Developmental Psychology
1992, Vol. 28, No. 2, 191-204

0012-1649/92/$3.00

Piaget's Enduring Contribution to Developmental Psychology

Harry Beilin
Developmental Psychology Program, City University of New York, Graduate School

Piaget's transformation of society's conception of childhood thought and intelligence is described in 4 periods in the history of his research program, which spanned from the 1920s to the 1980s. The account stresses the enduring contribution to developmental psychology of Piaget's constructivism, his description of developmental mechanisms, his cognitivism, his explication of structural and functional analysis, and his address of epistemological issues and nontraditional methodologies.

No one affected developmental psychology more than Jean Piaget (1896–1980).[1] From his earliest publications in the 1920s to the time of his death, the influence he exercised was extraordinary. His theory, which has no rival in developmental psychology in scope and depth, underwent change from beginning to end. With one posthumous publication appearing after another, it is still undergoing change. Nevertheless, the theory has maintained continuity in most of its core assumptions, despite one or another of its features being transformed by additions, deletions, or changes in emphasis and interpretation. In the end, it is more than a theory: It is a research program on a vast scale (Beilin, 1985). The number of experiments conducted by Piaget and his colleagues has never been tabulated, but it is unrivaled in the history of developmental psychology. At the same time, it is difficult to identify a theory that has been more debated and attacked than Piaget's. The curve of the theory's popularity looks more like a business cycle with peaks and troughs than a classical growth curve, with eventual decline. Although the theory appears to have passed its peak in popularity, it is difficult to imagine its disappearance.

After the Second World War, when Piaget's theory appeared in a new guise to the English-speaking community, it created a near sensation with its striking counterintuitive experimental data and bold theoretical claims that struck at the heart of the then-dominant neobehaviorism. The reaction at first was to attempt to replicate his findings or to attack the research on methodological or theoretical grounds. Investigators, for the most part, took the path of least resistance and focused on the most counterintuitive findings (e.g., the conservations) and on those phenomena that seemed to embody the clearest theoretical claims (e.g., the counterempiricist training claims). The strategy was to strike at Achilles's heel, and Achilles (Piaget's theory) would fall flat on his face. Thus, there were countless (ad nauseam) studies of conservation, the object concept, formal operational reasoning, training, and more, some of which continues. The negative consequence of this strategy has been a generally distorted picture of Piaget's theory that has hindered a full appreciation of the theory's potential contribution.

Correspondence concerning this article should be addressed to Harry Beilin, Developmental Psychology Program, City University of New York, Graduate School, 33 West 42nd Street, New York, New York 10036.

Why and how Piaget's theory has gone into a decline provides a prototypic case in the history and sociology of science that cannot be pursued in this limited space. Suffice it to say that it took place at a time when other structuralist theories of commanding presence, such as Levi-Strauss's sociological theory and Chomsky's linguistic theory, experienced the same loss of authority and interest. Piaget's theory, like the others, however, still exercises considerable influence and will continue to do so.

There are a number of reasons for this. To start, Piaget's theory represents a constructivist view of development so fundamental that it will always find a place among theories of development. Piaget's version of constructivism, for the present at least, is its prototypic representative. Second, it is a developmental theory to its core. It presupposes developmental mechanisms in a theory of equilibration, which even if it is not satisfactory to everyone, requires by its very presence that other theories offer alternative explanations of developmental change. Furthermore, the theory is built on two forms of explanation that cognitive accounts of development, by their very nature, cannot do without, namely, structural explanation and functional explanation. Although which of these forms of explanation is emphasized changes, as they did in Piaget's own theory building, a theory that emphasizes either form or function to the exclusion of the other is bound to be incomplete. Piaget's theory is still the best example of a developmental theory that integrates both. Again, the research program is of such scope and the empirical data it produced so prodigious and of such significance to numerous issues that it behooves investigators of cognitive development, if they aspire at all to scholarly standards, to locate Piaget's data and interpretations as a reference point for their own studies. Furthermore, the extent of the unexplored yet astonishingly productive, simple, and straightforward experiments he reported can keep generations of investigators yet unknown busy for their own lifetimes. Last, although

[1] An anonymous reviewer of a draft of this article, to whom I am grateful for a number of valuable suggestions, observed that "assessing the impact of Piaget on developmental psychology is like assessing the impact of Shakespeare on English literature or Aristotle on philosophy—impossible. The impact is too monumental to embrace and at the same time too omnipresent to detect." I agree. This article, then, is a modest and limited attempt to do the impossible.

these do not exhaust the reasons for Piaget's theory's continued influence, he was concerned with epistemological issues of an enduring nature to which, he argued, psychological research, particularly development research, provides important insights. His own theory was an example of this and in the 1960s was one of the first to gain the attention of philosophers of mind (Mischel, 1971), who up to then were wary of psychological theories for fear of contaminating their analyses and arguments with psychologisms.

Thus, Piaget is more than a historical figure, large as he looms in the historical landscape of developmental psychology. His theory is still very much a contending presence in the free-for-all that defines current psychological theorizing. What makes that presence more salient is that we have not heard the last from Piaget. As later books are translated and published, what is abundantly clear is that they represent a new era in the evolution of his theory. The emphases and the interpretations of developmental phenomena are sufficiently changed from his "standard" theory that I believe they require us to see it as a "new" theory (Beilin, 1989).

Four Phases in Piaget's Program

Piaget had a different effect on developmental psychology with each phase in his research program, which can be divided into four such periods (Montangero, 1985). His first books, in the 1920s and 1930s, provided a view of children's thought that was very much in keeping with the scientific mood in continental Europe. The first research reports were nonetheless sufficiently revolutionary to draw immediate attention. Then followed a period, different in both method and content, in which Piaget embarked on detailed observation and interpretation of his own three children's early cognitive development. The reports of these studies extended Piaget's theory (and his reputation) to global proportions. Before the Second World War, Piaget's research took off in yet another direction and, in the safety provided by Swiss neutrality, continued through the war years. When the war ended and communication was resumed among the previously warring and occupied countries, Piaget's theory came on the scene in a new guise, with a structuralist and cognitivist framework that electrified the psychological community, already oversaturated and disaffected with behaviorism and other functionalisms. Here was Piaget's "grand" theory laid out in a series of books that soon provided the standard interpretation of the theory. The structuralist-oriented theory initiated an era in developmental psychology that it almost completely dominated until the end of the 1970s. Piaget's influence, however, experienced a gradual decline in the 1980s.

It is interesting that from the 1970s on, in the last 10 years of Piaget's life, his research and theory took a turn in yet another direction. In part, it was a return to functionalism—not the functionalism of the 1920s and 1930s but a new version, influenced to a degree by the structuralism of the standard theory.

Each phase in the research program added something new and important to the theory in addition to whole bodies of empirical data. I would like to detail what some, if not all, of these additions were.

Phase 1: On the Child's Conception of Reality Mediated Through Language and Social Interaction

On language and thought. The first book-length report of his research, in 1923, on children's language and thought, brought Piaget immediate world-wide attention as the work was translated into many languages (Piaget, 1926). The ideas expressed are still controversial and bear on fundamental issues that will continue to be debated. The research addressed the question of the functions served and the needs satisfied by the use of language. Piaget's approach to children's speech was descriptive and classificatory but not without a functional explanation that was very much in the spirit of Claparede, who at the time was director of the Institut Jean-Jacques Rousseau and Piaget's predecessor in that post. Piaget made the point that descriptive categories are of little utility in themselves without knowledge of the functional origins of the behaviors classified. He applied this methodological dictum to the two principal categories that he identified in young children's speech, the egocentric and the socialized. *Egocentrism,* a term Piaget later rejected because, among other things, of its misleading connotations of emotional self-centeredness, was applied to various specific categories of speech (e.g., echolalia and monologue). These uses reflected the child's reference of all events to his or her own point of view. Thus, much of children's speech was said to be for themselves, not their audience, and did not take into account others' points of view. Socialized speech, which comes as a later development, was said to be for the purpose of communication and social engagement. Piaget detailed three stages in this development, reporting that at the age of 6 years, about 45% of speech is egocentric (not all the speech is egocentric, a point often overlooked). However, egocentric thought is not purely asocial. When children retold a story told by Piaget, they were well aware that they were trying to communicate. The difficulty was that young children did not differentiate their own from the other's point of view. Piaget's interest in the study of language was to provide a window into the child's processes of thought. His concern was only secondarily with the nature of language itself; language, in fact, never became a serious focus of study for Piaget (Beilin, 1975).[2]

Piaget's first major work, aside from its attempt to discern and differentiate form and function in the child's thought principally through language, delineated the stages in this development. Describing the stages, first through a scheme of descriptive classification and then largely as a functional explanation of the changes in the properties of these different forms of speech, set a pattern for Piaget's later research. He continued to use stage description to the very end of his career.[3] What also

[2] Piaget's notion of egocentricity and its decline with development has been considerably battered over the years. When Piaget learned that Vygotsky was among those critical of the linguistic version of this notion, he wrote (Piaget, 1962a) that had Vygotsky been aware of the later version that substitutes the concept of decentration for egocentricity, he would unlikely have approved. Vygotsky's English-speaking followers, at least, appear to have been anything but sanguine about the change.

