlier, the logico-mathematical principles of cyclic transitivity and cyclic integration have few unambiguous manifestations in purely physical, inanimate phenomena. There are, consequently, no standard tasks among the repertoire of usual Piagetian assessment procedures with which to assess these cognitive structures in the physical domain. Using bio-ecological content, however, it was possible to construct assessment procedures for cyclic transitivity and cyclic integration. It was then possible to compare performances in the societal domain to other measures which shared their open systems characteristics but which were not necessarily social in content.

(ii) Familiarity

The current focus on sequences of cognitive development across content domains raised an important methodologic problem concerning the respondents' relative familiarity with the materials used in different content domains. For example, cross-cultural Piagetian research shows that logical problems easily solved using familiar materials are often failed with unfamiliar testing materials (Greenfield, 1976). Since children participate only minimally in the political and economic life of a society, it is possible that the contents of this adult world might be like materials from a foreign domain.

6. The term "social" is ambiguous. Sometimes it is used to mean "interpersonal"; other times it is intended to mean "societal". In the present work the term "social" is never used to mean "interpersonal". Where it is warranted by the context, the term "social" may be used in the sense of "societal".
culture to them. Throughout this research the children were consequently queried about their familiarity with the materials being used. It was therefore possible to compare the familiarity of the societal domain materials with (a) performance on the societal domain tasks, and (b) the familiarity of materials in the other two domains. These comparisons provided certain checks and controls over the issue of familiarity and promoted the attempt to extend Piagetian theory to the understanding of society. They did so by beginning to describe the ways in which societal content is similar to, and different from, the content upon which Piaget based most of his theorizing, especially in his later works.

In summary, this study attempted the identification and documentation of two new cognitive structures necessary for the understanding of open systems features of societal organizations. That undertaking required preliminary groundwork on the generalizability of the Piagetian model to new content domains. That attempt to examine the extent of parallel sequencing of cognitive structures across domains necessitated the inclusion of (a) a physical yet animate domain, the bio-ecological domain, and (b) familiarity assessments for the contents of each domain.
II. STRUCTURES AND CONTENTS

Section A of this chapter begins with some clarification of terminology and continues with a description of some societal structures. In section B the cognitive structures examined in this research are described and various interpretations of what constitutes a stage of cognitive development are discussed. In section C the issues surrounding the role of content determining task difficulty are raised along with a consideration of age and stage issues related to task difficulty. Finally, the hypotheses of the study are formally stated and then explained in section D of this chapter.

A. Societal Structures

Since the purpose of this research was to chart the development of the child's understanding of social organizations, it is important to begin by articulating more explicitly what is intended by the concept of social structure. Before the substantive nature of the societal structures used in this study can be discussed in detail, the more generic concepts of structures and operations must be examined more generally.

(1) Structures and Operations

There are several interrelated terms that are used throughout this work (i.e., structure, operation, principle). In order to avoid later confusion, this section is included as an attempt to examine the relatively fine distinctions among these terms and the strong linkages among these corresponding concepts. The two most closely related concepts are structures and
Structures and operations are, according to Piaget, both based on logico-mathematical principles. The principle might be a topological pattern, a set of transformation rules, a relationship between symbols, etc. Logico-mathematical principles are always embedded in some kind of content. The content may be symbolic, behavioural, social, physical, or whatever. The principles, once understood, can be discerned in organized parts of the environment, (e.g., regular phenomena, various systems). When a logico-mathematical principle is manifested in some organized aspect of the world then that part of the world is structured according to that principle. The principle describes the structure of the organization.

One of the implications of taking a structuralist approach towards the environment as well as towards cognition is that logico-mathematical principles are assumed to reside in both thought and objects of thought. In other words, it is being assumed that if a tree fell in the forest and there were no one there to "hear" it (in this case, "think of it") there would nevertheless be a sound made by the tree hitting the ground. That is, the world is structured whether we appreciate it or not. Since the human mind is part of nature, it too is structured according to the same logico-mathematical principles by which the rest of nature is organized.

A swinging pendulum is an organized part of the world. Its structure is described by logico-mathematical principles derivable from the INRC group

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1. In Piaget's theory both of these terms are related to logico-mathematical principles. An attempt is being made in the present work to use these terms to mean the same thing that Piaget meant by them. However, his usage sometimes varies. Therefore, the reader may occasionally sense discrepancies between Piaget's use of terms and their use throughout this work.
(Piaget and Inhelder, 1956). An ecosystem is an organized part of the world. Its structure is described by logico-mathematical principles like cyclic transitivity and cyclic integration. The same can be said of a socio-economic system. To refer to the manifestation of a logico-mathematical principle in the organization of society I shall use the term "societal structure". To refer to its manifestation in the organization of human cognitive abilities I shall use the term "cognitive structure".

While structures are patterns of organization which exhibit the essential characteristics of logico-mathematical principles, operations are the implementation of the structures. The structures make certain kinds of performances possible. The operations are the performances made possible by the structures. The operations are the processing, transformation, coordination, reorganization, etc. of information and/or materials according to the various logico-mathematical principles.

Cognitive operations are performed internally, within individuals. In assessment situations where the individual is presented with a problem task, the person's problem solving cognitive activity is a cognitive operation, or more likely, a set of cognitive operations. The task is an organized part of the environment. It has a structure which for purposes of inferential clarity ideally manifests only one logico-mathematical principle. The person is also organized and has various cognitive structures at his or her disposal. When the person brings a particular cognitive structure to bear upon the structure of the task, he or she is performing a cognitive operation. When the structure of the task outstrips the sophistication of any of the cognitive structures available to the person, then we say that the person has not yet mastered the cognitive operation that would lead to task solution. The person has
not yet acquired the cognitive structure that matches the structure of the task.

Just as cognitive structures are the pattern of organization that make cognitive operations possible, societal structures are the patterns of organization that make social organizational operations possible. Social organizations and whole societies face problems presented by nature and/or other social groups. The structure of those problems may be more or less sophisticated than the structure of the social organization. Likewise, the social structure may be more or less sophisticated than the cognitive structures of various individual members of the society or organization. Indeed, social structures can exist without any members of the society fully understanding them. The Marxist notion of false consciousness is partially based on this premise. By following prescribed, routine procedures, by enacting assigned roles, etc., members can act cooperatively in such a way as to perform an (societal) operation on some information without anyone of them ever necessarily performing the corresponding cognitive operation on all the same information.

The six cognitive structures examined in this study have analogous social structures that are commonly found in the socio-economic systems of western industrialized societies. Two of the most common features of western social organizations are their hierarchical and systemic aspects. The hierarchical model of society has been part of the western heritage since at least as far back as the middle ages. Incomplete or fragmentary versions of the system model were implicit in the social commentary of the romantic movement and of Marx (Peckham, 1965; Wilkinson, 1971). Parsons (1950) presented another fragment which complemented the Marxist view. The full scope
of the systemic model has been made explicit only recently (Boulding, 1962; Easton, 1965; Sztomka, 1974; Mysior, 1977).

Societal hierarchies and systems are constituted from the combinations of societal structures. Hierarchies and systems almost always appear together in social organizations. For the purpose of analyzing their constituent social structures, however, they are discussed separately. The ones that are thought to be easier to understand are discussed first. The social structures implicit in hierarchies are discussed before turning to the two structures exhibiting systemic relations. The overall goal of the following review of societal structures is to clearly specify exactly what aspects of society are being singled out for study vis-à-vis the child's developing understanding of society.

(ii) Structures Implicit in Hierarchies

Elements of hierarchies can always be conceptualized as (a) points along a continuum, and as, (b) members of discrete classes or sets. Every hierarchy has at least one continuum, namely, its vertical ranking from the apex to the base. If the hierarchy is a classification system, the continuum might be one of abstractness or of logical priority. In some hierarchies the continuum may denote temporal priority. In some social organizations the continuum reflects decision making power and supervisory authority. Elements of hierarchies can also be conceptualized as members of discrete classes or sets insofar as the apex represents the set of all elements in the hierarchy and each subordinate element represents a subset of elements. In societies that are also nation states, for example, the subsets correspond to entities like provinces, states, municipalities, etc. A society's economy may be subclassified according to public versus private sectors or various industrial sectors.
A hierarchy can be decomposed into at least four constituent structures. In this research, the following are considered to be the most important social structures in a hierarchy: (a) seriation or ordination, (b) linear transitivity, (c) logical multiplication, (d) class inclusion. These correspond to the cognitive operations, of the same names. When they appear, the social structures of ordination and transitivity tend to invoke the arrangement of elements as points along a continuum. Logical multiplication and class inclusion, on the other hand, rely on the discrete categorical properties of elements.

**Seriation.** Seriation refers to the arrangement of elements (i.e., companies, committees, roles, etc.) such that along some dimension each successive element has an ascending value. For example, social organizations with different levels of supervisory staff allocate at least some of their resources (e.g., salaries, office space) according to supervisory rank. More abstract dimensions could be used to describe the vertical continuum. Supervisory rank might be indexed by the logical priority of tasks being performed by each element. For example, the top ranks might decide what goals the organization will attempt to achieve. The next lower level might decide what means will be used to achieve those goals. The bottom rank might then perform the tasks designed to achieve the goals. Elements

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2. It is impossible to prove that these are the only constituent structures that anyone ever has, or ever will, attribute to hierarchies. Moreover, the concept of hierarchy is not as logically precise as it may seem. There are different mathematical theories which utilize the concept but which all use different language to describe its features and make different assumptions about what relations may obtain among elements (e.g., set theory, lattice theory). The concept of hierarchy in itself, however, does not imply a single list of features. Rather, the term "hierarchy" is loosely used to refer to any arrangement which can be represented as a branching, tree-like structure. The list of constituent structures presented here seems to account for all of the important logical aspects of a hierarchy in the sense of a branching tree-like structure having at least two bifurcations in series.
could also be ordinated along a dimension of temporal priority either within or among levels of rank. Imagine a municipal revenue office where the first clerk to receive the tax returns checks the form for missing information. The second clerk checks the accuracy of calculations. The third clerk files the form for future reference. In this hypothetical example, the elements are ordinated in a temporal series corresponding to the cardinal numbers, 1st to nth, where n is the number of elements in the series.

**Linear Transitivity.** Linear transitivity is a type of social structure based on the logico-mathematical relation of the same name. In logical form it is exemplified by the statement "A is greater than B, and C is lesser than B, therefore A is greater than C". When manifested in social content it is exemplified by patterns of social organization as the following: "CPR corporation owns Marathon Realty, and False Creek Development Corporation is owned by Marathon Realty, therefore CPR owns False Creek Development Corporation".

**Logical Multiplication.** Logical multiplication as a logico-mathematical relation involves considering at least two sets of elements, those with attribute p and those with attribute q. Every element can be classified as being either inside or outside of either set (i.e., p or not p; q or not q). All elements can then be located in a two-fold classification matrix (i.e., p and q; p and not q; q and not p; not q and not p). In this simplest of examples, logical multiplication is the identification of those elements representing set intersection (i.e., p and q). In socio-economic terms logical multiplication could be illustrated by considering
various industries as elements in a national economy. In the first set we may find industries that have the attribute of being public (p). The complement would be private industries (not p). The second set may be based on attributes like primary (q) versus secondary (not q) processing. By logical multiplication we could then identify a subset of industries that were both public and primary (e.g., Petrocan).

Class Inclusion: Class inclusion is a logico-mathematical relation involving subordinate and supraordinate classes. Like logical multiplication, the elements (e.g., a1 and a2) have two attributes each. Unlike logical multiplication the attributes are nested. That is, subordinate classifying attributes are special cases of, or instances of, the supraordinate classifying attribute. The elements a1 and a2 are both examples of A elements. As a socio-economic example, consider postal workers (a1) and federal government clerks (a2). Both groups of people are members of a supraordinate class, federal government employees (i.e., class A). This social structure exists independently of whether or not any postal workers or clerks or other federal employees are cognizant of it.

(iii) Systemic Structures

The organizational structures described thus far reflect the important logical features of a hierarchy. The logico-mathematical principles implicit in hierarchies have received considerable attention from Piaget and others. As we begin to discuss systemic structures, however, we are moving onto more unfamiliar ground. A hierarchy is not necessarily a system although it can be if certain criteria are met. The classification of birds, for example, into waterfowl and non-waterfowl with waterfowl further subclassified into ducks and non-ducks is a hierarchy. It is not a system, however, because we
have not yet dealt with the flow of information and/or materials within and/or between levels of the hierarchy. If we go on to examine how changes in the feeding habits of the duck population effect the reproductive patterns of the waterfowl population, then we are treating the hierarchy as a system. In this research a system is defined as:

A set of elements in some ordered relationship such that information and/or materials flows, either directly or indirectly, from every element (or class of elements) to every other element in ways which affect the functioning of all elements.

The channels of such information flow are typically referred to as feedback loops (Lazlo, 1972). A cycle with at least two elements, each of which receives and transmits information and/or material, is a simple system which, in its limiting case, contains only one feedback loop.

Cyclic Transitivity. Cyclic transitivity, as the name suggests, is a social structure typified by a cyclical flow of materials and/or information. The movement of materials and/or resources from one element to another is called "transmission". In logico-mathematical terms a set of three elements (A, B, and C) would exemplify cyclic transitivity if A transmits to B, B transmits to C, and C transmits to A. Each element may or may not transform what it receives. In either case, the starting element eventually receives part of its own output back as input, perhaps in altered form. As an example of such a cyclic transitive structure drawn from the socio-economic realm, consider a company having several departments, all of which send monthly inventory reports to the company's accounting office. Suppose that within the accounting office, the first clerk receives the inventory report from the department head and puts it together with the reports for that department for the previous year. The first clerk then sends all that information to a
second clerk who calculates an index of inventory turnover for the immediately
previous month. The third clerk receives all that information and transforms
it into a comparison of last month's rate with the average rate for the pre-
vious year. A fourth clerk might express this information in the form of a
standardized monthly report and send a copy of it back to the department
head. The information has gone in a circle such that the department head
received his own output back in an altered form as input.

For a person to be able to appreciate the cyclic transitivity in the
arrangement described above, he or she would require a cognitive structure
equal in complexity with the societal structure being understood. Social
systems commonly incorporate the societal structure of cyclic transitivity.
Insofar as people understand that societal structure, they must perform the
appropriate cognitive operations needed to mentally model the cyclic transi-
tive operations transpiring in the social environment.

Cyclic Integration. Cyclic integration is to cyclic transitivity as
class inclusion is to linear transitivity. Both linear transitivity and
cyclic transitivity deal with one dimension while class inclusion and cyclic
integration entail subordinate/supordinate relations. In cyclic transitivity
there is only one cycle. The elements of the cycle are transmitted in one
circular line, and they are not nested within each other. In cyclic integra-
tion a subordinate set of elements receives feedback from, and issues feed-
back to, a supraordinate element or set of elements. The structure of a
computer program provides a familiar example. Consider a main program which
simply reads data, calls a subroutine, and writes the results. Without the
subroutine the main program would leave the data unaltered as if the main
program had never been run. The subroutine performs calculations on the
data but without the main program it too would leave the data unaltered. In order to work, the two programs must be "integrated". If the main program reads and writes data cases successively, as it would if the READ and WRITE statements were inside a FORTRAN DO-loop for example, then the executive control flows in a "cycle" back and forth between the main program and the subroutine. The "transmission lines" for the cycle would be the CALL statement and the RETURN statement. The transfer of control from the main program, to the subroutine, and back again in a cyclical fashion accomplishes their integration. Thus the relationship between a main program and a subroutine illustrates cyclic integration. With the addition of conditional control transfer statements (e.g., FORTRAN IF's and GO TO's) the main program and the subroutine acquire the capacity to alter each other's functioning according to contingencies.

For a socio-economic example, let us take the national government as the supraordinate system and the telephone company as a subordinate system. The government gives the company a license to operate and the company gives the government tax revenues. The company must obey government regulations on its operation but likewise the government must create and/or update legislation to deal with many changes and innovations in the company's operations (e.g., rate increases, technological advances). Sometimes governments must respond to changes in the policies of companies that the companies have made in response to earlier government regulations. Conversely, sometimes companies change their procedures in response to government regulations designed to deal with earlier company policies. The cycle of mutual influence exemplifies the social structure called cyclic integration. Readers may generate their own examples of cyclic integration using supraordinate/subordinate
pairs of systems such as the culture and individual personalities, the economy and individual careers, the federal government and particular provinces, the football team and individual player performances, and so on.

B. Cognitive Structures

The aim of this section is to specify exactly what patterns of cognitive organization are being studied in this research. The cognitive structures under study are described in themselves and are related to each other in terms of anticipated difficulty levels. Again, the reader is reminded that the purpose of establishing a case for the ordered acquisition of various cognitive operations is that if such an order holds, then the developing child's ability to comprehend various structures in the natural and the social environments can be understood to be limited by, and yoked with, his or her own developmental progress as described in Piagetian theory.

Theorists from Freud to Piaget have argued the necessity of postulating stage-like progressions in the course of human development. Although continuities in development can be found (Brainerd, 1974), their manner of manifestation and pattern of interrelationships have more commonly been seen to undergo discrete changes at predictable points in maturation. To date, no continuous, linear variables have been found capable of quantifying the qualitative pattern of structure of behavior and its development (Larsen, 1977). Nevertheless, it is clear from a macroscopic perspective that the achievements of earlier stages of development provide a necessary groundwork for suspecting that mastery over the cognitive operations of seriation (ordination), linear transitivity, logical multiplication, and class inclusion regularly
appear in that respective order within the stage of concrete operations (e.g., Ginsberg and Opper, 1969). Likewise, within the later stage of formal operations, it can be argued that mastery of cyclic transitivity precedes cyclic integration. Of course there are likely to be occasional variations in the timing of their appearance from child to child, but let us examine the arguments for their invariant sequential ordering within the major stages. Some of these arguments are empirical while others deal with the logical and cognitive prerequisites for mastery of particular operations. While the arguments for their invariant sequential ordering are being examined, an ancillary aim of this section is to also present more details about the nature of each cognitive structure. The order in which we discuss each cognitive structure is from the hypothesized least difficult to the most difficult.

(i) Concrete Stage

Seriation. When asked to order a set of sticks according to length, children who cannot seriate often generate apparently random orderings. During what is apparently a transitional period, the child can, by a trial and error method, correctly order a given set of sticks but makes errors when asked to insert a new stick into the series. Finally, by approximately the age of seven, the child can typically seriate without errors or hesitations.

Linear Transitivity. Any set of stimuli that can be seriated can also be subjected to linear transitivity. On the simplest materials and with the simplest mode of presentation, most seven year olds show evidence of having mastered this cognitive operation. Indeed, seriation is a prerequisite for beginning linear transitive operations if linear transitivity problems are
presented using heterotropic comparisons (e.g., A is greater than B, C is less than B). In order to seriate, the child need only compare A to B. For successful transitive inference the child must also compare A directly to C while abrogating B's former status as the one that was taller than C. This additional logical requirement leads to the prediction made here, and by others (e.g., Formanek and Gurian, 1976), that most children would find linear transitivity more difficult than seriation.

Logical Multiplication and Class Inclusion. The simplest procedure for assessing mastery of logical multiplication is the two-way classification task (Inhelder and Piaget, 1964). The child is presented with a 2 x 2 matrix having one empty cell which must be filled using one of five alternatives from an array of possible answers. The class inclusion tasks used were adapted from Inhelder and Piaget (1964). For example, in the physical domain the supraordinate class was "wooden beads" and the two subordinate classes were green beads (5) and red beads (2). When asked if there were more green beads or more wooden beads, children who had not mastered class inclusion often answered that there were more green beads. They confused the comparison between two subordinate classes with the comparison between a subordinate class and the supraordinate class.

Logical multiplications and class inclusion are, according to Piaget (1953, p. 13), part of the same grouping or "operational system". Empirically, it is not until the age of 8 or 9 that the majority of children become competent with this grouping (Piaget, 1953). Kohnstamm (1968), however, argues that this grouping does not exist and that competence with class inclusion operations develops independently of competence with logical multiplication. Inhelder and Piaget (1964) found logical multiplication to be mas-
tered later than class inclusion while others have found the reverse (Arlin, 1978). On logical grounds class inclusion was predicted to be the more difficult of the two. While both operations entail attending to two attributes per element, in logical multiplication the attributes need only be listed. For class inclusion, however, the attributes stand in a nested or embedded relationship to one another. One subsumes the other in much the same way that Miller, Kessel and Flavell's (1970) recursive thoughts about thoughts about thoughts ..., subsume each other. Barenboim (1978) found that type of recursive embedding to be challenging even to 16 year olds. Therefore, on the assumption that a list is easier to handle than an embedded relation, it was predicted that logical multiplication would be mastered by most children earlier than class inclusion.

(ii) Systemic Structures

While the cognitive structures of seriation, linear transitivity, logical multiplication and class inclusion have been much researched and debated, the systemic cognitive structures of cyclic transitivity and cyclic integration have not. In section A, part (iii) of this chapter the systemic societal structures of cyclic transitivity and cyclic integration were discussed as common features of the social organization of, at least most, western societies. What follows next is a discussion of the systemic cognitive structures presumably necessary for understanding the corresponding societal structures. Particular attention in this section is given to hypothesizing the order in which these systemic operations are mastered relative to each other and to more well studied cognitive operations. The systemic tasks involved understanding various aspects of particular cycles. An interview format was used to present substantive information about the cycles and to
querie the respondents level of understanding. The content of the cycles in the two domains is the first thing described in this section. Next, the two components of cyclic transitivity are illustrated. Then, the two components of cyclic integration are also examined before the discussion turns to a comparison of systemic cognitive operations with formal operations in terms of difficulty level and stage.

The Cycles. The cycle used in the bio-ecological domain systemic interview was the nitrogen nutrient cycle. The elements were a nitrogen molecule, a producer (one plant of a farmer's crop), a herbivore (a caterpillar), a carnivore (a bird), and a decomposer (a nitrifying bacteria). The plant used the nitrogen as a mineral nutrient. The caterpillar ate the plant. The bird ate the caterpillar. When it died the bird was eaten by nitrifying bacteria. The bacteria left more nitrogen in the soil for the plant.

The cycle used in the societal domain was the wheat cycle. The elements were the wheat farmer, the wheat marketing board (WMB), the flour mill, the bakery and the supermarket (grocer). Assuming that the farmer gets his bread at the supermarket, these form a commodity cycle. For both cycles each of the five elements was represented graphically on an individual index card.

Cyclic Transitivity. There were two components to the cyclic transitivity measure. It was not known beforehand whether or not they would turn out to be alternate forms of each other (i.e., highly correlated) as they were intended to be. The "layout" component required the respondent to place index cards indicating each element beside each other in such a way as to show which ones needed or depended upon which other ones. In both domains the correct "layout" in response to this request would be a circular arrange-
ment representing the nitrogen nutrient cycle for the bio-ecological domain, or the flow of wheat/flour/bread through the series of exchanges for the societal domain.

With the proper arrangement of index cards laid out in front of the respondent, the interviewer introduced the second measure of competence with the operation of cyclic transitivity. This measure was called the "transitive recycling" component. In the bio-ecological domain the respondent was told how a spraying of the plants with DDT could kill birds as well as caterpillars. The concept of a single molecule of DDT was also explained along with a representative drawing on an index card. Then the respondent was asked if the same single molecule of DDT could ever kill two birds. Optimal answers had the molecule traveling around the cycle in much the same way as a nitrogen molecule might. The molecule not only returns to the initial element but also passes through that element again.

In the societal domain the transitive recycling component involved the movement of a dollar bill through the cycle. The respondent was asked if the farmer could ever spend the same dollar bill twice. Optimal answers showed an awareness of the flow of money in the direction opposite to the flow of wheat. The farmer pays the grocer who passes the dollar on until the WMB gives it back to the farmer to spend again.

Cyclic Integration. For reasons outlined in the previous section, cyclic transitivity was predicted to be mastered earlier than cyclic integration. The former involves linking the elements without attending to the subordinate/supraordinate aspects of their relations to one another. In cyclic integration, however, one element or set of elements in some sense subsumes other elements. The links between the subordinate and the supraordinate elements
can be understood in terms of cyclic transitivity. But with cyclic integration there is a further requirement to keep the subordinate/supraordinate distinction in mind. By way of illustrating the importance of the subordinate/supraordinate dimension, the specific contents of the bio-ecological and the societal cyclic integration tasks are surveyed below. Upon reviewing their particular requirements it should become clearer why cyclic transitivity was predicted to be the easier of the two.

In the bio-ecological domain, the subordinate elements of the nitrogen cycle were the populations (e.g., the bird population, the amount of nitrogen in the soil). The supraordinate level was the ecosystem of the farm.

The subordinate elements in the societal domain were the businesses in the wheat cycle (e.g., the wheat farmer, the flour mill, the bakery). The supraordinate level was the government. The government influenced the viability of each element relatively by imposing taxes. Its positive influence on their viability was mediated through the WMB's subsidies to farmers when either supply (wheat crops) or demand was inadequate for the financial survival of individual farmers. The whole cycle would be harmed if too many of the farmers went bankrupt. Hence, by subsidizing farmers and by imposing production quotas to prevent costly overproduction, the government was influencing the viability of all the elements.

The cyclic integration scores were based on evidence of awareness of two types of interdependency between the whole system and its parts. These corresponded to the two components of cyclic integration and, as with the cyclic transitivity, it was not known beforehand how highly correlated these alternate measures would be with one another.
What is being called the "systems synthesis" component challenged the respondent to foresee how changes in one element could influence the whole cycle. For example, in the bio-ecological domain the introduction of DDT into the nitrogen cycle had the potential to alter the equilibrium sizes of the populations. The alterations might be so drastic as to entirely eliminate a whole trophic level (i.e., carnivores; birds). In another example, the amount of nitrogen in the soil was drastically and permanently reduced. The whole ecosystem would thereby be transformed into a trace desert.

In the societal domain, systems synthesis was exemplified by the understanding of the effects of the stockpiling of wheat by the flour mill. The stockpiling would have meant a lower volume of sales for wheat farmers. That, in turn, would have implied higher WMB subsidies and that would have necessitated higher taxes for every element in the cycle. In these cases the whole cycle was influenced by subordinate elements. The effect on the whole had to be "synthesized" out of a knowledge of how the parts would then be interrelated.

For what is being called the "systems analysis" component the respondent was presented with the problem of reducing the cycle to its essential core. The core was that set of elements in a particular relationship such that no one of them could be eliminated without the elimination of the whole cycle.

In the bio-ecological domain the two top trophic levels (i.e., the birds and the caterpillar) could have been removed without eliminating the remaining elements. The plant, bacteria and nitrogen were interrelated such that each one would eventually be depleted if one were removed. In the wheat cycle the most essential element was the wheat farmer. He could have made his own bread but those tasks would still have to be performed. The elements
that normally performed them were the flour mill and the bakery. Respondents could have eliminated any element besides the wheat farmer so long as the flour making function and the bread baking function were accounted for in the remaining set of elements (e.g., "The grocer could bake the bread and sell it in his store").

In effect, then, it was thought that mastering the cognitive operation of cyclic transitivity requires seeing how the parts of the cycle are related to each other while cyclic integration requires seeing how the interrelated parts are related to the whole, and vice versa. Since taking account of the whole cycle over and above the interrelated elements seemed to be an additional cognitive demand, it was predicted that cyclic integration would be more difficult than cyclic transitivity regardless of domain.

(iii) Compared to Formal Operations

Having ordered the two systemic structures with respect to each other, we now have occasion to ask how both of them might be ordered with respect to the more familiar concrete stage and formal stage cognitive structures of Piaget's model.

Cyclic transitivity and cyclic integration were predicted to be post-concrete stage cognitive achievements. We cannot, however, begin by assuming that they are therefore formal operations. Formal operations are based on abstract formal logic. Systemic operations are based on systemic logic. Assuming that these are indeed two distinct types of logic (see Appendix E for a defense of this assumption), it is possible that systemic operations may be a parallel development during Piaget's fourth stage or that they may be a fifth stage unto themselves. The criteria for identifying a stage deserve some attention in this regard.
First of all, the notion of a fifth stage is really just a vehicle for discussing the nature of adult cognition. No one study could ever establish the existence of a stage as a natural phenomenon. Besides, the usefulness of the whole concept of stages in Piagetian theory has been seriously challenged (e.g., Brainerd, 1978; Flavell, 1977). Wohlwill (1973) has suggested four different versions of the concept of a stage and concluded that the one which accounted for research findings the best was the one which was the least "stage-like". With these caveats in mind, let us review the criteria for identifying stages.

Piaget (1960) listed four criteria for a stage. First, there should be a qualitative change in cognitive functioning. Second, the stages should fit within a culturally universal invariant sequence with respect to one another. Third, there should be evidence of hierarchization. That is, the cognitive structures of each preceding stage should be included in each subsequent stage. Fourth, there should be an overall integration of the structures of each stage. Piaget refers to this as the principle of "structures d'ensemble". Flavell (1977) also lists four stage criteria. Two of them, structure d'ensemble and qualitative change, were also listed by Piaget. Flavell leaves out hierarchization and a universal invariant sequence but he includes concurrence and abruptness. By abruptness Flavell (1971a) means that, "each individual item functioned at asymptotic, adult-level proficiency as soon as it functioned at all, i.e., as soon as it could be said to have been 'acquired' in any sense". By concurrence Flavell means that all the child's operations should be observed to go through an abrupt, qualitative change simultaneously.

A full exploration of the qualitative differences between formal logic and systemic logic would require another dissertation. In lieu of that, an extra chapter has been written on the topic and is included as an appendix.
(see Appendix E). Since this criterion requires a judgement of qualitative rather than quantitative difference, the relevant arguments are philosophical and logico-mathematical. In Appendix E it was concluded that the two logics are qualitatively distinct. In a sentence, systemic logic focusses on the identification of wholes while formal logic focusses on the comparison and/or classification of wholes.

Taken together, Piaget's criteria of hierarchization and a universal invariant sequence imply that, empirically, stages should form a Guttman scale with respect to one another. Three formal operational tasks were included in the design of this study as representatives of the formal operational stage. If the systemic tasks were to become candidates for a fifth stage, they would have to be a Guttman step above the formal operational tasks on the whole.

The criterion of structures d'ensemble (literally "structures of the whole"; loosely "structured wholes") implies roughly equivalent difficulty levels within stages on the average. Evidence that would satisfy this criterion includes (a) the existence of the same size of a gap between the scalogram difficulty levels of concrete and formal tasks as between the systemic

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3. Formal logic operates on relations of similarity/dissimilarity and of inclusion. Systemic logic operates on topological relations and part-whole relations. The truth value of formal logical arguments can be decided in the abstract. The truth value of systemic logical propositions depends upon the prior specification of spatio-temporal particulars. Systemic logic applies to the mental constructions of wholes. Formal logic presupposes the known identity of the wholes and goes on to compare and classify them. Static wholes are closed systems and are apprehended through what Piaget called "sublogic". Systemic logic subsumes sublogic but also allows for the appreciation of dynamic wholes or open systems. Open systems are characterized by negentropic structures.

4. The hierarchization criterion implies logical subsumption as well as a Guttman scale arrangement of stages. In a Guttman scale of ability, the items are ordered from the least to the most difficult such that passing a particular item implies having passed all items of lesser difficulty. The intervals between adjacent items of a Guttman scale are Guttman steps.
and formal tasks, (b) smaller (than (a)) gaps among the difficulty levels of tasks within stages, and (c) cluster analysis results which group tasks of the same stage together.

Finally, Flavell's criterion of abruptness would require a short time span between cognitive functioning at one stage and functioning at the next higher stage. The ages at which formal versus systemic tasks are mastered becomes relevant here. For evidence of a fifth stage Flavell would require a sudden onset of mastery of the systemic tasks. Wohlwill (1973) on the other hand would allow for a gradual mastery of the systemic "ensemble".

The interpretation of formal and systemic logic as "parallel" post-concrete developments would be favored if several of the above criteria were not met. The parallel interpretation would appear especially strong if the systemic tasks turned out to be of the same difficulty as formal tasks and mastered at the same ages. The fifth stage interpretation would be weakened if the systemic tasks were more difficult but their greater difficulty could be wholly attributed to a greater unfamiliarity with the substantive content materials used in the systemic tasks. For that very reason, the next section deals with issues related to familiarity and domains of content.

C. Domains of Content

The empirical work to be described included several content domains. This section describes similarities and differences among domains (sub-section i) and then addresses the implications of differential familiarity
with domain content including task difficulty (ii) comparison with formal operational tasks (iii) and age related abruptness of mastery.

1. **Comparability of Contents**

   The content of standard Piagetian testing procedures is not directly comparable to the societal domain content, not only because their manifest contents differ, but because the two classes of phenomena encompassed by the physical and societal domains exhibit different types of logico-mathematical principles as well. In terms of manifest contents, the contents of the physical domain are physically palpable whereas those of the societal domain are not. In terms of logico-mathematical principles, the physical domain tends to over-represent closed systems whereas the societal domain emphasizes open systems. In order to extend the Piagetian approach to the study of children's understanding of societal systems, the bio-ecological domain was chosen as an intermediate step. The bio-ecological content is physically palpable like the physical domain content and unlike the societal content. On the other hand the bio-ecological content deals with animate, open systems like the societal domain does, while the physical domain content is inanimate and deals with more closed systems. The inclusion of three content domains.

5. For the specific details of the contents and materials employed in each domain, see Appendices A, B and C. Briefly, the content of the physical domain consisted specifically of objects like wooden beads of different colors, plastic flowers of different heights, cardboard cylinders of different heights, and so on. The bio-ecological domain dealt with birds, plants, fish, molecules, bacteria, and trees. The systemic tasks centered around the concepts of trophic levels, nutrient cycles, and population dynamics. The elements involved were all depicted graphically for the subjects except for printed verbal representation in the logical multiplication task. In the societal domain the contents were more conceptual but were still accompanied by graphic representations. The seriation task involved ranking people in terms of their rights of access to a jointly owned piece of machinery. The linear transitivity involved three occupational roles compared in terms of legislative authority (i.e., prime minister, judge, policeman). The logical multiplication and class inclusion tasks dealt with the economic situations of producers and consumers. The systemic interviews introduced concepts like profits, taxation, and the law of supply and demand into a consideration of the Canadian wheat industry.
allows for inferences about the direct effects of content on performance.

The bio-ecological domain provides a link between the impersonal contents of standard Piagetian research and the socio-economic content which constitutes the primary focus of this research. Children's understanding of the bio-ecological domain was judged to be like the more traditional physical domain in that elements of the task are palpable entities (e.g., birds, plants, fish). It is like the socio-economic domain in that, like social systems, its elements form open systems. These physical entities are alive and the networks which they form are open systems. Systemic structures, especially those that show the property of cyclic integration, are most often found in open systems. Ecosystems and socio-economic systems are, consequently equally well suited for illustrating the logico-mathematical principle of cyclic integration. It is difficult, in not impossible, to devise an inanimate exemplar of the same principles. Perhaps it is for this reason that Piaget's characteristic focus on inanimate physical phenomenon might have contributed to his neglect of systemic structures and systemic operations in post-concrete cognition.

