Steiner, Gerhard. On the Psychological Reality of Cognitive Structures: A Tentative Synthesis of Piaget's and Bruner's Theories. Child Development, 1974, 45, 891-899. The main concern of the present study is the question of the psychological reality of cognitive structures. After a brief outline of Piaget's structural and Bruner's representational theories of cognitive development, Piaget's concept of "internalization" is analyzed and related to the concept of "representation." Cognitive structures are shown to be real exclusively in an actual representation. In that sense, this interpretation approaches a synthesis of Piaget's and Bruner's theories. To account for the construction of representation-bound structures (e.g., operations), microlevel processes taking place in a multimedial feedback system are to be focused. Some empirical support for these considerations will be drawn from the experiments.

The concept of "cognitive structures" plays a crucial role in several theories of intellectual development. The more the cognitive structures become a central topic of a researcher's interest (e.g., the Genevans' emphasis on the structural aspect of behavior), the more they seem to be taken for something that really and almost substantially can be dealt with, changed, mobilized, or at least observed and described. In considering this trend, the question of the psychological reality of cognitive structures or, in a philosophical formulation, of the ontological status of these structures, arises. It is our aim to answer the question in psychological terms by analyzing the structures from the point of view of their construction.

We begin with prevailing theories. Piaget, as well as Bruner, interprets similar developmental facts in different terms: reactions of children in classification experiments or—as Bruner states it—in experiments on equivalence; on conservation problems; and on multiple ordering or on the multiplication of asymmetrical transitive relations (Bruner, Olver, & Greenfield 1966; Piaget 1952; Piaget & Inhelder 1941, 1959).

Piaget's Structural Theory

The core of Piaget's theory is the idea of a construction of cognitive structures. This notion is of great interest because (1) Piaget contrasts his constructive theory with an empiricist point of view, where the child is a passive receptor of environmental stimulus complexes that are mentally mapped: the child actively constructs his world by assimilating its elements into his already-formed behavioral schemes. (2) Construction is a progressive process: "If one considers the mechanism of that construction, one recognizes that each level is characterized by a further coordination of the elements given before" (Piaget 1947, p. 81). The level of the child's structural development is detected in a Geneva-type experiment. Yet, according to Piaget, development itself takes place outside the experiment, in the course of unobserved interactions with the social and material environment (Aebli 1963). Development is characterized by equilibration processes by which several assimilations (isolated parts of operations) are integrated into more comprehensive operational systems (Piaget's structures d'ensemble), the structure of which increasingly approximates logico-math-
Putting the learning process in focus, Piaget separates the learning process in a narrow sense from the equilibration process; only contents can be learned, for example, facts of the physical environment. The coordination of these facts into a structural system, that is, equilibration, can neither be learned nor induced, but must be awaited.

Equilibrated behavior—and this is of utmost importance for Piaget—is more mobile than are conflicting assimilation schemes or nonequilibrated regulations. In that sense, Piaget characterizes an operation as "a regulation that has become completely reversible in a completely equilibrated system" and that has become entirely reversible, "because it is entirely equilibrated" (Piaget 1957, p. 37). For Piaget, reversibility is the expression of enhanced mobility, which, in turn, is a typical feature of more developed and more complex cognitive behavior. Equilibration is intelligible only within the highest possible mobility; equilibration never means immobility. "On the contrary, we suppose that the best equilibrated states, in the sense we use the word, conform to a maximum of activity and a maximum of openness in the exchange processes," that is, assimilations and accommodations (Piaget 1957, p. 37).

Bruner’s Theory of Representational Media

For Bruner, development is not to be seen as structural construction. Rather, it occurs within the media by which the child represents his experience. The child constructs his world by successively representing it in an enactive, an ikonic, or a symtelic medium. Each of the three modes, or media, of representation "places a powerful impress on the mental life of human beings at different ages, and their interplay persists as one of the major features of adult intellectual life" (Bruner et al. 1966, p. 1).