[3] Some influential former colleagues of Piaget's have tried to diminish the role that stages plays in Piaget's theorizing. I frankly don't buy it. Whereas many aspects of the interest and interpretation of Piaget's stage theory are misleading (e.g., the age norms and structure-of-the-

characterized the first and second phases of Piaget's theory and research was their emphasis on functional description and explanation that was typical of both Continental and American psychology at the time. The significance of this theoretical and methodological commitment is made more evident by the radical shift in another direction that took place in the third phase of his research.[4]

The work on language and thought led to further insights that were to lay the groundwork for later theory. A study of children's spontaneous questions provided the basis for attributing a form of precausal thinking to the child, characterized by lack of differentiation between causal explanation and intentional explanation. In the developmental course described by Piaget, children at 3 years of age become concerned (in their first *whys*) with intentionality, although there is said to be no discrimination between causality and agency, as evident by their projection of intention onto physical objects. This precausal type of thinking yields to the differentiation of subject and object and by way of an explicatory function leads to the differentiated categories of causality, reality, time, and space in the child's thought. In this differentiation from precausal syncretism (i.e., the fusion of elements), there emerges the parallel implicatory function. Again, as subject and object are differentiated, the regulatory function leads to classification, naming, number, and logical relations. A mixed function of explication and implication leads to the motivation for action and rule justification. The distinction between explicatory and implicatory functions reverberates through Piaget's later theory in a variety of distinctions, such as those between causal and logical thought, between physical and logico-mathematical knowledge, and between physical abstraction and reflective abstraction.

On relations. *Language and Thought of the Child* (Piaget, 1926) was intended to be the first of a set of two. The other, *Judgment and Reasoning in the Child* (Piaget, 1928), concerned issues raised in the former, in some cases in greater detail and more systematically. For example, the study of why questions of the earlier book was followed now by a study of logical and causal connectives such as *because, therefore,* and *although.* In addition to expressing logical and causal relations, these terms also can express motivational (psychological) connections; their use by children appears at between 3 and 7 years, with logical uses appearing at about 7 years, paralleling the decline in egocentric speech. Many of the early uses attributed to the connectives reflected what Piaget referred to as *juxtaposition,* the tendency to link one thought to another successively when there was a causal or logical relation between them. This concept is the opposite of syncretism, the tendency to blend two thoughts together. Piaget saw the separation of juxtaposition and syncretism as representing the incomplete ability to understand part/whole relations. Piaget tied these notions into a model of equilibrium that was to play an increasingly important role in the theory. Juxtaposition and syncretism were seen as complementary aspects of an unstable equilibrium: In juxtaposition, the parts predominate over the whole; in syncretism, the whole dominates over the parts.

In *Judgment and Reasoning in the Child* (1928), Piaget also pursued the study of relations within a verbal context, a study that he would pursue extensively later in largely nonlinguistic forms. For this purpose, he used Simon-Binet's absurdities text, in which the typical assertion and question are, "I have three brothers: Paul, Ernest and myself. What is wrong with that sentence?" Together with a variation of this, children were studied from 4 to 12 years of age. Young children typically were unable to differentiate between two points of view, that is, between their own and others', a problem of relations as opposed to class, with which young children had less difficulty.

In a study of simple arithmetic reasoning, Piaget discovered that even when it appeared evident, for example from their mutterings, how young children were solving a problem, when asked how they solved it, they were unable to explain how they had done so or provided an ordering opposite to how they had actually solved the problem. This was the case even when they gave correct answers to the arithmetic questions. Chapman (1988) pointed out that this was an early defense by Piaget of his use of linguistic justification criteria for the attainment of a concept. Inasmuch as providing a correct answer can be achieved in a variety of ways, the child's verbal justification is required to determine whether the child in fact grasps the concept. The issue of whether to accept correct answers alone as a criterion for achievement of a concept was to become a contested issue in later research, as in the well-known conservation studies. This early insight into children's inabilities to indicate how they solved a problem was taken up in one of Piaget's last books, *The Grasp of Consciousness* (1976), and was shown to have relevance to an understanding of the nature of consciousness itself.

The study of verbal definitions led to consideration of the nature of contradiction because of young children's difficulties in handling a general term and particular features simultaneously. Beyond describing how children handle contradiction (by "amnesia," forgetting one judgement as they pass to the next, or "condensing" and assimilating the content to contrary categories), Piaget considered the differences between logical and psychological contradiction. Whereas logic asserts the impossibility of holding contradictory propositions, in logical thinking, contrary propositions are handled psychologically. To address this issue, Piaget again invoked the notion of equilibrium. Noting that logical noncontradiction is a state of equilibrium, the normal state of mind is one of disequilibrium—or, rather, a state of "moving equilibrium." He claimed that the psychological equivalent of the logical principle of noncontradiction is *operational reversibility,* that is, the simultaneous holding of relations that are the inverse or the reciprocal of one another (as he was to define operational reversibility later). Op-

whole concept), the stage notion is critical for the theory. The evidence of this is that the stage concept was used by him to the end; it is essential for understanding a number of important claims made by the theory, and in the later theory, he revised the stage idea he held previously.

[4] Implicit in the work just described, and in other research of this period, is the claim that the young child's thought is syncretic and undifferentiated in its understanding of reality and its own mind. This implies that the child has no coherent "theory" of reality. This conception has been vigorously contested in the child's-theory-of-mind literature (cf. Astington et al., 1988; Wellman, 1990).

erational reversibility refers to processes or logical relations that take place simultaneously rather than successively. This notion played a critical role in all of Piaget's later theories. At this point in the theory's development, he introduced two other notions that he adopted from biological theory, the *assimilation of reality to the mind* and the *imitation of reality.* Although the assimilation of current to prior events and the imitation of occurring events can occur independently, operational reversibility is achieved only in the balance of assimilation and imitation. Furthermore, as though to emphasize the systematic aspects of his theorizing by integrating the critical concepts of the theory into a coherent totality, Piaget asserted that assimilation by itself is the predominance of the whole (in the form of existing schemes) over the parts (the elements assimilated); imitation alone is the predominance of the elements themselves (the parts) over the relations among the elements (the whole). In parallel, syncretism and juxtaposition express these general functions specifically in children's thought (Chapman, 1988, p. 46). Later development of the theory led to the substitution of the more general concept of accommodation for the notion of imitation.

Piaget proposed two stages in an attempt to tie together the research covered in these first two books. In the first, three "global" stages were described in the development of children up to the ages of 7–8 years during which their thinking is nonreversible and transductive (transductive thinking, being reasoning from one particular to another in contrast with deductive thinking, going from the universal to the particular, and inductive reasoning, going from the particular to the universal). In the second stage, from 7–8 to 11–12 years, there is partial reversibility in thought, limited however to actual observations. From ages 11–12 onward, children's reasoning is not limited by observed reality but is capable of dealing with the hypothetical. In this progression are the seeds of the later distinction between preoperational, concrete operational, and formal operational thought.

Early critics reacted vigorously to a number of Piaget's striking claims. One criticism that Piaget felt needed an unequivocal response was the impression that his stage characterizations were confined to particular age norms. Although Piaget made clear in *Judgment and Reasoning in the Child* (1924/1928) that the ages delineated were a function of the methods he used, the disclaimer did not still the controversy or the misinterpretation of his intent.

A second criticism was directed at the description of early egocentric thought and language, both their reality and the explanation given for them. It was clear that the theory had to account for why earlier egocentrism gives way to socialized speech and thought. The mechanism for the transition, according to Piaget's at the time, was social interaction, in particular interaction with peers. Conflicts and arguments were said to force on children the need to examine their own views of the world relative to the views of others (Flavell, 1963). Piaget would again invoke social interaction as an explanation of cognitive change in his research on moral reasoning, but this type of social explanation was limited to the theory of the earliest period.[5]

On realism. Of the books that followed, the next two, which dealt with reality and causality, *The Child's Conception of the World* (Piaget, 1923/1929) and *The Child's Conception of Physical Causality* (Piaget, 1930) were a pair. The next book on moral judgment, *The Moral Judgment of the Child* (Piaget 1927/1932), although concerned with a different context, nevertheless reflected the same theoretical framework as the preceding four in its characterization of development proceeding from egocentricity to social reasoning.

Piaget's research on realism is another example of a topic that interests current investigators, albeit as an area in which Piaget's findings and explanations are largely contradicted. Piaget's claims concerned three concepts that he introduced. The first, *childhood realism,* results from the lack of differentiation between self and the world such that psychological and physical events are not clearly differentiated. The second, *animism,* refers to the reverse process of attributing to physical objects and events the properties of biological and psychological phenomena; that is, young children endow physical objects with life and consciousness. The third, *artificialism,* treats physical phenomena as the consequences of human invention.

With regard to realism, for example, Piaget claimed that young children identified thought with the voice as a material event rather than as a mental process (intellectual realism). Names were said to be located in their referents, so that the name *dog* is part of the properties of the animal itself and known from looking at the object (nominal realism). Dreams for the young child were said to be material entities existing external to the child, as in a room. Piaget saw in these instances a stagelike progression that pointed to a "general direction of thought, not a comprehensive and coherent system of beliefs" (Flavell, 1963, p. 283). This development, as with the others characterized in this period, was related to early egocentrism (seeing the world from one's own perspective). As has been pointed out by more than one sympathetic observer, although Piaget reported these developments as stagelike achievements, he did not claim that they were uniform or unitary. Levels of realism, animism, and artificialism could be achieved at quite different paces, not necessarily in synchrony.