Faced with this shortfall, a decision was made to include only standard measures of formal operations (i.e., isolation of variables, combination of variables, and probability) as an index of post-concrete level think-
As mentioned earlier, this decision allowed a comparison of difficulty levels between post-concrete tasks based on formal logic and systemic logic, as evidenced in the bio-ecological and societal domains. Necessarily missing, however, was any opportunity to directly compare systemic logic in the physical and societal domains. The systemic tasks of the bio-ecological domain partially filled the gap.

(ii) Familiarity Issues

The familiarity of task contents has relevance for the attempt to validate the extension of Piagetian theory to the bio-ecological and societal domains of content. If respondents are less familiar with one or both of these types of content then task performance could suffer. Such an outcome in itself would not vitiate the applicability of Piagetian theory to those content domains. It is important, however, to be able to distinguish content related performance differences from differences that might arise from more serious departures from the general picture of cognitive development contained in Piagetian theory. In the interest of being able to make that distinction clearly, it is necessary (a) to specify the variant of the familiarity con-

7. It would have been possible to devise tasks based on known formal operations for the bio-ecological and the societal domains. That, however, would have changed the topic of this research somewhat. This study was not intended to be a wholesale replication of Piagetian tasks in novel domains. To be sure, at the stage of concrete operations the same cognitive structures were examined across all the content domains in this study. Part of the reason for that was a desire to have observations available on the cognitive structures that can be seen as the lower rungs of the vertical ladder of cognitive structures within each domain. The concrete structures, according to Piaget, are the prerequisite underpinnings of later, post-concrete achievements. At the post-concrete stage, however, the cognitive achievements of primary interest were not the formal operations but rather the systemic operations. An examination of how well formal operations account for the child's understanding of various open systems is another topic. Very interesting work in that topic area has been started by Denis Kargbo at the U.B.C. Department of Science Education. His Ed.D. dissertation concerns the role of INRC cognitive operations in the understanding of ecosystems.
cept that is most relevant in this research and (b) to examine the relationship between content familiarity and horizontal décalage across whole domains.

**Unfamiliarity as Foreignness.** The subject's familiarity or lack of it with testing materials can powerfully influence task performance, as several cross-cultural studies have shown (for a review see Glick, 1975). There are, however, many ways in which materials can be unfamiliar. Glick notes cultural differences may arise due to two-dimensional representations of three dimensional objects, or due to differences in which features of objects it is usual to note and analyze. Used in this sense, the word "familiarity" means "not foreign". "Familiar" materials or perceptual/conceptual approaches are those indigenous to the subject's own culture. Awareness of the importance of cultural familiarity leads to a greater sensitivity to the possible effects of finer degrees of foreignness. Of particular importance in the present research is the possibility that the adult world of politics and economics might be somewhat like a foreign culture to children and that consequently developmental claims about children's abilities to comprehend such content might easily be confounded with the less theoretically interesting matter of familiarity.

**Unfamiliarity as Meaninglessness.** Thus far we have dealt with familiarity in the sense of cultural foreignness. The meaning of familiarity, however, looses some of its crispness when we move from cultural differences to developmental differences. It then becomes necessary to speak in terms of continuous degrees of familiarity or levels of familiarity. For example, one sense of the term comes from traditional verbal learning studies where the more familiar a stimulus is, the quicker it can be recognized or the quicker its association with another stimulus can be relearned. This is familiarity in the sense of prior "exposure" or "acquaintanceship".
At the opposite end of the continuum, we may speak of familiarity as knowing things about a stimulus, like what it does, what other objects it is importantly related to, what its significance is in a larger context, and, perhaps what its metaphorical and/or allegorical potential might be. This is familiarity in the sense of "meaningfulness". A stimulus that can be placed into the context of other knowledge is one with which the perceiver is more familiar. When it connotes "meaningfulness", the concept of familiarity is linked to the concepts of knowledge and understanding. In this sense cognitive development can be loosely described as the process of familiarization with the world. In this broad meaning, familiarity ceases to be importantly different from the issue of social understanding which this research set out to explore. Any attempt to control for or assess familiarity in this sense would either block, or prove equivalent to, the study as a whole. As a result, it is familiarity in the earlier sense of foreignness or acquaintanceship which must now be considered.

Horizontal Décalage. The proposition that the content of the societal domain tasks might be more foreign to children in any society leads to an expectation that all of the societal domain tasks might be more difficult than tasks from other more familiar content domains. This has implications for the attempt to verify the generalizability of Piagetian theory to the societal domain. If the societal domain tasks are found to be both (a) less familiar in terms of content and (b) more difficult in terms of overall success rates, then it is possible that respondents who pass formal operational tasks on more familiar turf might fail structurally less complex "concrete" tasks in the less familiar societal domain. At first glance this type of outcome might appear to falsify the Piagetian premise of a discontinuous shift in cognitive organization between stages. Alternatively, such "between-stage"
discontinuity for societal content might still be present, but simply occur at an older age. The stage transition might simply be delayed in the societal domain owing to either (a) the foreignness of its content or (b) the purely verbal, non-physical nature of its content.

If such evidence of décalage were observed only in the societal domain it could be attributed to the nonpalpability of the contents. If it were found in both the bio-ecological and societal domains equally, then the animate, open systems nature of both of these contents would be implicated and this greater difficulty would appear more formal or structural rather than simply a matter of unfamiliar content.

(iii) **Familiarity and Task Difficulty**

Apart from assisting in the evaluation of the applicability of Piagetian theory to other content domains, data about familiarity could also allow a comparison between systemic cognitive operations and formal operations. In particular, one could assess the relative importance of logical complexity versus content familiarity for both kinds of tasks. First, comparisons could be made between tasks that had the same logical requirements (i.e., involved the same cognitive structures) but differed in terms of the familiarity of their contents. Second, there may be cases where the contents involved in two cognitive operations were identical despite different logical requirements. An important issue that could be resolved in this manner is the matter of whether the systemic operations are more advanced than the formal operations. It was expected that both sets of operations would be post-concrete achievements. What remained to be determined was whether or not the systemic operations would prove to be a developmentally later achievement than formal
operations even when the effects of possibly less familiar content have been accounted for.

In sum, the data on the familiarity of task contents in terms of foreignness facilitates the interpretation of the data in two ways. First, it could index a constant factor of task difficulty across domains. This allows for an inference of the presence or absence of horizontal décalage and thereby clarifies the matter of how generalizable Piagetian theory is to bio-ecological and societal content in general. Second, the familiarity data might help establish the developmental priority of formal operations vis à vis systemic operations independently of the content related factors that influence performance on the tasks designed to assess mastery of those operations.

(iv) Age and Difficulty Level

The difficulty level of a task is always relative to other tasks administered to the same respondents. It is not an absolute level. With a sample of 7 to 9 year olds all formal operational tasks would appear to be of equal difficulty (i.e., no one would pass). With a sample of 11 to 15 year olds the same formal operational tasks would be ordered while the concrete staged tasks would show little variance. In the present study the sample of respondents covered a wide range of ages (8 to 18), to optimize the utility of data on the difficulty level of tasks with heterogeneous ability levels. The intention was to maximize the variance in the difficulty level data.

Although the difficulty level data were the central analytical focus in this study the age of mastery data were also useful for interpreting differences in difficulty levels. Where two tasks were found to be very different in terms of difficulty level, there could be no assurance from that data per se that one task is mastered at a later age than the other by most children.
Here the age of mastery data had to be brought in to clarify the interpretation of the difficulty level data.

D. Hypotheses

In the attempt to extend the Piagetian approach to relatively unexplored domains of content, this study attempts to show (a) on the microscopic level of analysis, that the order in which various operations are mastered remains the same across domains, and (b) on the macroscopic level of analysis, that the relative continuities and discontinuities in modes of cognitive organization (e.g., stages) also remain the same across domains. These points, once established, prepare the way for a consideration of the main focus of this study. The central focus is on the cognitive structures required to understand open systems. In understanding such systems respondents would presumably be performing cognitive operations at least as difficult as formal operations. The exact difficulty of these systemic cognitive operations vis-à-vis previously studied formal operations remains to be determined. At the same time some attention must be given to the relative contribution of content related (i.e. figurative) factors versus logical complexity (i.e. operative) factors in accounting for the observed difficulty levels of the systemic operations. The attempt to extend the Piagetian approach to further content domains translates into the macroscopic and microscopic aspects of the first hypothesis. The second and third hypotheses in this study deal with the issues related to the difficulty levels of the systemic cognitive operations. Although all the hypotheses are independent, they also stand in a contingent relationship with one another. Before the nature of that relationship is examined (in subsection (ii)), the hypotheses themselves will be listed (in subsection (i)). Each hypothesis is examined in more detail along with its
corresponding "null hypothesis" in subsection (iii).

(i) List of Hypotheses

The hypotheses of this study are as follows:

First.

Microscopic: The order of task difficulty as determined by a scalogram analysis will be the same across all domains. The difficulty ordering, from easiest to most difficult, for the concrete stage tasks will be as follows: seriation, linear transitivity, logical multiplication, class inclusion. In the physical domain all of the formal operational tasks will be more difficult than all of the concrete operational tasks. In the bio-ecological and societal domains the cyclic transitivity tasks will both be more difficult than all of the concrete operational tasks and the cyclic integration tasks will both be more difficult than both of the cyclic transitivity tasks.

Macroscopic: Whatever orderings are observed within stages, the most difficult concrete operational task will be a Guttman step less difficult than the least difficult post-concrete staged task in the same domain and there will be no Guttman steps between tasks of the same stage. This pattern will be found in all three content domains without exception.

Second.

At least one of the components of the systemic operations will, in both the bio-ecological and the societal domains, be more difficult than the

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8. The term "null hypothesis" is used here in a figurative sense. Usually the term is used in the context of quantitative analyses. It refers to the assumption of no statistically significant difference. In this work the term is used less formally to refer to "the theoretical position which would prevail were no evidence found to support the theoretical position contained in a proposed hypothesis."
most difficult formal operational task by a margin that is comparable to the difference in difficulty between the least difficult formal operational task and the most difficult concrete operational task. Moreover, the step between the most difficult formal task and the more difficult systemic task(s) will be a Guttman step.

Third.
The difficulty level of the most difficult systemic task(s) will not be wholly attributable to familiarity of task content variables.

(ii) A Contingent Succession

Strictly speaking, the three hypotheses of this study are independent of one another. It is possible to locate the difficulty levels (second hypothesis) of the systemic operations vis-à-vis formal operations even if the stage and sequence patterns found in traditional Piagetian research do not generalize to the bio-ecological or the societal domains (first hypothesis). Likewise, one could ferret out the influence of content on systemic task difficulty levels (third hypothesis) even if the systemic tasks are observed to be of the same difficulty levels as the formal operational tasks. Despite this strict independence, however, there is the possibility of all three hypotheses becoming successive steps in the testing of an overarching hypothesis. The overarching hypothesis is that the systemic operations are representatives of a fifth stage of cognitive development. The existence of a fifth stage could not be categorically demonstrated in only one study no matter how extensive. Nevertheless, future research explicitly directed at the fifth stage hypothesis could be pre-empted by the findings of the present study. The three hypotheses of this study could be viewed as tests of the preconditions required for positing a fifth stage. From this perspective the first hypothesis provides a test of the least stringent requirements for a fifth stage hypothesis to survive. If those conditions were met the second hypothesis could be seen
as a search for evidence of the next most basic conditions that would have to be met in order for a fifth stage hypothesis to remain viable. If this second set of prerequisites were found to obtain then the third hypothesis could likewise be construed as a successively more refined sets of conditions that would have to be demonstrated. Although each of the three hypotheses could stand or fall independently when considered individually, the relevance of each successive hypothesis to the fifth stage notion is contingent upon a rejection of the null hypothesis for each preceding hypothesis.

(iii) The Null Hypotheses

The first null hypothesis is that the Piagetian approach does not generalize to the bio-ecological or the societal domains. The vast bulk of Piagetian theory is based on research into children's understanding of the inanimate physical world. There is no assurance that the same theory can be extended to understanding the animate world, especially when it is a non-palpable world as is the case with societal reality. Specifically, the cognitive operations might be ranked in an unpredictable order based on difficulty level and the more macroscopic discontinuities in difficulty levels from one stage to another might not appear or might be less Guttman-like. In opposition to the first null hypothesis the first predictive hypothesis states that there will be ample evidence of Piagetian theory applying well in the bio-ecological and societal domains. If the first null hypothesis cannot be rejected then we have no evidence of any stages, as we know them, in the bio-ecological and/or societal domains. That automatically rules out the possibility of a fifth Piagetian type stage.

Cognitive operations of a fifth stage would have to meet the prerequisite of being more difficult than formal operations. Given that there are Piagetian
stages, the second null hypothesis asserts that there are only those Piagetian stages already discovered. There is no fifth stage. The systemic operations are at the same level of difficulty as the formal operations and are therefore another aspect of the fourth stage of cognitive development. The second predictive hypothesis anticipates that on the basis of difficulty levels and Guttman scale orderings, at least one of the systemic operations will be located about as far apart from formal operations as formal operations cluster apart from concrete operations. If that prediction proves correct, then, on the basis of their greater difficulty, candidates for a fifth stage would have been identified.

Given that there are some cognitive operations more difficult than formal operations, a fifth stage interpretation of that greater difficulty would require that it be a result of the greater operative difficulty of the assessment tasks. The third null hypothesis, on the other hand, attributes such greater difficulty to content related factors. If it could be shown that the greater difficulty of the tasks assessing the systemic cognitive operations could be wholly accounted for by the greater difficulty of the task content, then it would be unparsimonious to postulate the existence of a fifth stage.

If the predicted greater difficulty of some systemic operations cannot be written off as artifactual side effects of the tasks used to assess them, then further analyses can be performed and additional data can be introduced to assess the extent to which the criteria for a stage have been satisfied. For example, if there were more than one operation being proposed as a candidate for a fifth stage then it would make sense to put the structure d'ensemble criterion to a further test by performing a cluster analysis. The fifth stage candidates should form a separate cluster, as should the tasks for the third and fourth stages respectively. With more than one candidate for a fifth stage it would also be possible to check for non-Guttman steps among them.
III. METHOD

A. Measures

Briefly stated, there were three domains of content in which the cognitive operations were presented. These were (a) standard Piagetian materials involving common physical objects (see Appendix A), (b) bio-ecological content represented verbally and in mnemonic pictures (see Appendix B), (c) social organizational content also represented in drawings and words (see Appendix C). Within all three domains there were tasks assessing the concrete operational cognitive operations of (i) seriation (ii) linear transitivity (iii) logical multiplication and (iv) class inclusion.

In the bio-ecological and the societal domains the proposed cognitive operations of (v) cyclic transitivity and (vi) cyclic integration were also assessed (see Appendix D for scoring details). For reasons already discussed, there was no physical domain equivalent to these measures so instead measures were taken of the formal stage cognitive operations of combination of variables, probability and isolation of variables. What follows is a brief description of all the measures with selected reference materials concerning their use in other research.

1. Some of these simpler cognitive operations measured (e.g., seriation) were so elementary that there might appear to be very little across domain variation in the design of the tasks meant to assess them. That is, the variations in task content may appear trivial compared to the consistencies in task structure. This was an unavoidable side effect of insuring across domain consistency in the cognitive demands made by tasks assessing very simple cognitive operations.
(i) The Concrete Tasks

In all three domains the seriation task was based on the standard procedure described in many places (e.g., Formanek and Gurian, 1976). The interpolation variation was included in order to help distinguish pre-operational responses from concrete operational responses (Ginsberg and Opper, 1969; 137-138). If and when the objects have been correctly seriated, the interpolation variation involves asking the child to place an additional object into the series. In the physical domain version respondents were asked to seriate seven red cardboard cylinders. The bio-ecological version entailed arranging trees according to how deep their roots were. Only the crown of the trees were shown but respondents were told that the depth of the roots was proportional to the height of the tree. The trees were all hand drawn on individual index cards. Thus, the seriation was to be performed according to an invisible dimension (roots) that was represented by a visible one (crowns). Since the societal domain dimension of seriation was to be invisible, it was important to replicate the same distinction in the bio-ecological domain for purposes of comparison. The "objects" to be seriated in the societal domain version were people's rights. Respondents were told that seven farmers had all contributed different amounts of money to jointly buy a tractor. Where two farmers both wanted to use it at once, the one who had put in the most money had the right to use it first. For each farmer there was an index card showing how many $100 bills he had contributed. The respondents were asked to use the index cards to queue the farmers on a day when they all wanted to use the tractor at the same time.

The three linear transitivity tasks followed the standard procedures
investigated by Glick and Wapner (1968). Three cardboard cylinders of different heights and colors were employed in the physical domain task. In the bio-ecological domain it was three different species of birds which layed different numbers of eggs. They were depicted graphically on index cards. In the social content domain three occupational roles (prime minister, judge, policeman) were represented by three paper mache dolls, all the same size, wearing dress appropriate to their roles. The dimension of comparison was how much each one, "had to say about what the laws would be."

Mastery of logical multiplication in the three domains was assessed by the two-way classification task (Inhelder and Piaget, 1964). The intersecting dimensions in the physical domain logical multiplication task were shape (stars, squares) and color (red, yellow). A twofold matrix was presented on an index card. One of the four cells was empty. The child was asked which of the five alternative answers displayed at the bottom of the card would "fit best" in the empty cell. In both the bio-ecological and the social domain the stimuli for the matrices were typewritten words. The intersecting bio-ecological dimensions were genus (fish, bird) and diet (meat-eating, plant-eating). In the social domain the choices were between producers versus consumers of wheat versus flour.

Inhelder and Piaget's (1964) standard class inclusion task was adapted for use with content from the three domains. For the physical domain the superordinate class was wooden beads with color as the subclasses. The superordinate class in the bio-ecological domain was "birds" and the subclasses or categories included in that class were ducks and crows. These were typewritten in a haphazard spatial array on an index card. So were the particular elements of the superordinate class in the social domain. The index card
displayed noun phrases for each of the members of the wheat marketing board. Some were producer representatives; some were consumer representatives. All were government appointees.

(ii) The Formal Tasks

The combination of variables procedure was adapted by Arlin (1978) from a version by Sills and Herron (1976) which reconstructed the essential logical features of Inhelder and Piaget's (1958) "combination of Colored and Colorless Chemical Bodies" task. The chemicals are replaced by five push button electrical switches atop a small black box. Only one combination of three buttons pushed simultaneously would illuminate the red light also atop the box. One button was not wired (the analogue of water) and one broke, rather than closed, the circuit (the analogue of the neutralizing chemical).

The measure of comprehension of probability was Arlin's (1978) standardization of a less structured procedure described by Piaget and Inhelder (1975; 116-130). Six red, six yellow, and six green wooden beads were mixed in a bowl. Respondents estimated the probability of drawing a particular color twice without replacement.

The isolation of variables task was devised by Kuhn and Ho (1977) with minor adaptations by Chandler, Siegal and Boyes (1980) and the author. Respondents were faced with two arrays of plastic plants, seven roses and seven leafy plants. They were told to imagine that three types of plant foods were being fed to the plants. Plastic vials with lettered labels stood beside each plant to represent the plant food being fed to that plant. Some plants were taller than others. Respondents were asked to identify the most effective and efficient combination of plant foods to produce tall plants.
(iii) The Systemic Tasks

Cyclic transitivity and cyclic integration were assessed in an interview format devised for this study. A situation was described and then the respondent was asked what would happen next. This was followed by more specific standardized probes and whatever additional probes were needed to reduce ambiguity or confusion in responses. In the bio-ecological domain interviews, the respondents were asked about the systemic relations implicit in nutrient cycles (Kargbo, 1979). The social domain interview dealt with the systemic relations in the socio-politico-economic organization of the Canadian wheat industry. Specifically, it involved the wheat commodity cycle from the farmer, to the wheat marketing board, to the flour mill, to the bakery, to the retailer, back to the farmer.

(iv) Familiarity Assessments for Systemic Tasks

For every task there was at least one item assessing how familiar the respondent was with the materials and/or concepts being used in the task. For the concrete tasks the familiarity items were less conceptual (e.g., "Do you know what these beads are made of?"; "How do you tell how deep a tree's roots go?"; "Have you ever heard of a judge before? Do you know what he does?"). The post-concrete familiarity assessments were more conceptual and more extensive. For the systemic interviews some assessments took the form of preliminary problems. For example, familiarity with the concept of profit was assessed by asking, "If the grocer bought bread at 80¢/loaf, would he sell it for more than 80¢, less than 80¢, or 80¢?"

For reasons discussed in the introduction, it was important to distinguish familiarity from operative understanding even though they may be interdependent. It obviously would not do to familiarize subjects with the materials to such an extent that competence with the cognitive operation being
assessed becomes a prerequisite for presenting the task. Conversely, the attribution of failure to a lack of competence with a particular cognitive operation would be unjustified when there is a reasonable doubt that respondents knew enough about the constituent elements of the task to be able to apply that particular cognitive operation meaningfully in some context. These considerations suggested the strategy of identifying a minimum level of understanding of (or "familiarity with") the materials, concepts, premises, etc. for each task and then introducing the task with instructions designed to provide that level of understanding. The information gained by the use of this strategy allows one to gauge the influence of the familiarity/unfamiliarity of the task contents on the overall difficulty level of the task for the whole sample of respondents.

B. Respondents

A total of 96 subjects were tested. There were 8 males and 8 females in each of grades 3, 5, 7, 9, and 11. An additional 8 males and 8 females had completed grade 12 the previous academic year. The mean ages of respondents at each grade level, expressed in years and months, were: grade 3, 8-7; grade 5, 10-8; grade 7, 12-5; grade 9, 14-7; grade 11, 16-10; first year post-secondary, 18-11. The grade 3, 5, and 7 respondents were from an elementary school the grade 9 and 11 respondents attended a secondary school, and the post-secondary respondents were either full-time members of the workforce or post-secondary students. All schools were in the greater Vancouver metropolitan area.

2. This practice has always been followed in Piagetian research. The introduction procedures for the class inclusion task (p. 165) are a good example.
The elementary and secondary school students were randomly selected from a pool of potential respondents that remained after the following constraints has been met. First, the student had to be English speaking, but English did not have to be the student's native language. Second, the student had to verbally agree to voluntary participation. Third, the number of males and females had to be equal at each grade level. Fourth, the student's participation had to have been approved through the standard channels for obtaining permission to conduct research in schools.

An attempt was made to match the sample of first year post-secondary respondents to the population of graduates from the secondary school the previous academic year. The characteristic on which the matching attempt was made was full time educational or occupational status in the first post-secondary year. School records were available for graduates of the previous year. The records included the students' predictions about their anticipated educational and/or occupational activities for their first post-secondary year. Excluding those who gave no clear indication of what they would be doing, 47% of the students anticipated becoming full-time members of the work force. Forty-two percent anticipated attending a community college or technical school. Eleven percent anticipated attending a university. The proportion of first year post-secondary respondents in this study who were full-time members of the work force is especially low by comparison to the estimates obtained from the secondary school graduates. A good deal of time and effort was expended to ameliorate this condition but to little avail. The proportions obtained in this study were 25% full-time members of the work force, 37.5% attending a community college or a technical school, and 37.5% attending a university. The respondents attending a university were all enrolled in
Introductory Psychology at U.B.C. The respondents attending a community college were all enrolled in Introductory Psychology at the New Westminster campus of Douglas College. The respondents who were full-time members of the work force were recruited either through the participating university students who had eligible friends (two respondents were obtained by this means) or through the author's personal friends, relatives, and acquaintances (two more respondents).

C. Procedure

This section is divided into two parts: procedures for collecting the data and procedures for scoring the data. After describing the data collection procedure the training of scorers and the scoring procedure itself will be discussed.

(i) Data Collection

For all respondents the total participation time was approximately 50 to 55 minutes. These sessions were referred to as "interviews" even though, strictly speaking, part of the session was devoted to testing rather than interviewing. With the elementary and secondary school students the interviews were conducted in offices in the school. In the elementary school the interviewer or his assistant went to the classroom and led the child to the interview room. In the secondary school groups of 4 to 6 students were called to the main office when daily announcements were made. At that time the study was briefly explained to them and they were asked to volunteer. If they agreed a time was arranged for them to come to the interview room pending the approval of their teacher for that class time period. Students whose parents had not disallowed their participation were randomly selected from
class lists until 8 males and 8 females had been interviewed. With the first year post-secondary students the university students and the community college students were interviewed in Psychology Department research rooms. Two of the working respondents were also interviewed in a U.B.C. Psychology Department research room. One was interviewed in her own home and one was interviewed at the home of a mutual acquaintance.

The interviews themselves consisted of 19 tasks. These were 12 concrete operational tasks (3 domains x 4 cognitive operations), 3 formal operational tasks, and 4 systemic tasks/interviews (2 domains x 2 cognitive operations). The order of task presentation was

| Concrete Standard Domain (Appendix A., Sections (i) to (iv)) | 1. Seriation |
| Biological Domain (Appendix B, Sections (i) to (iv)) | 2. Linear Transitivity |
| Social Domain (Appendix C, Sections (i) to (iv)) | 3. Logical Multiplication |
| Formal Appendix A, Section (v) | 4. Class Inclusion |
| Systemic Biological Domain (Appendix B, Section (v) and Appendix D) | 5. Seriation |
| | 6. Linear Transitivity |
| | 7. Logical Multiplication |
| | 8. Class Inclusion |
| | 9. Seriation |
| | 10. Linear Transitivity |
| | 11. Logical Multiplication |
| | 12. Class Inclusion |
| | 13. Combination of Variables |
| | 14. Probability |
| | 15. Isolation of Variables |
| | 16. Cyclic Transitivity |
| | 17. Cyclic Integration |
Owing to scheduling difficulties four of the elementary school students received the systemic tasks, as a block, before the concrete and formal blocks. The order of task presentation within blocks was always the same.

The details of how each of these tasks were administered and scored are presented in the appendices indicated above. Written records were made of responses on the concrete and formal tasks. Responses on the systemic tasks were tape recorded and some were also written. The tasks covered a vast range of abilities with some being challenging to 8 year olds and others being challenging to 18 year olds. Since the series of tasks were presented in an order roughly thought, for theoretical reasons, to be correlated with their difficulty level, it was expected that the most diagnostic phases of the interview for particular responses would gradually shift from the earlier to the later tasks as the testing proceeded from the youngest to the oldest respondents. There are advantages and disadvantages to ordering presentation on an *a priori* basis. The danger in making the presupposition is that "experimenter" expectancy, in its various manifestations, might have contributed to insuring the expected difficulty ordering of tasks. The advantage is that steps can be taken to avoid loosing rapport with the respondent.

Before dealing with the nexus between order of task presentation and respondent rapport we will review the measures adopted to guard against experimenter expectancies influencing the results.

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3. Full counterbalancing of order of task presentation would have required over a million respondents in order to have one respondent per order. Full randomization of order of presentation would have extended the duration of each session beyond that permitted by both the school authorities and the attention spans of the children.
First, in the elementary school, a Ph.D. candidate in psychology was available as an assistant. The assistant administered the concrete operational and formal operational tasks and the author administered the systemic interviews. The communication between them was kept to a minimum at that point in order to minimize the communication of any expectancies.

The second step taken to guard against experimenter expectancy was the adoption of the general rule that all respondents would be presented with all tasks beyond the supposed difficulty level of their first unsuccessful task. It was not assumed the first failure after a string of successes necessarily signaled a string of failures to follow. Since one of the prime concerns in ability testing is to establish and maintain rapport with respondents, it was important to avoid (a) overwhelming the younger respondents with problems far beyond their abilities and (b) insulting the intelligence of young adults with problems far below their abilities. When presented with the more complex cyclic integration items the first three to five students interviewed in grades 3 and 5 became either "fidgety" or unresponsive. Patterson, Cosgrove, and O'Brian (1980) have documented reliable nonverbal indicants of non-comprehension in children. The most robust indicants are more hand movements and longer reaction times. Since their non-responding or monosyllabic responding had to be coded as "failing" responses anyway, it was decided that they would not be presented with the more difficult cyclic integration items unless they had succeeded at the simpler, quasi-prerequisite items. The implementation of this policy (after the first 3 to 5 respondents in each grade had been interviewed) made a marked difference in the moods of the children leaving the interview room. Especially with the grade 3 children, the difficult cyclic integration items led to quite despondent demeanours. None of the children actually began crying during that part of the interview, but there seemed to be little justification for bringing them so close to such emotions.
A reciprocal problem arises when a 14, 16, or 18 year old is presented with a seriation task. The tendency is to conclude that the interviewer is "playing games" given the "childish" level of the task. In pilot interviews adolescents tended to either become sullen or flippant when presented with concrete operational tasks. Either response is undesirable when respondents are finally presented with problems that do challenge their intellects. In view of this, the only concrete staged task presented to students in grade 9 or higher was class inclusion. Empirical justification for this resides in the finding that in grade 7, where all tasks were presented, only one of the seven students classified as formal operational failed any concrete task. Likewise, among the fifteen formal operational grade 9 students only two failed two of the three class inclusion tasks. Thus, even though the remote possibility remains that a very few grade 9 students might have failed even more concrete staged tasks had such tasks been presented, the benefits in terms of respondent interest and rapport seemed to outweigh the costs of foregoing that information. (ii) Data Scoring

The concrete and formal tasks were scored upon administration. The scoring criteria for all tasks are described in the appendices under the heading for each task. The systemic tasks were scored later according to the procedures described in Appendix D. The judges or "scorers", as they will be referred to here, scored only the cyclic integration interviews. What follows is a brief summary of the training and scoring procedures.

When all the data had been collected, the tape recorded sections of the interview were transcribed verbatim. The author scored the cyclic transitivity tasks (see Appendix D). The cyclic integration sections of the
transcripts were typewritten into protocols and independently rated by two female scorers.

It was impossible to tell how long it would take the trainees to reach the 90% criterion of agreement that had been previously chosen as a goal of the training. As it turned out, the scorers agreed with each other on 81.2% of the items by the time they had scored 1/5 of the data. They stayed between 83.2% and 86.4% for the remaining four fifths and for a rescoring of the first fifth. The overall agreement rate for the latter scoring was 84.8%. After an initial training session on one spare grade 11 protocol and two ficticious protocols, the scorers and author then met after each successive 20 protocols had been scored. Within each "batch" of 20 protocols the respondents were arranged in a second random order. The order in which the respondents had been interviewed was only random within grade levels. The order in which the scorers received the protocols was random across the whole sample. There were six of these "reliability check" meetings at a rate of approximately two per week. At each of the reliability check meetings specific items of disagreement were discussed. The criterion for setting final scores was a majority agreement. In 80% of the cases, however, spontaneous unanimity was achieved.

4. One was a 25 year old teacher and the other was a 20 year old psychology major. They were paid from a discretionary grant awarded by the Educational Research Institute of British Columbia. The scorers made their ratings from the protocols. This added clerical step had two advantages over having the scorers make their ratings directly from audio tapes themselves. First, it reduced the possibility of artifactual contamination of the scores on the basis of voice and speech cued information about the age of the respondents. The scorers might have been prone to assign lower scores to younger respondents and higher scores to older respondents on at least a partially a priori basis. The transcription of responses into protocols was an attempt to minimize the opportunity for such artifacts. Second, many of the audio tapes were flawed by high levels of background noise. If scorers had had to decode signals against such high noise levels, their task would have been immensely more cumbersome and time consuming.

5. One batch of protocols contained only 16 protocols since the total number of respondents was 4 short of 100.
IV. RESULTS

As mentioned in section F of the introduction, the hypotheses of this study are arranged such that a failure to reject earlier null hypotheses automatically implies a failure to reject later null hypotheses. At least one of the two levels (i.e., macroscopic vs. microscopic) of the first null hypothesis must be rejected before the conditions needed to test the second hypothesis are met. Likewise, if the second null hypothesis were not rejected the phenomenon dealt with by the third hypothesis would not have been observed. The third null hypothesis would therefore automatically remain unrejected. As it turns out, the phenomena predicted by the first and second hypotheses were observed. It was therefore possible to proceed through to testing the third hypothesis. The organization of this chapter reflects the contingent relationships among the three hypotheses. The first hypothesis is reviewed and its quantitative implications are made explicit. That is followed by the corresponding quantitative analyses. Then the second hypothesis is restated and the statistical approaches most appropriate for its quantitative evaluation are discussed. After those statistical analyses have been presented the third hypothesis is reviewed. Again, the statistical approaches most suitable for its evaluation are discussed and the results are presented.

The basic data in this study were dichotomous scores. Many authors have commented upon the relatively undeveloped state of the statisticians art with respect to dichotomous data and non-parametric analyses, especially for hypotheses such as those common in developmental psychology where order predictions are common (e.g., Wohlwill, 1973; Froman & Hubert, 1980). Fortunately, the relative clarity of the results in this study coupled with the ordinal nature
of the predictions make it easy to circumvent the difficulties posed by that lacuna. This is a situation in which the dichotomous data, the ordinal predictions, and the clean cut results make sophisticated statistics and parametric analyses (which are largely unavailable in any case) inappropriate.

The findings with respect to the first hypothesis included peculiarities that warranted more detailed attention. The composite scores for the systemic cognitive operations were of extremely diverse difficulty levels. Therefore they were decomposed into the component systemic scores and reanalysed in section B. Section C contains the results for the second hypothesis. Sections D and E show the analyses for hypotheses three and four respectively. In section F all of the results are summarized.

A. First Hypothesis with Composite Systemic Scores

The basic thrust of the first hypothesis is that the cognitive operations will have the same relationships to one another regardless of content domain. That is, one need not drastically reformulate Piagetian theory in order to examine cognitive development in the bio-ecological or societal domains of content. There will still be a concrete stage and a post-concrete stage. The cognitive operations will still be mastered in pretty much the same sequential order. More specifically, the first hypothesis makes two related predictions. One of these predictions is a more macroscopic version of the other. The more microscopic, or fine grained, part predicts that the difficulty orderings of cognitive operations will be the same across domains (i.e., seriation, linear transitivity, logical multiplication, class inclusion,
cyclic transitivity, cyclic integration\(^1\)). The more macroscopic version of hypothesis one complements the microscopic version, in allowing for some misordering among tasks within the same stage across domains while predicting that in no domain will tasks of different stages be misordered. Stated in a different way, the second or more microscopic variation of hypothesis one predicts that, whatever difficulty ordering of tasks may be empirically observed, all of the respondents who succeed at the least difficult postconcrete task will also have succeeded at the most difficult concrete stage task, but not vice versa. The null hypothesis, also in two parts, states (a) that the difficulty orderings of the task will vary haphazardly across domains, and (b) that all tasks will be of the same stage insofar as there will be no significant discontinuities in difficulty rankings between concrete stage tasks and post-concrete stage tasks in any domain.