The relations among the media give rise to conflicts, which include a constructive mobility that may—as is stressed by Bruner’s experiments—push development forward; if two representational systems do not correspond, as is the case if there is a "conflict between 'appearance' and 'reality,' the one being ikonic, the other symbolic" (p. 12), a disequilibrium arises that leads to the revision of the child’s problem-solving method. Likewise, learning processes take place in the transition from one to another representational medium (Bruner & Kenney 1965). Unfortunately, we are told neither which are the conditions of transition nor what remains invariant of an environmental event or of a mathematical fact when the representational medium has been changed. One must suppose that the organization of the elements of an event or the structure of the mathematical fact are the invariants of the representational constructs. Bruner scarcely considers this structural aspect of behavior.

What we need is a theory that explains processes such as the establishment of the relations between the parts of an event or the construction of the possible hierarchies of behavioral elements. Piaget emphasizes that these construction processes start from the interactions with the environment—in an enactive medium, so to speak—that is, from external activities that later become internalized. It is this concept of "internalization" that must be analyzed first, above all in relation to the concept of "representation," if one aims at understanding the psychological reality of cognitive structures.

Internalization and Representation

Some consider internalization as an increasing dissociation of a general behavioral scheme from a particular content, taking place in the course of cognitive growth. But this seems to be a fact that should rather be called "abstraction." Internalization as a dynamic process is of greater interest. Furth has coined the term "functional interiorization." "What I like to call functional interiorization is thus the specific condition of a knowing in which the external motor reaction is no longer an essential prerequisite, although it may well remain an accompanying phenomenon. It is this condition which Piaget has in mind when he speaks of interiorization in connection with an operational act" (Furth 1969, p. 76). By

1 "Concerning interiorization there is no doubt that for Piaget the real internalization of an imitative movement is something different from the functional interiorization of a sensory-motor act. Yet he keeps using the same French word intérioriser and does not warn the reader to interpret it differently. In English we do have two words that could be employed for the
the differentiation of “internalization” from “interiorization.” Furth focuses the rather static aspect of the phenomenon at issue. Instead we prefer to follow the rather dynamic aspect with the concept of “internalization.” One hint about internalization, although not leading much further, is contained in a paper by Piaget on the neurological problem of internalization of actions into reversible operations: “Each step of development of the child’s intelligence is characterized by an internalization of real actions to simply imagined actions and operations, the latter exhibiting a reversible character in their composition” (Piaget 1949, p. 241). What are the “simply imagined actions”? In terms of Piaget’s constructional theory, it is easy to state what they are not: they are not mappings of external facts that were perceived. They cannot be accounted for in an empiricistic manner, as a causal connection between an external event and an internal sign, without any modification of the external phenomenon by the internalization process. In Piaget’s constructional theory, the process of internalization occurs within an assimilation process, involving an active integration of an external event into the already-available behavioral schemes. This raises the question of whether the result of this internalization, namely, the “simply imagined actions,” can in fact be evidenced. Certain tasks in spatial thinking and reasoning (Piaget & Inhelder 1956) seem to be connected with the condition that spatial movements or actions are internally carried out. This is the case, for example, with a child trying to draw in a few lines the net of a stereometric solid such as a cylinder or a cube. Several children have no success. The reasons for failure are lack of correct dissociation of the surface parts of the solids or lack of representing the correct topological neighborhood of those parts. Perception of stereometric solids is not a sufficient condition for enrolling and drawing their nets; for success there must be motor change of perception, that is, inner unfolding or unrolling movements. Or take another example: the well-known conservation of liquids. Inhelder, Bovet, Sinclair, and Smock (1966) mention three typical arguments by which the children at the operational level evidence the conservation of a quantity of liquid. If the child—as is the case in the so-called reversibility argument—explains conservation by the fact of being able to pour back all the water, one is inclined to assume that his judgment is based on internalized actions. On the contrary, if the child mentions—in the so-called compensation argument—the different dimensions of the container (“high but thin”), it is difficult to recognize internalized actions unless one accepts the relating of the dimensions of the jar as “actions” (Piaget’s mise en relation). Actions like these certainly differ from the others in that they cannot occur externally. Neither can they be internalized. From the very beginning they are internal. These “acts” are typical for Piaget’s constructivism. They are not “actions.” In the compensation argument, the child seems to base his judgment upon the image of the liquid column or of the cylinder, not on actions. The characteristics of such images will be discussed later. Nor can a common version of the so-called identity argument be interpreted as an internalization of actions, for, paradoxically, no actions at all are executed, since the child notices that one has neither added nor taken away anything. It should be mentioned that identity may be expressed differently. Greenfield’s Wolof children, for example (see Bruner et al. 1966, pp. 225–256), give expression to the identity by recapitulation, that is, they describe a past state rather than a present one. In that case the argument seems, contrary to our interpretation, to be based on underlying actions. The identity schema has proved to be crucial to conservation, but it can be acquired by different means and therefore be uttered quite differently.