The current attacks on Piaget's notions of realism have come from the growing group of investigators studying the "child's theory of mind" (e.g., Astington, Harris, & Olson, 1988; Wellman, 1990), who claim that even young children (3 years) do not mistake the contents of mind (thoughts, feelings, and dreams) for material objects outside the head. Second, the young child is on the way to a coherent set of beliefs about mind that can be considered a theory of mind. Theory-of-mind counterclaims concerning childhood realism, for example, are not without controversy themselves (Beilin & Pearlman, in press), although the principal empirical counterclaims appear to have support.

Piaget's study of physical causality concentrated on the study of movement (of clouds, water, etc.) by predicting the outcome of an action or event and then questioning the cause after the event occurred (e.g., predicting the water level after dropping various objects into a glass vessel). In the process, Piaget identi-

[5] There have been a number of recent attempts to introduce social causation into some version of Piagetian theory (e.g., Chapman, 1992; Youniss & Damon, 1992). It is well to remember why Piaget abandoned his earlier reliance on that form of explanation (Piaget, 1950). As he put it, he came to see that instead of the effects of social influence being the basis of an explanation, they were a phenomenon to be explained.

fied 17 types of causal explanations, again within a developmental framework in which there is a gradual decrease in egocentricity and increase in socialization of thought, incorporating greater objectification and reciprocity of viewpoints.

On method. In *The Child's Conception of the World* (Piaget, 1923/1929), there was extensive discussion of one of the most controversial aspects of Piaget's work, his so-called clinical method (later referred to as *the method of critical inquiry*) based on questioning and counterquestioning. He contrasted his method with traditional methods in use at the time, noting the disadvantages of others and the advantages of his own. He was also very clear on the dangers in the use of the clinical method (e.g., spontaneous fantasy, suggestion, and chance) and the safeguards that are needed to avoid false conclusions. Piaget's clinical method has been faulted for many reasons. Experimentalists, working within an essentially logical empiricist framework, identified the method as more in the tradition of the "logic of discovery" than in that of the "logic of justification" or truth testing. Others faulted the method for allowing the introduction of theoretical biases, even into what appear like methodological safeguards. The status of Piaget's methods will be discussed again later, but there can be little doubt that the clinical method was extremely fruitful in the first phase and later in generating a wide variety of data that contributed to provocative interpretation and theory building.

Another aspect of methodological epistemology concerned Piaget in the early work *The Child's Conception of Physical Causality* (Piaget, 1927/1930). It was the distinction between reality as conceived by the child and reality as conceived by the scientist. Piaget was quite conscious that the scientist's frame of reference for interpreting the nature of reality, against which one relates the child's conception of reality, was a convention that was deliberately chosen yet was to be guarded against so as not to allow it to lead to "epistemological realism" (i.e., reification; Chapman, 1988, p. 54). Piaget declared that through psychology it would be possible to address significant problems in the theory of knowledge by the very contrast between the scientist's (and society's) and the child's conceptions of reality.

On moral judgment. The final work of this first period was Piaget's *The Moral Judgment of the Child* (1932). In this work, he considered children's knowledge of "rules of the game" (in playing marbles), notions of lying, and conceptions of justice. He described a general course of development, although again, he was aware of considerable variability among children and even among social classes (inasmuch as his sample consisted of poor children in Geneva). The developmental course was from what he termed a *morality of constraint* (based on conformity to "superior" adult norms) to a *morality of cooperation and reciprocity* (based on mutual respect among equals). This developmental course was manifest in different ways in each domain (rules, lies, and justice).

Again, the mechanism for the development from nonrational to rational morality, which underlays the development of rationality in general, was the give and take of peer interaction in the context of peers who try to cooperate: "This kind of interindividual exchange provokes a social decentration as well as cognitive decentration. Norms stem from the grasp of consciousness of the results of this decentration" (Montangero, 1985, p. 24).

After completing his work on moral judgement, Piaget never returned to it. Kohlberg (1969), however, undertook its study in the 1950s with a theory, modeled on Piaget's, that created a considerable and controversial literature of its own.

Summary. The first period in Piaget's research, spanning the years (in publication) from 1923 to 1932, was characterized by a theory of development based on the transition from egocentrism to socialized thought along with a theory of social causation in which the retreat from egocentrism is propelled by the consequences of peer interaction and the exchange between thought and action. It was a highly fecund period in which Piaget's study of language and conceptions of reality, causality, and moral judgment affected the course of much developmental research worldwide and introduced a theoretical orientation to be reckoned with that resulted in considerable controversy. It was a period, also, for the introduction of a definitively cognitive orientation to work on child development, with a discovery procedure (the clinical method) of considerable utility in detailing the course of cognitive development. It also offered the beginnings of a theory of knowledge that was to have lasting significance for developmental psychology.

Phase 2: Stages in Sensorimotor Development. The Theory of Adaptation

In the 1930s, there was a decided shift in Piaget's research and theory. It was an era marked by Piaget's close observation of the early development of his own three children (born in 1925, 1927, 1931). There were changes as well in the explanatory model for development. These were not the only changes, however.

Whereas the earlier research was based almost exclusively on verbal exchanges between experimenter and child or between children themselves, the studies of this period entailed to a greater extent observation of the child's action on objects. In fact, in a significant epistemological move from that period on, Piaget characterized his principal concern as the (dialectic) relation between subject and object.

On action. The six stages he delineated in sensorimotor development during this period are well-known. They led to the distinctly Piagetian conclusion that both language and thought are preceded and prepared for by a "logic of action" represented in the development of the schemes of sensorimotor action and coordination. The child's action was seen as the fundamental source of knowledge rather than the traditionally defined sources of perception and language. It is here too that Piaget's theory established itself with a distinctive point of view that only later would be widely accepted in psychological theory, namely, that the child is active in the creation of knowledge through constructive processes with which he or she is naturally endowed. Piaget adopted from biological theory the processes of assimilation and accommodation as functional invariants. In assimilation, existing structures (schemes) in mind incorporate the abstract properties of actions on objects; in accommodation, mind modifies existing structures to the varying properties of objects. Whereas assimilation stresses the functional identity of actions on objects, accommodation stresses the functional differences among objects. Organization provides a self-regulatory mechanism for the relations among the resulting structures. The compensatory balance between assimilation and accommodation through organization makes possible the organism's adaptation to the physical and social world. Thus,

the theory of adaptation that Piaget adopted at this point depended largely on endogenous processes such that the effect of socialization relied on for explanation in the prior period was no longer invoked or seen as relevant. In fact, social interaction and the effects of social exchange were themselves now explained by the theory of adaptation.

Theory of adaptation. The functional theory of adaptation explained the origin of the categories of thought. Assimilation was identified with what Piaget called the *implicative function,* which included the logic of classes (based broadly on functional equivalence) and the logic of relations (based on functional differences). Accommodation, in turn, corresponded to the *explicative function,* the categories of reality entailing objects and their causal relations in time and space. Organization functions to create totalities (relations of part/whole or reciprocities) and has a regulative function in adaptation.

The model of adaptation, with its shift away from a model of social to biological explanation, has not to be everyone's satisfaction to this day (Chapman, 1992; Youniss & Damon, 1992). Furthermore, despite Piaget's emphasis on the necessary role of the object in the dialectic of the subject–object relation, the theory rests primarily, although not exclusively, on endogenous processes and on the subject's own action and reflection. Contemporary contextualist theorists, from the mildest to the most radical, have not been happy with what they have seen as Piaget's exclusion or dismissal of social, historical, and interpersonal factors in the construction of knowledge (e.g., Dixon, 1987). Neo-nativist theorists, in turn, have been unhappy with Piaget's constructivism, being more inclined themselves either to differentiation theories or to (local) learning theories as well as to the assumption of greater naturally given mental structures and processes than Piaget was willing to warrant (e.g., Carey & Gelman, 1991). In Piaget's later theory, the adaptation model itself was modified away from implied biological adaptation to a more dialectic model in the theory of equilibration.

Structure d' ensemble: Theory of representation. In delineating the six stages of sensorimotor development, Piaget's theory emphasized the important role of the repetition of actions (in the "circular reaction," a notion he openly adopted from J. M. Baldwin) (Broughton & Freeman-Moir, 1982), the increasing role of intentionality, and the varieties of assimilation and accommodation evident in the child's developing repertoire. With respect to organization, he introduced the notion of *structure d' ensemble* (structure-of-the-whole) that was to be an important, if highly debated, aspect of the theory. A further feature of the exposition of sensorimotor development was the delineation of a developmental theory of signs. This was essentially a theory of representation leading from identification of the function of signals (i.e., conditioned responses) to the index function (further distancing of the representation from the stimulus), and then to the symbolic (later identified as the semiotic) function in which the representation need have no similarity to the referent. This representational development was to be later adapted and altered by Bruner (Bruner, Olver, & Greenfield, 1966) in his theory of representational development from the enactive to iconic to symbolic functions. Again, the theory of signs that Piaget (1962b) proposed, following in part on Saussure's model, anticipated many later theories of representation, although some still questioned the need of a developmental component of representational theories of mind (Fodor, 1975; see also Perner, 1991).