(i) **Scalogram Difficulty Orderings**

The basic data needed to obtain difficulty ordering are the frequencies of passes on each task across the whole sample. Scalogram analysis (Guttman, 1950) yields difficulty orderings as a preliminary step in gauging the Guttman scale properties of a set of items (in this case the "items" are "tasks"). Figure 1 shows the percentage of respondents failing each task. The three vertical vectors correspond to the three content domains. The tasks falling in the upper region of the graph can be said to be more difficult than those

---

1. Since no physical domain version of cyclic transitivity and cyclic integration exist, the complete range of tasks only appeared in the biological and societal content domains. However, since the systemic cognitive operations were predicted to be more difficult than any of the concrete operational tasks it was supposed that they would be at least the same difficulty level as formal operational tasks. Therefore three formal operational tasks appear in the physical domain as reference points against which the difficulty of the systemic tasks can be gauged.
Figure 1
Scalogram difficulty orderings with composite systemic scores by domain.

KEY
S = Seriation
LT = Linear Transitivity
LM = Logical Multiplication
C = Class Inclusion
Prob = Probability
Iso = Isolation of Variables
CV = Combination of Variables
CyTr = Cyclic Transitivity
CyIn = Cyclic Integration

Percentage Failing (Difficulty)

100
90
80
70
60
50
40
30
20
10

Physical
Biological
Societal
Domains

S(0)
LT(12)
C(18)
CyTr(61)
CyIn(73)
CyIn(74)

SM(5)
LM(9)
C(16)
LM(12)
LT(8)
LT(11)
S(4)

Prob(39)
Iso(44)
CV(53)
in the lower region. In figure 1 it can be seen that the predicted difficulty ordering of tasks was obtained in the bio-ecological and societal domains. In the physical domain, however, certain of the concrete operational tasks were misordered. This was mainly a result of the linear transitivity task being more difficult than the logical multiplication and the class inclusion tasks. The latter two were tied with each other. The seriation tasks in all domains were the easiest, so much so that there were no cases of failures at that cognitive operation in either the physical or the bio-ecological domain. Overall, the tasks conformed to the predicted difficulty orderings across domains.

The scalogram results also provide preliminary information relevant to the macroscopic version of the first hypothesis. The macroscopic version amounted to a prediction of stage-like discontinuities in difficulty rankings within each domain. The visual impression given by figure 1 is that there are stage-like gaps and they appear in every domain at approximately the same places. The concrete operational tasks all fall between the 0% to 18.8% failure level. The formal operational tasks span a range comparable to that covered by the concrete tasks (approx. 15 to 19 percentage points). The two cyclic transitivity scores encompass the formal operational scores and appear to be about the same distance from the concrete scores as the formal scores are. The distance from the highest concrete task (i.e., class inclusion, bio-ecological domain) to the lowest formal operational task is 21.8 percentage points. The distance to the lowest systemic (i.e., cyclic transitivity, societal domain) task is 17.7 percentage points. Therefore the distance that separates the most difficult concrete stage task from the least difficult post-concrete stage tasks is approximately 17.7 to 21.8 percentage points. That is roughly the same range covered by all the tasks in a single stage
(i.e., 15 to 19 percentage points). On the face of it, then, it appears that
there are at least two separate stages in all domains, the concrete and the
post-concrete. These data predispose one to reject the null hypothesis that
all the tasks are from the same stage. Moreover, given the assumption that
the data do reflect two different stages, a "stage sized gap" between tasks
can be estimated to be approximately 17.7 to 21.8 percentage points.

While the cyclic transitivity tasks fall in roughly the same difficulty
range as the formal operational tasks, the least difficult cyclic integration
task was 21.8 percentage points more difficult than the most difficult formal
operational task. This is exactly the same distance as that between the
highest concrete task and the lowest formal task. Since a stage sized gap
separates the cyclic integration tasks from the bulk of the other post-
concrete tasks, it make sense to inquire into the possibility of cyclic inte­
gration constituting a possible fifth stage of cognitive development.

(ii) Guttman Steps

The information presented on figure 1 does not indicate how much variance
there was in the difficulty level data. If there were no respondents violating
the mean ordering, then the increase in difficulty from one task to the next
most difficult task in the sequence would be called a "Guttman step." Where
the comparison between two tasks forms a Guttman step practically all of
the respondents who passed the more difficult task also passed the less dif­
ficult task but not nearly as many of those who passed the easier task also
passed the harder task. Non-Guttman steps are characterized by varying degrees
of equivalence between the adjacent tasks in terms of the probability of pass­
ing or failing either. With non-Guttman steps there will tend to be as many
respondents who passed the harder task but failed the easier one as vice versa. The macroscopic part of the first hypothesis predicts that there should be non-Guttman steps between adjacent concrete stage tasks, a Guttman step between the most difficult concrete task and the least difficult post-concrete task, and non-Guttman steps between adjacent post-concrete tasks.

(iii) Converging Techniques

There is no one statistic which adequately informs us about the Guttman-like nature of each step in the difficulty ordering. There are, however, several approaches which give partial information. By using all of these statistics conjointly as descriptive aids enough relevant information can be extracted to evaluate the second hypothesis. It must be emphasized, however, that the nature of this probing does not allow any significance testing. The results are reported in terms of degree of association or difference between and among tasks. The hypothesis does not and cannot stand or fall on the results of any one of these statistical analyses. The final decision on the second hypothesis is entirely dependent upon the composite picture provided by these various descriptive aids.

The Guttman-like nature of the difficulty orderings in each domain were examined by drawing together the results of several statistics. Figure 1, based as it is on percentages of respondents passing each task, has already provided some information. Guttman's coefficient of reproducibility for scalogram analyses contributes information about the Guttman scale qualities of the whole sequence of tasks in each domain. Looking at specific steps within sequences, the frequencies and proportions of respondents following or violating the predicted pass/fail pattern are reported. Using tests for the significance of differences between proportions, $z$ scores are obtained
which, used for description only, provide a more refined index of the Guttman nature of the relationship between adjacent tasks.

With each of the above mentioned statistics there are strengths, weaknesses and general operating characteristics which must be made explicit. This is undertaken as each of these statistics is introduced and brought to bear upon a particular hypothesis. Hopefully, this serial presentation will contribute to clarity by staying close to the data and avoiding a contextless debate about the pros and cons of various statistical alternatives.

(iv) Reproducibility Coefficient

Guttman's coefficient of reproducibility is a statistic that gives information about the overall Guttman-like qualities of an ordered set of items. It gives no information about which steps in the ordering are Guttman steps. Coombs, Dawes, and Tversky (1970) state that a reproducibility coefficient of 0.90 is "good". The reproducibility coefficient for all of the tasks in figure 1, ordered together irrespective of domain, is 0.918. The coefficients by domain are (a) physical 0.958, (b) biological 0.942, and (c) social 0.950. Therefore this criterion tells us that the observed task orderings do, in fact, constitute Guttman scales. The problem is that this is not precisely what we want to know. The huge Guttman step between the easiest seriation task and the most difficult cyclic integration task contributes to the magnitude of the reproducibility coefficient. The hypothesis under consideration does not deal with that huge Guttman step. It deals only with steps between adjacent tasks. Therefore Guttman's coefficient of reproducibility is in itself essentially irrelevant for the present purposes.

The coefficient of reproducibility, however, can be combined with the coefficient of minimum marginal reproducibility to produce a more useful index called "the coefficient of scalability". The coefficient of minimum marginal reproducibility (MMR) is the minimum coefficient of reproducibility that could
have been obtained given the proportion of respondents passing and failing each of the items. It is affected by ceiling effects and extreme skews on individual items. When the MMR is subtracted from one (i.e., 1 - MMR = the "reciprocal" of the MMR) the result is a measure of the range in which the coefficient of reproducibility was free to vary. When the MMR is subtracted from the coefficient of reproducibility the result is a measure of the "percent improvement" in prediction that the obtained pattern yields over the MMR base level of prediction. The coefficient of scalability uses both of these measures. Dividing the percent improvement by the reciprocal of the MMR yields the coefficient of scalability. The coefficient of scalability "should be well above .6 if the scale is truly undimensional and cumulative (Nie, Hull, Jenkins, Steinbrenner, and Bent, 1975, p. 533)."

The scalability coefficient for all of the tasks in figure 1, ordered together irrespective of domain is 0.585. This is as one would expect considering that these are three domains corresponding to three correlated but distinct dimensions in the data. The scalability coefficients by domain are (a) physical 0.838, (b) bio-ecological 0.696, and (c) societal 0.714. This criterion tells us that, within domains, the tasks may form undimensional, cumulative scales. We do not know that they do form undimensional, cumulative scales but one falsification test has been passed.

Two other descriptive statistics are used to provide information that is relevant to the second part of the first hypothesis. First, in subsection (v), we examine the frequencies and proportions of respondents failing the easier task of a pair while passing the supposed harder task. Second, in subsection (vi), we look at the differences between the proportions of
respondents passing one task of a pair while failing the other. Particulars concerning the use of each statistic are discussed when the statistic is first introduced.

(v) **Frequencies and Proportions**

The information presented in figure 1 strongly suggests that the well documented discontinuity between concrete operational tasks and formal operational tasks in the physical domain is paralleled by a similar gap between concrete tasks and systemic tasks in the bio-ecological and societal domains. What remains to be shown is that these latter two stage-like gaps are as clean cut as the gap between the concrete and the formal tasks. If the bio-ecological and societal steps from concrete to post-concrete stages are less Guttman in character than the corresponding physical domain step then the predictions of parallel sequencing across domains are less than fully supported.

Table I is presented in three parts, one for each content domain. The table shows the frequencies of respondents passing one task of a pair while failing the other. This includes pairs that are adjacent in the difficulty orderings. The highest ranked (most difficult) concrete operational task to the physical domain (table I, part A) was linear transitivity. It is adjacent to the least difficult formal operational task (i.e. probability). Note that as one reads from left to right it is at the juncture between these two tasks where the failure rate increases dramatically for the group of respondents who passed each of the successive concrete operational tasks (i.e. the top four rows). By contrast, the bottom three rows show data for respondents who had passed formal operational tasks. When one reads the frequency data from left to right for these respondents, there is no dramatic
Table I

Frequencies and proportions of respondents passing one task of a pair while failing the other.

**Part A: Physical Domain**

<table>
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<tr>
<th>Passed Task</th>
<th>Total Passes</th>
<th>Logical Multiplication</th>
<th>Class Inclusion</th>
<th>Linear Transitivity</th>
<th>Probability</th>
<th>Isolation of Variables</th>
<th>Combination of Variables</th>
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### Table I (cont'd)

#### Part C: Societal Domain

**Failed Task**

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<th>Logical Multiplication</th>
<th>Class Inclusion</th>
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increase in failure frequencies as the concrete to post-concrete juncture is crossed. This pattern reflects the well documented discontinuity between modes of cognitive organization in the concrete operational stage versus the formal operational stage.

Parts B and C of table 1 indicate that this pattern is replicated with the non-traditional content and the systemic post-concrete operations. The bio-ecological domain frequencies are shown on part B of table 1. The concrete to post-concrete discontinuity in failure rates is replicated here. In fact, it is even more pronounced. In the physical domain (table I, part A) the failure frequency for the easiest formal task was 27 respondents higher than for the hardest concrete task. In the bio-ecological domain (table I, part B) however, the easiest post-concrete task is 43 respondents more difficult than the hardest concrete task. This rate drops considerably in the societal domain (table I, part C) to a difference of 19 respondents. The reason for this attenuation of the between stage gap seems to have something to do with one task, the societal cyclic transitivity task.

The societal cyclic transitivity failure rates are closer to those for concrete tasks than to those for the societal cyclic integration task. The societal cyclic transitivity task was always presented after the bio-ecological version of the same task. Perhaps the cyclic transitivity operations are particularly susceptible to practice effects. Perhaps one of the components of cyclic transitivity is actually a concrete stage operation. In section B of this chapter, that possibility will be explored with an examination of the performances of the components of the systemic operations.

The overall impression given by a left to right reading of the frequency tables is that the stage-like discontinuities in difficulty levels of tasks
are found across all domains. The societal cyclic transitivity task seems to be a somewhat intermediate case but overall it appears that the Piagetian notions of stages can safely be extended to the bio-ecological and the societal content domains.

On all three parts of table I there is a diagonal of blank cells running from the top left to the bottom right. The entries below this diagonal represent frequencies of cases where respondents passed the harder task of the pair but failed the easier one. These are cases of non-Guttman patterns. In the physical domain the cells at the intersection of passed formal tasks and failed concrete tasks have the lowest frequencies. This indicates a Guttman step between concrete operations and formal operations. The frequencies of non-Guttman cases is higher for tasks of the same stage. In other words, it is more probable that a respondent would pass a harder concrete task, for example, while failing an easier one than it is that he or she would pass a formal task and fail a concrete task. Likewise, there were more cases of non-Guttman performance among the formal tasks when paired with each other. Looking across domains, again, we see that the pattern found with traditional Piagetian task contents is repeated with bio-ecological contents (part B) and, to a lesser extent, with societal contents (part C). In the societal domain the cyclic integration task shows the stage-like discontinuity more clearly than does the cyclic transitivity task. Again, the analysis of the data with the systemic scores grouped by components is intended to help clarify the interpretation of this finding.

The proportions presented in table I show the same pattern of results as the frequencies. There are discontinuities in difficulty levels across stages in all domains and in all domains the evidence for Guttman steps is
stronger across stages than within stages. The advantage of considering proportions over frequencies is that the proportions take into account how many respondents passed the first task of the pair being considered. This facilitates the comparison of pairs. The proportions are included in table I mainly for their relevance to the analyses presented in the next subsection where the differences between proportions are examined (table II).

(vi) **Z Scores for Proportions**

Thus far Guttman steps have been discussed in general terms. In this section an attempt is made to give some quantitative definition of the concept so far as is possible. At the same time one more statistical approach is brought to bear upon the part of the first hypothesis dealing with across domain patterns in difficulty groupings. By using proportions it is possible to take into account the variability in the number of respondents passing the "passed" member of each "pass A/fail B" pair of tasks. This allows for the informative comparison of the "pass A/fail B" pair with the "pass B/fail A" pair. It must be reiterated, however, that no significance testing is possible. These statistics are presented for purely descriptive purposes. The closest we can come to significance testing is to set out criteria for unequivocal cases of a Guttman step and a non-Guttman step. In ambiguous cases the statistics are reported for the sake of completeness but no attempt will be made to use those cases in determining the fate of the hypotheses.

The degree to which a step is a Guttman step can be indexed by z scores produced by tests of significance between proportions of respondents passing or failing ordinally adjacent tasks within domains. The formula for the z scores (Bruning & Kintz, 1968) has the difference between the two proportions being divided by the standard error of the difference. The z scores compare
rates of non-disconfirmation against rates of disconfirmation for both tasks. They take into account the number of respondents passing each task of a pair regardless of performance on the other task. If A and B are two adjacent tasks, then the step from A (the easier task) to B (the more difficult task) would not be a Guttman step if the proportion of respondents simultaneously passing A while failing B were much the same as the proportion passing B while failing A. The step would be a Guttman step if the proportion passing A while failing B were much greater than the converse proportion. Those who passed B would have also passed A, not failed it, because A would be easier than B for everyone. A certain amount of error must, of course, be allowed. The question is, how much?

There are no conventional criteria for deciding when a z score does or does not reflect a Guttman step. Also, having decided that significance testing would be inappropriate here, it would be inappropriate to retreat to the traditional criterion of a 95% confidence interval. Instead, available theoretical criteria will be applied. On the basis of well accepted theoretical statements backed up by years of research, it can be safely assumed that the step from the most difficult concrete operational task to the least difficult formal operational task is a Guttman step. If it is not a statistically perfect Guttman step, it is at least as Guttman-like as it needs to be for the purpose of indexing a stage-like discontinuity in difficulty levels for the tasks administered to the present sample of respondents. The least difficult formal operational task was the probability task. The most difficult concrete operational task was the class inclusion task in the bio-ecological domain. The proportion of respondents passing probability while failing bio-ecological class inclusion was 0.053. The proportion passing bio-ecological class inclusion while failing probability was 0.308. The difference between these two proportions (Bruning and Kintz, 1968, p.199) was $z = 5.822$. It might be
argued, however, that this z underestimates the size of the difference. The bio-ecological content might have added to the difficulty of the class inclusion task. In that case figurative factors alone would be leading us to deem some gaps as stage-like or Guttman-like. Therefore a more stringent criterion was adopted. Instead of taking the difference between the proportion passing and failing the probability task and the highest concrete task from any of the three domains, it was decided to replace the latter task with the highest concrete task in the physical domain only. That was the physical domain linear transitivity task. This restriction to physical domain tasks is also more in accord with the supporting theory and research that justify choosing the concrete to formal difference as an example of an unequivocal Guttman step. The research was largely based on tasks containing physical content. The proportion of respondents passing probability while failing physical linear transitivity was 0.018 (see table I, part A). The proportion passing linear transitivity while failing probability was 0.333. The difference between these proportions was \( z = 7.663 \). All \( z \) scores that are equal to or greater than \( \pm 7.663 \) will consequently be taken to be unequivocal Guttman steps.  

At the other end, there is a need for an unequivocal example of a non-Guttman step. One possible criterion might be based on the assumption that the step between tasks of the same stage are non-Guttman steps. Given that assumption, one might use the average \( z \) for differences between adjacent tasks within stages as the criterion for a non-Guttman step. That would probably be a fair estimate but since the aim is to have an unequivocal criterion, 

2. Since the older respondents did not receive all concrete tasks and the younger ones did not receive all systemic tasks, this criterion is conservatively biased. The grade 7 students were given all tasks. The criterion \( z \) for a Guttman step calculated on their data alone is \( z = 1.214 \). The criterion of \( z = 7.663 \), therefore, is very stringent.
a more stringent criterion would be desirable. A second possibility would be to take the z for the smallest step within a stage. In the physical domain the smallest step is between logical multiplication and class inclusion. In fact, these two tasks were tied in terms of difficulty level. That means that the smallest step in the physical domain was no step at all. This seems to be the most unequivocal example of a non-Guttman step that one could expect to find. It is not only a non-Guttman step, it is a non-step. The proportion of respondents passing logical multiplication while failing class inclusion was 0.044. The same proportion of respondents passed class inclusion while failing logical multiplication. The z score for the difference between these proportions was \( z = 2.380 \). Therefore, z scores equal to or less than 2.380 are taken to be unequivocal cases of non-Guttman steps. Again, the intermediate scores (between 2.380 and 7.663) are categorized as ambiguous cases ("?"") and left at that.

Table II shows the z scores for all the steps by domain of content. These are on the diagonals. For the standard domain the only unequivocally Guttman step is between the concrete tasks and the formal tasks. Within each of those stages there is one clear non-Guttman step and one ambiguous case. In the biological domain clear Guttman steps separate the concrete tasks from all the systemic tasks. There is a non-Guttman step between linear transitivity and logical multiplication. The other steps are ambiguous. In the societal domain the diagonal contains two non-Guttman steps between concrete stage tasks and one ambiguous case. The cyclic transitivity task is only an ambiguous step apart from any of the concrete tasks except the easiest one (i.e. seriation). The cyclic integration task was a Guttman step more difficult than all the other tasks in the societal domain including the cyclic transitivity task.
Table II

Z scores for differences between proportion of respondents passing one task of a pair while failing the other.

Part A: Physical Domain

Less Difficult Task of Pair

<table>
<thead>
<tr>
<th>More Difficult Task of Pair</th>
<th>Seriation*</th>
<th>Logical Multiplication</th>
<th>Class Inclusion</th>
<th>Linear Transitivity</th>
<th>Probability</th>
<th>Insolation of Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Inclusion</td>
<td>-</td>
<td>2.380</td>
<td>(NG)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear Transitivity</td>
<td>-</td>
<td>2.489</td>
<td>(G)</td>
<td>2.698</td>
<td></td>
<td>(G)</td>
</tr>
<tr>
<td>Probability</td>
<td>-</td>
<td>9.396</td>
<td>(G)</td>
<td>9.396</td>
<td>7.663</td>
<td>(G)</td>
</tr>
<tr>
<td>Isolation of Variables</td>
<td>-</td>
<td>10.356</td>
<td>(G)</td>
<td>10.356</td>
<td>9.148</td>
<td>2.315</td>
</tr>
<tr>
<td>Combination of Variables</td>
<td>-</td>
<td>12.230</td>
<td>(G)</td>
<td>11.451</td>
<td>9.126</td>
<td>4.064</td>
</tr>
</tbody>
</table>

* No variance on this variable

NG = Non-Guttman step (≥2.380)
G = Guttman step (≥7.663)
? = ambiguous step (between 2.380 and 7.663)
Table II (cont'd)

Part B: Bio-ecological Domain

Less Difficult Task of Pair

<table>
<thead>
<tr>
<th>More Difficult Task of Pair</th>
<th>Seriation*</th>
<th>Linear Transitivity</th>
<th>Logical Multiplication</th>
<th>Class Inclusion</th>
<th>Cyclic Transitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logical Multiplication</td>
<td>-</td>
<td>0.378</td>
<td>(NG)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Inclusion</td>
<td>-</td>
<td>3.488</td>
<td>2.653</td>
<td>(?)</td>
<td>(?)</td>
</tr>
<tr>
<td>Cyclic Transitivity</td>
<td>-</td>
<td>13.648</td>
<td>13.463</td>
<td>11.783</td>
<td>(G)</td>
</tr>
<tr>
<td>Cyclic Integration</td>
<td>-</td>
<td>18.166</td>
<td>17.946</td>
<td>13.985</td>
<td>2.813</td>
</tr>
<tr>
<td>More Difficult Task of Pair</td>
<td>Seriation</td>
<td>Linear Transitivity</td>
<td>Logical Multiplication</td>
<td>Class Inclusion</td>
<td>Cyclic Transitivity</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-----------</td>
<td>---------------------</td>
<td>------------------------</td>
<td>----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Linear Transitivity</td>
<td>3.316</td>
<td>(?)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logical Multiplication</td>
<td>3.604</td>
<td>0.377</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Inclusion</td>
<td>4.259</td>
<td>1.758</td>
<td>1.265</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyclic Transitivity</td>
<td>8.317</td>
<td>6.319</td>
<td>6.142</td>
<td>4.407</td>
<td></td>
</tr>
</tbody>
</table>
To summarize, the first hypothesis was generally supported by the data. The stages and discontinuous gaps between them were found in the two new domains. The finding that the societal cyclic transitivity task was intermediate between the concrete stage tasks and the cyclic integration task deserves further attention. In the next section the systemic scores are grouped by their constituent components in an attempt to provide a finer grained analysis.

B. First Hypothesis with Component Systemic Scores

The systemic tasks were devised to assess the upper reaches of the child's developing understanding of social organizations. While the formally stated hypotheses bear upon interpretations of the ontogeny of that understanding, the systemic cognitive operations in themselves are an attempt to fathom the nature of that understanding when it is developed. Therefore let us take a closer look at those tasks.

Since the systemic tasks were newly devised for this study, there remains scope for their refinement. The reporting of detailed item analyses leading to improved versions of the task is an undertaking for another study. For now, however, there are some immediate refinements that can be attempted in order to sharpen our understanding of what these systemic cognitive operations entail. Specifically, both the cyclic transitivity and the cyclic integration scores can be easily decomposed into pairs of subscores which seem to reflect the mastery of quite different cognitive operations.

(i) Cyclic Transitivity Components

The scores for the systemic tasks were based on working definitions of their cognitive operations. For cyclic transitivity the definition was operationalized in two ways. First, in the "layout" procedure respondents were:
presented with five cards, each showing a picture of an element in the cycle. The respondent was asked to arrange the pictures beside one another in a way that would show how they were related. The wording of the request varied depending on the content of the cycle but successful performance always involved arranging the cards in a circle. Second, the "recycling" procedure involved the respondent in explaining how a commodity could pass through the same element twice. In the biological domain the commodity was a DDT molecule and in the social domain it was a $1 bill. Correct explanations had the commodity moving around the circle from one adjacent element to the next. This procedure presupposed that respondents had the correct circular arrangement of cards displayed in front of them. Thus an understanding of the relations underlying the "layout" was a prerequisite for the "transitive recycling" component. Since it was not known a priori whether these two procedures would be of equal difficulty, it was decided that their scores would be combined in order to have an overall picture of the respondents ability with the cyclic transitivity operation (see Appendix D for scoring rules and rules for combining scores). Below, these two components are treated separately in a reanalysis of the data.

(ii) Cyclic Integration Components

In the cyclic integration task the cycle used in the cyclic transitivity task remained displayed on cards in front of the respondent but the cycle itself was construed as one of three levels of organization. The elements of the cycle were the subordinate level and the forces which integrated the cycle across time and changing circumstances were the supraordinate level. The component that is being called "systems analysis" involved the ability to explain the impact of cyclic processes on individual elements of the cycle.
The other component of the overall cyclic integration score is being referred to as "systems synthesis". Systems synthesis involved explaining how the nature of the cycle itself would change under the impact of supraordinate forces. There were no graphic representations of the supraordinate level. Rather, it had to be inferred, discovered or "synthesized" out of the available knowledge about the cycle and its parts. The cyclic integration scores were combinations of the scores for systems analysis and systems synthesis (see Appendix D for scoring rules and combining rules).

The combination of component scores into cyclic transitivity and cyclic integration scores was based on the assumption that the components measured aspects of the same cognitive operation. This assumption can be verified by reanalysing the data while substituting two component scores for each of the four composite systemic scores.

First, a scalogram analysis is examined to see how difficult the components were relative to other tasks and to each other. Then a table of z scores is reviewed to see how well the first hypothesis fared with the component scores.

(iii) Scalogram and Z Scores for Components

Scores by Domain. The difficulty levels are shown in figure 2. The most notable revelation is the relative easiness of the cyclic transitivity layout procedure, especially in the societal domain. Table III shows the z scores for pairwise comparisons of the component scores with each other and with the other tasks. The z scores for the societal domain cyclic transitivity layout procedure with each of the four concrete tasks shows that in no case is it an unambiguous Guttman step apart. This was not true for the layout procedure in the bio-ecological domain nor for any other component score.
Figure 2

Scalogram difficulty orderings with component systemic scores (a) by domain, and (b) across domains.

KEY

S = Seriation
LT = Linear Transitivity
LM = Logical Multiplication
C = Class Inclusion
Prob = Probability
Iso = Isolation of Variables
CV = Combination of Variables

Lay = Layout Component of
Cyclic Transitivity
SyAn = Systems Analysis Component of
Cyclic Integration
SySy = Systems Synthesis Component of
Cyclic Integration
TRec = Transitive Recycling Component of Cyclic Transitivity

(a) Scores by Domain

(b) Across Domains
Table III, Part A

Bio-ecological domain Z scores for differences between proportions of respondents passing one task of a pair while failing the other, reported with systemic scores in components

<table>
<thead>
<tr>
<th>More Difficult Task of Pair</th>
<th>Seriation</th>
<th>Linear Transitivity</th>
<th>Logical Multiplication</th>
<th>Class Inclusion</th>
<th>Layout Procedure</th>
<th>Systems Analysis</th>
<th>Systems Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logical Multiplication</td>
<td>-</td>
<td>0.378 (NG)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Inclusion</td>
<td>-</td>
<td>3.488 (?)</td>
<td>2.653 (?)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layout Procedure</td>
<td>-</td>
<td>12.161 (G)</td>
<td>11.984 (G)</td>
<td>9.041 (G)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systems Analysis</td>
<td>-</td>
<td>13.383 (G)</td>
<td>13.200 (G)</td>
<td>10.671 (G)</td>
<td>0.889 (NG)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systems Synthesis</td>
<td>-</td>
<td>14.491 (G)</td>
<td>14.301 (G)</td>
<td>10.671 (G)</td>
<td>1.894 (NG)</td>
<td>0.936 (NG)</td>
<td></td>
</tr>
<tr>
<td>Transitive Recycling</td>
<td>-</td>
<td>17.711 (G)</td>
<td>17.495 (G)</td>
<td>15.541 (G)</td>
<td>4.632 (?)</td>
<td>3.084 (NG)</td>
<td>2.319 (NG)</td>
</tr>
</tbody>
</table>
Table III, Part B

Social domain Z scores for differences between proportions of respondents passing one task of a pair while failing the other, reported with systemic scores in components

<table>
<thead>
<tr>
<th>Less Difficult Task of Pair</th>
<th>Seriation</th>
<th>Linear Transitivity</th>
<th>Logical Multiplication</th>
<th>Class Inclusion</th>
<th>Layout Procedure</th>
<th>Systems Analysis</th>
<th>Systems Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear Transitivity</td>
<td>3.316</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear Transitivity</td>
<td>(NG)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logical Multiplication</td>
<td>3.604</td>
<td>0.377</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Inclusion</td>
<td>4.259</td>
<td>1.758</td>
<td>1.265</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layout Procedure</td>
<td>7.238</td>
<td>4.930</td>
<td>4.738</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
These results parallel those obtained with the composite cyclic transitivity score. Apparently it was the layout component of the cyclic transitivity score that was pulling that operation towards the concrete tasks and away from the cyclic integration task.

The scalability coefficients by domain are (a) physical 0.838, (b) bio-ecological 0.5868, and (c) societal 0.5436. These coefficients are considerably lower than these obtained using the composite scores for the systemic tasks (i.e. physical 0.838, bio-ecological 0.696, societal 0.714). The physical domain had no systemic tasks so it is the same. With component scores the bio-ecological and the societal domains fall below the 0.6 criterion for being undimensional and cumulative scales. The drop in the scalability coefficients may partially reflect the relatively greater weight that the post-systemic tasks have when the tasks for the domain include component scores rather than composite scores. There are 2 composite scores per domain. Since there are 4 concrete tasks, the composites are one third of the six item total. Therefore the systemic tasks affect the scalability coefficients more when they are reported as components than when they are reported as composites.

Even though the "percent improvement" values stayed about the same, the minimum marginal reproducibility coefficients were lower when the domains contained component scores than when they contained composite scores. This means there was more possible variation to be accounted for by the ordering patterns. However, there were also more violations of the ordering patterns when the systemic tasks were reported as components. This is consistent with the z scores in the bottom right corners of parts A and B of Table III. The
implication is that there is considerable misordering of the systemic components amongst themselves in both domains.

Across Domain Scores. The rightmost column in figure 2 shows the difficulty ordering of the components when we collapse across domains. This "across domain" ordering is based on across domain scores. The across domain component scores were produced by counting simultaneous passes of both domains as passes on the across domain score. If the component score for one domain had been a fail, then the across domain score would also be a fail. The across domain column in figure 2 shows the formal scores clumped together below the systemic scores. Table IV shows the z scores for the steps between the formal tasks and the systemic component tasks. Those systemic tasks which are a clear Guttman step more difficult than two out of the three formal tasks are marked with a "G" (for Guttman step) in the step column. Those that are clear non-Guttman steps apart from two of the three formal tasks are marked with an "NG" (for non-Guttman step). Question marks indicate the ambiguous cases.

The overall impression from figure 2 and table IV is that a stage-sized gap separates both transitive recycling and systems synthesis from the formal operational tasks. If the stage-sized gap results from the greater developmental maturity required to master the systemic cognitive operations involved then it could be argued that those systemic operations constitute a fifth stage of cognitive development. The data available are inadequate to settle the fifth stage question conclusively but further analyses could establish how well the data meet some of the criteria for a stage interpretation. The z scores have already contributed to proving the size of the gap. A further contribution is provided by cluster analyses (see section C(i)).
Table IV

Z scores between formal tasks and systemic components

<table>
<thead>
<tr>
<th></th>
<th>Probability</th>
<th>Isolation of Variables</th>
<th>Combination of Variables</th>
<th>Overall Step Type*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Formal Tasks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probability</td>
<td>-</td>
<td>-2.315</td>
<td>-4.064</td>
<td>NG</td>
</tr>
<tr>
<td>Isolation of Variables</td>
<td>2.315</td>
<td>-</td>
<td>-2.545</td>
<td>NG</td>
</tr>
<tr>
<td>Combination of Variables</td>
<td>4.064</td>
<td>2.545</td>
<td>-</td>
<td>NG</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bio-ecological Components</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layout</td>
<td>3.943</td>
<td>2.493</td>
<td>0.415</td>
<td>NG</td>
</tr>
<tr>
<td>Transitive Recycling</td>
<td>9.669</td>
<td>7.794</td>
<td>6.013</td>
<td>G</td>
</tr>
<tr>
<td>Systems Analysis</td>
<td>5.046</td>
<td>4.141</td>
<td>1.672</td>
<td>?</td>
</tr>
<tr>
<td>Systems Synthesis</td>
<td>6.991</td>
<td>5.547</td>
<td>2.234</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Social Components</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layout</td>
<td>-3.010</td>
<td>-4.936</td>
<td>-5.953</td>
<td>?</td>
</tr>
<tr>
<td>Transitive Recycling</td>
<td>8.720</td>
<td>7.699</td>
<td>3.042</td>
<td>G</td>
</tr>
<tr>
<td>Systems Analysis</td>
<td>6.040</td>
<td>4.004</td>
<td>2.371</td>
<td>?</td>
</tr>
<tr>
<td>Systems Synthesis</td>
<td>9.915</td>
<td>7.984</td>
<td>4.357</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Across Domain Scores</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layout</td>
<td>4.115</td>
<td>2.812</td>
<td>0.605</td>
<td>?</td>
</tr>
<tr>
<td>Transitive Recycling</td>
<td>11.730</td>
<td>10.682</td>
<td>7.522</td>
<td>G</td>
</tr>
<tr>
<td>Systems Analysis</td>
<td>5.716</td>
<td>4.802</td>
<td>2.314</td>
<td>?</td>
</tr>
<tr>
<td>Systems Synthesis</td>
<td>10.875</td>
<td>8.643</td>
<td>4.997</td>
<td>G</td>
</tr>
</tbody>
</table>

*The overall step type for each component against all three formal operations is determined by whatever step type two out of three of the Z scores happen to be. Where all three Z scores are of a different type, the overall type is a "?".*
C. Second Hypothesis

The second hypothesis states that the systemic operations, or at least some of their components represent a fifth stage of cognitive development above formal operations. The corresponding null hypothesis is that the systemic operations and all of their components are alternate forms of adult cognition, equal in difficulty to formal operations. The quantitative testing of this hypothesis amounts to an attempt to locate the difficulty levels of the systemic tasks in relation to those for the formal operations. Do they cluster together or is the difference in their difficulty levels enough to set at least some systemic components apart from the formal operational cluster? As the terminology used in phrasing the problem suggests, the most appropriate statistic to assess the second hypothesis is cluster analysis.

(1) **Cluster Analysis of Components**

Cluster analysis is often referred to as an analogue of factor analysis for dichotomous data. The clustering algorithm used was an agglomerative one by Ward (1963). It produces a dendrogram which, at one end, indicates which of the \( n \) items entered are most similar and, at the other end, shows which of the clusters of items built up in the middle are least similar. Figure 3 shows the dendrogram produced by this analysis on all the concrete, formal, and component systemic scores. The last two clusters to be forced together by the algorithm are the concrete tasks and the remaining formal and systemic tasks. The error produced by forcing these two clusters into one cluster is by far the greatest error produced by any joining operation in the entire analysis. This dramatic rise in the error term, however, must be interpreted with some caution. According to Everitt (1974; p.78), Ward's method typically, "...produces
Figure 3

Clustering Analysis Dendrogram with Scores by Domain and Systemic Scores by Component

Domain Code

The last capital letter in each abbreviated task label (see KEY for Figures 1 and 2) indicates the domain. A = Physical B = Bio-ecological C = Societal
a dendrogram with large changes in level, especially going from two groups to one group. This would probably lead the investigator to infer the presence of two groups." Everitt made these comments in comparing Ward's method with the single linkage method and the centroid method. Each method has its advantages and disadvantages. The investigator can avoid being misled if the distorting operating characteristics of each algorithm are kept in mind and taken into account in interpreting the results. With Ward's method it is important to remember that the error term for the last joining will be unusually high and may obscure equally important differences between the groups joined in going from 3 to 2 groups.  