Bruner et al. (1966) have shown that correct arguments of reversibility or compensation are not sufficient for the child’s recognition of conservation. Bruner explains the justification of conservation through the identity argument (“just the same water”), in terms of representation in a medium—a verbal (symbolic) coding of the pouring procedure. The problem of internalization turns out in this instance to be a problem of representation (in Bruner’s sense). In other words, one cannot explain internalization, the prerequisite to the construction of operational structures, without recourse to the concept of representation. At this point two different meanings, at least in connection with Piaget’s theory. We could use ‘interiorize’ for the functional dissociation between general schemes of Knowing and external content and the word ‘internalize’ for the real literal diminutions of imitative movements that according to Piaget lead to internal images or internal language” (Furth 1969, p. 78).
Piaget's and Bruner's theories touch each other. This is a central topic of our research: the complementarity of the structural (Piaget) and the representational (Bruner) aspect of behavior.

We now consider the role in Piaget's theory of representational media and of the concept of representation. Piaget (1969) does have the term "representation." He speaks of representation in a wide and in a narrow sense. While the former means thought, that is, "all forms of intelligence being based not only on perceptions or movements (sensorimotor intelligence) but on a system of concepts or mental schemes" (Piaget 1969, p. 90), the latter "is reduced to the mental image, the memory-image, i.e., to the symbolic evocation of absent realities." Thus, representation in the narrow sense is identical with what Piaget calls the symbolic—or, more comprehensive—the semiotic function of intelligence. Its products are symbols or images and linguistic signs. The difference between image/symbol on the one hand and sign on the other hand originates in the research on sensorimotor behavior. "The mental image remains individual, because it is proper to the individual and merely serves to reproduce his personal experiences, thus preserving an irreplaceable role besides the system of collective signs. Therefore internalized speech, although internal, remains much more socialized than the image and keeps a tendency to externalization. It is therefore at all levels a sketch of possible external speech. On the other hand, the transformation of imitation into images includes more genuine internalization" (Piaget 1969, p. 96). The crucial fact for Piaget is that each symbol (image) has an operational aspect referring to meaning and a figurative aspect being linked with a sensory or motor event. Not so the linguistic signs.

In discussing the conservation-of-liquid problem, we saw that the compensation argument is based on an image. To understand the operational mechanism, the question of how the images of a beginning and an end state are put into relation to each other arises. In other words, how is the transformation conceived? On the whole, Piaget speaks extensively, but rather inconsistently, of the importance of the images for the construction of operations. Those children who accurately anticipate the rise of the water level in a thin cylinder surpass those who do not. They do not immediately infer the conservation from their correct anticipations, but in the course of further development they complete conservation before the others. "Thus there is a positive contribution of the image effecting a better knowledge of the facts brought about by the pouring procedure and of the 'states' that are to be understood then as a transformation with regard to both the modification and the conservation" (Piaget & Inhelder 1966, p. 443). But regarding representation of the transformation itself, Piaget and Inhelder come to the conclusion: "On the whole . . . we did not find any serious indication of a preparation of the operations by the intervention of preoperational images" (1966, p. 444). In a further passage, the image seems to be of greater importance: "If it is useful, it is because it serves as a springboard for the deduction, and thanks to its symbolism it allows to sketch what the operational construction continues and perfects" (p. 446). Nowhere, however, does Piaget explain how the representation of the transformation occurs. At best we read: "There are many cases where we have seen the subject capable of verbal prediction, but global and vague, a long time before being able to imagine the detail . . . , then, once the image is possible, by means of it, able to attain a more precise deduction of the transformations themselves" (p. 446; italics mine). Or: "In such cases (where transformation is understood), the image, having become anticipatory through the operations, serves once more as a support for the latter. Approximative and symbolic as it may remain, it does not only support the knowledge of states and results of the transformation or movement but also the understanding of these transformations" (p. 446; italics and parentheses mine). In all these explanations no cognitive mechanism is made explicit.