The object concept and space. Piaget's description of particular developments in this period also elicited extraordinary interest, research, and debate, as in the case of the development of the object concept (i.e., the concept of a permanent object). As in many later experiments, Piaget's reports of his observations were initially so counterintuitive (especially the so-called stage IV A, not B phenomenon, in which the child looks to where an object was originally hidden rather than to the place to which it was seen to be displaced) that countless studies were undertaken to test (and contest) Piaget's findings. Piaget's report of the phenomenon has withstood extensive experimentation, although controversy still exists over the theoretical interpretation that he applied to its developmental course (Harris, 1983). (For a different view, see Wellman, Cross, & Bartsch, 1986. Representative of more recent experimental work are Baillargeon, DeVos, & Graber, 1989, and Diamond, 1988.) The same was true of Piaget's characterization of the sensorimotor development of spatial concepts, although not to the same degree. In this case, Piaget applied Poincaré's concept of the mathematical group to space (Piaget & Inhelder, 1956), a notion on which he was to expand considerably in his later theory. In this early proposal, Piaget already claimed that every closed system of operations had the properties of a group (Chapman, 1988, p. 112).

Causality. Piaget's study of causal thinking in the sensorimotor phase laid the groundwork for two later studies in causality. The explanation of causal thought was to concern Piaget throughout his later work. His first intent was to account for scientific and prescientific theories of causality, which had troubled philosophers for centuries. His further interest was in the relation of causal thought to operational thought within his own system.

In this second phase of the theory, Piaget recognized in a new way the importance of language in development and tried to account for its developmental course. His account showed its relation to the evolution of concepts, arguing that the child's first words represent preconcepts. His analysis of early language was clearly influenced by Saussure's semiotics, from which Piaget adopted the idea that the referents of words are concepts, rather than objects or events, as usually conceived. Piaget's own studies of language were limited to observations of development in the sensorimotor period. A basic tenet of his position, which was to be more clearly enunciated in his later debates with Chomsky (Piatelli-Palmarini, 1980), was that a long period of nonlinguistic cognitive development precedes and makes possible the acquisition of linguistic forms. Sinclair, in the 1960s, was to undertake a comprehensive study of language within the Piagetian framework (see Sinclair, 1992, for a history of this research).

Method and explanation. Much criticism in this period was directed at Piaget's extensive generalizations and claims for the universality of functions and structures made on the basis of observations and experiments on his own three children. Almost forgotten was the fact that the studies of the earlier period were based in some cases on hundreds of children.

Piaget's methodological approach in the 1930s studies of his own children was to detail the children's behavior toward ob-

jects in their natural surroundings as well as toward objects that he introduced. The observation protocols reported, although clearly selected from countless hours of observation and experiment, were essentially factual descriptions of the children's behavior, with further interpretations by Piaget of their functional significance. At another level of explanation, Piaget mapped his biological model of adaptation onto the data and, more particularly, various other theories (such as Saussure's, Poincaré's, and Baldwin's) to explain more local phenomena. The model throughout was basically functional. In the next period of the theory's development, a marked shift occurred wherein the implicit and subtly explicit structural elements of the theory were made the central focus of explanation.

Phase 3: The Structuralist Period. Logico-Mathematical Models, Concrete and Formal operations, and the Standard Theory

In the late 1930s and early 1940s, Piaget's books on numerical and physical quantities signaled a new turn in the theory. These initiated the structuralist period that was to last until the 1960s and 1970s and was marked by the use of structural analysis and explanation as well as the introduction of models adapted from logic and mathematics.

The transition to this phase was easily enough accomplished inasmuch as it built on an approach implicitly in place. Starting with an intensive examination of a particular domain of knowledge, such as number, a variety of experiments were undertaken that exposed the child's ways of dealing with the conceptual elements and complexities of the domain, as well as their limitations.

Studying children at different ages yielded information of the functional characteristics of the child's thought, but in studying younger children in the formative stages of development, Piaget also emphasized constructive elements in the process of formation. Piaget has often been criticized by one group of critics (among them Bruner, Flavell, and Gelman) who claim that his approach in characterizing development was negative; that is, in describing a particular stage, he detailed what the child lacked in relation to the stages that follow. This type of criticism fails to recognize Piaget's usually extensive description of the achievements of the stage over that of the prior one. It also fails to recognize that in detailing what was missing in a stage, Piaget wished to emphasize the ways in which the developmental history of the phenomenon studied was not complete.

Armed with a functional description of natural logic in the ages of operational thought (from 6 or 7 years on), what was missing from Piaget's theory up to that time was an adequate explanation for these more powerful forms of thought. Piaget was aware before this time of Poincaré's mathematical models applied to space (Piaget & Inhelder, 1956) and later of the work of the Bourbaki (the group of French mathematicians), which led to his adapting their models and mapping them onto the description of natural logic emerging from his current empirical work (Beth & Piaget, 1966). In this third phase of his work, he had a sophisticated group of collaborators, the principal among them being Bärbel Inhelder, who undertook an extraordinarily wide range of experiments on logical, mathematical, and scientific thinking.

Out of this research, Piaget defined the developmental periods of concrete operations and formal operations, the first starting at around the age of 6–7 years, the second at around 11–12 years. A large number of claims were made in relation to the developments of these periods that were consolidated into a view of the theory that were strikingly different from the character of the theory prior to that time. When this work, which was carried out shortly before and during the years of the Second World War, became known after the war, it created a revolution in thinking about cognitive development. The constituents of the theory developed at this time became what many consider to be the standard version of the theory. The central concept on which the logical architecture of the standard theory was built was the logical operation, interpreted as the mental interiorization of a physical action, with the property of (simultaneous or concurrent) reversibility. In the period after World War II, with the progressive demise of behaviorism and its strictures against mentalistic constructs, there was greater acceptability of Piaget's cognitivism and its lexicon of mentalisms only indirectly tied to observable behavior. Piaget, however, very carefully distanced himself from an idealist position, consistently claiming that the cognitive elements of the theory were always tied to some observed behavior, usually in the form of repeated patterns of a particular kind that would imply the existence of a mental structure.

Groupings and groups. Thus, the (mental) action of combining classes of objects or object properties into a larger class was said to be indicative of logical addition, whereas other mental actions were involved in logical subtraction, multiplication, and negation. Paralleling the system of logical operations was a system of logic very much like the formal systems of traditional logic. There was, however, one difference that some critics either did not see or did not appreciate. In adapting these logical theories to a psychological system, they were no longer the axiomatic of logic itself or of the operational structures of natural logical processing; they constituted a "psychologic," as Piaget called it, a formal psychological model for the underlying structures of rational thought. The psychological reality of these structures was to be supported by their ultimate tie to the evidence of thought in actual problem solving and reasoning.

The central concept of this psychologic was group structure, the model of which came from the (closed) mathematical group, with its properties of composition, associativity, identity, and inversion. However, inasmuch as these were not mathematical but psychological groups, they had other properties (special identities) such as tautology and resorpsion. The logical structures first constituted in the period of concrete operations were said to lack the properties of group structures in part because these logical systems were tied to the actual manipulation of objects. Instead, Piaget differentiated and identified what he called *groupings* (groupement), which had some but not all the properties of a group. The groupings were said to underlie (or map onto) the logic of classes and the logic of relations, which together with the reversibility operations of the conservations of quantity characterized the structural underpinings of rational thought of the concrete operational period. The groupings were defined by the logical addition of symmetrical and asym-

metrical classes as well as (ordering) relations and by the logical multiplication of one-to-one and one-to-many relations between classes and (ordering) relations. The groupings were said to be manifest in classification thinking in such instances as the class-inclusion task, which became a classic among Piagetian methods. When two classes, such as x roses and y violets are combined into single (superordinate) class, flowers $(x + y)$, and children are asked which there are more of, flowers or roses, proper understanding of the relation of inclusion is said to be the critical test of understanding part/whole organization, the most fundamental structures of which are the groupings. The logic of classes and the logic of relations were said to become integrated in the understanding of the nature of number, which integrates these logics into a single system (reflected in the cardinal and ordinal numbers). Whereas almost everyone at the time thought that Russell and Whitehead, following Peano and Frege, had succeeded in reducing number to logic (the logicist program; Benacceraf & Putnam, 1964), Piaget instead believed he had succeeded in reducing the logic of number to a psychological phenomenon that reflected the (mental) interiorization of action and, by doing so, had established that number was not reducible, by virtue of the definitions of set or class logic alone, but had to entail an integration of class and order (seriation) logics.

Conservations of quantity: Decalage and structures-of-the-whole. Piaget's study of the conservation of quantity (number, mass, weight, length, area, etc.) turned out to be among the most visible, engaging, and provocative of his many experiments. The reports of young children's failures at conservation were so counterintuitive that they led to a veritable avalanche of studies to verify the phenomenon. When the child's developmental course in achieving conservation was tied by Piaget, in his equilibration theory, to the limitations of assimilation, because the child was said to lack the structures to permit acquiring conservation, a large number of training studies were undertaken to challenge this claim. The training studies, in the main, represented an attack on the very foundations of the equilibration theory. Piaget trivialized these studies at first as merely designed to show that development could be accelerated, reflecting a controversy that had plagued discussion of Piaget's theory from the 1930s onward. The training studies (principally of conservation), however, brought a number of features of the theory to general attention, many of which are still controversial (Beilin, 1971, 1978, provide extensive reviews of this literature).