Scores by Domain. The logarithmic graph of error terms shown along the ordinate of figure 3 is designed to give an approximate visual correction for the distortion. The higher the error rate and the steeper the slope the more dissimilar are the groups being joined in that step. In the present analysis the concrete versus non-concrete groupings are the most different. The difference that separates them is not proportionately as large as the error term would indicate. The difference is probably more comparable to that separating the clusters joined in the second last grouping. That is, the concrete tasks are not much further from the other tasks than the predominantly formal operational cluster is from the systemic tasks.

While the z scores indicated that the top cluster was smaller than the formal cluster, this cluster analysis showed the reverse. The ambiguous cases

3. It is actually the last 5% ± 3% of the joinings which are subject to the distortion in error terms. In the present case, with 17 items, the distortion only takes noticeable effect in the last 2 joinings (i.e., from 3 to 2 groups and from 2 to 1 groups).
were grouped upwards. The fact that they split away from the formal tasks and joined the top systemic tasks only emphasizes how ambiguous these cases are.

**Across Domain Scores.** Some of the ambiguity can be reduced by entering the across domain scores into a cluster analysis. Figure 4 shows the dendrogram produced by the cluster analysis on the across domain scores. From this perspective, the impression gained from the z scores is corroborated. The cyclic transitivity recycling score and the systems synthesis score form a separate cluster above formal operations in difficulty. To simplify the discussion of these two scores we will refer to them as the "upper systemic" scores or tasks, as the case may be. Even with the logarithmic scaling, the error term for the last joining still appears disproportionately large relative to the earlier error terms. Also the systemic cluster would appear more distinct from the formal cluster if the lower systemic scores (systems analysis and the layout component) were not included in the analysis. Deleting those scores makes sense if we are mainly interested in seeing how far and upper systemic operations are from the standard formal operations alone. It is, after all, the three standard formal operations by themselves which give us the best estimate of where formal operations fall relative to systemic operations. Therefore, two additional cluster analyses are presented in order to gauge the size of the gap between formal operations and the distinctive upper systemic operations.

Figure 5 shows the dendrogram for a cluster analysis of across domain scores. The concrete operational scores were coded as "passes" if two out of the three examples of that cognitive operation had been passed. The logarithmically scaled error term increases on the ordinate show that the increase
Cluster Analysis Dendrogram with Across Domain Scores and Systemic Scores by Components

Coding of Across Domain Scores

ST pass = pass 2/3 of seriation tasks
LT pass = pass 2/3 of linear transitivity tasks
MT pass = pass 2/3 of logical multiplication tasks
CT pass = pass 2/3 of class inclusion tasks
Lay pass = at least a 3-level pass in one domain and not less than a 2-level fail in the other.
SyAn pass = same as Lay pass
SySy pass = same as Lay pass
TRec pass = same as Lay pass
Figure 5

Cluster Analysis Dendrogram on Across Domain Scores with Lower Systemic Scores Deleted
(see Figure 2 for KEY and Figure 4 for Coding of Across Domain Scores)
caused by joining the systemic operations with the formal operations is fairly comparable to that caused by joining the concrete operations with the rest.

**Summary Scores.** Finally, in order to get the broadest overview, the concrete and formal stage scores were reduced to one number each and were submitted to a cluster analysis along with the scores for the lowest of the upper systemic components (i.e., across domain systems synthesis). We should expect a fairly even sized error term increase across the two joinings only if the systemic score were as far from the formal stage score as the formal stage score is from the concrete stage score. This is precisely what is shown in figure 6. Numerically, the increase in error for the joining of the formal score with the systemic score (67.5) was only 1.5 error units more than the increase in error for the joining of the latter two with the concrete score (66.5). The two increases were virtually identical. These results corroborate the impression given by Table III parts B and C where non-Guttman steps were found among the upper systemic tasks, while Guttman steps separated them from the formal tasks (see Table IV). The patterns displayed on three tables and in this cluster analysis are consistent with the *structures d'ensemble* criterion for a stage. These analyses indicate that it is unquestionably plausible to consider systems synthesis and transitive recycling as cognitive operations belonging to a fifth stage of cognitive development. The next section reports the available data which contribute to an evaluation of the "fifth stage" interpretation.

D. Third Hypothesis

Transitive recycling and systems synthesis are the two cognitive opera-
Figure 6
Cluster Analysis Dendrogram for Stage Scores and Least Difficult Upper Systemic Score Across Domains
tions which are being considered as candidates for a fifth stage. The four component task scores indexing mastery of these cognitive operations have been shown to be the most difficult tasks used in this study.

The third hypothesis is that the greater difficulty of the upper systemic tasks is due to their greater structural complexity. That is, the operations needed to solve them belong to a fifth stage. The corresponding null hypothesis is that the greater difficulty of these tasks is wholly attributable to non-structural content related factors. The fifth stage interpretation would be weakened if it could be shown that at least part of the greater difficulty of the upper systemic tasks is attributable to factors other than the greater difficulty of the cognitive operations they require. This section examines the data available on the familiarity of the task content and its difficulty relative to the tasks.

(i) Unfamiliarity vs. Complexity as Reasons for Difficulty

If Piaget's approach extends to the study of systemic operations as well as the study of social understanding then the universalist flavor of his theory should be vindicated with the upper systemic tasks. That would require evidence that competence with the upper systemic operations would be manifested evenly across variations in content. Large differences in how familiar respondents were with various contents should make a negligible difference in the difficulty levels of the tasks. If, on the other hand, there were evidence that task performance varied along with the familiarity of the content then (a) a limit would have been discovered to Piaget's universalist approach, and (b) the difficulty

4. A stage, of course, is a whole group of cognitive operations that form a "structured whole" (e.g., Inhelder and Piaget, 1958). Two cognitive operations would not likely constitute a stage in themselves but they may be representatives of a stage.
of the upper systemic tasks could be attributed to factors other than the subsumptive power of the cognitive operations involved. That would amount to suggestive evidence against a fifth stage interpretation.

In this section the familiarity data are compared with the task performance data in an attempt to discern whether or not there are grounds for believing that successful task performance on the most difficult systemic tasks required anything over and above familiarity with contents of those tasks. Two main arguments are marshalled in support of the null hypothesis. First, data are presented to show how differences in familiarity with whole domains of content produced no correlated differences in performance on tasks. Second, the complementary case is made that when familiarity with content is held constant and it is the structural complexity of the task that is varied, corresponding changes in task performance are observed.

(ii) Varying Familiarity with Constant Complexity

In the concrete stage performance on all tasks fell within a fairly consistent range regardless of the familiarity of the task content. More particularly, the bio-ecological and societal tasks showed a striking degree of parallellism in their difficulty levels despite the fact that the content of the societal tasks was considerably less familiar to the sample as a whole. Table V, part A shows the frequencies of respondents familiar with the contents of each of the concrete stage tasks in each of the three domains. The unfamiliarity rate for the bio-ecological domain varies between 0 and 10 respondents. By contrast the unfamiliarity rate for the societal domain ranges from 24 to 56 respondents. While the societal content is clearly less familiar there is never more than a negligible difference (i.e., four respondents) between the
Table V, Part A

Frequencies of passes and Z scores between concrete operational tasks and familiarity assessments

<table>
<thead>
<tr>
<th>Seriation</th>
<th>Linear Transitivity</th>
<th>Logical Multiplication</th>
<th>Class Inclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency of Pass</td>
<td>Frequency of Pass</td>
<td>Frequency of Pass</td>
</tr>
<tr>
<td>Famili-</td>
<td>Task arity</td>
<td>Task arity</td>
<td>Task arity</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>Z</td>
<td>Z</td>
</tr>
<tr>
<td>Physical</td>
<td>96 96 0.0</td>
<td>84 96 5.071</td>
<td>91 95 3.226</td>
</tr>
<tr>
<td></td>
<td>(NG)</td>
<td>(?)</td>
<td>(?)</td>
</tr>
<tr>
<td>Bio-ecological</td>
<td>96 96 0.0</td>
<td>88 93 2.714</td>
<td>87 86 -0.247</td>
</tr>
<tr>
<td></td>
<td>(NG)</td>
<td>(?)</td>
<td>(NG)</td>
</tr>
<tr>
<td>Societal</td>
<td>92 70 -7.135</td>
<td>85 72 -3.706</td>
<td>84 55 -7.578</td>
</tr>
<tr>
<td></td>
<td>(?)</td>
<td>(?)</td>
<td>(?)</td>
</tr>
</tbody>
</table>

(NG) Not Given
Table V, Part B

Frequencies and Z scores between bio-ecological domain tasks and familiarity assessments

<table>
<thead>
<tr>
<th>Familiarities</th>
<th>Frequency of Passes</th>
<th>Nitrogen Molecule</th>
<th>Bacteria</th>
<th>Reproduction</th>
<th>Starvation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layout</td>
<td>41</td>
<td>44 (NG)</td>
<td>67 (G)</td>
<td>59</td>
<td>65</td>
</tr>
<tr>
<td>Procedure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transitive</td>
<td>23</td>
<td>6.920 (?)</td>
<td>13.122 (G)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recycling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyclic</td>
<td>35</td>
<td>2.675 (?)</td>
<td>8.251 (G)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transitivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systems</td>
<td>36</td>
<td>2.121 (NG)</td>
<td>6.297 (?)</td>
<td>4.548 (?)</td>
<td>6.749 (?)</td>
</tr>
<tr>
<td>Analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systems</td>
<td>32</td>
<td>2.879 (?)</td>
<td>8.194 (G)</td>
<td>6.378 (?)</td>
<td>7.864 (G)</td>
</tr>
<tr>
<td>Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyclic</td>
<td>22</td>
<td>5.822 (?)</td>
<td>9.660 (G)</td>
<td>8.408 (G)</td>
<td>11.505 (G)</td>
</tr>
<tr>
<td>Integration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**KEY**

Nitrogen = familiarity with concept of nitrogen molecule
Molecule = familiarity with bacteria
Reproduction = familiarity with concept of population reproduction
Starvation = familiarity with concept of starvation in a population
### Table V, Part C

Z scores and frequencies of gates for societal domain tasks and familiarity assessments

<table>
<thead>
<tr>
<th>Task</th>
<th>Frequency of Passes</th>
<th>WMB</th>
<th>FM</th>
<th>Bakery</th>
<th>Profits</th>
<th>Taxes</th>
<th>S/D</th>
<th>Own Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layout Procedure</td>
<td>67</td>
<td>29</td>
<td>81</td>
<td>92</td>
<td>73</td>
<td>78</td>
<td>46</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>(G)</td>
<td>(?)</td>
<td>(?)</td>
<td></td>
<td>(G)</td>
<td></td>
<td></td>
<td>(?)</td>
</tr>
<tr>
<td>Transitive Recycling</td>
<td>27</td>
<td>0.282</td>
<td>14.697</td>
<td>16.926</td>
<td></td>
<td></td>
<td></td>
<td>13.878</td>
</tr>
<tr>
<td></td>
<td>(NG)</td>
<td>(?)</td>
<td>(G)</td>
<td></td>
<td>(G)</td>
<td></td>
<td></td>
<td>(G)</td>
</tr>
<tr>
<td>Cyclic Transitivity</td>
<td>61</td>
<td>-8.310</td>
<td>5.940</td>
<td>8.818</td>
<td></td>
<td></td>
<td></td>
<td>5.535</td>
</tr>
<tr>
<td></td>
<td>(G)</td>
<td>(?)</td>
<td>(G)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(?)</td>
</tr>
<tr>
<td></td>
<td>(NG)</td>
<td>(G)</td>
<td>(G)</td>
<td>(G)</td>
<td>(G)</td>
<td>(G)</td>
<td>(?)</td>
<td>(G)</td>
</tr>
<tr>
<td></td>
<td>(NG)</td>
<td>(G)</td>
<td>(G)</td>
<td>(G)</td>
<td>(G)</td>
<td>(G)</td>
<td>(?)</td>
<td>(G)</td>
</tr>
<tr>
<td></td>
<td>(?)</td>
<td>(G)</td>
<td>(G)</td>
<td>(G)</td>
<td>(G)</td>
<td>(G)</td>
<td>(?)</td>
<td>(G)</td>
</tr>
</tbody>
</table>

**KEY**

- **G** = Guttman step (**7.663**)
- **NG** = non-Guttman step (**2.380**)
- **?** = ambiguous step (between 2.380 and 7.663)

WMB = familiarity with the wheat marketing board
FM = familiarity with the flour mill
Bakery = familiarity with the bakery
Profits = familiarity with concept of profits
Taxes = familiarity with concept of taxes
S/D = familiarity with law of supply and demand
Own Wheat = Introductory item for transitive recycling component, "Could the farmer ever eat bread made from his own wheat if he sells all the wheat that he grows?"
success rates for societal tasks and the success rates for bio-ecological tasks. The z scores on part A of table V tell the same story in a more synoptic form. The z scores are for differences between proportions. The first proportion represents those respondents who were familiar with the contents but who failed the task. The second proportion represents respondents who passed the task but were unfamiliar with the content. When the difference between these two proportions yields a negative z score then the task was passed by more people than were familiar with its contents. Positive z scores arise when more people are familiar with the contents than are capable of succeeding on the task. Z scores in the non-Guttman range indicate a negligible difference between rates of task success and rates of familiarity with task content. Negative z scores of the Guttman step magnitude indicate that respondents as a whole were quite unacquainted with the contents of the task but nevertheless performed quite well on it. Such is the case for the societal domain. The z scores are all negative and within or close to the Guttman step range. The situation is reversed for the bio-ecological domain. Two of the z scores are non-Guttman and the other two are ambiguous range positive. The contrast between the large negative z scores for the societal domain and the near zero to moderately positive z scores in the bio-ecological domain indicates once again that the content of the societal domain was much less familiar to respondents as a whole. Yet this unfamiliarity was not accompanied by any decrement in success rates on the task. It did not inflate the difficulty level of the societal domain tasks. Thus one potential source of corroborative evidence for a content related interpretation of the greater difficulty of the upper systemic components has been abrogated.

Of more direct relevance are the data for the upper systemic components
themselves. Here again, differences in the familiarity of task content are not accompanied by similar differences in task performance. Part B of table V shows the data for the bio-ecological domain. The columns are headed by the four most important content items in the bio-ecological interview. The rows show both the systemic components and the composite systemic operations. Part C of table V shows the comparable data for the societal systemic scores. For both domains the most important familiarity items to note are the ones that were most unfamiliar. These items set the limits on the sample's familiarity with the respective systems under consideration. The most unfamiliar item in the bio-ecological domain was the nitrogen molecule. Only 44 respondents were familiar with that concept. In the societal domain the most unfamiliar item was the wheat marketing board (WMB). Only 29 respondents were familiar with this item. An inspection of the familiarity rates with special emphasis on these two items indicates that, as with the concrete tasks, the societal content was less familiar than the bio-ecological content. Also, the rate of successful task performance on the upper systemic components was again roughly within the same range (22 to 32 passes). Unlike the concrete stage pattern, however, successful task performance in both domains was less frequent than familiarity with the most unfamiliar content items. Hence, there are no

5. The details of the familiarity assessments are given in Appendicies A, B, and C along with procedures for task administration.

6. For the bio-ecological and societal domain cyclic transitivity tasks, the same two familiarity items sufficed for the materials used in both the layout and the recycling procedures. Likewise with cyclic integration, the analytic and synthetic components used the same materials and concepts. Hence, the same set of familiarity assessments apply to both components. Since the systemic tasks were arranged such that information gained in prior tasks continued to be of relevance for later tasks comparisons are reported between all systemic familiarities and all systemic tasks.
negative z scores for comparisons of the upper systemic components with the most unfamiliar content items. Nevertheless, the pattern of differences among the z scores is the same as in the concrete stage. Specifically, the societal domain z scores are again lower than those in the bio-ecological domain. This means that once again the greater unfamiliarity of the societal content is not accompanied by a task performance deficit of similar magnitude. Hence the greater unfamiliarity of the systemic task content does not appear to account for the bulk of the greater systemic task difficulty. Success on the upper systemic tasks in both domains apparently depends on factors over and above familiarity (or unfamiliarity) with their contents.

In the societal domain the layout procedure does fall a Guttman step away from the familiarity score for the least familiar element in the cycle (i.e., the wheat marketing board; see table V, part C). Although the element was less familiar, task performance was more successful than in the bio-ecological domain. This would seem to be evidence for a practice effect with the layout procedure. Even though order of presentation is confounded with domain of content it was known that the content in the second domain (i.e., societal) was more novel. Despite that countervailing factor, performance across the whole sample still improved on the layout component of cyclic transitivity.

7. Ordinarily, it would be appropriate at this point to present correlation (e.g., Phi) coefficients for the above comparisons. With the present data, however, most respondents either passed both variables or failed both variables. Correlation coefficients give distorted information on this present data because none of the variables are sensitive across the whole range of ability levels in the sample.

8. At the individual level of analysis this conclusion is also upheld. For example, of the 22 respondents who passed societal systems synthesis, 13 (59%) were unfamiliar with the WMB. Nor was familiarity with the most difficult content sufficient for task success. Of the 29 respondents who were familiar with the WMB, only 9 (34%) passed societal systems synthesis.
In summary, when the bio-ecological and the societal domain are considered together, however, the fifth stage idea appears stronger. Referring back to the scalogram that produced figure 2 and the z scores on table IV, it can be seen that the upper systemic scores are of more or less the same difficulty level regardless of content domain. This implies that variations in content familiarity such as exist between the bio-ecological and societal domains do not affect the difficulty levels of the upper systemic tasks very substantially. In the next subsection we consider cases where the content is held constant but performance nevertheless varies.

(iii) Varying Operations with Constant Content

The above conclusion is corroborated by the data for the lower systemic components. If less familiar content of the systemic interviews really caused detriments in task performance then the detriment should have been just as evident in the lower systemic tasks as the upper. Both sets of tasks used the same cycles with the same elements. Yet despite the same familiarity/unfamiliarity of the task contents within domains the upper components were more difficult. This suggests again that the greater difficulty of the upper systemic components cannot be written off as an artifact of their more difficult figurative contents.

9. One final item of interest from Table V, C is the rightmost column labeled "Own Wheat". This was an item used to introduce the transitive recycling problem in the societal domain. The respondents were asked, "Could the farmer ever eat bread made from his own wheat if he sells all the wheat he grows?" Approximately 75% of the respondents were able to trace the trail of the wheat around the cycle, back to the farmer in the form of bread. The actual transitive recycling item required tracing the trail of a one dollar bill along exactly the same path but in the opposite direction. Only about 25% of the respondents could do this. The two items were a large Guttman step apart \( (z = 13.878) \). On the face of it, the two items seem logically equivalent. The obvious existence of psychological differences between them impels us to refine the transitive recycling concept.
Overall, it appears that the third hypothesis cannot be rejected. The greater difficulty of the upper systemic tasks is not, for the most part, attributable to the unfamiliarity of their contents. Thus a fifth stage interpretation of their greater difficulty remains viable.

E. Age of Mastery Data

In this section ancillary data are reported that are relevant to the stage issue. Flavell (1971a) posed abruptness of transition criterion for the identification of a stage but Wohlwill (1973) suggested a model wherein most of the time spent "in" a stage was actually a long gradual transition period preceding final consolidation. Table VI shows age data that is relevant to these differing views of how long a transition period might last.

Table VI shows the frequencies of successful performances on various scores related to age of mastery for formal versus systemic logic. The scores for all three formal operational tasks are shown along with a calculated score intended to classify respondents as either formal operational or pre-formal. This measure of formal operational stage attainment simply indicates whether or not the respondent passed at least two out of the three formal operational tasks. For the purposes of comparison, a similar summary score was calculated for overall mastery of systemic logic. This "summary systems thinking score" assigns a "pass" to those who have passed at least three of the following four tasks: 1) biological domain transitive recycling, 2) social domain transitive recycling, 3) biological domain systems synthesis, 4) social domain systems synthesis. In addition table VI presents all the across domain systemic component scores and all of the component scores by domain.
Table VI

Age profile for passes on formal and systemic scores and on the most difficult systemic familiarities

<table>
<thead>
<tr>
<th>X Age Grade</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen Molecule</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>11</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Wheat Marketing Board</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>12</td>
</tr>
</tbody>
</table>

**Systemic Familiarities**

<table>
<thead>
<tr>
<th>Systemic Familiarities</th>
<th>Number out of sixteen/grade passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formal Stage</td>
<td>0 0 6 15 16 16</td>
</tr>
<tr>
<td>Summary Systems</td>
<td>0 0 0 6 3 9</td>
</tr>
</tbody>
</table>

**Summary Scores**

| Thinking Score | 0 1 3 11 |

**Formal Tasks**

| Probability | 1 0 9 14 16 16 |
| Isolation of Variables | 0 0 6 15 16 15 |
| Combination of Variables | 0 1 5 7 14 15 |

**Cyclic Transitivity**

| Bio-ecological: layout | 0 1 7 10 11 12 |
| Bio-ecological: recycling | 0 0 1 5 7 10 |
| Bio-ecological: combined | 0 1 5 8 9 12 |
| Social: layout | 4 5 12 16 16 14 |
| Social: recycling | 0 0 2 8 8 9 |
| Social: combined | 1 3 11 16 15 15 |
| Across Domain: layout | 0 1 6 10 11 15 |
| *Across Domain: recycling | 0 0 0 5 3 7 |

**Cyclic Integration**

| Bio-ecological: sy.analysis | 1 2 4 5 10 14 |
| Bio-ecological: sy.synthesis | 0 1 2 8 10 11 |
| Bio-ecological: combined | 0 1 1 4 7 9 |
| Social: sy.analysis | 1 1 6 5 9 10 |
| Social: sy.synthesis | 0 1 0 8 7 6 |
| Social: combined | 0 0 0 2 5 3 |
| Across Domain: analysis | 1 1 3 5 11 13 |
| *Across Domain: synthesis | 0 0 0 7 8 8 |

*Best indicators of age profiles for top systemic scores
As expected, the 8 and 10 year olds rarely succeeded on any of the tasks. Successes on the formal operational tasks start appearing at age 12 but it is not until age 14 that the majority of the respondents pass the majority of the formal operational tasks.

The overall impression given by the frequencies for the systemic scores in table VI is that systemic thinking lags about two years behind formal abstract thinking. Successes start appearing in some numbers around age 14. At age 16 several of the scores show successful performance for the majority of the respondents. At no age level, however, does any systemic score show frequencies of success that match those for the formal stage score. Most striking in that regard is the across domain transitive recycling score. We do not know at what age, if ever, the majority becomes competent with this operation. There are high failure rates on systemic scores throughout the older age groups. The transition into the formal stage appears to satisfy Flavell's abruptness criterion. The mastery of the upper systemic tasks is more in line with the pattern of gradual transition that Wohlwill suggests as a characteristic of Piagetian stages. The contrast may be a function of the inherent difficulty of the operations chosen to represent each "stage". The formal tasks used in this study might be relatively easy compared to other formal tasks which might show a more gradual transition pattern.

F. Summary of Results

In accord with the prediction made in the first hypothesis, the Piagetian approach appeared to generalize well to the bio-ecological and
societal content domains. The prediction made by the second hypothesis was supported for two subcomponents of the systemic operations. The systems synthesis and transitive recycling components were more difficult than the formal operational tasks. The difference was of a stage sized magnitude and it was Guttman-like. Meanwhile, the societal cyclic transitivity layout component tended to fall towards the concrete stage cluster in terms of difficulty level and the systems analysis component fell within the same range of difficulty as the formal operational tasks. Under the third hypothesis the respondents' relative familiarity with the content of tasks was examined. The greater difficulty of the upper systemic components is not attributable in any substantial way to the relatively novel content of the tasks assessing them. The systemic tasks and their subcomponents were found to be mastered approximately two years later than the formal operational tasks but within each age level the frequencies of success on the systemic tasks were generally lower than those for the formal operational tasks. It appears that the upper systemic tasks represent a fifth stage of cognitive development although the parallel development interpretation has not been ruled out.
V. DISCUSSION

This chapter begins with a review of the results corresponding to each of the three hypotheses and then proceeds to an examination of the issues related to the interpretation of the results.

A. The Three Hypotheses

The recurring theme of this section concerns the relative difficulty of the "upper systemic" tasks and the merits of evoking a fifth stage of cognitive development in an effort to account for this fact. The first hypothesis deals with groundwork that is prerequisite to an examination of this issue. In the second subsection (ii) the findings with regard to the second hypothesis are evaluated against the structures d'ensemble and the Guttman scale criteria for identifying a stage of cognitive development. In the third subsection the content related alternative interpretations are examined. Then age related stage criteria are discussed with reference to the age data. In the final subsection the evidence for and against the stage versus parallel development interpretations is summarized.

(i) First Hypothesis: Extending Piagetian Theory

Before an examination of children's understanding of social organization could be undertaken it was necessary to first identify and document some of the cognitive operations involved in understanding such open systems. This requirement led to the use of hitherto seldom studied types of contents in the assessment tasks (i.e., contents more often containing open systems). Before these content domains could be used to introduce novel cognitive operations, it was necessary to demonstrate that the more thoroughly studied cognitive operations were not drastically altered by a shift to open systems contents.
The first hypothesis, which states that Piaget's account of cognitive development in the impersonal sphere can be extended to bio-ecological and societal content, was generally supported. Data bearing upon this hypothesis were examined from two viewing distances. These macroscopic and microscopic analyses are briefly summarized below.

**Microscopic Level of Analysis.** At this level it was predicted that the difficulty orderings of equivalent tasks would be the same across all domains. Specifically, it was predicted that the order of these tasks, from least difficult to most difficult, would be as follows: seriation, linear transitivity, logical multiplication, class inclusion, cyclic transitivity, and cyclic integration. This is exactly the order that was observed in both the bio-ecological and societal domains. For reasons outlined earlier, measures of only the first four of these cognitive operations were potentially available within the physical domain. Contrary to expectations, the physical domain class inclusion task was tied for difficulty with the logical multiplication task and they were both less difficult than the linear transitivity task. Somewhat paradoxically, then, the order of difficulty predictions based upon Piagetian theory were more accurate in the novel bio-ecological and societal domains than in the more familiar standard physical domain. The observed equivalency of the class inclusion and logical multiplication tasks could be a simple function of sampling peculiarities and it might be assumed that with a larger number of subjects, individuals might have emerged who demonstrated the expected pattern of understanding logical multiplication, but not class inclusion. The misordering of linear transitivity is more difficult to explain away, however. The current research was designed to determine what the difficulty orderings of these tasks were and why they did or did not conform to their hypothesized
ordering is not readily apparent from these data. This single difficulty aside, however, supporting data were obtained for thirteen of the ordering relationships predicted by hypothesis one. In only one case was there a direct violation of expectations. From this evidence it seems reasonably safe to conclude that the same reasoning developed by Piaget to account for the order of difficulty of tasks in the physical domain may be extended to the bio-ecological and societal domains as well.

Before turning to the macroscopic level in order to see how well the discontinuities predicted by Piagetian theory apply to the novel content domains, the matter of stages as structured wholes must be discussed with regard to the stage of concrete operations. The first to be dealt with is the matter of stages as structured wholes. After that the possibility of a concrete staged systemic operational task is discussed.

Structured Wholes. The difficulty orderings of cognitive operations change quite readily from person to person, from mode of presentation to mode of presentation and from domain to domain. Moreover, it appears that each cognitive operation is differentially sensitive to these, and other, forces. The difficulty of one cognitive operation may be reduced on second presentation, regardless of changed content, while another operation's difficulty may be independent of number of trials but closely linked to the novelty of the materials and/or content.

The inconsistencies observed across domains imply that at the most fine grained level of analysis the stages really are structures d'ensemble or "structured wholes" as Piaget has claimed they are (e.g., Inhelder and Piaget, 1958). The inconsistencies evident in the present data would not have arisen if all the concrete operations were not interrelated in some structural way.
(i.e., by virtue of their common stage). The idiosyncrasies of each cognitive operation may arise from our viewing them as parts separated from the structured whole. Their individual operating characteristics become unpredictable when they are taken out of that context and then compared with each other. As a whole stage of operations, however, the concrete operations are predictable. Specifically, they are all mastered in middle childhood. The impetus to compare individual concrete operations with one another comes from earlier empirical evidence that they are ordered within the stage of concrete operations. The present data, by also comparing them across diverse content domains, shows that the earlier evidence of systematic orderings was something of an artifact of task content. That is, all the assessment tasks tended to employ inanimate physical objects as testing materials (e.g., Glick and Wapner, 1968; Kohnstamm, 1968; Formanek and Gurian, 1976). Content areas that deal with non-physical entities (e.g., economic situses) can only be represented verbally and they may yield different sequences. The work on ordering operations within stages must be tempered by the present evidence that changes in content can change the orderings. Perhaps because it was less focused on the relative difficulty of only a few tasks of similar content, the present data support the idea of "structured wholes." That is not to say that there are no predictable orderings within stages. If extensive enough comparisons are made among concrete operational tasks on very large samples of respondents, such orderings do emerge. The search for such overall within-stage orderings, however, is now seen as a much more elaborate undertaking. A greater sensitivity to type of content is required.

Macroscopic Level of Analysis. At this level of analysis the first hypothesis predicted Guttman steps between stages in all three domains. This
is precisely what was observed with the exception of the societal cyclic transitivity task. That exception is discussed in more detail below. Generally, the central Piagetian notion of a discontinuity between concrete and post-concrete thought was supported by the appropriate corresponding pattern in the difficulty level data. Given the support provided by these macroscopic and microscopic analyses, the general Piagetian approach would appear to apply quite well to the bio-ecological and societal domains. Hence, we can be more confident that there were no major hidden confounds vitiating the comparisons that were to be made between the systemic operational tasks and the formal operational tasks.

Before the discussion goes on to the comparisons between the systemic tasks and the formal tasks there is one more issue that must be mentioned. That is the interpretation of the unusually low difficulty levels for the layout components of cyclic transitivity.

Concrete Stage Systems Logic? It was suggested earlier that the societal domain layout procedure may have been extraordinarily easy owing to a practice effect. It is also possible that the layout procedure may be a concrete stage example of a systemic operation. Future research could compare the difficulty levels obtained across factorial variations of element familiarity and order of presentation (practice) with a smaller range of respondents. For example, Kates and Katz (1977) studied uninstructed understanding of the hydrologic (water) cycle in 3, 4, and 5 year olds. With the pretest familiarization entailed in the layout procedure, all the elements of the water cycle would be familiar enough to concrete operational and early formal operational children to inform us better about the earliest appearance of mastery over this type of operation.
The second hypothesis was supported by the difficulty level data. Hypothesis two predicted that there would be a gap in difficulty levels of the same size between at least some systemic components and the most difficult formal operational task as there was between the least difficult formal task and the most difficult concrete task. This amounted to a prediction that the gap in terms of difficulty levels between the formal tasks and the upper systemic components would be a stage sized gap. In other words, it was predicted that the difficulty levels data would suggest the possibility of a fifth stage. Since the corroboration of the overall first hypothesis precludes an interpretation of the predicted greater difficulty of the upper systemic tasks in terms of confounding content related differences in the discreteness of stages, any observed greater difficulty is all the more reasonably interpreted as a function of the greater structural complexity (i.e., form related difficulty) of the upper systemic components. The results of the Guttman step analyses (i.e., z scores for the differences between proportions) and the cluster analyses show that the systems synthesis and transitive recycling components were indeed a stage sized gap more difficult than the formal operational tasks. The third hypothesis dealt with a content related alternative to a fifth stage interpretation. Before the viability of the fifth stage interpretation is examined in that context, the argument for its reasonableness is discussed in detail with respect to the second hypothesis.

The second hypothesis entailed analyses which were relevant to the structures d'ensemble criterion (Piaget, 1960; Flavell, 1971a) for identifying a stage and to the criterion that stages form a Guttman scale (i.e., Piaget's (1960) sequence
and hierarchy criteria). The upper systemic tasks did indeed appear to be structures d'ensemble. They clustered exclusively together in the cluster analyses. They were separated from each other in difficulty by non-Guttman step (i.e. passing transitive recycling and failing systems synthesis was about as common as the reverse). Also, the scalability coefficients indicated that the systemic components were not unidimensional and cumulative amongst themselves. The criterion that stages form a Guttman scale was also satisfied with respect to the upper systemic tasks. The z scores for differences between proportions gave unequivocal evidence of this. Evidence relevant to the abruptness and concurrence criteria (Flavell, 1971a) for identifying stages is examined in subsection A, (IV) of this chapter ("Age Related Criteria").

The systems analysis and layout component were not a Guttman step more difficult than the most difficult formal operation. Strictly speaking this neither corroborates nor detracts from neither the fifth stage interpretation nor the parallel interpretation. Nevertheless the fact that the societal domain layout component was so close to the most difficult concrete operation does suggest that concrete staged systemic operations might exist. If such operations were found, systemic operations would be parallel to more than just formal operations. They would be a whole class of logical operations developing along with those exemplars of, and precursors of, formal logical operations studied by Piaget and his colleagues.

(iii) Third Hypothesis: Greater Content Difficulty

The third hypothesis predicted that the difficulty of the most difficult systemic tasks would not be wholly attributable to any greater unfamiliarity of task content peculiar to those tasks. The z scores for the differences
between the proportions of respondents passing the familiarity assessments and the associated tasks, and the frequencies of passes on both preclude any straightforward attribution of the greater difficulty of the upper systemic tasks to content difficulty (see tables V and VI). With these results the fifth stage interpretation has survived a significant falsification attempt.

To decide what effect content familiarity has on task difficulty it is necessary to distinguish the content from the required operative knowledge. A priori it seemed that the elements of the nitrogen cycle and the wheat cycle would be the only concepts that a respondent needed to be familiar with in order to apply the operations of cyclic transitivity and systems analysis to those contents. Empirically, however, it turned out that some respondents mastered the tasks even without complete initial familiarity with those elements. The systems synthesis components seemed a priori to require further familiarity with the concepts of starvation and reproduction on the population level in the bio-ecological domain and with profits, taxes, and supply/demand relationships in the social domain. Again, the empirical evidence is that some respondents who mastered the systems synthesis tasks were unfamiliar with the entailed content. Added to this is the evidence that within domains the lower systemic components were not as difficult as the upper components despite the fact that the most unfamiliar elements were integral contents in both. Finally, the variations in content familiarity across domains was not accompanied by as large variations in the difficulty of the tasks. All of these findings make it very difficult to argue that the greater difficulty of the upper systemic tasks is attributable in large part to the greater difficulty of their contents. This does not prove that content difficulty never influences task difficulty
for the upper systemic tasks. Nor does it prove that the upper systemic tasks required more sophisticated cognitive operations. There may be alternative explanations that cannot be assessed with the data at hand but none spring to mind. The interpretation that the tasks were more difficult because the cognitive operations they required were more difficult remains viable.