Structure and Representation

Furth summarizes the above statements as follows: "Consequently, symbols, as signifiers, have a status quite different from that which they refer to, namely operative schemes" (Furth 1969, p. 105). The passages in Piaget and Inhelder very often refer to operations and their "efficacy" ("having become anticipatory through the operations"; see above) or to operational schemes. The characteristic feature of an operation is its structure. Its status is obviously quite different from the status of the symbols that are mere signifiers. What is, however, the philosophical, or ontological, status
of Piagetian structures? Logicomathematical structures as described by Piaget are the result of inferences from typical patterns of the child's behavior. These patterns are observable. They are verbal statements of justifications, graphic responses like drawings, or actions within an experimental situation. Their structure ("sequence" or "organization") is always inherent in one of these modes of behavior. These can be divided into three broad categories. Bruner calls them the three "media of representation." Thus, structure and representation are in their psychological reality intrinsically linked. Structures do not exist as such but exclusively in a representation. Hence, the concept of construction of structures undergoes an expansion in media. Constructions at any time new and original processes, in virtue of the variability of the elements to be represented. Time lags in the appearance of certain expected structural levels can thus be explained. Piaget's décälagcs hoiizontaux (horizontal lags) and the controversial concept of transfer prove to be—from our point of view—the consequence of the representation in a medium of particular structures. Because structures are realized only by speaking, perceiving, imagining, or acting, they always have to be represented and organized anew. Otherwise they have no behavioral reality. This is imminent in the Aebl-Stciner representation-bound concept of structure. The whole structure does not have to be constructed from the very beginning each time it is actualized; more comprehensive patterns become available in the course of growth. This is not a mere hypothesis, but rather corresponds to several accounts of information processing in the recent cognitive psychological research (Miller 1956; Neisser 1967; and others).

On the Construction of Representation-bound Structures

The concept of representation-bound cognitive structures will elucidate the transformations as considered in a prior section of this article. As Aebli (1963) has shown in a replication of Piaget's three-mountains experiment (Piaget & Inhelder 1956), certain changes in the presentation of the experimental material (mountain models), for example, less surface complexity, less color, etc., lead to considerable time lags in regard to the acquisition of operativity (correct coordination of the viewpoints). From experiments like that it follows that no operational structure exists independently from a representation; no general, that is, representation-free, level (1) of "operativity" can be indicated for a child at a given moment of his concrete-operational development. Likewise, the ability to verbally communicate a solution or to resist extinction, as a proof for "operativity," depends on the representation chosen.

Consider now the numerous learning experiments that aimed to teach operational behavioral schemes. (For an overview, see Beilin 1971, pp. 81–124; Montada 1970.) It is surprising that, although an extraordinary variety of experimental techniques has been used—induction of cognitive conflicts, reversibility training, mobility training, verbal pretraining, acquisition of learning sets (behavioristic approach), multiple training methods, etc.—success in introducing operations has been obtained in most experiments, although not within each one of the diverse tests. Even verbal methods have led to success, although the Genevans emphatically assert and—for particular circumstances—have proved that verbal measures do not contribute much to the construction of cognitive structures (Sinclair-de-Zwart 1967; 1969, pp. 315–336). It is paradoxical, however, that the Genevans, who make extensive use of the clinical method for uncovering the child's structure of thinking, have systematically minimized the importance of verbal interactions with the child for the construction of operational structures. "The Piagetian clinical interview is itself a source of some ambiguity, however, since it has not been carefully analyzed in relation to the character of the information conveyed to the child through the form of the question asked, their order, the vocabulary content of the messages, the rule-ordered properties of the organization of inquiry as well as the organization represented in the materials themselves" (Beilin 1971, p. 114). Aebli (1963, 1970) in his book Über die geistige Entwicklung des Kindes [On the child's mental development], which is little known in English-speaking countries, has analyzed just this clinical procedure and has summarized all points mentioned above by Beilin with the phrase of the "prestructuring function of the problem posed by the experimenter" (Aebli 1963, p. 37). Geneva-type experiments therefore do not merely uncover structures, as the Genevans think they do. Cognitive structures are constructed ("elaborated," as Aebli puts it) ad hoc, even in the Geneva-type experiments.
The acquisition of operational behavior through diverse experimental techniques, however, seems to support—as Beilin remarks—the assumption "that the logical operational system is under the control of a genetic mechanism that only permits the programmed development of defined cognitive structures through interaction with the environmental inputs" (Beilin 1971, p. 114). On the other hand, the child is able to construct conceptual systems (operations) through different techniques of interaction with the environment. The child's activity transcends the methodologies of the investigating psychologists. This is not to say that there are no differences of efficacy among the diverse techniques relating to the construction of operations. What we essentially need is a multimedia model or feedback system (e.g., Miller, Galanter, and Pribram's TOTE-model functioning in a multimedia manner). "Multimedia" may be understood in Bruner's sense, although his categories of representation seem somewhat too broad, as will be shown.