Two of these are intimately related: the problem of (principally horizontal) decalages and the issue of the *structure d' ensemble* (structure of-the-whole), which bears on the constitution of stages. It was almost immediately apparent in the replication of Piaget's experiments that the achievement of the many conservations of quantity were not concurrent. That is, children did not achieve number, length, liquid quantity, weight, and such at the same time. It was assumed by most investigators that this was at variance with Piaget's theory in that the logical structures of the concrete operational period, the groupings, would be achieved on an all-or-none basis and that the structures-of-the-whole represented by the groupings would require concurrent achievement not only of the conservations but of the elements of class and seriation logics. Piaget's early writing on this score may have led to this view inasmuch as he often reported concurrent achievements, as in the achievement of length, area, and volume measurement. But as Chapman (1988) made clear in a painstaking analysis of Piaget's writings on these issues (particularly those of 1941), Piaget never intended that a structure-of-the-whole should encompass the whole of the contents, or the domains of knowledge, in a stage. Rather, each of the 8 or 9 groupings functioning in a given content area is a structure-of-the-whole unto itself and is functionally distinct (Chapman, 1988, p. 149). Thus, synchrony in development was to be more the exception than the rule in development. Knowledge was not only dependent on the grouping structure in question but also on its domain of application, that is, the content and form of the domain (e.g., weight would offer different properties to be conserved from mass even though both are quantities). Consequently, the domains of application would represent different levels of difficulty for a child. Montangero (1985) held that Piaget's early account of decalage assumed priority of one concept over another such that the concept of mass, involving the retrieval of matter, would precede weight, which would involve the weighing of matter. Piaget's later explanation had more to do with the varying resistances of objects to being acted on and with the figurative aspects of the situation, such as the location of an object, and the physical laws applying to objects (Piaget, 1985, p. 41). Inhelder, Sinclair, and Bovet (1974) developed further the idea that achieving a concept such as a conservation is a function of the basic logical structure of the system (e.g., the groupings) and the special physical properties of the domain (weight, number, etc.). Nevertheless, Piaget did hold that in some cases various groupings did appear to develop at the same time, but this was not necessarily a consequence of the structure-of-the-whole of a given stage (Chapman, 1988, p. 151). Horizontal decalages are to be expected (but not of necessity) when formally equivalent groupings are applied to qualitatively different areas of content, as in the conservations. Synchrony is to be expected when the same grouping is applied to different objects in the same content domain (Chapman, 1988, p. 152).

The manner of Piaget's description of the relations between logical structure and domain contents argues against the oftencited view that Piaget believed that logical structures are acquired and function in a content-free manner. To the contrary, even in this very structuralist of periods in his theory, he maintained that there is no structure without function and no function without structure. Nor is a structure achieved at once in an all-or-none fashion and then applied to specific contents. Rather, structures are the logical organizing properties of operations, and operations are, by definition, contentful. Again, contrary to the prevailing view held of Piaget's standard theory, he did not maintain that a child passes from one stage to the next in an all-or-none fashion. Instead, the child is at different stages for different content domains at the same time. Owing to the association of the notion of "global" stage progressions to the stage concept, there has been a retreat among a number of investigators from the stage concept to concepts of domain specificity, except among some neo-Piagetians such as Case (1985; Case et al., 1986). The domain-specificity argument is that if structures of organizations in mind exist, they do so within domains and not within structures that cut across a stage (e.g., language, areas within language, classification, weight). There is, however, no necessary incompatibility between the stage

concept and domain specificity, as Piaget's own later conception of stage development as spiral suggests. (See Levin, 1986, for a discussion of the issues.)

The nature of developments in concrete operational thought was delineated in considerable detail in books devoted to the study of time, space, movement and speed, and geometry. Less well-known, although published during the same period, was a series of essays on sociology (see Chapman, 1988) in which Piaget elaborated a theory of social exchange, although again, within a structuralist framework.

Genetic epistemology. The work of the structuralist period continued into the 1950s as Piaget's group or "school" began to identify itself as established in a new discipline, genetic epistemology (for the study of which they established the International Centre for Genetic Epistemology). The aims of this program have led a number of people to characterize Piaget as a philosopher in that his intent was to illuminate traditional questions in epistemology on the basis of the study of cognitive development, principally. The essential plan was to study the history of ideas relating to knowledge and its forms in each of the sciences, although his analyses were confined in large measure to the physical sciences and mathematics. (In Piaget's 1970 *Structuralism,* his analysis also concerned the biological and social sciences.) Piaget was interested in showing that there was a parallel development in the history of ideas in a science and the development of concepts in children relative to concepts in that science. More importantly, Piaget (later with Garcia) claimed that the mechanisms underlying evolutionary developments in the science and in child cognitive development are analogous. Aside from this long-term project in genetic epistemology, which did not reach fruition until the end of Piaget's life (in *Psychogenesis and the History of Science,* Piaget & Garcia, 1989), the structuralist period was rounded out with a characterization of the nature of formal operations.

Equilibration, causality, and formal operations. Of considerable general significance was Piaget's continued elaboration of the theory of equilibration. To this end, the generation and generalization of structures had to be more precisely accounted for than "merely" detailing the functions of assimilation, accommodation, and self-regulating and self-organizing processes. In accord with the distinction between physical knowledge and logico-mathematical knowledge, on which the studies of the concrete operational period focused, Piaget proposed two forms of mental activity or mental processes that augmented the prior equilibration account. In this instance, physical abstraction was said to be the source of physical knowledge, the knowledge that comes from experience with objects, the properties of which (such as size or shape) are abstracted, generalized, and organized into classes. This process was said to lead to the physical knowledge of objects and events. This knowledge-generating process, however, does not account for logico-mathematical knowledge of the kind manifest in the concrete operational period. Instead, Piaget proposed that another process, reflective abstraction, results in the construction of newer and higher forms of knowledge from those at lower levels (e.g., operations at the level of thought as opposed to schemes at the level of action), with a reflective aspect involving another level that integrates new and old knowledge to yield novel forms and structures. The reflective abstraction concept was developed further in the last phase of Piaget's thought and was to become one of the cornerstones of the theory of constructivism by accounting for transitions in cognitive development and in the construction of new knowledge structures.

A continuing puzzle for Piaget that emerged in this phase of his work was the understanding of causality: how causal relations come to be seen in the actions of objects on one another in the real world, how the conception of causality undergoes change in development, and how, finally, causal relations relate to operational thought. It took Piaget two books (Piaget, 1930; Piaget & Garcia, 1974) to arrive at a reasonably satisfactory solution. In essence, Piaget argued that the focus of the child's own actions on objects is projected onto or attributed to the objects themselves, such that an object becomes the surrogate agent in its action on another object. In the later works, Piaget more formally contrasted causality and operations in thought.

One of the most contested aspects of Piaget's theory is the characterization of the formal operational period and the logical operations of that level of thought. Piaget brought the full armament of his logical theory to bear on the thought of this period, ostensibly because the theory was capable of accounting for the generation of advanced thought of a physical, mathematical, and logical nature in the adult.

To this end, Piaget sought to merge the groupings of concrete operational thought and integrate them into a now-closed, logical system, the logico-mathematical groups proper. The logical system adopted that was to carry all the weight of explanation variously described by logicians as propositional logic, first-order logic, extensional logic, and truth-table logic. As already indicated, although Piaget adopted this formal logic, he adapted it for the purpose of constructing his psychologic, particularly in the explanation of formal operations. The later logics that he used were intrapropositional relations and interpropositional relations. The former are involved in concrete operations (in the groupings), and the latter, more elegant in their functions, apply to hypothetical and combinatorial thinking in the period from adolescence onward and reflect the operation of group structures.

Piaget's claim was that taking single propositions (e.g., the book is on the table) and relating them to other single propositions by way of the basic logical connectives (e.g., conjunction and disjunction and their linguistic counterparts, *and* and *or*, respectively) leads to a system of 16 binary operations the truth values of which can be tested in a systematic way. Whereas concrete operational child's thought is characterized by the associations between classes and relations so that binary propositions can be solved only on a trial and error basis, formal operational adolescent's thought, armed with group structure competence, can conceive of these associations in advance of facing a problem-solving task and treat them as hypotheses to be tested. The adolescent is now said to have a technique (the implicit truth table) for testing all possible combinations of such propositions as he or she enters into logical and scientific problem-solving situations. The full power of adolescent and adult thought comes from the interpropositional operations in which a given propositional operation, such as *p or q* (disjunction), is transformed in logical ways into other propositions. Thus, the negation of the disjunctive proposition changes everything in the propositional pair. Consequently, the negation of *p or q* results in *not p and not q.* There are four such transformations in Piaget's so-called "4 group": identity (I), negation (N),

reciprocal (R) and correlative (C). Applying the transformations successively leads back to the original propositional disjunction; hence, the group is referred to as a closed system. The 4-group structure was used by Inhelder and Piaget (1958) to explain problem solving with verbal logics problems and the experimental application of logical relations to physical operations.