(iv) Age Related Criteria

The data presented on Table VI were not connected with any hypothesis but they are relevant to the abruptness and concurrence criteria (Flavell, 1971a) for identifying stages. These data indicated that the mastery of various systemic operations is concurrent (with the noted exception of the layout component of cyclic transitivity) but not abrupt. The concurrence criterion is actually subsumed by Piaget's interpretation of the structures d'ensemble. Flavell made a more strictly logical interpretation of the structures d'ensemble criterion but supplemented it with the concurrence criterion. Therefore the data already discussed in connection with structures d'ensemble (see subsection A(ii); "Second Hypothesis") are more relevant to the concurrence criteria than are these age data. The age data do not indicate whether or not the mastery occurred as concurrently within individuals as it did among individuals within age groups. The z scores between the upper systemic tasks, however, do indicate concurrence within individuals.

The abruptness criterion requires that the transition into the next higher stage be short in duration. The age data have bearing on this requirement at the level of groups of same aged peers but not at the level of the individual. If the transition appear abrupt across independently sampled age groups then it was likely to have been abrupt for the individuals also. If, however, the
cross-sectional data shows a gradual rise across age groups in the frequency of mastery then it remains impossible to determine whether or not the individuals undergo the transition abruptly. The cross-sectional data reported in Table VI showed an abrupt transition into the formal operational stage but a gradually increasing frequency of mastery over the upper systemic tasks. In fact, the frequency for successes on the upper systemic components never goes as high at any of the ages sampled as the frequencies for the formal tasks. Perhaps the upper systemic operations do not blossom in the majority until an age beyond the oldest sampled here. Perhaps systemic thinking is simply not all that common in adults. The criteria for identifying stages do not require that a fifth stage would have to be acquired by all adults.

The viability of the fifth stage interpretation remains unaffected by the abruptness criterion mainly because there are no relevant data available. Even if appropriate data were obtained that showed a gradual mastery of the upper systemic tasks, the fifth stage interpretation might still survive. Wohlwill (1973) argued that abruptness of transition is not a necessary condition for a stage. Flavell (1977) commented that Wohlwill's more dynamic notion of a stage seemed unconvincing. Flavell's view is that the whole idea of stages may have to be abandoned since attempts to save it lead to such a dilution of the concept that it ceases to be useful. Flavell may well be correct but what is at issue here is the extent to which the upper systemic tasks meet stage criteria at least as well as do other tasks in other Piagetian stages. None of Piaget's stages may be very stage-like but we want to know if the upper systemic cluster is any less stage-like than the others.
(v) **Summary**

All three hypotheses were corroborated. The upper systemic operations (transitive recycling and systems synthesis) seem to meet the criteria for being representatives of a fifth stage at least as well as other operations do for other stages. The abruptness of transition criterion could not be evaluated with the present data. The parallel development interpretation also remains viable even though it requires one to speculate that the upper systemic operations were merely unusually difficult representatives of a typical easier set of operations. The issue is far from settled.

B. Interpretations of Systemic Difficulty Levels

In this section the parallel development interpretation is given more attention. Then interpretations which involve cultural evolution as well as cognitive development are considered. First, however, the next subsection examines some of the limitations that must be borne in mind when interpreting the results.

(i) **Interpretive Caveats**

This is not intended to be an exhaustive list of the factors constraining interpretation of the findings. The method and results chapters contain several comments on possible artifacts and sources of unreliability. What follows here are the most important caveats to bear in mind as one considers various interpretations of the greater difficulty of the upper systemic tasks.

*Sample.* The age profile data show that not even among the 18 year olds was there a substantial majority of respondents who had mastered the upper
systemic tasks. We do not know how even older respondents might have performed. It would be interesting to search for the earliest age group at which mastery of those tasks was more or less universal. There might be no such age group but from the present sample of ages it is impossible to know one way or the other. Also, although an attempt was made to match the 18 year old group to the other age groups in terms of projected educational/occupational status upon leaving secondary school, the match was far from perfect. Ideally the 18 year old group would have contained a majority of respondents who were or who wished to be full time members of the labour force.

Task Definitions. To some extent this is a semantic problem. The question is whether or not the systemic operations of cyclic transitivity and cyclic integration should be dispensed with in favor of the more elementary component scores. On logical grounds it seems justifiable to group the layout component together with the transitive recycling component and to group the systems analysis component with the systems synthesis component. Now that the difficulty level results are available, however, those groupings can be questioned on empirical grounds. The difficulty levels between the components of the same systemic operations were quite different. Perhaps the safest procedure is the one that has been followed here. That is to report the results by components as well as by composite operation. Future research will have to be based on further refinement of these concepts. The identification of this problem for future theory and research can be seen as one of the heuristic contributions of this study. Meanwhile, a measure of circumspection is in order when interpreting any of the composite scores reported here. This issue is taken up further in Chapter V section A, where the possible variation in
the logico-mathematical forms of cyclic transitivity and cyclic integration are considered.

A partially related problem concerns the composition of the component scores themselves. Appendix D details the items from which these scores were obtained. Future research ought to include some analyses of the internal consistency of the items used here along with whatever novel items can be devised. In this regard it would also be desirable to devise assessment procedures based on other open systems cycles. The nitrogen cycle and the wheat cycle certainly seem appropriate for the purposes at hand but the examination of additional cycles would provide an opportunity to increase the reliability and validity of the assessment procedures. Again, no one study can settle a question as broad as either the existence of a developmental stage or the existence of a parallel type of logic.

Task Administration. Most of the issues surrounding the fixed order in which the tasks were presented have already been discussed in the method chapter. Now that the results are available hindsight raises one further issue. It turns out that the tasks which were administered last were also the ones that appeared most difficult. After close to an hour of testing some respondents might have experienced mental fatigue and therefore performed less than optimally on those very tasks. There are some grounds for discounting this possibility. First of all, a fatigue hypothesis would predict a more or less steady performance decrement. This was not the case. The bio-ecological systems synthesis and transitive recycling tasks were presented before any of the societal systemic tasks but performance on some of the latter was actually superior. The societal systems analysis component and, especially, the layout component were much easier than the upper systemic tasks in the
bio-ecological domain. To the extent that fatigue might have shortened attention spans, the effect would probably have been most pronounced among younger respondents. Although the relative easiness of the lower systemic tasks in the societal domain argues against any such interpretation it is not known how much better performance, especially that of the younger respondents, might have been on those lower systemic tasks had they been presented earlier. Therefore one ought to remain undecided on this issue. Were future research to circumvent the possibility of a fatigue effect, the relative lateness and infrequency of mastery of the systemic tasks might disappear. Note that this caveat is more damaging to the fifth stage interpretation than to the parallel development interpretation. If the difficulty levels for the upper systemic tasks are artificially inflated then the case for a parallel development interpretation is stronger.

Statistics. The most obvious problem with the statistical analyses is the novelty of using Z scores for differences between proportions. This statistic was not designed for this use. It was meant to be related to the normal distribution. In adapting the Z score for use in indexing the Guttman like nature of steps between adjacent tasks great pains were taken to avoid any reference to the normal distribution and associated confidence intervals. The rationale for the use of this statistic is given in the results chapter. Perhaps its greatest shortcoming as it has been used here is its cumbersome character. A more elegant technique has been recently published by Froman and Hubert (1980). Aside from its novelty, however, that technique appears to be suited for more fine grained analyses of order hypotheses than was appropriate for the overall first hypothesis. Froman and Hubert's technique would require prior specification of the precise size of gaps between tasks within stages.
and within content domains as well as specification of corresponding orders of difficulty. For the purpose of justifying the extension of Piagetian theory to the two novel content domains their technique seems inappropriately specific. It would be more appropriate for studies with larger samples of respondents within a much more restricted age range.

Bart and Airasian's (1974) ordering method might have been used with the present data with regard to the structures d'ensemble criterion. That method, however, uses pairwise comparisons of "pass/fail" cases with "fail/pass" case to approximate the order in which tasks may have been mastered by respondents even though the respondents, whose data are used to construct the ordering may actually have followed a different order themselves. Only longitudinal observation could properly establish an ordering at the individual level of analysis. Also, Bart and Airasian's relation of "independence" may actually obscure real longitudinal orders by construing joint-necessity as independence. In their system it is impossible to distinguish between a situation wherein the child must master one or another task before proceeding to more advanced tasks and a situation wherein the child must master both tasks before proceeding. This shortcoming could become critical where Bart and Airasian's method was being used to assess the extent to which a group of tasks were structures d'ensemble. One might be misled into postulating two "independent" sets of tasks where actually relations of joint necessity were in effect. That shortcoming was not shared by the statistics that were used in the present study. They were less sophisticated but they served their function adequately.

(ii) Piaget's Parallel Position

So far the fifth stage interpretation remains viable. However, the
same can be said of the parallel development interpretation. In fact a
version of the parallel position was favored by Piaget, albeit before the
evidence from the present study had been obtained. Piaget holds that no
further qualitative developments occur after formal operations. There are
no more subsumptive operations. According to Piaget, development beyond for­
mal operations progresses in terms of higher and higher orders of concatena­
tion of operations, not new stages. Piaget (1972) admits, however, that there
may be more cognitive operations than those that he has identified. He con­
cedes that his work has focused on formal logic and that less formally logi­
cal operations or whole classes of operations may yet be discovered. From this
perspective one could view systemic operations as qualitatively different
from formal operations yet not subsumptive of them. They would represent
an aspect of post-concrete diversification in cognitive development. Some
individuals may specialize in one type of post-concrete logic or the other.
For the whole species, however, the two types constitute "parallel" develop­
mental paths.

The parallel development interpretation is not ruled out by the fact of
the greater difficulty of the upper systemic tasks. Within the structural
ensemble of formal operations one finds variations in difficulty level from
one cognitive operation to another. The "parallel" interpretation would allow
for the same amount of variation among systemic operations. It must be remem­
bered that there are probably many other systemic operations besides the ones
used in this study. Therefore the parallel interpretation is not diminished
by evidence that some systemic operations are a Guttman step more difficult
than some formal operations because possibly just as many reverse cases exist.
Also, with a judicious selection of the more difficult concrete operational
tasks (e.g., transitivity and conservation of weight; Miller, Schwartz and
Stewart, 1973) and the less difficult formal operational tasks, the gap between stages could be made to appear non-Guttman. If this can be done for the gap in difficulty levels between the third and fourth stages, presumably it could also be arranged for the gap between the fourth and proposed fifth stages. In other words the parallel interpretation gains by default to the extent that the whole concept of stages is found to be inconsistent with the actual course of development.

(iii) Labouvie-Vief's Parallel Position.

Labouvie-Vief (1980) offers an interpretation of life span differences in preferred types of logic which would account for the less than abrupt age profile observed on the systemic components. She argues that pure formal logic is good for exploring possibilities in a culture's adaptation to its environment and that the more pragmatic approach of older adults is good for conserving accumulated cultural artifacts that have proven adaptive value. For a biological population sharing a common culture it would be advantageous to have adults capable of both types of logical thinking. Also, the generation related specialization in each type of logic would enhance the population's adaptiveness by setting up a homeostatic mechanism for regulating the adaptive value, vis à vis a stable or changing environment, of the cultural knowledge available to the population's members. Hence, although it was found that the ability to perform systemic operations was available at age 14, very few of the teen-aged respondents in this study showed signs of being specialists in this type of logic. On the other hand, almost all of them excelled at the type of logic that suited the socio-biological cultural function of their
(iv) Stages and Paradigms

One way to discount the non-abrupt age profile data and thereby strengthen a fifth stage interpretation, would be to argue that the fifth stage logic is in the process of being created in our culture. If adult cognitive structures are assumed to be a product of the structures available in the particular culture then the very fact of cultural evolution guarantees the emergence of new sets of cognitive operations among the adult members of that culture. Systemic operations may be part and parcel of a "cultural paradigm shift". Hence one would expect their prevalence to be low but increasing. The prevalence of successful use of systemic logic was low for the teen-aged respondents in this study. Long term follow up studies would be required to determine whether or not a cultural paradigm shift is underway. If it is, there is still a chance that perhaps at around ages 18 to 21 (common ages of majority) or perhaps 27 to 30 (see Gilligan and Murphy, 1979) systemic logic would come to supercede formal logic in a culture where systemic logic was well accepted among adults.

1. By way of adding texture to Labouvie-Vief's thesis I would like to relate two pieces of anecdotal information obtained from secondary school teachers. An ecology teacher told me that the grade 11 students who he found to be more adept in understanding ecological systems also tended to be those who were more conservation minded. Conserving, of course, is the cultural role that Labouvie-Vief notes is the specialty of older persons, those who use more pragmatic logic. A history teacher made a similar observation with regard to understanding social systems. He noted that his grade 12 students who were more adept at this were those who had more practical experience in political activity. Further, he felt that the students who were more "bookish", in his words, were less quick to see the systemic nature of societal organization. Again, this corroborates the equation of systemic thinking with long term activities aimed at maintaining a heritage and serving a structure to which one has made a personal commitment. As Labouvie-Vief (1980, p.153) states, "This conscious commitment to one pathway and the deliberate disregard of other logical alternatives may indeed mark the onset of adult cognitive maturity."
One could, however, also imbue the parallel position with a modified version of the "paradigm shift" argument. The modified paradigm shift approach would again assume that culture influences the form of adult cognition (Buck-Morss, 1975; Buss, 1977; Riegel, 1976; Luria, 1979) but would not assume that one form was universally superior to, or subsumptive of, another. Rather, the form of logic preferred by a culture would be a matter of adaptation to a particular environment and/or niche. Labouvie-Vief's thesis could be asserted simultaneously. In this case it would produce an interpretation to the effect that our culture must adapt itself to a very quickly changing environment. Another variant is that our culture has chosen the adaptation strategy (niche) of being very quickly changeable, very flexible. In either case, that would necessitate emphasizing formal logic and suppressing systemic logic as the preferred adult form of cognition. Hence, the appearance of systemic cognitive structures might be a little delayed as deserved in the age profile data. Also, the majority of persons would never develop a full facility with, or consolidation of, the systemic structures exactly because they would be culturally non-preferred. Again, this is consistent with the age profile data.

In summary then, it is impossible, given only the present data to decide whether the upper systemic operations develop in parallel with formal operations or are actually representatives of a fifth stage. To a certain extent the uncertainty may be a reflection of the ambiguity that exists in the literature on Piaget's first four stages. In any case, with regard to the more fundamental issue of elucidating the nature of adult cognition, the present study serves to emphasize the importance of systemic operations.
V. Implications for Three Areas of Study

The specific contents of the systemic interviews are most relevant for some areas of study while the form of the cognition studied is of more interest for other areas. This chapter outlines some of the implications of the results for past and future research and theory in the areas of cognitive development, social development, and social psychology.

A. Cognitive Development

The results reported here raise a host of questions for future theory and research in cognitive development. The postulation of a different type of logic is perhaps the most far reaching notion. The relationship between formal and systemic logic cannot be fully elucidated without more work. Logico-mathematical analyses will be required simply to identify the presence or absence of each in any particular case. Empirical studies will be needed to settle questions of developmental priority versus simultaneity at all stages of development. Systemic logic bears similarities to the type of thinking that several authors have suggested typifies mature adult cognition. It also, however, seems to be an extension of the concrete stage topologically based sublogical operations that Piaget claims precede an euclidian conception of space (Piaget and Inhelder, 1956; Piaget, Inhelder and Szeminska, 1960). If systemic logic does indeed develop in parallel with formal logic then it would have precursors in middle childhood and early adolescence. Future research in concrete stage cognitive development might look for those precursors. By way of clarifying what it is we are to look for, this section begins with an examination of the characteristics of mature adult cognition.
(i) Corroborative Work on Adult Cognition

While the present research was in progress, several articles have appeared on various aspects of adult cognition. In the realm of moral development, Gibbs (1979) reconceptualized Kohlberg's theory as a two-phase model. For the present discussion the relevant aspect of Gibbs' reconceptualization is his fourth and last stage during the pre-existential, pre-adult phase. His fourth stage is called the "systems" stage. Gibbs, after an apology for the sketchiness of his descriptions of the stages describes the systems stage as follows:

Evidence for a fourth stage is apparent primarily in the sociomoral realm, although such a distinction may also be helpful in the logico-cognitive realm (e.g., Wyatt and Geis, 1978). Over the course of the adolescent years, there is a progressive ability to discern the systematic arrangements which are necessary to form a viable society, real or hypothetical (see Adelson and O'Neil, 1966; Adelson et al., 1969). In their seminal studies, Adelson et al. found that the adolescent comes to appreciate law and the relation between the individual and society not simply in terms of prosocial intention and benevolent authority (stage 3), but more broadly in terms of social functions and practices. Thus, there is an 'expansion' (Selman, 1976, p. 307) in second-order thinking such that an overall perspective is applied not only to face-to-face relationships, but also to complex social systems as represented by modern society (cf. Edwards, 1975, in press). (Gibbs, 1979, p. 102)

Although the present study was not concerned with the moral aspects of understanding social systems, it is interesting that Gibbs should independently characterize thinking about society as systemic. There seems to be a consensus emerging that (a) society is best described as a system, and (b) understanding of society requires systemic thought.

To be fair, the latter comment actually requires qualification. Piaget
(1972) did come to stress that there were some problems created by the identification of optimal cognitive development with scientific analysis. In his own consideration of some form of parallel development interpretation, Piaget states:

We could, therefore, formulate the following hypothesis: if the formal structures described in part 1 do not appear in all children of 14-15 years and demonstrate a less general distribution than the concrete structures of children from 7-10 years old, this could be due to the diversification of aptitudes with age. According to this interpretation, however, we would have to admit that only individuals talented from the point of view of logic, mathematics and physics would manage to construct such formal structures whereas literary, artistic and practical individuals would be incapable of doing so. In this case it would not be a problem of under-development compared to normal development but more simply a growing diversification in individuals, the span of aptitudes being greater at the level of 12-15 years, and above all between 15 and 20 years, than at 7-10 years. In other words, our fourth period can no longer be characterized as a proper stage, but would already seem to be a structural advancement in the direction of specialization. (Piaget, 1972, p. 9)

Boswell's (1979) finding that mature thought is more synthesizing and, as I would call it, systemic, is corroborated by life-span research showing differences across professional specializations in the ages at which creative contributions are most frequent (e.g., Dennis, 1966). Mathematicians tend to make their best contributions earliest. Natural scientists, artists, philosophers, and historians follow in that approximate order. Mathematics, of course, is the epitome of formal abstraction. History, on the other hand, is incomprehensible without a rich base of contextual details out of which the story of the evolution of society can be synthesized.
The fifth stage interpretation received some corroboration in a study by Michael Basseches (1980) on the development of dialectical thinking. As mentioned in Appendix E, the overlap between systems logic and what is usually meant by dialectical logic is considerable. Basseches claimed to have found support for, "the idea of a post-formal-operational stage of cognitive organization based on the elaboration of dialectical thinking."

(ii) Post-Concrete Diversification.

The results of the present study contribute to the growing consensus that there's more to post-concrete thought than just formal operations. In order to avoid confusing adolescent and adult thought in general from formal operational thought in particular, I prefer to refer to the fourth stage of cognitive development as the "post-concrete" stage. Post-concrete thought encompasses formal operations, systemic operations, and yet-to-be-discovered operations. Post-concrete thought is characterized by a growing diversification of abilities. The present study has found evidence suggesting only one gross bifurcation, that between formal logic and systemic logic.

The parallel interpretation of the results of the present study along with Boswell's findings and Labouvie-Vief's arguments suggest an overall view of cognitive development that is similar to Piaget's but broader. This expanded view of cognitive development sees additional lines of development moving along in parallel with the development of abstract logic. In later writings Piaget (1972) also considered this expanded view. The overarching notion is that with increasing age individuals become more different from one another insofar as some logical abilities get more elaborated and sophisticated in some individuals but not in others. The "others", however,
might be specializing in different logical abilities.  

(iii) Problem Finding and Solving in Either Logic

One interesting feature of the upper systemic tasks is that their emphasis on feedback loops and dynamic interrelatedness allows the person using these operations to discover hidden, non-obvious implications and ramifications of particular events. With formal logic the variables or elements maintain their identities, or their identities are recoverable, through reversibilities of thought, regardless of whatever transforming operations may be performed upon them. With systems logic the elements are constantly changing each others' organization and/or capacity. Perhaps "co-evolution" is the best term to describe the cycle of continuous mutual influence characteristic of systems operating according to the principle of cyclic integration. The identities of the elements involved are not fixed. They evolve. Hence, the use of systemic logic may make it easier in some situations to discover unexpected interactions or phenomena. In this sense systemic logic overlaps with Arlin's (1975) candidate for a fifth stage, "problem finding". Arlin distinguished problem finding from "problem solving", which is seen as a hallmark of formal logic. But Labouvie-Vief (1980) notes that formal logic also generates novel and untried solutions. If the terminology is adjusted, it can be seen how both forms of logic can both promote and inhibit creativity.

1. The more advanced systemic operations are still being articulated by mathematicians and philosophers. The principles of General Systems Theory seem the most likely candidates here. Principles such as emergence, equifinality, and co-evolution are a few examples. For researchers interested in taking up this quest, von Bertalanffy (1968), Klir (1972), and Weinberg (1975) provide good introductions. Also, Jantsch and Waddington (1976) have compiled a panoramic sampling of the applications of these principles in various sciences.
Problem solving could also be called "solution finding". That label brings out Labouvie-Vief's point about the creativity of formal logic just as Arlin's phrase brings out its foreclosing properties. "Problem finding" suggests the creative side of systemic logic. New definitions of problems are the key to new invention. On the other hand, if problem finding is taken to mean finding reasons for not attempting new solutions we can see the inhibitory role it plays in creative exploration. Creativity is a multifaceted phenomenon and thankfully neither form of logic seems to have it cornered.

Cyclic Transitivity and the Feedback Concept.

Cyclic transitivity is based on the fundamental systemic concept of feedback. The recycling component clearly requires an understanding of the feedback concept. The layout procedure, however, could be solved without it. Adjacent elements could be considered successively without ever entertaining any notion about how an element receives its own output back as input. In Selman and Jaquette's (1977) stage theory of social perspective taking, the stage 3 child can see all the perspectives but cannot see them all at once. Likewise, the cyclic transitivity layout procedure could be solved by considering the links between elements successively only. At the next phase in Selman and Jaquette's framework the child can deal with mutualities and see two perspectives simultaneously. The basic features of feedback could be read into the layout procedure through the simultaneous appreciation of an element's input as its output and of its output as its input. This level of sophistication, however, would not be necessary to produce a correct answer for the layout procedure. In a two element cycle, the equation of one element's outputs with its later inputs amounts to solving the layout problem through the
use of a transitive recycling operation. Perhaps the layout component, with a more familiar content, would prove to be a task simulating the operations underlying Selman and Jaquette's second stage (self-reflection). Likewise, what underlies their third stage (mutual perspectives) might be the operation of transitive recycling. Future research in the area of social perspective taking might examine the relevance of this systemic cognitive operation. Conversely, future research on cyclic transitivity might examine the effects of reducing (or increasing) the number of elements in the cycle. A two element cycle would be a closer analogue of the perspective taking problem.

One of the most curious findings with respect to cyclic transitivity was in the social domain transitive recycling section. The introductory "Own Wheat" item (see table V), which assessed the ability of respondents to trace the commodity flow in the direction opposite to that of the dollar flow, was not intended to measure ability with cyclic transitive operations. Nonetheless, as the data came in, the item began to appear more and more interesting. The "own wheat" item was serendipitously constructed to be an exact mirror image of the "same dollar twice" item from which the social transitive recycling scores were obtained. The only logical difference was that the wheat went from the farmer to the WMB first (let us call this the clockwise direction) while the dollar went from the farmer to the grocery store.

2. If it proved fruitful, this line of reasoning might lead future investigators to the next logical question: what more sophisticated version of cyclic transitivity might underlie Selman and Jaquette's fourth stage (social and conventional system)? At first glance it appears that the fourth stage (social and conventional system)? At first glance it appears that the fourth stage moves away from any sort of transitive operation towards a classification of all the elements under one heading. The elements cease to be viewed as distinct entities and come to be seen as parts of an integrated whole. This sounds like systems synthesis.
first (counterclockwise direction). Surprisingly, the clockwise item was much easier than the counterclockwise item. If we look closer at the nature of what is being cycled we see that tracing bread around the wheat cycle is easier than tracing money around it. Maybe this is because the younger children can imagine wheat, flour, and bread moving without the reciprocal movement of money. They might have more trouble thinking of money moving without the reciprocal movement of goods. If so then the movement of goods is an "unidirectional" transitive recycling because only one thing moves in only one direction. The movement of money would be like a "bidirectional" transitive recycling because every time the money moves in one direction there must be goods moving in the opposite direction. This interpretation is consonant with the findings of Furth, et al. (1979) that children understand that you get food from the grocer before they understand that you have to give the grocer money in return. In any case future research ought to examine the differences between more clearly constructed cases of unidirectional and bidirectional transitive recycling.

Another possible interpretation of the difference has to do with what happens to the recycled commodity when the farmer receives it. The bread stops going around the cycle because the farmer eats it. The "same dollar twice" item, on the other hand, makes specific reference to the release of the recycled commodity for a second time. The bread goes around once but the dollar can go around an indefinite number of times. The wheat/flour/bread travels in a single circle; the dollar travels around the circle an indefinite number of times, giving the impression of a spiral motion. Future research might also examine the importance of this additional variable in cyclic transitivity.
(v) Cyclic Integration and Its Components.

The systems analysis sections of the interviews assessed the respondent's ability to decompose the whole cycle, into its minimally essential subcycles while still preserving its integrity. In the bio-ecological domain, for example, this meant displaying a realization that the carnivores and herbivores could be eliminated without eliminating the remaining elements but that none of the three remaining elements (producers, decomposers, nutrients) could be eliminated without destroying the whole cycle.

The systems analysis operation seems to be a systemic analogue of the isolation of variables operation in formal logic. Some systems theorists consider the phrase "systems analysis" to be a contradiction in terms since analysis per se entails untangling the complex web of interconnectedness. Perhaps it is for that very reason that the term "systems analysis has come to refer to the study of more closed systems, notably computers. During the late 1950's and early 1960's, systems theory was synonymous with systems analysis. Later systems theorists, concerned with more open systems (e.g., biologists like Ludwig von Bertalanffy and Conrad Waddington), tried to expand systems theory into areas concerned with synthesis, co-evolution and emergence. This latter thrust seems to require the type of thinking that the systems synthesis component has tapped.

As originally conceived, cyclic integration was to subsume cyclic transitivity insofar as the subordinate (bottom) and supraordinate (top) levels mutually influence one another through bidirectional feedback loops. Part of the influence flows from the bottom to the top and part of it flows from the top to the bottom. The systems synthesis component captured more of the
flavor of what cyclic integration was intended to be than did the systems analysis component. The systems synthesis section dealt directly with the flow of influence from the subordinate level to the supraordinate level (see figure 7, part A).

There is need for further logico-mathematical refinement of the cyclic integration construct before what was intended by it can be more effectively assessed. Is systems synthesis to be considered the bottom to top component of a larger grouping of operations to be called cyclic integration? If so, shouldn't there also be some operation included in the grouping that treats the subordinate level by each single element and traces their effects on the multiple facets of the supraordinate level (see figure 7, part B)? Or should we consider integration to be a type of multiple concatenation involving transitive recycling? If so, then both the supraordinate and the subordinate levels would be treated by single elements (see figure 7, part C).

The same questions could be posed in reverse when dealing with the top to bottom part of cyclic integration. Obviously, there is much room for future work at the most advanced levels of systemic thinking.

B. Social Development

The implications of this research for social development in the sense of understanding interpersonal interaction were mentioned in section A (iv) of this chapter in connection with Selman and Jaquette's (1977) stage theory of social perspective taking. The present section deals exclusively with social development in the sense of interaction between the individual and society.
Figure 7

Some possible forms of bottom to top processes in cyclic integration.

A. Many to one: systems synthesis

B. One to many: like Marx's "internal relations"

C. Transitive form: takes representative entities from both populations

Supraordinate Level

Subordinate Level

single entity

multiple entities

e.g., a population

multiple entities

e.g., an individual

multiple entities treated singly
In terms of the development of understanding of social systems, we have begun to formalize, or perhaps a better word would be "mathematize", the child's progress. The pioneer work of Furth (1977), Jahoda (1979) and others was largely descriptive, as it should be at that initial stage of investigation. Now that several studies have accumulated, the present study attempted to unearth the underlying cognitive operations. Since some of the individual cognitive operations show a sensitivity (in terms of difficulty level) to slight changes in content, perhaps that is not the most useful level on which to report the results. Instead, the findings are described at a grosser but more stable level, the level of groupings of operations.

As far as can be determined from the research done up to now, children seem to go through four phases in their progress towards an adult understanding of social systems. This proposition should be treated as a hypothesis rather than a conclusion. This is an area where the findings of the present study are of heuristic value. With that in mind, let us proceed to a more detailed examination of this "four phases" hypothesis.

It is being suggested that the first two phases appear during the stage of concrete operations. The last two seem to appear during the post-concrete stage. All children would presumably go through the stages in the same sequence but the appearance of phases within stages is subject to a great deal more individual variation in ordering than their appearance between stages.

(i) Ordination

The first thing that children seem to appreciate about social organization is that some people are more important than, or "come before" others. There are the people at the top, the people in the middle, and the people at the bottom. This realization is reflected in everything from their understanding of the "first come first serve" rule to their threats to tattletale on each other.
(ii) Hierarchy

The understanding of nested classifications and whole-part relationships usually develops a little later. This is when government starts to be seen as a permanent apparatus of power, a state structure. Prior to that children often speak of the government as "he", and "he" has personal power (Connell, 1971; Easton and Dennis, 1969). The understanding of hierarchical social ordering also extends to geo-political areas (Jahoda, 1964). Children begin to realize that being a Vancouverite does not preclude one from being a British Columbian and a Canadian at the same time.

(iii) Systems Analysis

The ability to mentally remove elements from a social feedback loop without destroying the cycle itself would appear to emerge early in the post-concrete stage. Adelson and his colleagues (Adelson, Green and O'Neil, 1969; Adelson and O'Neil, 1966; Adelson, 1970) has commented on the extremely draconian and authoritarian approach that adolescents often take to social order. Perhaps this is a natural result of being able to cognitively remove (e.g., execute, outlaw, ban) the elements that a cursory causal analysis identifies as the precipitating causes of the disorder (e.g., lawbreakers, unions, opposition parties). The adolescent relying solely on systems analysis starts by taking the social system as a given. The changes that are seen as possible involve changes in the parts of the system, not the whole system. There is little appreciation for how the whole evolves into something else when one of its interdependent parts is changed.

(iv) Systems Synthesis

With the mastery of systems synthesis the adolescent can now also envisage changes in the whole social system arising from the actions and interactions of the parts across time. Systems synthesis allows the adolescent to relate effects across personal and societal levels. For example, seeing the interrelatedness
between personal finances and the national economy was counted as evidence of systems synthesis. The amount of taxes paid are related both to how much one earns and how much the government spends. Likewise, government expenditures are related to how much the government charges in taxes and how much the national currency will fetch internationally. Note here that there are two levels of finance, the personal and the national. Each level is affected by factors on the same horizontal level. Discretionary personal income for an individual or profits for a business are affected by both gross income and cost. The balance of a national budget is affected by the value of the currency and that in turn relates to the governments "productivity" in terms of foreign policy, internal stability, international trade agreements, etc. Those are the feedback loops that operate on each respective level alone. But the financial picture for each level is also influenced by feedback loops that operate across levels. The individual's discretionary income and the business's profits are influenced by taxes and government expenditures. The balance of the national budget is conversely influenced by the amount of goods and services produced by the individuals (GNP private sector). There are, of course, innumerable other influences across levels too but the ones cited here are sufficient to make the point. The point is that systems synthesis applied to societal affairs involves tracing the lines of mutual influence across levels of organization. These vertical feedback loops provide control information for both levels of organization simultaneously. The wheat cycle could be treated as a horizontal feedback loop if the WMB is conceived as a type of wholesaler. Such a conception would indicate a failure to perceive the hierarchical arrangement between taxpayer and government. The concrete operational achievement of mastering hierarchies is a prerequisite for systemic thinking. When the
respondent gave responses displaying an appreciation of the WMB's role in the vertical feedback loop, as well as the horizontal loop, then a pass was scored on systems synthesis.

In general then the chart of development in the child's understanding of society starts with understanding social ordering, then social hierarchies. With the advent of the post-concrete stage systems analysis becomes possible. Systems synthesis might become possible at the same time but its employment may depend much more on a pre-requisite base of societal knowledge. Perhaps systemic logic is simply neglected by the culture (Buck-Morss, 1975; Buss, 1977b) and so the use of its more difficult forms (e.g., systems synthesis) has not become prevalent among adolescents.

Perhaps by their interactive nature, feedback loops cannot be apprehended thoroughly without interaction of some sort. Partaking of the interactions that these loops describe would at least help one to acquire a broader base of facts about the system. Insofar as understanding feedback loops requires interacting with them systemic thinking is more pragmatic in nature. If a systemic understanding of society carried with it a heavy prerequisite of interaction on the societal level, it would be no wonder that only a minority of the oldest adolescents in this study evinced a mastery of systems synthesis.

C. "Social Psychology"

The present study takes a step towards correcting some of social psychology's shortcomings identified by critics in what has come to be called "the crisis literature". In the crisis literature several authors have criti-
cized the tendency for psychological social psychology (PSP) to isolate itself from developments (a) outside North America (Smith, 1978; Silverman, 1977), and, (b) in other disciplines (Sherif, 1977). In the sociological wing of social psychology (SSP) there has been concern over an opposite trend. What is essentially social psychological research tends to be presented and labeled as belonging to a substantive subfield of sociology thus promoting the dissipation of SSP (Liska, 1977; Hewitt, 1977). Starkly stated, the situation is this: those who pursue various interdisciplinary lines emanating from social psychology seldom relate their work back to the discipline itself while those who are committed to the discipline tend towards isolationism. Both responses are unhealthy for the discipline.

(i) Towards an Interactive Framework

It needn't be one or the other. There is another alternative. Social psychology stands at the interstice between the complexity of the person and the complexity of society. The task of understanding how the two relate to one another is an uniquely social psychological problem. Yet it is a problem that recurs in all branches of social science. The nature of person-society interaction is of vital importance in anthropology, economics, geography, history, political science and sociology as well as psychology. For this reason, social psychologists are in an excellent position to fill the role of social science generalists. In order to make this type of contribution, however, there must be a general framework for studying person-society interaction. G.H. Mead (1944) made a fruitful contribution along those lines. It led to a good deal of empirical research on various aspects of the topic but that research has become diffuse. There is a need for an interdisciplinary social psychological...
framework that will integrate all the diversity of insights that have accumulated with regard to person-society interaction (Boutilier, Roed, and Svendsen, 1980). There are satisfactory theories about the social system and satisfactory theories about the person-system but in the author's opinion there are no adequate theories about the processes that characterize the interaction of those systems. DiRenzo (1977) has suggested that a desideratum in such a framework would be the description of both systems in isomorphic terms. That is, the person and the social organization should be described in a common metatheoretical language. The present research is an attempt to move towards the kind of integrative framework than Boutilier, et al. and DiRenzo called for.