Several learning experiments seem to give support to our hypothesis of a multimedia feedback system. In Kohnstamm's (1963, 1967), Ojemann and Pritchett's (1963), and Seiler's (1968) experiments, the experimenter himself gives feedback in a verbal or nonverbal manner. It is this kind of learning experiment that leads to high operational success. These learning experiments make clear, furthermore, what Aebl (1970) has pointed to: the child does not acquire operational structures necessarily through cognitive conflicts and the corresponding equilibration processes; there is construction without conflict and without equilibration processes in Piaget's sense, for example, in the case that an adult is teaching or explaining a certain fact to a child.

**Construction Processes at a Microlevel**

If one tries to account for the construction processes in terms of Piaget's concepts of reversibility or equilibration, one always ends up with a theory of quasi maturation. Consideration of representation when dealing with cognitive structures is not only necessary because of the nature of structures; it is also supported by the results from the learning experiments. Yet, Bruner's categories of enactive, ikonic, and symbolic representations do not seem to be sufficiently differentiated. Construction takes place within more subtle processes. Symbolic representation works long before extensive syntactic systems exist in it; it works at the level of minimal spontaneous verbalizations, in part rudimentary, going along with perceptual processes and lasting no longer than the next act of synthesis is accomplished (Neisser 1967). To take an example, the child who classifies Dienes-type logic blocks will not only act overtly, giving an enactive representation of the order, but will, while perceiving the blocks and his own actions, verbally code some of the features of the blocks as well as some parts of his actions on them. These verbal representations of minute parts of the construction process may remain quite sketchy and incommunicable. Although we do not know enough about the cognitive psychology of the microprocesses occurring as the child deals with problems such as classifications, conservations, etc., we do see possibilities of replacing prevailing explanations for operational constructions and for the efficacy of the mental image, equilibration, etc.

An interpretation of these cognitive constructions at a microlevel is necessary because we cannot at a macrolevel grasp the media differences between the single constructional elements and between parts of operations. Take, for example, a classification task (Piaget & Inhelder 1959). Two different sets of elements (blocks and pictures of animals) are to be classified. From a macrolevel view, classification for both kinds of elements will take place in an equivalent process of enactive and ikonic representation. Yet, from the time lag for correct classification of the two different materials, one must infer that considerably different constructions with either material are performed that cannot be accounted for except in terms of microlevel processes. Concerning those processes, we find some hints in Piaget's as well as in Bruner's work; above all, Piaget's concept of mental image and Bruner's concept of ikonic representation assume more subtle processes in the construction of an image through selective acts: "A picture or an image has certain properties as a medium. A picture is a selective analogue of what it stands for" (Bruner 1966, p. 6), or further: "They are obviously and universally selective in what it is they depict and also highly conventionalized" (p. 10). Similar references to the selectivity of the image are found in a publication of Piaget and Inhelder, where they speak of images "although very approximative and symbolic" (Piaget & Inhelder 1966, p. 446) as favoring operational thinking and enabling the child to understand...
the transformations. If ikonic representation results from selection and processing of the perceptual input, a great many cognitive processes must be involved, expressing by their number and sequence the complexity of the representation. Among other processes there certainly are verbal short-term coding processes, that is, microprocesses of verbal representation, contributing to the whole construction (see also Loftus 1972; Mackworth & Bruner 1970; O'Bryan & Boersma 1971). Interactions of representational media, as shown by Bruner, will—in my opinion—take place at the micro-level, too, and we assume that there are several learning techniques stimulating just such microprocesses.