Piaget's logical claims for group structures, in particular the combinatorial system, the INRC group, and Genevan empirical claims generated considerable controversy among logicians and psychologists. (For one of the most critical and detailed analyses of Piaget's early logic, see Ennis, 1982.) In addition, a different sort of argument has risen as to whether Piaget's proposals for formal operational thought, and its attendant psychologic, represent the final form of thought in adolescent and adult cognition (see, e.g., Alexander & Langer, 1990). With regard to adult cognition, various sources claim that it is not. One type of claim misses the point of Piaget's argument, which is that with respect to rational, scientific, and mathematical types of thought and problem solving, no other logical systems or forms of thought are likely beyond formal operations, not on principle but on the basis of what is evident in human development. On this score, no counterclaims have been forthcoming from Piaget's critics as to the existence of other logical systems of thought. Other criticisms, based on the assumption that adult thought forms in domains other than the scientific (e.g., the aesthetic) entail other kinds of thinking, have been quite reasonable, although Piaget always made clear that he was not studying all forms of thought and their development. Furthermore, although Piaget's theory was designed to account for novelty and generativity in cognitive development, he did not deal with intellectual creativity as such. Some of the alternative proposals do, and they may account for some of the creative features of adult production with which Piaget did not deal.

The structuralist period was rounded out by studies of mental imagery, perception, and memory, collectively characterized as the figurative aspects of thought. These components offer structures that are complementary to those of operative thought and on which operative structures act.

The structuralist period did not end abruptly. Gradual dissatisfaction with various important aspects of the theory accumulated, which resulted in changes both in the body of Piaget's ideas and in the direction the theory was taking. The resulting work, beginning in the late 1960s and 1970s, led to further radical changes in the theory, which were of such a nature that it is fair to say that the work of the 1970s leading up to Piaget's death in 1980 constituted a new theory (Beilin, 1989, 1992).

Phase 4: Return to Functionalism. Preoperational Thought, Strategies, Intentional Logic, and the Theory of Meaning

Functions and correspondences. In Piaget's description of the progression from sensorimotor intelligence to formal operations, the preoperational period from 2 years to 7 years of age was relatively neglected. If any aspect of Piaget's work could have been said to be deformed by default, this period was it. For the most part, preoperational thought, for example, was described by the lack of the properties of reversibility typical of operational and other types of thought. If there was a case in which it could be said that Piaget dealt with a period in a somewhat negative fashion, this was it, although, at the same time, it was also characterized as the period of representational thought and many concepts developed in this stage were detailed. In the 1960s, Piaget returned to this stage in development and, with a continuation of structural analysis, defined the underlying nature of thought in the form of functions and correspondences. In the process, Piaget changed and augmented one of the fundamental assumptions to which the theory up to that time adhered, namely, that thought entails transformations and the construction of invariants in the face of such transformations. In the new work, Piaget discerned that childrens' thought also reflected the construction of invariants through establishing correspondences by acts of comparison. The other product of these studies was the description of functions that are intermediate between simply having concepts and relating concepts in reversible operations. The intermediate step, now described, included one-way functions, or semi-logics, in which the child was said to be capable of understanding an asymmetrical logical relation (e.g., *Joan is taller than Ann* but not concurrently *Ann is shorter than Joan*). The logical model from which Piaget drew to explain the results of studies with correspondences was the newly developed mathematical category theory of MacLane (1972). In addition to describing correspondences, Piaget saw two types of functions that also defined preoperational thought, the preparatory or *constitutive functions* and the later quantified *constituted functions* of operational thought. The importance of functional thought, Piaget claimed, is that the functional relations, of which actions consist, are the source of both logico-mathematical operations and causality; they develop in parallel in some contexts and in interaction in others. The study of functions, besides filling a significant gap in Piaget's stage theory, marked a shift in emphasis of the work in Geneva toward functionalism, despite the structuralist character of the introduction of category theory into the logical architecture of Piaget's theory.

Strategies and procedures. The shift in emphasis was first evident in the training studies reported by Inhelder, Sinclair, and Bovet (1974). In the new work, the emphasis shifted to the study of strategies in children's actions and thought and to the procedures that are used in problem solution. Two components define children's problem solving and reasoning: structural knowledge and procedural knowledge. Piaget and Inhelder argued for a dialectical process involved in the progressive development of structures into more advanced, integrated, and coherent forms, in contrast with procedures that progressed only by diversification and accretion. Nonetheless, they claimed, "Every structure is the result of a procedural construction, and every procedure makes use of some aspects of structure" (Inhelder & Piaget, 1980, p. 26).

The last period of Piaget's research, from the end of the 1960s to 1980, was rich in its productivity and in the significance of its empirical content and theory. Any other investigator would be renowned on the basis of the works of this period alone. Unfortunately, Piaget's writing of this period is not generally known, and not all the major works of the period are available in English. I have detailed the nature of much of this later work (Beilin, 1989, 1992 see also Chapman, 1988) and so will give only the briefest account of it here.

Causality and consciousness. As already indicated, Piaget

was dissatisfied with his early explanations of causality and therefore, along with Garcia, a philosopher of science and a physical scientist, returned to its study in the late 1960s. The general result of the new research (Piaget & Garcia, 1974) was the claim that causality entails the attribution of operational structures to the object but is more than a system of transformations reduced to relations of cause and effect. Going further, they claimed that operations are causal structures applicable to extratemporal forms and are distinguishable from physical causality, which is a system of operations brought about by natural objects. This correspondence between operations and causality works because an operation (a mental action) is itself a "physical" object subject to causality, as are all other objects. The study of causality was to have even broader consequences, however, to be described later.

Two closely related books of research were completed in this period, *The Grasp of Consciousness* (Piaget, 1976) and *Success and Understanding* (Piaget, 1978). Piaget proposed that cognizance of an action transforms the action scheme into a concept so that cognizance is in essence an act of conceptualization. This process only provides the "knowing how" aspect of cognizance. The "knowing why" requires seeking functional reasons for it. Some strikingly simple studies were reported that at first are counterintuitive (e.g., the inability of many adults to recount what they did when walking "on all fours"; an experiment in hitting a target with a ball in a sling, which after being successfully done without cognizance results in failure when the process is conceptualized by the child). The results of these studies, although important in themselves, led to further development of the theory of equilibration and in particular the refinement of reflective abstraction. The studies of success and understanding involved the effects of "resistances" of objects on the development of reasoning. They led to a theoretical description of how action that is initially autonomous progresses to a form of conscious conceptualization that becomes a central mechanism in thought and then has the reverse effect of influencing the action itself. The experiments showed that at first, conceptualization lags behind action, but later, by virtue of reflective abstraction, conceptualization can totally predate and anticipate actions. These studies led to theoretical progress in the proposal that the most general characteristic of conscious states is the expression of "significations," which are connected by what Piaget called *signifying implications.* In essence, he redefined mental operations as *signifying actions.* That is, connections in mind are implicative and are unlike causal actions; hence, Piaget's reference to operations as internalized actions. The significance of this theoretical move is that the system of signifying implications provides for understanding in thought that extracts the reasons for things and events, in contrast with mental processes that reflect effective application or use.

Other studies explored why young children have more difficulty with negations than with affirmations and why the neglect of negative elements in reasoning produces all sorts of conflicts and contradictions. In the spirit of the new theory, the studies of contradiction (Piaget, 1980a) redirected attention from logical and formal aspects of contradiction and their structural properties to their functions alone. In the new view, functions precede and prepare for structures through disequilibrium inherent in contradictions. Also new was the view that the oppositions that result from disequilibria are dependent on the contents of thought and action alone.

Possibility and necessity. One of the most important redirections of Piaget's theory, as I see it, was the new emphasis on possibility (Piaget, 1987a, 1987b). In this view, the development of knowledge results from previously created possibilities. That is, each creation of a structure in cognitive development, by its very nature, embodies new possibilities for how the structure functions in thought. The new functions in turn lead to new structures with their own new possibilities. The reverse side of the coin is that each set of possibilities does not engender unlimited flexibility; rather, there are inherent constraints that lead necessarily to some outcomes and not others. Thus, there is a dialectic relation between possibility provided by procedural freedom (flexibility) and necessity, which is provided by the self-regulating aspects of the equilibration process and system-binding organization. Strikingly, in the new theory, operations are the product of possibilities, not of their source, and with the differentiation of possibility, necessity, and reality, operations are now integrated and subordinated by a new type of equilibrium between differentiation and integration. Revision of the theory of equilibration, which the new studies of possibility and necessity led to, resulted from considering each new possibility as a simultaneous construction and a new "opening." Possibility generates innovation at the same time that it fills a gap, a limitation, or a disturbance that has to be compensated for.

Equilibration. The theory of equilibration (Piaget, 1985), which is at the heart of the functional and processing aspects of Piaget's theory, underwent considerable refinement in the last phase. The new theory rests on the distinction between observable and nonobservable coordinations between objects and actions. Empirical abstraction is applied to observable features and reflective abstraction to the coordination of internalized (nonobservable) actions. Action, however, gives rise to both forms of abstraction. There are said to be two levels of reflective abstraction: One, unconscious, is the source of inferential coordinations; the other is conscious and involves reasoning. Equilibration is the key element in the constructive process of thought, but because constructions invariably entail contradictions (and disequilibrium), they necessarily involve regulations of various kinds. The notion of regulations was thus revised from an earlier version of the theory. Regulations serve to avoid incoherence and consequently move thought processes in the direction of equilibration—equilibriums, however, that are always temporary. Even logico-mathematical structures are only local and temporarily stable inasmuch as new structures reopen and create new problems. Consequently, the central problem becomes one of accounting for successive improvement in forms of equilibration. In essence, improvement is the result of new regulations that act on new forms that are richer than earlier ones by virtue of being constituted of greater and more complex component elements; as each new structure is created, it opens up new possibilities.