Current theories in PSP tend to construe the individual as a passive observer of an active environment (Neisser, 1980). The soviet psychologist, S.L. Rubenstien (cited by Payne, 1968), attempted an alternative approach. He sought a theory which would view the individual as an active participator in an active environment. Since open systems must, by definition, remain active in order to ward off entropy, an interactionist view of both the person and the social environment promises to provide a framework for theories that postulate an active person in an active environment. Piaget's theory of the person's cognitive modeling of the environment is a good example of how an interactionist position could be applied to describing the person system. Piaget construes the individual as an active and interactive constructor of reality. In several places one can already find corresponding theories of the active social system (e.g., Ball, 1978; Boulding, 1962; Easton, 1965; Mysior, 1977; Sztompka, 1974). The task, then, was to extend Piaget to bear upon the person's interaction with the social system. It was hoped that this would help provide the framework needed to (a) integrate the social psychology being done
in diverse disciplines, and, (b) facilitate bringing the socio-cultural context to bear upon the study of the individual.

Numerous social psychological topics can be better understood once we have a framework for describing how well individuals understand those aspects of society that they are influencing (i.e., active person) or that are influencing them (i.e., active social system). For example, locus of control with respect to society, especially politics, is a subfactor of the I-E scale (Lao, 1970; Collins, 1974). The analogous construct in sociological social psychology is alienation (Seeman, 1959). Scale scores on the political control factor do not tell us if a person's feelings of powerlessness, for example, are a result of a lack of understanding of the political system or real disenfranchisement or both. The present study provides a means of describing the person's level of understanding of the political system in more detail.

According to Piaget (e.g., 1970) understanding advances through interaction with a particular environment. Extending this principle to the understanding of social systems, we should expect a microgenetic recapitulation (Werner, 1948) of the ontogenetic sequence found in this study. Each time a person enters a new organization, for example, their understanding of the organization should progress through the phases described earlier (i.e., ordination, hierarchy, systems analysis, systems synthesis).

The principle of understanding through interaction also predicts that, for any individual, lower levels of understanding will be found with respect to those aspects of society that they interact with less. For example, medical doctors might have a very poor understanding of the relationship between welfare agencies and their clients. Extending this idea, we might even be able to characterize peoples general views of society as being built around those aspects of it with which they have the more frequent and/or important interactions. Thus we would predict that the core cycles in a lawyer's view
of society would involve government and legislation. The central cycles in a
housewife's view of society may involve the various phases of family life from
marriage, through childrearing, to grandparenthood. Members of industrial
labor unions might be prone to see the inflationary spiral as the most signifi-
cant cycle that makes society meaningful to them. Rokeach (1973) has found
that different occupational groups have different sets of values. Political,
social, and economic value orientations may well arise from individuals' and
group's understandings of what moves do and do not produce desired outcomes in
interaction with society through some particular feedback loop. For example,
Kohn (1969) finds that working class people value obedience much more than do
middle class people. In terms of financial security, obedience gets workers
more of what they want than autonomy or disobedience. Workers and management
are in a relationship of cyclic integration where autonomy produces negative
feedback for the workers. In general then, values and attitudes may be signifi-
cantly related to, and perhaps, generated by, the types of feedback loops
that individuals participate in in their interactions with various aspects of
society.

(ii) Towards Specifying the Structure of the Social Situation

For some time now social psychologists have emphasized the power of "the
social situation" to control behavior. The Milgram (1963) obedience study and
Zimbardo's prison study (Zimbardo, Haney, Banks, and Jaffe, 1972) are
classic examples. The work on bystander intervention emphasizes the role of
the individual's interpretation of the situation in controlling behavior. As
yet, however, no system has been devised for analysing or classifying social
situations. Perhaps the levels of understanding society presented in this study
would help do that by providing a framework for describing the individual's construction of the situation. The phases reported, and perspectives discussed in the present study could help social psychologists specify just what features of "the situation" are salient to different persons. The version of interactionism advocated by Bowers (1973) sees behavior (B) as a joint function of the person (P) and the situation (S) such that \( B = f(P, S) \). That form of interactionism leaves the problem of defining the situation unsolved. Buss (1977a), Endler and Magnusson (1976), Overton and Reese (1973) advocate a form of interactionism where the situation and the person are functions of each other such that \( P \leftrightarrow S \). This type of interactionism would be facilitated by the framework presented here because the situational side of the interaction could be specified in terms that relate to the subject's own construal of the situation. Note that this is very different from defining the situation (a) exactly as the subject does, accepting his verbal reports purely at face value, and (b) autistically, without any reference to what subjects or anyone else say they find salient in the situation. Extended to the understanding of social reality the Piagetian approach promises to identify only the form of the subjects phenomenal situation. The content will vary from person to person. This is where the trait side of interactionism becomes important. Few, if any, social situations can have only one possible form. Unless social psychologists can describe the possible forms that a situation may take for different people, the only person by situation interactions that will produce consistent results will be those where the situation is construed more or less the same way by everyone. Personality variables are poor predictors of behavior in the Milgram obedience situation. Perhaps this is because its actually several situations overlaid, one upon the other. Personality variables might be more predictive if their
interaction with the form of the situation (i.e., ordinal, hierarchical, systems analytic, systems synthetic) being perceived by the subject were examined.
Piaget's original notion of stages as structured wholes fares quite well when the tasks used to test the notion are not restricted to a particular type of content and when a wide range of ability levels are sampled. The general Piagetian approach seems to generalize quite well to bio-ecological and societal content. The observed difficulty orderings and stage related discontinuities were generally as predicted. The systemic tasks, which appeared only in the two open systems domains, were therefore not likely to have been confounded with any abnormal content related artifacts.

The cyclic transitivity and cyclic integration structures identified and examined in this study turned out to be composed of four quite distinct components which are cognitive structures in their own right. The most difficult operations for the sample were the transitive recycling component and the systems synthesis component. These upper systemic tasks were as much more difficult than the formal operations as the formal operations were more difficult than the concrete operations. Moreover, the gap in difficulty levels was a Guttman step but there were no Guttman steps among the upper systemic tasks. The greater difficulty of the upper systemic tasks could not be clearly attributed to the more unfamiliar nature of their contents. These results raised the possibility that these tasks might assess operations representative of a fifth stage of cognitive development.

The upper systemic tasks satisfied all the criteria for a fifth stage except concurrence (for which there were no relevant data available) and abruptness of transition. The upper systemic components were first mastered
by respondents who were about two years older than those beginning to master the formal operations. The majority of respondents at all age levels never mastered the systemic components; whereas from age 14 onward the vast majority had mastered the formal operations. It was noted that gradual stage transitions are not incompatible with stage interpretations. It was suggested that success on the upper systemic tasks might be observed to be more frequent were future research to sample older age groups.

Although the fifth stage possibility remains viable, so does the alternative position that systemic operations develop in parallel with formal operations as a complementary aspect of cognitive diversification in the post-concrete stage. A related suggestion was put forward to the effect that formal logic and systemic logic are complementary and develop in parallel throughout the concrete stage as well as the post-concrete stage (and perhaps even throughout all stages).

The child's understanding of society was described as going through two stages with two overlapping phases within each stage. According to this description, in the concrete stage, first ordinal, then hierarchical structures would become comprehensible to the child. Early in the post-concrete stage the adolescent would be able to use systems analysis to make societal reality meaningful. Later, systems synthesis would emerge as a conceptual tool.

This research was designed to allow ample scope for exploration and discovery. Quite a few discoveries were made and even more questions were raised. Perhaps the most important outcome was the empirical vindication of the existence of a second type of logic. In this research the philosophical possibility of systemic logic was successfully translated into procedures for assessing the presence of systemic logical structures.
REFERENCE NOTE


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APPENDIX A: Physical Domain Tasks

The methods for assessing mastery over each of the eight cognitive operations in the standard domain is described herein. For each cognitive operation the source of the task and miscellaneous background information is given in the introduction. Then the materials are described before the questions assessing the respondent's familiarity with them are presented. The instructions and probes to be directed towards the respondent appear next and are followed by a description of the scoring procedures and criteria.

Since Piaget was not especially concerned with studying the understanding of open systems, there are no standard Piagetian tasks for cyclic transitivity and cyclic integration. Instead, the physical domain contained three formal operational tasks that acted as markers in the scalogram analyses. They made it possible to locate the difficulty levels of the systemic tasks with respect to formal operations.

A. Seriation

(i) Introduction

The standard seriation task, described in many places (e.g., Formanek and Gurian, 1976) was used. The respondents were also required to interpolate an element into the series. The interpolation requirement helped to distinguish stage II responses from stage III responses (Ginsberg and Opper, 1969, pp. 137-138).

(ii) Procedure

Materials. -Seven cardboard cylinders that stand on end, all one color (red), ranging in height from 2" to 8".
- One interpolation cylinder 5½" in height.

Familiarity Assessment. The seven cylinders were placed standing on end in a random array in front of the respondent. The respondent was asked, "Can you tell me what these things are?" and, if not already answered by the respondent, "Do you know what they are made of?"

Pass: Tubes, Cardboard. Fail: Other, Don't know, No response.

Instructions,

Part A: The respondent was asked to arrange the cylinders in order. Size was not mentioned in order to test whether the respondent seriated spontaneously.
Part B: The respondent was told to arrange the cylinders going from the "smallest to the largest", or from the "littlest to the biggest" if this had not already been done.

Part C: If the cylinders were seriated correctly, the respondent was shown the interpolation cylinder and was asked to, "Put it in the right place with the rest."

(iii) Scoring

The responses were classified into three stages. Only stage III responses were counted as evidence for the mastery of ordinal relations for the purpose of dichotomous scoring.

I (Fail): The child often divides the objects into two groups such as large and small.

II (Fail): The child sometimes divides the objects into three groups: small, medium, and large. Correct seriation sometimes occurs after considerable unsystematic trial and error. In stage II the interpolated object is misplaced.

III (Pass): The child is able to seriate all eight objects correctly.

B. Linear Transitivity

(i) Introduction

Following the standard procedure (Glick and Wapner, 1968) for determining the ability to perform transitive operations we used three objects differing in magnitude along one dimension. The objects were cardboard cylinders varying in height, each one a different color. The cylinders were presented in pairs with the cylinder of intermediate length being a member of both pairs.

The respondent memorized the relations between the members of both pairs (e.g., shorter than) and the designations of each member (e.g., names, colors).

The relations between the member of each pair were presented heterotropically. In heterotropic presentation the relational terms used in each pair are antonyms (e.g., "A is longer than B" and "C is shorter than B"). Glick and Wapner found heterotropic relations to be more difficult than isotropic relations with this procedure. Heterotropic relations were used because they focus attention on the bivocal nature of the intermediate element.

(ii) Procedure

Materials: Three cardboard cylinders (A,B,C) varying in length and color.

<table>
<thead>
<tr>
<th>Color</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Red</td>
<td>9&quot;</td>
</tr>
<tr>
<td>B. White</td>
<td>6&quot;</td>
</tr>
<tr>
<td>C. Blue</td>
<td>3&quot;</td>
</tr>
</tbody>
</table>
Familiarity Assessment. The cylinders were presented in pairs (B with A, and, B with C). The child was told that he/she would be shown two pairs of cylinders (or "tubes") and would than be asked, "Which was the tallest?" and "Which one was the shortest?"

The child was asked to name the color of each cylinder as it was presented. The white cylinder (B) was displayed first and then the red cylinder (A). The red one was to the child's right vis à vis the white one. The cylinders were then removed from sight and the child was asked, "Which cylinder did I show you first?"

Pass: White

"Which cylinder did I show you second?"

Pass: Red

The same procedure was repeated for the second pair with the white cylinder being displayed to the subject's left vis à vis the blue one and the blue one being presented first.

Instructions. When the investigator was certain that the child remembered the colors of all three cylinders, he asked, "Which one was the tallest?" and "How can you tell that?" followed by, "Which one was the shortest?" and "How can you tell that?"

(iii) Scoring

I (fail): Incorrect choice for one or both endpoints.

II (Fail): Correct choice of endpoints but incorrect explanation for choice (e.g., tautology; temporal order as height predictor)

III (Pass): Correct choice of endpoints with correct rationale for choice.

C. Logical Multiplication

(i) Introduction

The logical multiplication of classes is the operation underlying multiple classification. It also underlies the concept of the "greatest lower bound" in lattice structures. Logical multiplication is sometimes referred to in logic as the "intersection" of sets of "conjunction" (Gorovitz and Williams, 1969) in truth tables, symbolized by the operator "∩".

The simplest procedure for assessing mastery of logical multiplication is the two-way classification task (Inhelder and Piaget, 1964).
(ii) Procedure

Materials. - A two-fold matrix with (a) yellow shapes in the left column and red shapes in the right column, and (b) star shapes on the top row and square shapes on the bottom row, thereby yielding:

- Left top cell: yellow star
- Right top cell: red star
- Left bottom cell: yellow square
- Right bottom cell: BLANK (to be filled by respondent with correct entry of a red square)

-Below the matrix was a row of five alternatives that may be selected for the right bottom cell. These were:

1. red star
2. red square
3. yellow star
4. yellow square
5. red circle

Familiarity Assessment. The investigator pointed to each object in the matrix and asked the respondent what it was. If shape or color were not mentioned, the investigator asked what shape or color each object was.

Pass: Correct shape and color.

Instructions. The investigator then pointed to each object in the matrix from column to column, saying "OK, so here is a yellow star. Here is a red star. Here is a yellow square. Which of these (points to row of five alternatives at bottom) goes best here (points to blank cell) with this yellow star, this red star and this yellow square?" Respondents' explanations were recorded.

"Can anything else fit in this empty place just as well as your choice of __________?"

(iii) Scoring

I (Fail): Incorrect choice

II (Fail): Correct choice; incorrect explanation

III (Pass): Correct choice; correct explanation
D. Class Inclusion

(i) **Introduction**

The operation of class inclusion requires a combined understanding of logical addition and inclusion relations. Logical addition is sometimes referred to in logic as the "union" of sets of "inclusive disjunction" in truth tables (Gorovitz and Williams, 1969), symbolized by the operator " $U$". Inclusion relations are implicit in the concept of "least upper bound" in lattice structures.

The class inclusion task used was adapted from Inhelder and Piaget (1964). The "whole" class was the construction material (wood) and the "part" class was the color (red vs. green).

(ii) **Procedure**

**Materials.** -Seven wooden beads, five green and two red, in a bowl.

**Familiarity Assessment.** -The respondent was asked "Can you tell me what I have here?" If the subject failed to mention color the investigator asked what color the objects were. Likewise, if construction material (wood) was not mentioned, a prompt was given for that.

**Instructions.** When the respondent had affirmed these premises, the investigator asked "Are there more wooden beads in this bowl of more green beads?" While recording the responses the investigator continued with, "If I took away all of the green beads would there be any beads left in the bowl? If I took away all the wooden beads would there be any beads left in the bowl? Which are there more of in this bowl, green beads or wooden beads?"

(iii) **Scoring**

I (Fail): More of the part class than the whole class.

II (Pass): More of the whole class than the part class.

E. Combination of Variables

(i) **Introduction**

This version of the problem was adapted by Arlin (1978) from a version by Sills and Herron (1976) which reconstructed the essential logical features of Inhelder and Piaget's (1958) "Combination of Colored and Colorless Chemical Bodies" task. The basic idea was for the respondent to engage in a systematic search for the right combination of variables that would produce the desired outcome.
(ii) Procedure

**Materials.** A black box (10 cm. x 5½ cm. x 4 cm.) with a row of 5 numbered momentary push buttons and a red indicator light on the top. The depression of three buttons simultaneously turned on the light. A fourth button turned it off again. The fifth button was not wired to the battery.

**Instructions.** The investigator placed an index card between the five buttons and the light such that the respondent could not see which buttons were being depressed but could see the light. The investigator said, "Now watch what happens (DEPRESS BUTTONS TO ILLUMINATE LIGHT). I made this light go on by pressing down on some of these buttons. Would you like to try to make the light go on by finding the buttons to push?" The investigator recorded the attempts of the respondent to illuminate the light, noting which buttons were pressed in which sequence. The respondent was then asked why he/she pushed the buttons which had been attempted. The respondent was encouraged to continue trying and was permitted to look at the numbers which the investigator had written down representing each of the respondent's tries. If the respondent was successful in turning on the red light he/she was asked "What would you do to find any other possible combinations of buttons which might also turn on the light?"

(iii) Scoring

The scoring was the same as that used for the Piagetian "Combination of Colored and Colorless Chemicals" task (Inhelder and Piaget, 1958; 110-122).

**Fail**

Concrete II A (1-2 points): Empirical associations, precausal explanations and 2 x 2 trials of pairs of buttons.

Concrete II B (3-5 points): Multiplicative operations with the trial and error introduction of n x n combinations.

**Pass**

Formal III A (6-8 points): Formation of systematic n x n combinations.

Formal III B (9-10 points): The combination and, more particularly, the proofs appear in a more systematic fashion.

F. Probability in Random Drawing

(i) Introduction

This task was Arlin's (1978) standardization of the less structured procedure described by Piaget and Inhelder (1975; 116-130). With each child
Piaget and Inhelder changed the number and color of items to be drawn. This more standard version made the results more quantitatively comparable across children and simplified the procedures for the investigator.

(ii) **Procedure**

<table>
<thead>
<tr>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>-box</td>
</tr>
<tr>
<td>-beads: 6 yellow, 6 green, 6 red</td>
</tr>
</tbody>
</table>

**Instructions.** The beads were counted into the box in front of the child. The investigator said, "What do you think are your chances of drawing a red bead on your first reach into this box? Why do you think so?"

If the child did not understand the question, the question was rephrased to: "How many turns do you think you will need to take before you will get a red bead from this box?".

The investigator let the child draw one bead. Then the child was asked, "What do you think are your chances of getting another ... (the color the child had drawn was named) bead on your second turn? Why do you think that?"

(iii) **Scoring**

I (Fail) Absence of systematic probability.

II (Pass) Beginnings of quantified probability (e.g. 1/3 for first draw).

III (Pass) Successful quantification again after each drawing (e.g. 5/17 for second draw).

G. **Isolation of Variables**

(i) **Introduction**

This task was devised by Kuhn and Ho (1977) with minor adaptations by Chandler, Siegel and Boyes (1980). The basic idea was to show the respondent two arrays of outcomes with the inputs that produced each. In the first array the respondent had to discern which two input variables were equally efficacious in independently producing an outcome. In the second array, the desired outcome could only have been obtained through the use of two particular inputs conjointly. The respondent had to discern how the outcome was achieved.

(ii) **Procedure**

<table>
<thead>
<tr>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Empty vials with plant food labels</td>
</tr>
<tr>
<td>-Plastic plants</td>
</tr>
</tbody>
</table>
### First array:

<table>
<thead>
<tr>
<th>Plant Food Label</th>
<th>Height of Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEAFY PLANTS</td>
<td></td>
</tr>
<tr>
<td>no food</td>
<td>3&quot;</td>
</tr>
<tr>
<td>a</td>
<td>3&quot;</td>
</tr>
<tr>
<td>b</td>
<td>6&quot;</td>
</tr>
<tr>
<td>c</td>
<td>6&quot;</td>
</tr>
<tr>
<td>ab</td>
<td>6&quot;</td>
</tr>
<tr>
<td>ac</td>
<td>6&quot;</td>
</tr>
<tr>
<td>bc</td>
<td>6&quot;</td>
</tr>
<tr>
<td>abc</td>
<td>6&quot;</td>
</tr>
</tbody>
</table>

### Second array:

<table>
<thead>
<tr>
<th>Plant Food Label</th>
<th>Height of Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOWERY PLANTS</td>
<td></td>
</tr>
<tr>
<td>no food</td>
<td>3&quot;</td>
</tr>
<tr>
<td>1</td>
<td>3&quot;</td>
</tr>
<tr>
<td>2</td>
<td>6&quot;</td>
</tr>
<tr>
<td>3</td>
<td>6&quot;</td>
</tr>
<tr>
<td>1,2</td>
<td>6&quot;</td>
</tr>
<tr>
<td>1,3</td>
<td>6&quot;</td>
</tr>
<tr>
<td>2,3</td>
<td>9&quot;</td>
</tr>
<tr>
<td>1,2,3</td>
<td>9&quot;</td>
</tr>
</tbody>
</table>

**Instructions.** One array at a time was placed in front of the respondent. The investigator said, "We're trying out different types of plant food. The types we used on each plant are shown by the bottles in front of each plant. All these plants were started at the same time. We're starting a new plant and we have to decide which would make the tallest plant. (INDICATE PLANTS AND FOOD INDIVIDUALLY AND STRESS THE HEIGHT). Now we don't want to use any more food than we have to, because it's very expensive. Now, think about it for a minute and tell me what you think we should feed the new plant we're starting in order to make it grow tall." When the subject had responded the investigator asked, "Why do you think that would be the best thing to make the new plant grow tallest?" Then the investigator asked "Does a,b,c,1,2,3 (ONE AT A TIME) have anything to do with how the (leafy/flowery) plants turn out?" The procedure was repeated for the second array and then the subject was asked to compare both arrays as follows: "Now, the plant foods we're using on these plants are the same foods we're using on the flowery plants. A is a. B is b. C is c. Do the plant foods work differently on the two types of plants? Does the type of plant make any difference to how the plant food work?" If the subject did not explain his/her answer the following probes were given: "How can you tell that?" "What is the difference?"
(iii) **Scoring**

The scoring was the same as that used by Kuhn and Ho (1977);

**Fail**

I Concrete: Reasons solely on the basis of isolated instances, ignores instances contradictory to own conclusions, makes logical error of false inclusion.

II Emergent Formal. Begins to logically exclude the inoperative variables if specifically questioned.

III Transitional. Spontaneously excludes the inoperative variable and includes operative ones but fails to differentiate between the two problems (alternative in first array; additive in second).

**Pass**

IV Early formal. Comprehends either alternative or additive causes.

V Consolidated formal. Comprehends and differentiates between alternative and additive causes.
APPENDIX B: Bio-ecological Domain Tasks

Except for the systemic relations, Appendix B parallels Appendix A in the tasks used. The tasks are from the same sources as those in Appendix A. For the seriation, linear transitivity, logical multiplication and class inclusion tasks the scoring is identical to that used in Appendix A. The reader is referred to Appendix A for scoring procedures. In all Appendix B tasks where printed words were the focal stimuli the words were read to all respondents as often as seemed necessary. The same general rule was applied to the highly verbal tasks of Appendix C (Societal Domain). Also, as in Appendix C, concrete memory aids were used to reduce the memory load on the respondent.

A. Seriation

(i) Introduction

In the physical domain seriation task, as in this one, the dimension of comparison was the vertical length. In the societal domain seriation task, as in this one, the correct solution required translating each item's ordinal position on one dimension of comparison into its ordinal position on another.

Herein, the height of eight trees had to be verbally recoded as an index of each tree's roots. The stimulus card bearing the fourth shortest tree was used as the interpolation card.

Although verbal seriation problems could have been constructed to necessitate strategies such as numbering and counting, these operations are not identical to seriation. It was therefore decided that numerical strategies would not be encouraged over any others. For this reason, the items were not numbered on any of the stimulus cards. Instead, individual items were identified by qualitative rather than quantitative features (i.e., height). The varying heights of the trees on each card presented sheer perceptual gradations that presumably were apparent to even pre-literate respondents. To this extent there is no such thing as a purely verbal, non-perceptual seriation task that does not invoke metric concepts and abilities.

(ii) Procedure

Materials. - Eight index cards with trees of different heights depicted. A person was pictured beside each tree to indicate relative size. The fifth tallest (fourth shortest) tree was used as the interpolation stimulus.

Familiarity Assessment. Seven of the cards depicting trees (minus the interpolation card) were displayed in front of the respondent and the investigator said, "Here are some pictures of some trees. The boy standing beside
the trees is the same boy in every picture. All trees have roots that go into the ground. You can tell how deep a tree's roots go by looking to see how tall the tree is. The taller the tree is, the deeper its roots go into the ground. Which of these two trees has the deeper roots? (Point to two trees of clearly different heights).

Here a note was made of the respondent's understanding of the correlation between height and depth of roots. If the respondent did not understand the relationship, it was explained again.

Pass: The taller tree had the deeper roots.

Instructions.

Part A: The respondent was asked to arrange the cards going from the one with the deepest roots to the one with the shallowest roots.

Part B: If the cards were seriated correctly, the respondent was shown the interpolation card and was asked to, "Put it in the right place with the rest."

(iii) Scoring

See Appendix A, Section A (iii).

B. Linear Transitivity

(i) Introduction

Following the standard procedure (Glick and Wapner, 1968) for determining the ability to perform transitive operations, three objects differing in magnitude along one dimension were used. The dimension was the number of eggs laid by three different species of birds.

Glick and Wapner found heterotropic relations to be more difficult than isotropic in the verbal mode. Heterotropic relations were used because they focused attention on the bivocal nature of the intermediate element.

(ii) Procedure

Materials. -Drawings of: an eagle, a robin, a duck. The drawings did not indicate how many eggs each laid. These were simply memory aids.

Familiarity Assessment. The investigator said that he was going to tell the respondent how many eggs were laid by the three different kinds of birds and then ask him or her which kind lays the most eggs and which lays the
fewest. The investigator then presented the child with two separate verbal statements as follows:

- "Robins lay more eggs than eagles."
- "Robins lay fewer eggs than ducks."

The respondent was required to memorize and to repeat both premises aloud. The drawings were presented in the appropriate pairs (i.e., robin and eagle; robin and duck) as the premises were rehearsed.

Pass: Memorization of the two premises.

Instructions. After the investigator was sure that the respondent had memorized the premises, the respondent was then asked, "Which bird lays the most eggs?" and "How can you tell that?" Immediately afterward, the respondent was asked, "Which bird lays the fewest eggs?" and "How can you tell that?"

(iii) Scoring

See Appendix A, Section B (iii):

C. Logical Multiplication

(i) Introduction

The task was essentially the same as that described in Appendix A, section C except for the use of printed words in the place of colored forms.

(ii) Procedure

Materials. A two-fold matrix with the (a) "Plant-eating" in the top row and "Meat-eating" in the bottom row, and, (b) "Fish" in the left column and "Bird" in the right column, thereby yielding:

- Left top cell: "Plant-eating Fish"
- Right top cell: "Plant-eating Bird"
- Left bottom cell: "Meat-eating Fish"
- Right bottom cell: BLANK (To be filled by respondent with correct entry being the words "Meat-eating Bird").

Below the matrix was a row of five alternatives, one of which was to be selected for the right bottom cell. These were the words:
1. "Plant-eating Fish"
2. "Meat-eating Fish"
3. "Meat-eating Animal"
4. "Meat-eating Bird"
5. "Plant-eating Bird"

**Familiarity Assessment.** The investigator read the cell entries to the respondent and then pointed to each one asking what it was. If eating habits or phylum were not mentioned, the investigator queried about them.

**Pass:** Mention of the correct diet and phylum.

**Instructions.** If necessary the features of each item were stressed again. Hereafter the instructions were the same as those in the physical domain task (Appendix A, Section C (ii) except that color and shape were replaced by eating habits and phylum.

(iii) **Scoring**

See Appendix A, Section C (iii).

D. Class Inclusion

(i) **Introduction**

Again the standard procedure was followed except that the array presented to the respondent was an array of words printed on a page and the classes were from biological science.

(ii) **Procedure**

**Materials.** —A sheet of paper with the word "Crow" typed on it in two places and the word "Duck" typed on it in five places, according to the spatial arrangement shown in figure B-1.

**Familiarity Assessment.** The words were read to all respondents and were re-read as often as was necessary to pre-literate or partially literate respondents.

**Pass:** Knowledge of what a crow, duck and bird are.

**Instructions.** The premises were reviewed with the respondent as follows:

"Are the ducks birds?"
"Are the crows birds?"
"Are they all birds?"
Figure B1

Display card for bio-ecological domain class inclusion task.
When the respondent had affirmed these premises the investigator asked, "Are there more birds here or more ducks?" While recording the responses the investigator continued with, "If I took away all the ducks would there be any birds left here? If I took away all the birds would there be any things left here? Which are there more of here, ducks or birds?"

(iii) Scoring

I (Fail): More of the part class than the whole.

II (Pass): More of the whole class than the part class.

E. Systemic Structures of Cyclic Transitivity and Cyclic Integration

(i) Introduction

The tasks used for assessing cyclic transitivity and cyclic integration do not easily decompose into one section for each cognitive operation. Therefore, they are discussed together. The scoring of all systemic relations tasks is covered in Appendix D. Therefore, only brief mention of scoring is made herein. The familiarity assessments and corresponding explanations are presented at the appropriate points throughout the interview. The interview schedule that follows can double as a data record sheet. The scoring manual is cross referenced with the items in the interview schedule.

The bio-ecological system to be used was a nutrient cycle comprised of plants, herbivores, carnivores, decomposing bacteria, and inorganic plant nutrients. When attempting to draw simplifying generalizations, ecologists often represent both aquatic and terrestrial ecosystems in terms of these five stages (e.g., Odum, 1971, p.207). Closer analysis reveals this schematic to be a compound of many interacting cycles (Sutton and Harmon, 1973, p.136). This nutrient cycle, however, was well suited for the proposed task. It was comprehensive enough to permit the elaboration of one or two levels of subcycles while remaining simple enough to explain quickly to those respondents who were not familiar with the entire cycle. The respondents did not need to be familiar with the relations among the elements of the cycle because each element was described to them (see below). Nonetheless, few younger respondents thoroughly understood concepts like bacteria and nutrient chemical in the soil. Since it might have taken days to thoroughly teach younger children these concepts it was practically impossible to insure that all respondents were equally familiar with the materials of this task. Instead the respondent's degree of familiarity with the materials was measured.

The interview proceeds in two main phases. Phase one is the cyclic transitivity phase. It contains (i) familiarization items, (ii) the layout procedure items, and (iii) the transitive recycling items, in that order. Phase two, the cyclic integration section, contains (i) further familiarization items, (ii) the systems synthesis items, and (iii) the systems analysis items, in that order. The interview schedule presented below is a step by step guide which includes instructions to the interviewer for displaying materials, reading explanations, and recording answers. It appears in a format suitable for use as a data record sheet.

(ii) Procedure
Materials. - Tape recorder.

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>EXEMPLAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawings of (a) a producer</td>
<td>a plant</td>
</tr>
<tr>
<td>(b) a herbivore</td>
<td>a caterpillar</td>
</tr>
<tr>
<td>(c) a carnivore</td>
<td>a bird</td>
</tr>
<tr>
<td>(d) a decomposer</td>
<td>a microscopic magnification of bacteria</td>
</tr>
<tr>
<td>(e) a mineral nutrient</td>
<td>a molecule of nitrogen</td>
</tr>
</tbody>
</table>

and, - a molecule of DDT
-multiples of (b) and (c)

Interview Schedule.

Phase One: CYCLIC TRANSITIVITY

PRESENT PLANT DRAWING

"Do you know what this is? Can you tell me something about it?"

RECORD FAMILIARITY Pass = It's a plant

READ FAMILIARIZATION

This is a plant. It takes in nutrients from the soil and combines them with sunlight and air to make new leaves and to grow. The plant foods in the soil are chemicals like nitrogen. Sometimes plants lose their leaves because insects or animals eat them.

PRESENT REST OF DRAWINGS ONE BY ONE IN AN IMPROPER ORDER IN A VERTICAL PILE
SECOND DRAWING PRESENTED WAS

"Do you know what this is? (IF NOT, NAME IT) Can you tell me something about it?"

RECORD FAMILIARITY

READ FAMILIARIZATION

THIRD DRAWING WAS

REPEAT

FOURTH DRAWING WAS

REPEAT

FIFTH DRAWING WAS

REPEAT
CATERPILLAR FAMILIARIZATION: This is a caterpillar. It eats the leaves off of certain kinds of plants. Some birds catch caterpillars and eat them.

Pass: It's a caterpillar

BIRD FAMILIARIZATION: This is a bird that eats all sorts of insects and caterpillars. When this bird dies its body gets eaten by the bacteria that live in the ground.

Pass: It's a bird

BACTERIA FAMILIARIZATION: These are various kinds of tiny animals called bacteria. They are so small that you can only see them with a powerful microscope. Bacteria live in the soil, the ground. They eat the dead bodies of plants, insects, birds and animals. Bacteria turn these dead bodies into chemicals like nitrogen that plants can then use for food.

Pass: It's a very small animal; like a germ; etc.

NITROGEN FAMILIARIZATION: This is a little piece of nitrogen. Nitrogen is a chemical that plants need to live and grow. It's a kind of plant food. A lot of nitrogen gets put in the soil by the bacteria which live in the ground.

Pass: It's a chemical; a kind of plant food

LAYOUT PROCEDURE

"Put the drawings in their proper order?"

?MISORDERED? "OK, that's good. Now put the drawings in an order which shows which ones depend on which other ones for their being there."

?STILL MISORDERED?

START WITH LAST ELEMENT PUT IN PLACE AND REPEAT THE FOLLOWING QUESTIONS FOR DRAWINGS IN REVERSE ORDER.

RECORD ELEMENT UNDER DISCUSSION

"Which one does this (element) depend on?"

"How does it depend on (the last one)?"

IF EITHER OF THESE TWO QUESTIONS ARE ANSWERED INCORRECTLY, REPEAT THE RELEVANT PART OF THE FAMILIARITY EXPLANATION.

REPEAT ② AS OFTEN AS NEEDED
?NOT A CIRCLE? "OK, now is there any way you can think of to show which ones depend on which other ones besides putting them in a straight line? Could the same thing be shown by some other arrangement of the cards?"

RECORD

?ANYTHING STILL SUBOPTIMAL? WHAT?  

"You've put the drawings in this order that's a good way to do it. Now let me show you another way it could be done."

CREATE PROPER CYCLIC ORDER

READ SUMMARY OF NUTRIENT CYCLE

SUMMARY OF NUTRIENT CYCLE: In this order the plant depends on the nitrogen for its food so the nitrogen molecule is beside the plant. The nitrogen depends on the bacteria for being there so the bacteria is next to the nitrogen molecule because the bacteria are what make the nitrogen that's in the soil. The bacteria depend on the dead bodies of all sorts of living things for their food because they eat dead bodies. So we put the bird beside the bacteria because the bacteria will need the bird's body for food when the bird dies. The bird depends on the caterpillar for its food because it eats caterpillars so lets put the caterpillar beside the bird. The caterpillar eats plants so it depends on the plant for its food. The plant goes next to the caterpillar. OK, now lets leave the drawings in this order and I'll ask you some riddles about the things in the drawings."

CYCLE DISPLAYED IN PROPER ORDER

PRESENT DDT DRAWING

"This is a molecule of DDT. Can you tell me what DDT is?"