Some Empirical Support for This View of the Construction of Representation-bound Structures

Essentially, learning experiments can be viewed under the aspect of construction and of representation. Concerning construction, one of the most efficient training procedures seems to be the mobility training by Montada (1968). This author's point of departure is a modification of Piaget's concept of mobility. Behavioral mobility may be considered as the ability to realize numerous actions in quick succession, all relating to the same object or situation, and to integrate them into a systematic whole (Piaget's structures d'ensemble). While Piaget considers mobility as a relative end state of a behavior pattern and does not consider different degrees of mobility, Montada begins with states of low mobility (at the preoperational level). His training procedure consists in mobilizing some or all possible actions referring to the same object. The child thus brings together single actions, constitutes relations among them, and finally integrates them into a system. This procedure is intended to mobilize what Piaget calls the mise en relation (putting into relationship). Montada's subjects show operational success in logical multiplication (matrices) and in inclusion problems. Even if the essential construction processes take place at a microlevel, in a manner as yet insufficiently known and controlled, Piaget's concept of mise en relation—dynamically interpreted as the basis for the mobility procedure—proves to be extremely productive.

In my own experiments (Steiner 1973), I took up and extended the mobilizing idea as a procedure inducing constructional processes and complemented it, as will be shown, by two training procedures in different media, the one taking place in an ikonic, the other in a symbolic medium. The topic was the logical multiplication of asymmetrical transitive relations or, simply, multiple ordering. The children (67 first graders from Bernese suburban primary schools, with an age range from 6-6 to 8-1) were confronted with a $4 \times 4$ matrix in which round wooden blocks of four different colors (white, grey, dark grey, and black) and four different sizes (tiny, small, big, and huge) were laid out in an ordered way. The aim was to teach the child, after removing the blocks from the matrix board and mixing them up, (1) to reconstruct the matrix (fig. 1a) and (2) to transform it, starting from one given block put at a certain place by the experimenter (fig. 1b-e). After a pretest, all children received special mobility training for mobility (1) of classification, (2) of seriation, and (3) of direction. In the typical mobilizing procedure, the child had to carry out several actions on the same selected set of three, four, or five blocks, but always had to change the actual configuration. The example on the left (fig. 2) shows, to the reader: only, one possible position of five elements in that sequence of training items for direction mobility. For each item the block in the center and one further block were given. The child had to fill up the empty places (marked by dots) with the remaining blocks. In every case the second block determined one of the dimensions of the whole configuration. During the training procedure, the child experienced the different possible directions of the other dimension that were not yet determined. In a following training sequence the task was made more difficult by using some blocks that did not fit into a given configuration. There were a total of 40 mobility training items. The training was carried out in two groups according to two representationally different but otherwise exactly parallel procedures. The children of the ikonically trained group (ITG) were taught in an ikonic medium, that is, with blocks before them; the symbolically trained group (STG) performed with word cards ($2 \text{ cm} \times 8 \text{ cm}$) representing the features of the blocks in the form of linguistic signs ("white," "small," etc.), so that instead of one block, two word cards were used from the beginning. Instructions were the same for both groups. A third group served as control (CG). My assumption was that the cognitive structures underlying the
successful solution of the matrix tasks might be constructed in either medium. Compared with CG, improvement was observed in both experimental groups, although it was only significant for ITG (.025). The ITG and STG, as was hypothesized, did not differ significantly. Although the training procedure with STG consumed much more time than with ITG, the improvement was poorer. This result could be interpreted at a macrolevel by saying that ikonically trained children were superior to their symbolically trained peers because operations cannot be induced by verbal training methods. Such an assumption has to be viewed critically, however. I prefer to say that the construction process in the ITG was facilitated by the clearness of the material and that it allowed, at a microlevel at least, for an unambiguous and spontaneous verbalization of the perceived features, which is a prerequisite of further microprocesses of mise en relation. Just this was probably not the case with STG because difficulties relating to the reading process interfered with the construction from the very beginning.
To continue the exploration of the construction process, especially concerning verbal representations at a microlevel, I recently used blocks of more complex forms and an easy symbolic form of number cards. The outline of the experiment remained the same. The hypothesis related to the fact that construction processes of cognitive structures do not so much depend on the media of representation at a macrolevel but rather on the extent and the kind of the representations in micro-processes. In fact, the symbolically trained children of these recent experiments were superior to their iconically trained peers; the latter, moreover, consumed much more training time.

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