The new theory of equilibration augmented the earlier theory principally in fleshing out its functional components and further differentiating its properties. It was essentially a conservative move. A radical move in the research program came in the last year of Piaget's life, although the events leading up to it started in the late 1960s in Piaget's work on causality. The new work that followed on correspondences, functions,

possibility and necessity, contradiction and consciousness, among others increasingly exposed the limitations of truth-table logics (essentially propositional logic) on which the standard theory of the structuralist period rested. These limitations within the theory itself, as well as knowledge of debates among logicians over these logics, led to a new direction in thinking about the logical models that informed Piaget's views of how to explain and account for rational thought.

Theory of meaning. Piaget and Garcia (1991) emphasized that the new direction that developed in Genevan thinking "converged" with Anderson and Belnap's (1975) development of relevance-entailment logic. The result was that in 1980 Piaget (Piaget, 1980b) declared that he had been in error in placing primary emphasis on truth-table or extensional logic and proposed that a new theory of meaning was necessary that would integrate a "decanted" version of his earlier extensional logic with a new component that paralleled the intensional logic of Anderson and Belnap. The description of the new theory of meaning, however, did not deliver on the decanted version of extensional logic; instead, it offered a programmatic statement of what such a theory should look like. Piaget's death prematurely ended this project, although a body of studies remains with some striking claims. Piaget's central thesis was that at all levels, starting from the most elementary, knowledge always involves inference. In addition, the first evidence of (proto-) logical thought is in the period of sensorimotor development when the child anticipates an action and understands the relations among actions, well before language and later developing forms of propositional thought. Anticipation of action entails inference that denotes a logical relation, namely, implication. Thus, a relation between actions is already a logical implication but not in the extensional sense of requiring a truth-value determination. Rather, it is a meaning implication, an intension. Meaning exists from the start in objects, that is, in their description and in what can be thought of them (e.g., classifying and relating them). The meaning found in actions is in what they lead to, in the transformations they produce in objects or situations. In this, Piaget was proposing a new theoretical model for understanding sensorimotor development, a model that I have called a *logical hermeneutics of action* (Beilin, 1992). The model, as applied to the sensorimotor and preoperational periods, requires a functional analysis of how subjects approach a task, such as pushing or pulling blocks, and details the actions of the child, the objects acted on, and above all an interpretation of the inferences that the child makes in carrying out the task (e.g., "If I push the block, it will hit the car in its path").

In this last work, Piaget provided a final (if uncompleted) integration of the theory. He took the classical division between meaning and truth (or sense and reference) in the philosophy of mind (following Frege) and integrated them into a single dialectical system. In this system, developing cognitive competencies are constituted of the rational features of mind that enable logical thought to pursue truth by increasingly sophisticated means and concurrently to give meaning to objects and events by the progressive elaboration of concepts and implications.

Conclusion

At the most general level, Piaget, more than anyone before him, changed our conception and understanding of the cognitive resources of children. Piaget showed that from birth onward, intellectual competencies undergo continuous development until they attain their adult forms. And, as his later work emphasized, that development never ends. It is therefore highly ironic that a number of otherwise astute investigators, in a shortsighted view of our history, have faulted Piaget for underestimating the cognitive competencies of young children.

What Piaget did most directly for the philosophy of mind was to show that perennial questions in epistemology can be better understood from an empirical demonstration of how mind works and develops than from analysis alone. Furthermore, his own work did much to break the behaviorists' long stranglehold on the study of cognition.

To developmental psychology, he bequeathed a powerful conception of mind, through a constructivist perspective, as active in the construction of knowledge that swept away a variety of views of the subject as passive in the process of knowledge acquisition. At the heart of his theory was the dialectic relation between subject and object that a number of social determinist critics faulted as not taking the object (i.e., social influences) seriously, and nativists faulted for not taking the subject (i.e., natively given influences) seriously. He stood his ground firmly against both types of assault, although not always for the best of reasons.

In the spirit of Darwinism, and the earlier influences of J. M. Baldwin and G. S. Hall, he offered a distinctly biological model for developmental change in cognitive functions. Although that model, the theory of equilibration, has often been attacked as vague and untestable, no more convincing models of developmental change engage the loyalties of developmental psychologists. In the present debates between computational theories and biologically based connectionist theories, my own view is that despite the likelihood that some form of computational models will survive, the day will be won by the biological theories, although not of the associationist kind. Recent dynamic system theories of the Prigogine type (Prigogine & Stengers, 1984), to which Piaget was sympathetic, also buttress the Piagetian biological model of development. On one score, Piaget expended much effort in the attempt to convince biologists and developmentalists of his neo-Lamarkian theory of evolution. Not many, including myself, were convinced.

Piaget's research program was itself a model for the integration of functionalist and structuralist forms of explanation, although at various times the emphasis was on one or the other forms. As Piaget liked to put it, there is no form without function and no function without form. Theories that use one form of explanation to the exclusion of the other are bound to fail in providing an adequate account of development.

Piaget's mappings of logico-mathematical models onto cognitive development, in his structuralist period in particular, were a bold attempt to account for diverse kinds of rational and scientific thought. As I have previously argued (Beilin, 1985), Piaget was not committed to any one of these models and substituted others or added and modified them when their mappings onto the child's thought or activity were found to be wanting. Others can do no less.

Methodologically, Piaget made respectable his so-called clinical method, despite much criticism from behaviorists, neobehaviorists, and others and his own disposition to use classical experimental methods when needed (as in his experiments on perception). Although he did not rely on traditional forms of

causal explanation, his analyses intended to serve the same purpose. Whether his essential discovery procedure adequately served this way or not, his studies yielded insights into development that were singularly important and better served science, as he often pointed out, than did scores of controlled experiments.

Piaget has left a monumental body of ingenious, provocative, and theory-rich research. The many, as yet, unexplored treasures in that trove, which are anything but hidden, will serve as resources for generations of investigators to come. From this body of experiments and findings it is nearly impossible to predict what will capture the interest and imagination of future investigators, as the recent child's-theory-of-mind research illustrates with respect to the realism, animism work of the 1920s.

Some veins are nearly, if not thoroughly, exhausted, as in the case of the conservations and training studies. Piagetian-type studies of language acquisition are few and will probably remain so, although the Piagetian claim of cognitive precursors to language is not likely to die. Nevertheless, research on sensorimotor development, classification, concept, and logic-based research will probably continue unabated with Piaget's research and theory acting as a reference point, at the very least. If in the future, Piaget's theory and research is to actively compete in the marketplace of ideas, it will be, I believe, with respect to the new theory and the attendant experimental work.

But Piaget's theory has formidable competition and adversaries, despite the widespread diffusion of Piagetian concepts and assumptions in other frameworks. The competition (Beilin, 1983) comes principally from neo-nativists, neo-computationalists (information processors and those influenced by them), contextualists, "theory" theorists, and neo-pragmatists (a diffuse group of investigators with no clear theoretical allegiances). One needs no crystal ball to know that no one of these positions will survive intact by the end of the next century. Nevertheless, if present trends continue, some form of biologically oriented theory will have a greater role in developmental theory and research as neuroscience expands into the field. It is difficult to see how contexualism, in one form or another but without radical relativism, will not have a significant place in its debates with modularity theory and nativism. In other words, everything will change, but some things will remain the same. Piaget's theory, as at present, in some form should mediate in staking out a vigorous middle ground between nativism and environmentalism.

It cannot be ignored that Piaget was a product of the Enlightenment, which manifested itself most cogently in his interest in describing and explaining the development of rational thought. We live at present in an intellectual climate in which radical relativism undermines claims to truth and in which nonrational and irrational aspects of mind are the focus of much attention. Utopian post-Enlightenment dreams of a world made up of rational minds and institutions organized on rational principles are now seen for what they always were, utopian. But life in this world cannot do without rationality any more than it can do without Piaget.

References

Alexander, C. N., & Langer, E. J. (Eds.). (1990). *Higher stages of human development: Perspectives of adult growth.* New York: Oxford University Press.

Anderson, A. R., & Belnap, L. (1975). *Entailment: The logic of relevance and necessity.* Princeton, NJ: Princeton University Press.

Astington, J. W., Harris, P. L., & Olson, D. R. (Eds.). (1988). *Developing theories of mind.* Cambridge, England: Cambridge University Press.

Baillargeon, R., DeVos, J., & Graber, M. (1989). Location memory in 8-month-old infants in a non-search AB task: Further evidence. *Cognitive Development, 4,* 345–367.

Beilin, H. (1971). The training and acquisition of logical operations. In M. F. Rosskopf, L. P. Steffe, & S. Toback (Eds.), *Piagetian cognitive-developmental research and mathematical education* (pp. 81–124). Washington, DC: National Council of Teachers of Mathematics.