RECORD FAMILIARITY

Pass: It's a pesticide; a chemical; poison for bugs; etc.

READ DDT INTRODUCTION AND FAMILIARIZATION:

Let's suppose that these plants are being grown by a farmer on his farm. He doesn't want the caterpillars to eat his plants so he sprays the plants with a chemical called DDT that will kill the caterpillars but won't kill the plants."

POINT TO DDT DRAWING "This is a little piece of DDT. DDT is a chemical that kills insects and animals if they eat enough of it. Farmers put DDT on their plants in order to kill the caterpillars and other insects that would otherwise eat the plants. The molecules
of DDT are so small that the insects and animals don't tell when they're eating it. The DDT molecule then stays in the insect's or animal's body until he has eaten enough of it to kill him. Plants can absorb DDT if its in the soil but it doesn't kill plants."

"When the caterpillar eats a leaf that has been sprayed with DDT the DDT goes into the caterpillar's body and stays there until the caterpillar dies. When a caterpillar has eaten a lot of molecules of DDT it dies. What might happen to a bird that eats a lot of caterpillars that are all full of DDT?"

?NO PREDICTION OF FATALITY? EXPLAIN IT.

TRANSITIVE RECYCLING

"Could the same molecule of DDT ever help kill two birds?"

?NO? "Why Not?"

?YES? "How could that happen?"

?UNSURE? "What happens to the bird's body after it dies from eating too many molecules of DDT?"

"And so what happens to the molecules that were in the bird's body?"

?STILL UNSURE? "So could the same molecule of DDT ever help kill two birds? Why not/How?

Phase Two: CYCLIC INTEGRATION

FAMILIARITY

READ GENERATION SPAN FAMILIARIZATION

This kind of plant (POINT TO DRAWING OF PLANT ELEMENT) grows very fast. If you put a seed from one of these plants in the ground, it would only take 3 months for that seed to grow into an adult plant that has seeds of its own. We say that three months is the "generation span" of this kind of plant.

These caterpillars (POINT) go through their life cycle even faster. It only takes 1 month for a caterpillar to grow from an egg to an adult that can lay eggs of its own. The generation span of these caterpillars, then, is 1 month.
This kind of bird only lays one nest full of eggs a year. It takes 1 year or 12 months for one of these birds to go from being an egg to being an adult bird that lays eggs. Therefore the generation span of these birds is 12 months.

Reproduction Familiarity Item

POINT TO DRAWING OF MULTIPLE CATERPILLARS AND BIRDS

"If there were these six caterpillars and it takes 1 month for their offspring to grow up into adult caterpillars then how many caterpillars would there be in just over a month? More, less or the same number?" (CIRCLE ONE)

Pass: More

"Why?"

?UNFAMILIAR? READ GENERATION SPAN EXPLANATION (REPRODUCTION):

When there are more caterpillars being born than dying then every month there will be more caterpillars than there was before. That's because they keep multiplying. There are more eggs becoming adults than there are adults dying so if conditions are good, the total number of caterpillars will go up.

Stavation Familiarity Item

MULTIPLE CATERPILLAR AND BIRD DRAWING STILL DISPLAYED

"If there were these two birds and each one needed 142 caterpillars to live for 12 months but they only had these 6 to eat between them, how many birds would there be in 12 months? More, same number or fewer?" (CIRCLE ONE)

Pass: Starvation

?UNFAMILIAR? READ STARVATION EXPLANATION:

"When there are so many birds that they don't all have enough food to live for 12 months then some of them will starve to death. If they starve faster than they can have babies then the number of birds will go down."

Caterpillar Population Item (Population Fluctuations)

"Suppose that when the farmer sprayed his plants with DDT, 9 out of every 10 caterpillars died but 1 out of every 10 survived. Tell me everything you can about the effects this would have. What would happen

(a) 1 month after spraying?"

(b) 3 months after spraying?"

(c) 12 months after spraying?"
SYSTEMS SYNTHESIS

BELOW EFFECTS NOT MENTIONED? PROBE FOR THEN AS FOLLOWS:

Rate Item "Could the DDT spraying ever lead to a time when the number of
caterpillars starts to rise sharply/rapidly? How? (MORE FOOD)/Why not?
(RECORD PREDICTION & REASON)

Renewed Infestation Item "Could the DDT spraying ever lead to fewer new leaves
sprouting on plants or to plants not being as healthy as before the spraying?
How? (MORE CATERPILLARS)/Why not?"

Birds Item "Could the DDT spraying ever lead to an increase in the number of
birds living in the area of the farm? How? (MORE CATERPILLARS)? Why not?"

Nitrogen Desert Item

ALL DRAWINGS STILL ARRAYED. DDT & MULTIPLES DRAWINGS REMOVED FROM VIEW READ
NITROGEN DESERT INTRODUCTION:

"At the end of the growing season when he had harvested all his crops, the
farmer got busy preparing the soil for the next spring. While he was ploughing
and cultivating, he usually added some fertilizer to the soil." Younger respond­
dents have the term "fertilizer" explained to them in terms of plant food. "This
year the farmer was trying some new kinds of fertilizer that he made at home
from a receipe he got from a friend. Well, he didn't follow the receipe
properly and instead of making fertilizer he accidentally made a chemical which
destroyes almost all of the nitrogen in the soil. The farmer didn't know that
he'd made this mistake until it was too late. He had already put the chemical in
his soil and it had already destroyed most of the nitrogen. There was nothing
he could do. Even if he put more nitrogen in the soil, it would be destroyed
by the chemical too."

"What do you think happened to the land?"

"What would the place look like after a while?"

SYSTEMS ANALYSIS

DRAWINGS STILL ARRAYED AS ABOVE

5 MINUS 1 Item

"Which of these (POINT TO DRAWINGS OF ELEMENTS) five steps could you remove
without entirely destroying any other step?" REMOVE IT

"How would the TWO ADJACENT) survive without the (ONE REMOVED)?"

Core Item

"Which of the remaining three could survive without the other two?"

"Why wouldn't (THE ONE/THE OTHER) be able to survive without the other two?"
The respondent's understanding of the cognitive operations of seriation, linear transitivity, logical multiplication, class inclusion, cyclic transitivity and cyclic integration, as manifested in content dealing with social organization was engaged by the problems presented during the social systems interview. The substantive content of the problems for all cognitive operations deal with a mixed agrarian economy with a representative democracy. Familiarity with the concepts used in the problem are assessed and the concepts are explained, as they were in the bio-ecological domain interview. The problem are intrinsically verbal in their mode of presentation but figures and drawings were used to help maintain interest and reduce memory load, especially for younger respondents.

All of the problems were evolved from questions posed during pilot interviews with groups of 10, 8, and 17 subjects ranging in age from 5 to 25. The questions tested during the pilot interviews came from a variety of sources. Sometimes the form of the question was borrowed and in other cases it was the substantive issue. I acknowledge a debt in this early phase to Jahoda (1964), Adelson, Green, and O'Neil (1969), Greenstein and Tarrow (1970), Connell (1971), and Furth, Baer, and Smith (1976). The version of the interview presented here is in no way a comprehensive treatment of the development of understanding of social organization. The substantive problems contained in this interview, however, were designed to exhibit the structure of most political and economic hierarchies and cycles.

A. Seriation

(i) Introduction

This task was similar to the physical domain task and the bio-ecological task insofar as it required that a one-to-one correspondence be established just as in Piaget's walking stick seriation task (Ginsberg and Opper, 1969, p. 140). The dimension of ordering here was the priority of access that each of the 8 farmers had to the use of a cooperatively owned tractor. Priority of access rights were in a one to one correspondence with the number of shares that the farmer had in the coop.

(ii) Procedure

Materials.

-Toy Tractor
-8 cards corresponding to the 8 farmers. Each card showed:
the farmer's name - color designation rather than nominal numbers
the number of shares ($100 each) that the farmer had

i.e. Farmer Brown $100
Farmer Black $100 $100
Farmer White $100 $100 $100
Farmer Green $100 $100 $100 $100
Farmer Blue $100 $100 $100 $100 $100
Farmer Gold $100 $100 $100 $100 $100 $100
Farmer Rose $100 $100 $100 $100 $100 $100 $100
Farmer Gray $100 $100 $100 $100 $100 $100 $100 $100

Familiarity Assessment. The concept of shared ownership was explained
in the instructions. Then the respondents were asked, "Who owns the tractor?"
or "Whose tractor is it?" Incorrect responses were corrected. The respondent
was counted as unfamiliar with the task materials if either of the above two
concepts had to be explained to him or her.

Instructions. The problem was introduced with this anecdote. "Once there
were 8 farmers. None of them had a tractor. They got together and decided that
if they all put in some money they would have enough money to buy one tractor
amongst the 8 of them. (POINT TO TOY TRACTOR. ASK TRACTOR FAMILIARITY
QUESTION. IF NECESSARY, EXPLAIN). They all had different amounts of money
to put in. They kept track of how much each one of them has put in towards
buying the tractor. Then they bought the tractor when they had enough money.
(ASK WHO OWNS THE TRACTOR. IF NECESSARY EXPLAIN COOPERATIVE OWNERSHIP).
Whenever no one was using it, anyone of them could go get it and use it. If
two of the 8 farmers wanted to use the tractor at the same time they would
look and see which one had put the most money towards buying the tractor.
That's what these cards here show. (POINT TO SHARE CARDS, READ NAMES OF FARMERS
TO YOUNGER SUBJECTS. PRESENT CARDS IN A RANDOM ARRAY). Farmer Black, for
example, has put in this many hundreds of dollars. Farmer Blue has put in
this many hundreds of dollars. If farmer Black and Farmer Blue both wanted
to use the tractor at the same time, who would get to use it first?"

Errors were corrected explaining that the amount of money initially
contributed determined priority for access.

"Now one day 7 of the farmers wanted to use the tractor at the same time.
Put the farmers in order from the one who gets to use it first to the one
who gets to use it last."
The interpolation element was the $400 farmer, Farmer Green.

"Here comes Farmer Green. Now he wants to use the tractor too at the same time as the rest of them. Put Farmer Green in the place that shows which it will be his turn to use the tractor."

(iii) Scoring

Respondents were counted as having mastered seriation in this domain only when all the cards were placed in the proper order without trial and error and with the interpolation card in its proper place.

B. Linear Transitivity

(i) Introduction

The dimension of comparison used here was the degree of "power to make and change laws." The three elements in the linear series are the prime minister, a judge, and a policeman. This task extended one used by Greenstein and Tarrow (1970). Greenstein and Tarrow were interested in whether or not the children had assimilated the idea of the supremacy of the law over the lawmaker. The present task examined the ability to infer the ordinal relation between a prime minister, a judge, and a policeman in terms of power to make and change laws.

(ii) Procedure

Materials. Three dolls with attire appropriate to occupation and with the names of the occupation written on a card on which the doll stood:

- prime minister doll
- judge doll
- policeman doll

Familiarity Assessment. Respondents were presented with the dolls one at a time in a random order. Respondents were asked what each occupational role was, and if the child could not say that any one occupation had to do with the law, he or she was counted as unfamiliar with the materials. For respondents whose description of each role seemed inadequate the following explanations were given:

Prime Minister. The prime minister is the elected leader of parliament. Parliament decides what the laws will be for the country. The prime minister is the main person in charge of making up the list of new laws every year. He also makes up the list of changes to old laws that already exist.
Judge. The judge knows the laws made by the prime minister and parliament. The judge runs the courtroom and the trials that are held in the courtroom. When the police arrest someone the judge decides whether or not the person has really broken the law. The judge is the one who has to decide what the law really means.

Policeman. It's the policeman's job to make sure that nobody breaks the law. If someone does break the law, the policeman has to find the lawbreaker and bring him to court where the judge decides if the policeman has caught the right man.

After the above familiarization information was given the investigator said that he was going to tell the respondent about the role figures just introduced and then ask the respondent which has the least power to make and change laws and which has the greatest power to make and change laws. The investigator then presented the respondent with the judge doll (to the respondent's right) and the prime minister doll (to the respondent's left) with the accompanying statement:

"The judge has less power to make and change laws than the prime minister".

The respondent was required to memorize and to repeat this premise aloud. Then the first pair of dolls were replaced by the judge doll (again to the respondent's right) and the policeman doll (to the respondent's left) with the accompanying statement:

"The judge has more power to make and change laws than the policeman."

Again the respondent was asked to memorize and to repeat the premise.

Instructions. When the investigator was satisfied that the respondent had memorized both premises, the respondent was then asked, "Which person has the most power to make and change laws?", and "How can you tell that?" Immediately afterward the respondent was asked, "Which person has the least power to make and change laws?", and, "How can you tell that?"

(iii) Scoring

I (Fail): Incorrect choice for one or both endpoints.

II (Fail): Correct choice of endpoints but incorrect explanation for choice (e.g., tautology, temporal order as power predictor).

III (Pass) Correct choice of endpoints with correct rationale for choice.
C. Logical Multiplication

(i) Introduction

Like the physical and bio-ecological logical multiplication tasks, this one was based on the format of the two-way classification task of Inhelder and Piaget (1964). The two dimensions to be intersected were (a) the form of a commodity a person deals with (i.e., wheat vs. flour), and, (b) the person's economic function in the exchange of the commodity (i.e., the producer vs. consumer).

(ii) Procedure

**Materials.** -Spice bottle of flour.

-Printed two-fold matrix with words naming (a) consumers in the top row and producers in the bottom row, and, (b) wheat dealers in the left column and flour dealers in the right column, thereby yielding:

-Left top cell: "Wheat Consumer"

-Right top cell: "Flour Consumer"

-Left bottom cell: "Wheat Producers"

-Right bottom cell: BLAND (to be filled by respondent with the correct entry being the words "Flour Producer").

-Below the matrix was a row of five alternative selections for the right bottom cell. These were the words:

1. "Wheat Producer"
2. "Wheat Consumer"
3. "Flour Consumer"
4. "Flour Inspector"
5. "Flour Producer"

**Familiarity Assessment.** Respondents were asked if they knew where the flour came from. If not, its derivation from wheat was explained. Respondents could not say what a producer or a consumer were, were told that a producer was someone who makes something and a consumer is someone who uses what the producer has made. Respondents who needed any of this explained to them were counted as unfamiliar with the conceptual materials.
Instructions. The investigator pointed to each cell in the matrix from column to column, saying, "Here is a wheat consumer. Her is a flour consumer. Here is a wheat producer. Which of these (POINT TO ROW OF FIVE ALTERNATIVES AT BOTTOM) goes best here (POINT TO BLANK CELL) with this wheat consumer, this flour consumer and this wheat producer. The respondents choice was recorded.

"Why did you choose ______?" Respondent's explanation is noted.

"Can anything else go in this empty place just as well as your choice of ______?"

(iii) Scoring

I (Fail): Incorrect choice.

II (Fail): Correct choice; incorrect explanation.

III (Pass): Correct choice; correct explanation.

D. Class Inclusion

(i) Introduction

As with the physical and bio-ecological domain tasks the class inclusion task used here was adapted from Inhelder and Piaget (1964). The "parts" to be classified were members of a wheat marketing board. The wheat marketing board itself was later used as an element in the cyclic integration problem. The use of the same conceptual entities in several tasks was intended to minimize memory load for the respondent and to save time for the investigator. The supraordinate class here was the class of government appointed members of the wheat marketing board. The subordinate class was composed of the two economic situses mentioned in the logical multiplication task (i.e. producer vs. consumer). There were more representatives of producers than of consumers on the board. All were government appointees.

(ii) Procedure

Materials. -A 4" x 6" piece of paper with the phrases "Government Appointed Consumer Representative" and "Government Appointed Producer Representative" typed on it. "Government Appointed Consumer Representative" was typed in two places and "Government Appointed Producer Representative" was typed in five places according to the spatial arrangement shown in figure C-1

Familiarity Assessment. The two concepts to be introduced here were that of government appointee and that of the marketing board. Respondents were asked, "Can you tell me what a government appointee is?", and, "Can you tell me what a wheat marketing board is?" Respondents who could not accurately describe both were classified as unfamiliar with the materials. The concepts were then explained to all respondents.
Figure C1

Display card for societal domain class inclusion task.
Government appointees were described as, "People who the government picks to do a job. They get picked for the job. They don't have to be elected."
The wheat marketing board was described as, "A group of people whose job it is to decide how much wheat the farmers should grow and how much the wheat should cost when it is sold. So everybody who grows wheat has to ask the people on the wheat marketing board how much they'll be allowed to grow and how much they'll be able to sell it for."

The words typed on the display card were read to all respondents and were re-read as often as was necessary to pre- and quasi-literate respondents.

Instructions.
The premises were introduced as follows:

"All of the people on the wheat marketing board are government appointees. Some are representatives of wheat producers. Some are representatives of wheat consumers. Now I'm going to ask you some questions about the wheat marketing board."

The premises were reviewed as follows and any errors were corrected.

"Are there more producer representatives or more consumer representatives?"

"Are the producer representatives government appointees?"

"Are all the members of the wheat marketing board government appointees?"

When the respondents had affirmed all these premises, the investigator asked, "Are there more government appointees on the wheat marketing board or more producer representatives?" While recording the response the investigator continued with, "If I took away all the producer representatives, would there be any government appointees left on the wheat marketing board?" "If I took away all the government appointees would there be any board members left?" Which are there more of here, producer representatives or government appointees?"

(iii) Scoring
I (Fail) More of the part class than the whole class.
II (Pass) More of the whole class than the part class.

E. Systemic Structures of Cyclic Transitivity and Cyclic Integration

(1) Introduction
The tasks used for assessing cyclic transitivity and cyclic integration
could not be broken down easily into one section for each cognitive operation. Therefore, they are discussed together. The scoring of all systemic relations tasks is covered in Appendix D. Therefore, only brief mention of scoring is made herein.

The organizational system to be used was one illustrating the cyclic flow of money in one direction and commodities in the opposite direction. The commodity chosen was a commonplace basic necessity so that a minimum of time was wasted explaining the nature of the commodity. It also involved government as well as private economic interests. The commodity chosen for the task was wheat.

There were five elements in the "wheat cycle": 1) the farmer, 2) the wheat marketing board, 3) the flour mill, 4) the bakery, 5) the retailer. In Canada, wheat marketing is controlled, or at least moderated, by the federal government through the wheat marketing board (Lipsey, Sparks, and Steiner, 1976, p. 120). Thus, the wheat cycle is a subcycle of the political authority structure. In addition, the wheat cycle is embedded in various economic cycles which influence the supply and demand for both money and wheat (e.g., value of stock of flour milling company). Therefore, while being embedded in a hierarchy of cycles complex enough to defy a thorough scientific explication, the wheat cycle is simple enough to be easily explained to even the youngest subjects. Every attempt was made to explain the concepts behind each element of the cycle to those subjects who were unfamiliar with the elements. Whatever differences in comprehension remained after that were taken as part of the phenomena under study. The familiarizing explanations are presented throughout the interview schedule at the appropriate places.

The interview proceeds in two main phases. Phase one is the cyclic transitivity phase. It contains (i) familiarization items, (ii) the layout procedure items, and (iii) the transitive recycling items, in that order. Phase two, the cyclic integration section, contains (i) further familiarization items, (ii) the systems synthesis items, and (iii) the systems analysis items, in that order. The interview schedule presented below is a step by step guide which includes instructions to the interviewer for displaying materials, reading explanations, and recording answers. It appears in a format suitable for use as a data record sheet.

(ii) Procedure

Materials.

<table>
<thead>
<tr>
<th>Pictures of</th>
<th>ELEMENT</th>
<th>DEPICTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>a farmer</td>
<td>photo of wheat field with combine harvester</td>
</tr>
<tr>
<td>(b)</td>
<td>wheat marketing board</td>
<td>drawing of business meeting in a board room</td>
</tr>
<tr>
<td>(c)</td>
<td>a flour milling company</td>
<td>photo of exterior of a mill with grain elevators</td>
</tr>
<tr>
<td>(d)</td>
<td>a bakery</td>
<td>interior photo of a bakery with ovens, loaves, and baker</td>
</tr>
</tbody>
</table>
(e) a retailer drawing of exterior view of a supermarket

and, -a Canadian $1.00 bill
-tape recorder

Interview Schedule

Phase One: CYCLIC TRANSITIVITY

FAMILIARITY

PRESENT DRAWING OF WHEAT FARM

"Can you tell me what this is a picture of?"

RECORD FAMILIARITY

Pass: It's a farm

READ FARM FAMILIARIZATION:

This is the wheat farmer harvesting his wheat. He sells his wheat to the wheat marketing board for whatever price they set. The farmer grows as much wheat as the wheat marketing board will let him. He buys his own bread from the supermarket.

PRESENT REST OF DRAWINGS ONE BY ONE IN AN IMPROPER ORDER IN A VERTICAL PILE

SECOND DRAWING (BESIDES FARM) WAS

"Do you know what this is?"

NAME IT

"Can you tell me something about it?"

READ FAMILIARIZATION

THIRD DRAWING WAS

REPEAT

FOURTH DRAWING WAS

REPEAT

FIFTH DRAWING WAS

REPEAT
WMB FAMILIARIZATION: This is a meeting of the wheat marketing board. The WMB is a part of the federal government. The board buys wheat from farmers at a price set by the board itself. The board then sells most of its wheat to flour mills for whatever price they can get for it. If the flour mills pay less for the wheat than the board paid for it, then the board looses money but the government gives the board more money to make up for whatever it looses. The wheat marketing board tries to keep the price of wheat the same all year so that farmers won't lose so much money that they would have to sell their farms. In order to keep wheat prices even, the wheat marketing board decides how much wheat will be grown each year. The board tells each farmer how much he can grow so that there's never too much wheat or not enough wheat.

Pass: WMB buys and sells wheat, subsidizes farmer, controls prices paid to farmers, imposes quotas of quantity grown

FLOUR MILL FAMILIARIZATION: This is the flour mill. It's a kind of factory where they turn wheat into flour. They buy their wheat from the wheat marketing board, grind it up into flour and then sell most of it to bakeries.

Pass: They turn wheat into flour

BAKERY FAMILIARIZATION: This is the bakery. It's a kind of factory where they turn flour into bread. They buy their flour from the flour company and use it to bake bread. Then they sell their bread to supermarkets.

Pass: They bake bread

SUPERMARKET FAMILIARIZATION: This is a supermarket where they sell all sorts of food including bread. They buy their bread from the bakery. They sell their bread to everyone, including the wheat farmer.

Pass: It's a supermarket, grocery store.

LAYOUT PROCEDURE

"Put the drawings in their proper order."

RECORD ORDER:

?MISORDERED? "OK, that's good. Now put the drawings in an order which shows which ones buy wheat, flour, or bread from which other ones."

RECORD ORDER

?STILL MISORDERED?

START WITH LAST ELEMENT PUT IN PLACE AND REPEAT THE FOLLOWING QUESTIONS FOR DRAWINGS IN REVERSE ORDER
RECORD ELEMENT UNDER DISCUSSION

"What does this one buy?"

"Who does he (do they) buy it from?"

IF EITHER OF THESE TWO QUESTIONS ARE ANSWERED INCORRECTLY, REPEAT THE RELEVANT PART OF THE FAMILIARITY EXPLANATION

REPEAT (?) AS NEEDED

?NOT A CIRCLE? "OK, now is there any way you can think of to show which ones buy from which other ones besides putting them in a straight line? Could the same thing be shown by some other arrangement of the cards?"

RECORD

?ANYTHING STILL SUBOPTIMAL? WHAT?

"You've put the drawings in this order. That's a good way to do it. Now let me show you another way it could be done."

CREATE PROPER CYCLIC ORDER

READ SUMMARY OF WHEAT CYCLE:

In this order the farmer buys bread from the supermarket. So we put the supermarket beside the farmer. Now the supermarket buys its bread from the bakery. We put the bakery beside the supermarket. The bakery makes the bread out of flour. The bakery buys its flour from the flour mill so we put the bakery beside the flour mill. The flour mill makes the flour out of wheat. The flour mill buys its wheat from the wheat marketing board. Let's put the wheat marketing board beside the flour mill then. The WMB buys the wheat from the farmers who grow it so the farmers go here on the other side of the wheat marketing board. OK, now let's leave the drawings in this order and I'll ask you some riddles/ questions about the things in the pictures.

TRANSITIVE RECYCLING

CYCLE DISPLAYED IN PROPER ORDER

PRESENT CANADIAN $1.00 BILL

"Could someone, a farmer for example (POINT TO FARM DRAWING), ever spend the same dollar bill twice?" (IF SO) How? (IF NOT) Why not?"

?UNSURE? PROBE UNDERSTANDING: "Who does the farmer give money to?. Does he ever get money from that person?"

OWN WHEAT ITEM

"If the farmer never keeps any of his wheat for himself, could he ever eat his own wheat? (IF SO) How? (IF NOT) Why not?"
Phase Two: CYCLIC INTEGRATION

FAMILIARITY

Supply/Demand Item

PRESENT JAR OF FLOUR

"This is flour. If one kilogram of flour costs $1.00 when there is just enough flour to go around, how much will it cost when there's only 1/2 as much to go around as is wanted? Will it cost more, the same, or less than $1.00/kg.?" (CIRCLE ONE)

"Why?"

Pass: More, because more people will want it so they will charge more. People will pay more to be the ones who get it.

?UNFAMILIAR? READ S/D EXPLANATION:

The flour would cost more because when there’s not enough flour to go around the people who want flour will pay more for it because the person who's selling it will sell it to whoever pays the most money. If there were more flour than was needed the price would go down because the people who are buying flour would buy from whoever would sell theirs for the lowest price.

Profit Familiarity Item

"If the supermarket bought its bread from the bakery for 30¢/ loaf, how much will the supermarket sell the bread for? Will it be less than, the same as, or more than 80¢/ loaf?" (CIRCLE ONE)

"Why?"

Pass: More because they want to make a profit

?UNFAMILIAR? READ PROFIT EXPLANATION:

The supermarket will sell the bread for more than it paid for the bread and it will keep that extra money to pay the people who work in the supermarket. That's how the supermarket people make money for their own use. They buy food at a low price, sell it to customers at a higher price and keep the difference for themselves. The difference is called their profit.

Taxation Familiarity Item

"Sometimes the WMB looses money instead of making a profit. The WMB sometimes gives the farmers $1.00/kg. for their wheat but only asks a price of 90¢/kg. from the flour mills. The wheat marketing board gets the extra 10¢/kg. from the government. Where does the government get its money from?"
Pass: From taxes

?UNFAMILIAR? READ TAXATION EXPLANATION:

The government gets its money from taxes. At the end of every year the government asks every person and every business in the country how much profit they've made that year. Those who've made a lot of profit have to give more money to the government in taxes than those who have made a small profit or no profit.

SYSTEMS SYNTHESIS

READ INTRODUCTION TO WHEAT STORAGE AND FLOUR SURPLUS:

Suppose that the flour milling company built some huge grain elevators of its own in which to store wheat. Then the flour company buys all the wheat it can when the price is low. Then after a few years the flour company has stored up all the wheat it needs and doesn't need to buy hardly any from the farmers for one year. Tell me about all the things you can think of that would happen as a result of this."

RECORD

Flour Mill Profit Item

"Would the flour milling company make a bigger profit or a smaller profit?"

"Why?/Why not?"

Wheat Farmer Profit Item

"Would the wheat farmers make a bigger profit or a smaller profit? Why/Why not?"

WMB Do Item

"What would the wheat marketing board do? Why?"

Taxes Items

"What would happen to taxes?" "Why?" National Taxes

"How does the wheat marketing board both lower and raise the farmer's income in some way?" Farmer's taxes

WMB Role Item

"What is the intended overall effect of the WMB's work?"
SYSTEMS ANALYSIS

No WMB Item

"What would happen in this situation of wheat surplus if there were no WMB?" "Why?"

"What would happen to the wheat farmers?" "Why?"

FM Reaction Item

"What would the flour milling company try to do?" "Why/How? What would happen then?"

Least Important Item

"Which one of these steps in the cycle do you think could be gotten rid of with the least amount of trouble for the remaining four?" "Why?"

Most Important Item

"Which of these steps do you think would cause the most trouble for the rest if we got rid of it? Which is hardest to do without?" "Why?"
APPENDIX D: Scoring Manual for Systemic Interviews

A. Systemic Scores to Be Obtained

The basic scores being sought are the systemic component scores by domain. There are two domains, bio-ecological and societal. Within each domain there are four component scores. They are:

- the layout component of cyclic transitivity (CyT/lay)
- the transitive recycling component of cyclic transitivity (CyT/rec)
- the systems synthesis component of cyclic integration (SySy)
- the systems analysis component of cyclic integration (SyAn)

This yields eight scores, four for each domain. Those scores can be combined and condensed in various ways. One way is to ignore the distinction across domains. That yields four scores, one for each across domain component. Another way to reduce the number of scores is to combine the two cyclic transitivity scores together within each domain and combine the two cyclic integration scores together within each domain. That also yields four scores. Finally, if the latter scores were combined across domains the result would be two summary scores, across domain cyclic transitivity and across domain cyclic integration.

The eight basic component scores are obtained from the more elementary items presented in the interview schedules for each domain (see Appendix B, Section E (ii) and Appendix C, Section E (ii)). The responses to those items are categorized and assigned a dichotomous pass/fail score. In the case of the cyclic transitivity components, that score becomes the component score. For the cyclic integration components it is necessary to combine the dichotomous elementary scores into the component scores.

B. Scoring Materials and Procedure

Part of the data to be scored will have been written directly on the interview schedule since the schedule was designed to double as a data record sheet. The cyclic integration sections of the interview should also have been tape recorded. The tape recordings should be transcribed onto individual protocols for each respondent.

For the cyclic transitivity components the component scores can be taken directly off of the data record sheets. It is the cyclic integration component scores that require blind judges and, hence, protocols. The scores assigned to the responses to the cyclic integration items can be recorded on a streamlined score sheet. This facilitates the later construction of the component scores.
Once the scorer is familiar with the scoring criteria he/she simply (a) reads the response on the protocol, (b) derives and records the component score, and (e) later uses those scores to derive the summary scores. The latter two steps could actually be done automatically be computer, if so desired.

C. Ecosystem Scoring Criteria

The scorers should be fully acquainted with these criteria. The items to be scored are all labeled. These labels can be matched with those in the interview schedules (Appendices B & C, Sections E (ii) in each) in order to find the actual wording and context of the question.

(i) Cyclic Transitivity

Question: Layout component

Answers: 1/F = Wrong order
2/F = Correct order but in a line instead of a circle
3/S = Prompted circle; correct order
4/S = Spontaneous circle; correct order

Question: Transitive Recycling component

Answers: 1/F = No solution
2/F = Linear solution
3/S = DDT returns to soil, is absorbed by plant, eaten by caterpillar, then by bird

(ii) Familiarity

Question: Reproduction

Answers: 1/F = To say that they didn't have "babies"
2/S = To say that there would be more or that they's reproduce

Question: Starvation

Answers: 1/F = More birds predicted but the reason is simply that they have babies. No mention of what they're going to eat for the year.
2/S = Realizes that 6 caterpillars aren't enough and therefore predicts starvation
3/S = Realizes that the food shortage needn't necessarily lead to starvation if both prey and predator populations increase in parallel proportion

(iii) Perturbation Effects

Introduction. This three part open ended question may elicit direct spontaneous answers to later specific items.
Question: **Caterpillar Population (Cat. Pop.)**

This question is about rate of reproduction but many respondents answer as if they had been asked the possible changes in the absolute size of the caterpillar population through reproduction. Therefore this item can be used to index the depth of understanding of the relation between individual members of a species population and the whole population in terms of reproduction.

Answers:

1/F = The caterpillar population will definitely increase again so any prediction to the contrary is wrong as is a prediction of more caterpillars for inadequate reasons (e.g., the DDT makes them grow faster).

2/S = At the level of individual caterpillars the respondent sees that the immune survivors will reproduce thus yielding a larger population. At this level, however, rate of increase is conceived of solely in terms of length of time for one individual to complete the life cycle (e.g., "They won't multiply faster because it still takes them one month to reproduce. Their numbers will go up at the same speed as before").

3/S = At this level the whole population can be dealt with conceptually. Rate of increase in population terms can be predicted by treating individuals as statistical averages. Doubling the food supply does not decrease mortality for the population if the number of individuals competing for the food has tripled. The 10% surviving caterpillars have a better chance of having their offspring survive because there is less competition for food among the offspring and because at least at first, their numbers are too small to attract many predators. Therefore their rate of increase would increase (e.g., "The numbers would rise faster because there is plenty of food to go around for so few caterpillars and there is also plenty of good hiding spots to keep away from birds").

Question: **Renew Infest**

The burgeoning of the caterpillar population would have a deliterious effect on the plant population. Normal reproduction would eventually put the caterpillar population up to the level it was at before so that the plants would be in just as bad shape but not worse. However, there is a lag time in which the predator population remains proportionally smaller than it was before the spraying. This allows for even greater numbers of caterpillars than before the spraying and this permits the conclusion that the plants would actually be doing worse at some time after the spraying.

Answer: 1/F = Denies that the plants could do worse or just as bad after the spraying. Attributes ill effects on plants to some factor other than renewed infestation by caterpillars.
2/S = Attributes ill effects on plants to increased numbers of caterpillars without saying why the numbers could increase more than before. Says numbers would be the same as before and therefore the effect on the plants would be the same too. Attributes ill effects to more caterpillars and explains the greater number of caterpillars by reference to reproduction or immunity or both.

3/S = Sees that the dearth of birds contributes to the plants doing worse than before.

Question: Birds

At first there would be fewer birds because (a) there are 90% less caterpillars and (b) the remaining caterpillars are full of poison. Slowly the bird population would increase provided that the farmer only sprayed once. Even though the caterpillars are immune to DDT they won't be poison to the birds unless they (the caterpillars) have eaten DDT. Predictions could be based solely on the availability of for this level of understanding in the "Cat. Pop." and "Renew Infest" items. In this item the criterion of success is raised. The answer must take into account the quality of the food available to the birds (its toxicity) as well as the quantity. It doesn't matter whether more or less birds are predicted so long as the quality related reasons are given. If the bird too became immune more birds are predicted so long as the population of caterpillars increased. Otherwise the birds would be poisoned and decrease in numbers unless the DDT has vanished from the caterpillars' diet. Then even non-immune birds could increase in numbers.

Answers: 1/F = Prediction unrelated to quantity or quality of food (caterpillars) 2/F = Prediction of more birds due to more caterpillars or fewer birds due to fewer caterpillars. No reference to DDT poisoning or immunity. 3/S = Prediction of more birds, if they are immune, due to more caterpillars or fewer non-immune caterpillars due to food poisoning. Prediction of bird numbers proportional to caterpillar numbers if DDT disappears from the scene. The disappearance of DDT must be explicitly mentioned.