Beilin, H. (1975). *Studies in the cognitive basis of language development.* San Diego, CA: Academic Press.

Beilin, H. (1978). Inducing conservation through training. In G. Steiner (Ed.), *Psychology of the 20th century: Vol. 7. Piaget and beyond* (pp. 260–289). Zurich, Switzerland: Kindler.

Beilin, H. (1983). The new functionalism and Piaget's program. In E. K. Scholnick (Ed.), *New trends in conceptual representation: Challenges to Piaget's theory?* (pp. 3–40). Hillsdale, NJ: Erlbaum.

Beilin, H. (1985). Dispensable and core elements in Piaget's theory. *The Genetic Epistemologist, 13,* 1–16.

Beilin, H. (1989). Piagetian theory. In R. Vasta (Ed.), Six theories of child development: Revised formulations and current issues. *Annals of Child Development, 6,* 85–132.

Beilin, H. (1992). Piaget's new theory. In H. Beilin & P. B. Pufall (Eds.), *Piaget's theory: Prospects and possibilities* (pp. 1–17). Hillsdale, NJ: Erlbaum.

Beilin, H., & Pearlman, E. G. (in press). Children's iconic realism: Object vs. property realism. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 23). San Diego, CA: Academic Press.

Benacerraf, P., & Putnam, H. (1964). *Philosophy of mathematics.* Englewood Cliffs, NJ: Prentice Hall.

Beth, E. W., & Piaget, J. (1966). *Mathematical epistemology and psychology.* Dordrecht, The Netherlands: Reidel.

Broughton, J. M., & Freeman-Moir, D. J. (Eds.). (1982). *The cognitive-developmental psychology of James Mark Baldwin: Current and research in genetic epistemology.* Norwood, NJ: Ablex.

Bruner, J. S., Olver, R. R., & Greenfield, P. M. (1966). *Studies in cognitive growth.* New York: Wiley.

Carey, S., & Gelman, R. (Eds.). (1991). *The epigenesis of mind: Essays on biology and cognition.* Hillsdale, NJ: Erlbaum.

Case, R. (1985). *Intellectual development: Birth to adulthood.* San Diego, CA: Academic Press.

Case, R., Marini, Z., McKeough, A., Dennis, S., & Goldberg, J. (1986). Horizontal structure in middle childhood. Cross domain parallels in the course of cognitive growth. In I. Levin (Ed.), *Stage and structure: Reopening the debate* (pp. 1–39). Norwood, NJ: Ablex.

Chapman, M. (1988). *Constructive evolution: Origins and development of Piaget's thought.* Cambridge, England: Cambridge University Press.

Chapman, M. (1992). Equilibration and the dialectics of organization. In H. Beilin & P. B. Pufall (Eds.), *Piaget's theory: Prospects and possibilities.* (pp. 39–59). Hillsdale, NJ: Erlbaum.

Diamond, A. (1988). The abilities and neural mechanisms underlying A $\bar{B}$ performance. *Child Development, 59,* 523–527.

Dixon, R. A. (1987). Wittgenstein, contextualism, and developmental psychology. In M. Chapman & R. A. Dixon (Eds.), *Meaning and the growth of understanding: Wittgenstein's significance for developmental psychology* (pp. 49–67). Berlin: Springer-Verlag.

Ennis, R. (1982). Children's ability to handle Piaget's propositional logic: A conceptual critique. In S. Modgil & C. Mogdil (Eds.), *Jean Piaget: Consensus and controversy* (pp. 101–130). New York: Praeger.

Flavell, J. H. (1963). *The developmental psychology of Jean Piaget.* Princeton, NJ: Van Nostrand.

Fodor, J. A. (1975). *The language of thought.* Cambridge, MA: Harvard University Press.

Harris, P. H. (1983). Infant cognition. In P. H. Mussen (Series Ed.) and H. H. Haith & J. J. Campos (Vol. Eds.), *Handbook of child psychology: Vol. 2. Infancy and developmental psychobiology* (4th ed., pp. 689–782). New York: Wiley.

Inhelder, B., & Piaget, J. (1958). *The growth of logical thinking from childhood to adolescence.* New York: Basic Books. (Original work published in French in 1955.)

Inhelder, B., & Piaget, J. (1980). Procedures and structures. In D. R. Olson (Ed.), *The social foundations and language and thought: Essays in honor of Jerome S. Bruner* (pp. 19–27). New York: Norton.

Inhelder, B., Sinclair, H., & Bovet, M. (1974). *Learning and the development of cognition.* Cambridge, MA: Harvard University Press.

Kohlberg, L. (1969). Stage and sequence: The cognitive developmental approach to socialization. In D. A. Goslin (Ed.), *Handbook of socialization theory and research* (pp. 347–480). Chicago: Rand McNally.

Levin, I. (1986). *Stage and structure: Reopening the debate.* Norwood, NJ: Ablex.

MacLane, S. (1972). *Categories for the working mathematician.* New York: Springer-Verlag.

Mischel, T. (Ed.). (1971). *Cognitive development and epistemology.* San Diego, CA: Academic Press.

Montangero, J. (1985). *Genetic epistemology: Yesterday and today.* New York: CUNY, Graduate School and University Center.

Perner, J. (1991). *Understanding the representational mind.* Cambridge, MA: MIT Press.

Piaget, J. (1926). *Language and thought of the child.* London: Kegan Paul, Trench, & Trubner. (Original work published in French in 1923)

Piaget, J. (1928). *Judgment and reasoning in the child.* London: Kegan Paul, Trench, & Trubner. (Original work published in French in 1924)

Piaget, J. (1929). *The child's conception of the world.* London: Kegan Paul, Trench, & Trubner. (Original work published in French in 1923)

Piaget, J. (1930). *The child's conception of physical causality.* London: Kegan Paul, Trench, & Trubner. (Original work published in French in 1927)

Piaget, J. (1932). *The moral judgment of the child.* London: Kegan Paul, Trench, & Trubner. (Original work published in French in 1932)

Piaget, J. (1950). *The psychology of intelligence.* London: Kegan Paul, Trench, & Trubner. (Original work published in French in 1947)

Piaget, J. (1952). *The origings of intelligence in children.* New York: International Universities Press.

Piaget, J. (1962a). *Comments concerning Vygotsky's critical remarks concerning* The language and thought of the child *and* Judgment and reasoning in the child. Cambridge, MA: MIT Press.

Piaget, J. (1962b). *Play, dreams, and imitation in childhood.* New York: Norton.

Piaget, J. (1970). *Structuralism.* New York: Basic Books. (Original work published in French in 1968)

Piaget, J. (1976). *The grasp of consciousness.* Cambridge, MA: Harvard University Press. (Original work published in French in 1974)

Piaget, J. (1978). *Success and understanding.* London: Routledge & Kegan Paul. (Original work published in French in 1974)

Piaget, J. (1980a). *Experiments in contradiction.* Chicago: University of Chicago Press. (Original work published in French in 1974)

Piaget, J. (1980b). The constructivist approach: Recent studies in genetic epistemology. *Cahiers de la Fondation Archives Jean Piaget.* No. 1., 1–7.

Piaget, J. (1985). *The equilibration of cognitive structures.* Chicago: University of Chicago Press. (Original work published in French in 1975)

Piaget, J. (1987a). *Possibility and necessity: Vol. 1. The role of possibility in cognitive development.* Minneapolis: University of Minnesota Press. (Original work published in French in 1981)

Piaget, J. (1987b). *Possibility and necessity: Vol. 2. The role of necessity in cognitive development.* Minneapolis: University of Minnesota Press. (Original work published in French in 1981)

Piaget, J., & Garcia, R. (1974). *Understanding causality.* New York: Norton.

Piaget, J., & Garcia, R. (1989). *Psychogenesis and the history of science.* New York: Columbia University Press.

Piaget, J., & Garcia, R. (1991). *Toward a logic of meaning.* Hillsdale, NJ: Erlbaum.

Piaget, J., & Inhelder, B. (1956). *The child's conception of space.* London: Routledge & Kegan Paul. (Original work published in French in 1948)

Piatelli-Palmarini, M. (Ed.). (1980). *Language and learning: The debate between Jean Piaget and Noam Chomsky.* Cambridge, MA: Harvard University Press.

Prigogine, I., & Stengers, I. (1984). *Order out of chaos.* New York: Bantam Books.

Sinclair, H. J. (1992). Changing perspectives in child language acquisition. In H. Beilin & P. B. Pufall (Eds.), *Piaget's theory: Prospects and possibilities* (pp. 211–228). Hillsdale, NJ: Erlbaum.

Wellman, H. M. (1990). *Children's theories of mind.* Cambridge, MA: Bradford Books/MIT Press.

Wellman, H. M., Cross, D., & Bartsch, K. (1986). Infant search and object permanence: A meta-analysis of the A not B error. *Monographs of the Society for Research in Child Development, 51*(3, Serial No. 214).

Youniss, J., & Damon, W. (1992). Social construction in Piaget's theory. In H. Beilin & P. B. Pufall (Eds.), *Piaget's theory: Prospects and possibilities*(pp. 267–286). Hillsdale, NJ: Erlbaum.

Received March 12, 1991
Revision received October 31, 1991
Accepted November 4, 1991 ■