Question: Immunity Implications

The score is inferred from the answers to all of the above items including the open-ended questions. The purpose of this score is to give more weight to successes like those required for 3/S scores on the Renewed Infest and Birds Items. These successes require more than predicting the effect of DDT on the ecosystem. They further require predicting the effects of immunities which are countereffects to DDT. If DDT is the "action" then the immunity is the "reaction". We wish to use this item to given extra credit for the accomplishment of being able to predict the ecosystem's reactions to the caterpillar reaction (immunity) to the farmer's action (DDT).
Answers:  
1/F = None of the answers gave any indication of understanding what effect the caterpillars' immunity would have on other populations.
2/S = The implications of the immunity for either the plant or the bird populations were mentioned in answers to previous items. For the plant population this involves some mention of how the immunity of the surviving caterpillars to DDT has made renewed infestation of the plants possible. For the birds there must be some mention of how the immunity affects the quality of their food supply. This could involve the birds either being poisoned or becoming immune to DDT themselves.
3/S = The implication of the immunity for both the plant and bird populations were mentioned.

Question: **Nitro Desert**

This is a simpler version of the same logical move behind the DDT story. This time instead of adding a toxin to the system we are removing a vital nutrient (nitrogen) from it. This version is simpler because there is no analogue of the immunity reaction. The removal of nitrogen, however, is still a change in one element of the cycle which causes evolution of the whole ecosystem. The farm evolves into what ecologists call a "trace desert". There would be little life left because there are only "traces" of vital nutrients present.

Answer:  
1/F = Wrong or inadequate predictions confusion of the chemical fertilizer with DDT.
2/S = Correct predictions about the numbers of various populations that would be left but no explanation of the chain reaction that led to this circumstance.
3/S = Correct predictions with explanation of how the food shortage chain reaction works from plants to birds. No predictions about what would happen to the bacteria are required. Comments about the fate of the bacteria are essentially irrelevant.

(iv) **Systems Synthesis**

This is a second order score. It is a summary of the previous four items and is derived from them according to fairly mechanical rules. The only scores allowed are 1/F, 2/F and 3/S. Missing data assignments are not permitted. The scoring rules are as follows:

- **Maximum Constituency.** The only items that are counted are: Renew Infest Birds Imm. Imp. Nitro. Desert

- **Majority Rule.** These four items constitute the maximum constituency Subject to the below constraint, the systems synthesis score is normally whatever the majority of the constituents are in terms of success/failure.
No S without 3. In order to score 3/S on systems synthesis there must be at least one 3/S among the voting constituents.

Mutual Cancellation. Pairs of constituents can cancel out each others votes and thereby remove each other from the voting. The following cancel each other:

1/F with 3/S = no vote for either
2/F with 2/S = no vote for either

The following do NOT cancel each other:

1/F with 2/S = 1 "fail" vote and 1 "success" vote
2/F with 3/S = 1 "fail" vote and 1 "success" vote

Ties. Where the voting, after cancellations, yields either 1 Fail vs. 1 Success or 2 Fails vs. 2 Successes, the systems synthesis score will be 2/F.

Other 2/F's. Since a score of SySy = 3/S is not permitted unless one of the voting constituents is a 3/S, it is possible to obtain a score of 2/F without having a draw. If the majority vote is "S" but there is no 3/S among the voting constituents then the systems synthesis score is 2/F.

Missing Data. Missing data simply reduce the size of the voting constituency. Sometimes the open-ended and Cat. Pop. items contain information that can be used in judging the extent to which the respondent appreciated the implications of the immunity and so on.

(v) Element Elimination

Question: 5 minus 1

Answers: 1/F = Any other than the bird (or caterpillar under circumstances outlined below)
2/S = Bird, the top trophic level, or, caterpillar given that respondent explicitly states what the bird would eat instead of caterpillars without being prompted.

Question: 4 minus 1

Answers: 1/F = Anything other than caterpillar. If 5 minus 1 answer was caterpillar with new food for bird spontaneously specified than "bird" is a permissible answer here.
2/S = Caterpillar, or, under conditions specified above, bird.

Question: Core

Answers: 1/F = Fails to see the interdependence among bacteria, nitrogen, and plant
2/S = Claims that none can exist by itself
3/S = Realizes the interdependencies but knows that nitrogen can exist independently.
(vi) **Systems Analysis**

The scoring is programmable. There are three constituent items that combine to determine the systems analysis component score (i.e., 5 minus 1; 4 minus 1; core). The possibilities for the component score are:

1/F = requires that at least two of the constituents items have scores of 1/F.
2/F = requires that none of the constituent items be a 3/S and that not more than one of them be a 1/F.
3/S = requires that one of the constituent scores be a 3/S (i.e., core) with not more than one 1/F OR, that all three constituent scores be 2's.

These rules generate the following table:

<table>
<thead>
<tr>
<th>Core</th>
<th>5 minus 1</th>
<th>4 minus 1</th>
<th>Sy An</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
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<td>1/F</td>
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<tr>
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<td>1/F</td>
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<td>3/S</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3/S</td>
</tr>
</tbody>
</table>

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**D. Similarities Across the Two Systems**

Fluctuations in profit per unit commodity are analogous to the fluctuations in population size dealt with in the bio-ecological interview.

If food supply goes up, reproduction allows births to exceed deaths and population size goes up, all else equal. If demand goes up, profit goes up, all else equal.

If starvation causes deaths to exceed births, population size decreases. If supply catches up with and then exceeds demand, profits decrease.
The exogenous factor of predation decreases population size especially when population size is at the higher end of its range of fluctuations. Theoretically, the exogenous factor of taxation decreases profits especially when profits are in the upper brackets.

Predation relates the population size of the higher trophic level to the population size of the lower trophic level. Taxation relates the income of the higher order system to the income of the lower order system.

E. Societal Scoring Criteria

(i) Cyclic Transitivity

Question: Layout procedure

Answers: 1/F = Wrong order

2/F = Correct order but in a line instead of a circle

3/S = Prompted circle; correct order

4/S = Spontaneous circle, correct order

Question: Recycling component

Answer: 1/F = No solution

2/F = Short cut around the cycle; gets dollar back as change for a larger bill spent later

3/S = Dollar passes around the cycle.

(ii) Familiarity

Question: Supply/Demand (S/D)

This item assesses familiarity with the law of supply and demand sometimes referred to as "the law of price." An understanding of this concept is a prerequisite for understanding transactions within exchange cycles like the wheat cycle.

Answers: 1/F = The price is predicted to stay the same or decrease.

2/F = The price is predicted to rise but for an inadequate reason (e.g. "They're so greedy they want more money so they raise the price." "There'd be more bags of flour so it'd cost more.").
Answers:  
1/F = It would have no effect or taxes would go down.  
2/F = The taxes of the elements making a bigger profit (FM) would go up. Taxes would go up for irrelevant reasons (e.g., inflation).  
3/S = Taxes go up to pay the WMB's deficit.

Question: **Famer's Taxes**

Treating this as two independent questions (1. lowers, 2. raises) will be considered less indicative of systemic thinking than treating it as a single question about a single money cycle (i.e. WF → Gov't → WMB).

Answers:  
1/F = WMB sometimes pays less and sometimes pays more.  
2/S = Treated as two separate questions answered thus:  
(a) WMB raises WF's income by subsidizing wheat prices or ideas to that effect.  
(b) WMB lowers the WF's income by causing him to pay higher rates of income tax (specification of other types of tax also acceptable). This higher rate need not be part of a national tax hike. It could merely be a result of higher taxable personal income one year.  
3/S = Statements to the effect that the WF is in part paying himself because higher national tax rates are caused by the WMB's subsidy of the WF himself.

Question: **WMB's Role**

Scores for this item can also very often be inferred from answers to previous items. The scorer should check back to see if there is other relevant information in previous answers.

Respondents who understand the WMB's overall role give answers (a) to this and previous items, that do not contain any erroneous implications (e.g., saying that the WF wouldn't have any one to sell his wheat to), (b) that attempt to describe its regulatory economic function, (c) that describe its role in terms of its interactions with more than one other element, and (d) that implicitly or explicitly refer to its effects upon the whole wheat cycle.

Answers:  
1/F = Incorrect or inadequate descriptions  
2/F = Correct but partial answers. Answers that only refer to the WMB's dealings with one other element. Answers that only refer to the WMB's physical handling of wheat. The WMB as only a private wholesaler or a middleman. Answers that would qualify as "3/S" but are preceded by erroneous statements in previous answers.  
3/S = Wholistic answers describing the WMB's responsibility for the whole cycle. The WMB as a market stabilizer, an economic regulator.
3/S = Price rise is attributed to things like the scarcity of the flour, the greater clamour (demand) for each bag, the maintenance of profit margins given undersupply.

Question: **Profit**

The concept of profit applies to one economic unit's transactions. Together these units form various exchange cycles, like commodity cycles, like the wheat cycle. The respondent has to understand what these elementary units are doing before he can understand their transactions with each other.

Answers: 1/F = Thinks that the supermarket won't take a profit or that, if the selling price is set higher than the cost, this is what you call "inflation." Any similarly inadequate explanation of the profit.
2/S = Sees profit as a normal means of obtaining income. Explains the price rise explicitly in terms of profit.

Question: **Taxes**

This item comes after an exercise in explaining that the government uses tax money to make up WMB deficits. This item relates government revenues back to profits through probing for the correlation between income earned and taxes paid. Understanding this concept is a pre-requisite for being able to see how the WMB also lowers the farmer's income.

Answers: 1/F = No idea that making more money means paying more taxes.
2/S = Knows at least that making more money means paying more taxes.

(iii) **Perturbation Effects**

This open-ended item may elicit spontaneous answers to later specific items.

Question: **FM Profits**

The FM pretty well has to make more money because they bought the wheat cheap and have at least a steady demand. Inflation also works in their favor.

Answers: 1/F = Same profit as previous year or less. More profit but for inadequate reasons (e.g. Just having more wheat doesn't justify predicting that they'll make more money. The wheat has to be in greater demand than normal supplies could satisfy.)
2/S = Adequate reasons for predicting a bigger profit are:
(a) lower than normal costs of the surplus wheat
(b) inflationary rise in selling price without concomitant rise in cost of the surplus wheat.
(c) greater volume of sales, provided respondent explicitly mentions a concomitant demand for the volume.
Question: **WF Profits**

If the respondent remembers what he's just been told about how the WMB works, he should realize that the F's profits are controlled by the price set by the WMB. Failure to mention the WMB's intervention in this matter indicates a failure to appreciate the WMB's role as a regulatory arm of a larger, more encompassing system (i.e., the government).

**Answers:**  
1/F = WF's profits unrelated to WMB decisions. Direct link to FM (e.g., "The FM's not buying any wheat so the farmer won't have anyone to sell his wheat to.").

2/S = Impossible that the WF would lose a lot of money. His income might go down a little if the WMB paid him less for his wheat but whatever happens, the price paid by the WMB is the crucial factor.

Question: **WMB Do**

Besides just plain wrong answers, some ostensibly correct answers are also counted as failures here because we are interested in identifying those respondents who demonstrate an understanding of how the WMB can act upon the wheat cycle from a long range perspective that is not constrained by the exigencies of immediate profits and losses.

**Answers:**

1/F = Wrong or confused answers. Correct answers that display no understanding of the WMB's role.
- e.g., Glut "The WMB would end up with a lot of wheat that they couldn't sell"
- Loose $ "The WMB would lose money."

2/S = These are correct answers that got the WMB out of its own immediate glut situation but do nothing to remedy the imbalance in the whole wheat cycle.
- e.g., Sell elsewhere "They could sell it to another country/FM"
- Store "They could keep it until the FM ran out."
- Get gov't $ "They could go to the government for more money."

3/S = These are answers that describe actions that would restore a balance.
- e.g., Quotas "They could tell the WF to grow less next year."
- "They could put a limit on how much the'll allow the FM to buy in one year."
- Destroy "They might burn the wheat so that there would be a demand for next year's crop."

Question: **National Taxes**

One way of misunderstanding this question is more advanced than others. Correct understanding indicates an awareness of how the actions of one element (FM) in one subsystem (the wheat cycle) can influence the supraordinate system (the national economy).
(iv) Systems Synthesis

The rules are exactly the same as those for systems synthesis in the EGOSYSTEM. The maximum constituency is, again, four items. They are:

WMB Do
Nat'l Taxes
Farmer's Taxes
WMB's Role

(v) Element Elimination

In this section, instead of going from effects on subsidiary elements up to the supraordinate system, we go in the opposite direction. We start with the whole system and see if the respondent can simplify it by picking out viable independent subsystems latent within the supraordinate system.

There are two parts to this section. First we see if the respondent can appreciate the readjustments that would be required to make a particular subsystem viable. Second we let the respondent choose his own subsystem and explain what readjustments would be required for it to be viable.

Question: No WMB

It takes a certain amount of understanding to realize that with the WMB gone the WF could sell directly to the FM. It takes even more understanding to see that the WF would suffer heavy financial losses given a situation of wheat surplus. It is the latter realization that we wish to count as success on this item.

Answer: 1/F = Misses the financial implication for the WF (e.g. "The WF would have a lot of wheat laying around.").
2/S = Explicitly states that the WF would loose money or even go broke.

Question: FM Reaction

Success on this item requires at least seeing that the FM would experience a supply shortage later on if too many farmers lost too much money. Seeing this implication requires moving from the level of the individual farmer's profit picture to the level of the average profit picture for the whole population of farmers. Short-term remedies to this stockpiling generated problem all involve the FM in exercising more self-restraint. These are possible but improbable solutions because the FM operates on the profit motive and that precludes deliberately neglecting profit opportunities in the future. More credit is given to solutions which incorporate readjustments in the functional relationships between the elements. That is, the system either evolves into a new form or it evolves right out of existence. The readjustments mean that at least one element must substantially alter its role in the scheme of things or else an analogue of the WMB must be reintroduced.
The future supply problems of the FM are not anticipated. Realizes that a supply problem would develop for the FM but attempts to resolve the supply problem do not involve any change in the functional relationships between elements. Often the solution suggested involves a change in the "motives" or "traits" of the economic elements involved.

e.g., "The FM shouldn't try to stockpile cheap wheat anymore." "The FM should be more careful about how much wheat he buys at one time." "The FM should sell more flour to the bakery so he can buy more wheat from the farmer."

Sees that the FM depends on the survival and financial well being of the farmers.

e.g., "The FM would go broke too because they can't get no wheat."

Evolutionary solutions (including devolution)

3/S = Evolutionary solutions (including devolution)

e.g., "The FM could buy out the farmers and just pay them a salary to grow wheat."
"The farmers could form a coop that does what the WMB used to do."
"The farmers could set up their own flour mill and sell to the bakery."
"The federal government could make special loans to farmers to keep them going."

Question: Least Important

The better answers here demonstrate a concern for how the remaining elements would take up the functions that were previously performed by the removed element.

Answers: 1/F = No adaptation of remaining elements mentioned. Adaptations suggested are unrealistic (e.g. "The farmer could sell his wheat to the supermarket.")
2/S = Functions of the departed element are taken over by others (e.g. "The supermarket could bake the bread." "The bakery could retail the bread." "The FM could bake the flour into bread." etc., etc.)

Question: Most Important

The answer to this one is fairly unanimous – the wheat farmer. The economic system is predicated upon the exploitation of nature. Failures to recognize this indicate a very shaky understanding of the interrelationships among the elements in the cycle. In this sense this item is almost like a FAMILIARITY item.

Answers: 1/F = Any answer other than the WF.
2/S = The WF.
(vi) Systems Analysis

This score is a summary of items No WMB, FM Reaction, Least Important, and Most Important. The scoring is mechanical except where 2 of (1) No WMB, (2) FM Reaction, and (3) Least Important have missing data (*). In that case the remaining item determines the score unless there are comments in answers elsewhere which would lead the scorer to judge otherwise. If the remaining score is a 2/S it becomes a 3/S. The rules for combining items into systems analysis scores are:

**Constituency.** The only voting constituents are FM Reaction, and Least Important. They combine according to the following table:

<table>
<thead>
<tr>
<th>FM Reaction</th>
<th>Least Important</th>
<th>Systems Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/F</td>
<td>1/F</td>
<td>1/F</td>
</tr>
<tr>
<td>1/F</td>
<td>2/S</td>
<td>2/F</td>
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<tr>
<td>2/S</td>
<td>1/F</td>
<td>2/F</td>
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<tr>
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<td>3/S</td>
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<tr>
<td>3/S</td>
<td>2/S</td>
<td>3/S</td>
</tr>
</tbody>
</table>

**Vetos.** No WMB can "veto" FM Reaction and Most Important can veto Least Important. That is, if No WMB = 1/F, then FM Reaction = 1/F, no matter what was said under FM Reaction.

Likewise, if Most Important = 1/F then Least Important = 1/F no matter what was said under Least Important.

**Missing Data.** If least Important = * (has missing data) then count it as a vote of 1/F in the voting constituency.

If FM Reaction = * then the voting constituency becomes No WMB and Least Important. They yield scores according to this table:

<table>
<thead>
<tr>
<th>No WMB</th>
<th>Least Important</th>
<th>Systems Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/F</td>
<td>1/F</td>
<td>1/F</td>
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<tr>
<td>1/F</td>
<td>2/S</td>
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<tr>
<td>2/S</td>
<td>2/S</td>
<td>3/S</td>
</tr>
</tbody>
</table>

F. Summary Scores

(i) Across Domain Components

Layout. The two cyclic transitivity components that go into this scores are (a) the bio-ecological domain layout procedure, and (b) the societal domain layout procedure. On each of these components the possible scores are 1/F, 2/F, and 3/S. They are dichotomous pass/fail scores (S,F) with two levels of failure (1,2). The across domain summary score has two levels 1/F and 2/S. A passing score (2/S) requires at least a 3/S on one of the components and not less than a 2/F score on the other. The following table lists the possible combinations of component scores with their accompanying summary scores:
<table>
<thead>
<tr>
<th>Bio-ecological Component</th>
<th>Societal Component</th>
<th>Summary Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/F</td>
<td>1/F</td>
<td>1/F</td>
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<tr>
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<td>2/F</td>
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<tr>
<td>3/S</td>
<td>3/S</td>
<td>2/S</td>
</tr>
</tbody>
</table>

**Transitive Recycling.** The transitive recycling components for the bio-ecological and societal domain go into this summary score. The possible score on these components are again, 1/F, 2/F, and 3/S. The summary score is again dichotomous (1/F, 2/S). The summary score is constructed according to the same rules that yield the table for the layout component score.

**Systems Analysis.** Same rules as those encoded in the table for the layout component score.

**Systems Synthesis.** Same rules as those encoded in the table for the layout component score.

(ii) **Within Domain Components**

**Cyclic Transitivity.** The two components comprising this summary score were the layout and the recycling components (within domains). For a summary score of 2/S the layout component had to be an "S" (either a 3/S or a 4/S) and the recycling component could not be a 1/F.

**Cyclic Integration.** For a summary score of 2/S both component scores (SyAn and SySy) had to be 3/S.
"QUANTITY DOES NOT DETERMINE PATTERN. It is impossible, in principle, to explain any pattern by invoking a single quantity...quantity and pattern are of different logical type and do not readily fit together in the same thinking. What appears to be a genesis of pattern by quantity arises where the pattern was latent before the quantity had an impact on the system. (Bateson, G. Mind and Nature: A Necessary Unity. New York: Bantam Books, 1979. p. 58)"

The need to postulate another type of logic first arose out of my attempts to understand society. At that point I was thinking in terms of a new paradigm approach to social theory. As my attention turned to the development of understanding of social systems, the new paradigm was translated into some specific cognitive structures. After the data had been analyzed, these cognitive structures came to be seen less as direct translations of the new paradigm and more as possible examples of a whole class of structures that seem to follow a different sort of logic. Only at this point did I formulate the question addressed in this chapter: How do formal logic and systemic logic differ?. In attempting to answer that question I began scanning the psychological literature on types or classes of logics. It was then that I discovered some startling (to me) passages in Piaget and Inhelder's (1956) The Child's Conception of Space. That is where Piaget and Inhelder present their most extensive treatment of sub-logical operations and topological relations, both of which are features of what I mean by systemic logic. At one point Piaget and Inhelder even describe cyclic transitivity in logical notation (p. 463). Nevertheless they seem to have missed its significance. In other words, Piaget has dealt with systemic logic but calls it by another name and treats it in an unnecessarily restricted context. He and his colleagues did not realize its generality.

After summarizing Piaget's ideas on the roles of sub-logic and topological relations in cognitive development, the similarities to systemic logic will be examined. Then what I see as the inadequacies in Piaget's conceptions of sub-logic and topological relations will be discussed. Finally, the distinction between formal and systemic logic will be related back to various issues raised in the text.

A. Sublogic

Piaget sees the child's developing understanding of space and geometry as the main arenas for the use of sub-logic and topological relations. The child's initial ideas about space are topological. These give way to projective notions which in turn lead to Euclidian concepts of space. Topological relations are non-metric; euclidian space is metric. A rigid line is a prerequisite for measurement. Topological space is essentially
elastic (Piaget, Inhelder and Szeminska, 1960). The term "sub-logic" was inspired by Russel's Theory of Types. The lowest type of logic begins with objects already being identifiable. When he speaks of sublogic Piaget refers to those operations needed to construct the concept of the object in the first place. The parts of objects according to Piaget, are related to the whole object by the following topological relations: proximity, separation, order, enclosure, continuity. In understanding those relationships the child is performing the corresponding sublogical operations. Logical operations (as opposed to sublogical) begin with the euclidian assumption of shape constancy. Sublogical operations, being appreciations of topological relations, do not. Sublogical operations en when the construction of the constant object has been acheived.

Sublogical operations are identical in form to systemic operations. The truth value of propositions stated in formal logic can be decided in the abstract. Systemic logic requires the specification of spatio-temporal particulars before the truth value of its propositions can be evaluated. Because of the topological nature of the relations under consideration, sublogic also requires a specification of spatio-temporal particulars before truth value can be evaluated. Systemic logic and sublogic also differ from formal logic in the treatment of sets. In formal logic supraordinate sets are related to subordinate sets by class inclusion. In both systemic logic and sublogic the relationship is one of parts to wholes. Once again the difference is traceable to a more topological strain in systemic logic and sublogic. The latter define sets in terms of boundaries, enclosures and proximities. The proximities may be temporal as well as spatial. Formal logic, on the other hand, defines sets in terms of abstract attributes like color, phylum, construction material, and so on. These sorts of attributes express degrees of similarity/dissimilarity rather than proximity/distance.

B. Sublogic vs. Systemic Logic

Systemic logic and sublogic are not identical in their range of referents. Sublogic seems to me to be a special case of systemic logic. In describing sublogic, Piaget described the form of systemic logic well. What he failed to mention is that not all the spatio-temporal wholes contructed by the mind are physical objects. Sublogic, as described by Piaget, applies strictly to the construction of palpable, physical objects. Systemic logic, as I would have it, applies to all organized wholes. Kinship networks, economies and governments, are wholes in the sens of being systems. Their cohesion as unitary entities does not necessarily depend on spatio-temporal proximity so much as it depends on interactive relatedness. Static wholes, such as physical objects, maintain their integrity through proximity, enclosure, etc. Dynamic wholes, such as social systems, maintain their integrity through a synergistic interaction amongst the parts. Piaget tended to ignore dynamic wholes. He chose to study the developing understanding of physical phenomena.
Once attention is turned towards more social content, however, it becomes necessary to expand the role played by sublogic in cognitive development. Sublogic becomes systemic logic, an equal counterpart to formal logic.

(i) Dynamic Wholes and Open Systems

The difference between dynamic wholes and static wholes is like the difference between open and closed systems. In this research a system is defined as: a set of elements in some ordered relationship such that information and/or material flows either directly or indirectly, form every element (or class of elements) to every other element in ways which affect the functioning of all elements. Open systems exchange materials, energies, or information with their environments. A flame, then, is a simple, inanimate, open system. A cell is an animate open system. In closed systems there is no import or export of energies, materials, or information (Hall and Fagen, 1975) (e.g. a house, a chemical reaction in a vacuum chamber). Closed systems are subject to entropy. By contrast, open systems can become increasingly organized. They can repair and maintain their structure over time. This tendency to violate the second law of thermodynamics has been labelled "negentropy" by Brillouin (1961). An open system increases, or prevents a decline in, its level of organization by exchanging things with its environment. If an open system is considered together with its environment that coupled entity becomes a closed system subject to entropy. Eventually the open system would deplete the resources available to it in its environment. By considered the ratio of negentropy to entropy one can determine the boundaries of an open system. The boundaries would be set at whatever places yielded the most negentropic enclosure. The optimal lines of demarkation between an open system and its environment would be those which construe the negentropic structures of the system-environment coupling as parts of the open system. Therefore, the problem of perceiving or cognitively constructing dynamic wholes requires the ability to appreciate the presence of error reducing, uncertainty reducing, entropy reducing structures when one sees them.

(ii) Negentropic Systemic Operations

The system structures studied in the present research are examples of entropy reducing structures. The components of cyclic transitivity both deal with structures essential for positive and negative feedback loops. Negative feedback loops reduce entropy by providing for the correction of errors. They reduce the discrepancy between the goal and the obtained outcome. Positive feedback loops are associated with negentropic processes like growth and development. They amplify the discrepancy between the initial state and the attained state. For example, it is a positive feedback loop that makes it possible for the rich to get richer.

Negentropic feedback loops often appear in an hierarchically nested structure. Systems analysis entails successively abrogating all those elements of a system which are not essential for the existence of at least one negentropic feedback loop. The nitrogen cycle and the wheat cycle can be
depicted with more of fewer elements. Increasing the number of elements amounts to setting wider, more inclusive boundaries on the system. Decreasing the number of elements delimits the system more narrowly. If the number of elements were to be decreased by eliminating an element essential for the survival of all the other elements (e.g., the nitrogen in the nitrogen cycle; the wheat farmer in the wheat cycle), then the elements would cease to constitute an open system. There would not be even one negentropic subcycle left. Thus systems analysis is a cognitive structure by which a person can apprehend the presence of a system, a dynamic whole.

Systems synthesis is similar in that respect. It is the operation by which one apprehends the supraordinate level of coordination among the elements of a system. That supraordinate coordination might be effected by the emergence of a central element specializing in allocating resources to the others. Such is the case with the wheat marketing board in the wheat cycle. The supraordinate coordination, however, need not always be effected by a single element. In the nitrogen cycle, for example, the mutually accommodating operating characteristics of the various populations interact in such a way as to produce an overall regularity and order which could not be predicted from a knowledge of the single parts. The overall coordination is an emergent property of the interactions among the elements. The domain of influence of these negentropic coordinating structures are co-terminal with the boundaries of systems. Once again, the systemic operations have to do with the mental construction of dynamic wholes.

Before considering what implications the distinction between formal and systemic logic has for other issues let us review what has been discussed thus far. Formal logic operates on relations of similarity/dissimilarity and of inclusion. Systemic logic operates on topological relations and part-whole relations. The truth value of formal logical arguments can be decided in the abstract. The truth value of systems logical propositions depends upon the prior specification of spatio-temporal particulars. Systemic logic applies to the mental construction of wholes. Formal logic presupposes the known identity of the wholes and goes on to compare and classify them. Static wholes are closed systems and are apprehended through what Piaget called sublogic. System logic subsumes sublogic but also allows for the appreciation of dynamic wholes or open systems. Open systems are characterized by negentropic structures. The structures studied in this research are negentropic. They are indeed useful for the mental construction of dynamic wholes. They are examples of systemic logic.

C. Ancillary Distinctions

At this point the initial aim of this chapter has been accomplished. Systemic logic has been described and distinguished from formal logic. What follows is ancillary material intended to embue that distinction with greater
intuitive cogency. The distinction between these two logics will be related to other philosophical and psychological issues. The distinction manifests itself in many more areas than can be mentioned here. Hopefully this small sampling will suggest other manifestations to the reader. The first issue to be discussed is the treatment of contradiction and identity in either logic. Then the role of purposiveness in open systems and thinking about open systems is explored. Finally, the complementarity between systemic logic and formal logic is examined.

(i) **Contradiction and Identity**

The first related issue to be dealt with is the philosophical problem of contradiction and identity. Posing $A$ automatically poses $\neg A$ (not $A$), an exclusive distinct class. Once there are two mutually exclusive classes there is the possibility of contradiction. It is a contradiction to call something $A$ and $\neg A$ simultaneously. Thus, contradiction becomes possible once there is even one identity. Also, $A$ cannot be itself and $\neg A$ simultaneously. $A$ must always be $A$. This generalization recalls Piaget's statements that logic (i.e., formal logic as opposed to sublogic) assumes the existence of wholes from its start. In formal logic contradiction signals faulty reasoning and must be avoided. The tension between contradiction and identity can be resolved in the opposite manner. Contrary to formal logic, what is called "dialectic logic" assumes the permanence of contradiction and treats identity as the problematic (Riegel, 1978). Hegel makes the point as follows:

"But it is one of the basic prejudices of traditional logic and of common-sense conception that contradiction is not such an essential and immanent determination as identity; indeed, if we were to consider a rank order and if both determinations were to be kept separated, contradiction would have to be accepted as deeper and more essential. For identity, in contrast to it, is only the recognition of the single immediate the dead being; but contradiction is the source of all motion and vitality; only in so far as something contains contradiction does it move, has it drive and activity (Hegel, 1969 p. 545)".

The focus on establishing identity makes dialectic logic similar to systemic logic. The "motion and vitality" that Hegel speaks of are also characteristic of open systems. Dialectic logic and systemic logic may in fact be two aspects of the same greater ensemble but a full consideration of that proposition is beyond the scope of this chapter. A focus on establishing identity seems to require the use of systemic logic no matter how abstract or dynamic the system under consideration may be. For example, in his quest for a method leading to self identity Husserl (1969) proposed transcendental phenomenology. The method of transcendental phenomenology appears to this writer to be an example of
systems analysis applied to the self. To take another example, Nietzsche (1961) tried to posit a supraordinate coordinating telos that might guide human evolution and establish the dynamic identity of the species. His efforts seemed to have relied heavily on systems synthesis. These examples emphasize how a focus on establishing identity is often frustrating for those who seek clear, concise definitions of the entities under discussion. Systemic logic in itself does not begin by setting forth abstract definitions of systems. Rather, it takes the definition of particular systems as the empirical problem at hand.

(ii) Purposiveness and Open Systems

The study of purposive behavior in psychology is suffused with concepts based on systemic logic (e.g., Miller, Gallanter and Pribram, 1960; Powers, 1973). Systemic concepts also permeate the study of relevance in attention deployment (e.g., Hamilton, Hockey and Rejman, 1977). Open systems are purposive by virtue of their negentropic structures. The negentropic structures keep the system either (a) developing towards a homeostatic state, and (b) in a homeostatic state. The former is the teleological purposiveness typical of organic growth and development. The latter is homeostatic purposiveness more typical of mature organisms and even mechanical systems.

A feedback loop is a negentropic structure. It may serve either teleological or homeostatic purposes depending upon the nature of its reference point. The reference point of a negative feedback loop, for example, is the critical value on the input variable that devides one output from another. In a thermostat set at 18 degrees Celsius the reference point is 18 degrees Celsius. Input temperatures above that point yield output that consists of an "off" signal to the heater. Below that point the output is an "on" signal. The activity controlled by the feedback loop is always goal directed. The goal is to achieve a match between the input from the environment and the reference point.

In using systemic logic one is always involved in discerning the goal or purposes of systems. Information and/or activity which is not relevant to the system's purpose is ignored.

The cross cultural Piagetian research that finds adult cognition in non-Western cultures to be less abstract and more pragmatic (e.g., Luria, 1979) might be detecting the predominance of systemic logic over formal logic in those cultures. An assemblage of unstructured particular contents is dealt with pragmatically when it is dealt with according to some goal, intention or purpose. Purposiveness imposes structure by turning contents into context. The priority given to contextual particulars in non-Western thought might account for its seeming extremely pragmatic to visitors from industrial societies. In formal logic the rules of reasoning come first. They are the form and they play a greater role in determining the content. In systemic logic the form is unknown at the problem solving stage of interaction with a
novel system. The form emerges from the projection of an intention or purpose or goal into a field of content. While the form is emerging, the systemic thinker might appear to be operating intuitively. He is as yet unable to articulate the structures that guide his interactions with the system. This "intuitive approach" might be more tolerated, or even encouraged, in non-industrial cultures.

(iii) Complementarity

It should be borne in mind that systemic logic and formal logic are complementary. Although they are demonstrably distinct, they seldom appear apart. Persons may specialize more or less in one type of logic over another but I doubt that anyone could use one type of logic exclusively. Systemic logic yields the identities that formal logic compares, classifies and innumerates. Formal logic allows the products of systemic thought to be raised to a level of abstraction that makes knowledge generalizable to novel but similar situations. It removes the necessity of having to re-invent the wheel everyday.

Because it abstracts knowledge from particular contexts formal logic also lends a measure of objectivity to thought. That is, it allows one to perform mental feats like ignoring irrelevant variables, and constructing hypothetical situations (models) in which all else is equal except the variable being tested. The euclidian side of formal logic is intimately related to the development of the concepts of number and measurement (Piaget and Inhelder, 1956). In its quantitative aspects, formal logic allows for more objective comparisons of magnitude.

Systemic logic on the other hand may be characterized as less objective. It is intimately related to contextual particulars. This is no more a defect in systemic logic than abstract objectivity is a defect in formal logic. Objectivity can run amuck by losing sight of priorities and purposes. Unchecked by systemic thinking it can generate irrelevancies ad infinitum. Systemic logic, on the other hand, handles purposes and intentions quite comfortably.

If one uses systemic logic exclusively it is likely that a great deal of accumulated experience would remain tied to specific situations and goals. For example, Luria make the following comments about the thought processes of the Russian peasants he had interviewed in Uzbekistan in Central Asia:

"they tended to deal with the task as a practical one of grouping objects according to their role in a particular situation rather than as a theoretical operation of categorizing them according to a common attribute. As a result, each subject grouped the objects in an ideosyncratic
way depending on the particular graphic situation he had in mind. The concrete groups that our subjects created on the basis of this situational thinking were extremely resistant to change. When we tried to suggest another way to group the objects based on abstract principles, they generally rejected it insisting that such an arrangement did not reflect the intrinsic relations among the objects and that a person who had adopted such a grouping was "stupid". Only in rare instances did they concede the possibility of employing such a means of classification, and even then they did so reluctantly, convinced that it was not important. Only classification based on practical experience struck them as proper or important" (Luria, 1979; p. 69)

Just as abstraction can be carried to extremes so can contextual specificity. Of course, what is a maladaptive extreme in one socio-economic environment might be optimally adaptive in another. Likewise, at different stages of the life cycle one type of logic may be more adaptive than another. Younger people do not have a vast store of situated experiences to draw upon and they cannot tell what experiences they will encounter later in life. Therefore their best strategy would be to abstract generalized knowledge from their experiences in anticipation of future changes. Elderly persons have a shorter future ahead of them and therefore have little need to prepare generalized schemes for meeting future situations. The elderly do have enormous stores of contextual knowledge. They can therefore quickly dispense with irrelevant information and identify the goal relevant particulars.

In summary, systemic logic and formal logic are different; so are the environments and problems that people encounter. Chandler and Boyes (in press) suggest that research should look for matches and mismatches between the sophistication of people's cognitive structures with the complexity of their environmental challenges. The distinction between systemic logic and formal logic should help in the design of such studies by facilitating the descriptions of both structures.