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THE ORIGINS  
OF INTELLIGENCE  
IN CHILDREN

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## INTRODUCTION\*

### The Biological Problem of Intelligence

The question of the relationships between mind and biological organization is one which inevitably arises at the beginning of a study of the origins of intelligence. True, a discussion of that sort cannot lead to any really definite conclusion at this time, but, rather than to submit to the implications of one of the various possible solutions to this problem, it is better to make a clear choice in order to separate the hypotheses which form the point of departure for our inquiry.

Verbal or cogitative intelligence is based on practical or sensorimotor intelligence which in turn depends on acquired and recombined habits and associations. These presuppose, furthermore, the system of reflexes whose connection with the organism's anatomical and morphological structure is apparent. A certain continuity exists, therefore, between intelligence and the purely biological processes of morphogenesis and adaptation to the environment. What does this mean?

It is obvious, in the first place, that certain hereditary factors condition intellectual development. But that can be interpreted in two ways so different in their biological meaning that confounding the one with the other is probably what has obfuscated the classic controversy over innate ideas and epistemological *a priori*ism.

The hereditary factors of the first group are structural and are connected with the constitution of our nervous system and of our sensory organs. Thus we perceive certain physical radia-

\* Another translation of this chapter was published in *Organization and Pathology of Thought*, by David Rapaport (New York: Columbia University Press, 1951). The footnote commentary to that translation provides an introduction to Piaget's thinking, and may serve as an introduction to the investigations and thinking contained in this volume.

tions, but not all of them, and matter only of a certain size, etc. Now these known structural factors influence the building up of our most fundamental concepts. For instance, our intuition of space is certainly conditioned by them, even if, by means of thought, we succeed in working out transintuitive and purely deductive types of space.

These characteristics of the first type, while supplying the intelligence with useful structures, are thus essentially limiting, in contradistinction to the factors of the second group. Our perceptions are but what they are, amidst all those which could possibly be conceived. Euclidean space which is linked to our organs is only one of the kinds of space which are adapted to physical experience. In contrast, the deductive and organizing activity of the mind is unlimited and leads, in the realm of space, precisely to generalizations which surpass intuition. To the extent that this activity of the mind is hereditary, it is so in quite a different sense from the former group. In this second type it is probably a question of a hereditary transmission of the function itself and not of the transmission of a certain structure. It is in this second sense that H. Poincaré was able to consider the spatial concept of "group" as being *a priori* because of its connection with the very activity of intelligence.

We find the same distinction with regard to the inheritance of intelligence. On the one hand, we find a question of structure: The "specific heredity" of mankind and of its particular "offspring" admits of certain levels of intelligence superior to that of monkeys, etc. But, on the other hand, the functional activity of reason (the *ipse intellectus* which does not come from experience) is obviously connected with the "general heredity" of the living organism itself. Just as the organism would not know how to adapt itself to environmental variations if it were not already organized, so also intelligence would not be able to apprehend any external data without certain functions of coherence (of which the ultimate expression is the principle of noncontradiction), and functions making relationships, etc., which are common to all intellectual organization.

Now this second type of hereditary psychological reality is of primary importance for the development of intelligence. If

there truly in fact exists a functional nucleus of the intellectual organization which comes from the biological organization in its most general aspect, it is apparent that this invariant will orient the whole of the successive structures which the mind will then work out in its contact with reality. It will thus play the role that philosophers assigned to the *a priori*; that is to say, it will impose on the structures certain necessary and irreducible conditions. Only the mistake has sometimes been made of regarding the *a priori* as consisting in structures existing ready-made from the beginning of development, whereas if the functional invariant of thought is at work in the most primitive stages, it is only little by little that it impresses itself on consciousness due to the elaboration of structures which are increasingly adapted to the function itself. This *a priori* only appears in the form of essential structures at the end of the evolution of concepts and not at their beginning: Although it is hereditary, this *a priori* is thus the very opposite of what were formerly called "innate ideas."

The structures of the first type are more reminiscent of classic innate ideas and it has been possible to revive the theory of innateness with regard to space and the "well-structured" perceptions of Gestalt psychology. But, in contrast to the functional invariants, these structures have nothing essential from the point of view of the mind: They are only internal data, limited and delimiting, and external experience and, above all, intellectual activity will unremittingly transcend them. If they are in a sense innate, they are not *a priori* in the epistemological sense of the term.

Let us analyze first the functional invariants, and then (in §3) we shall discuss the question raised by the existence of special hereditary structures (those of the first type).

§1. THE FUNCTIONAL INVARIANTS OF INTELLIGENCE AND BIOLOGICAL ORGANIZATION.—Intelligence is an adaptation. In order to grasp its relation to life in general it is therefore necessary to state precisely the relations that exist between the organism and the environment. Life is a continuous creation of increasingly complex forms and a progressive balancing of these forms with the environment. To say that in-

telligence is a particular instance of biological adaptation is thus to suppose that it is essentially an organization and that its function is to structure the universe just as the organism structures its immediate environment. In order to describe the functional mechanism of thought in true biological terms it will suffice to determine the invariants common to all structuring of which life is capable. What we must translate into terms of adaptation are not the particular goals pursued by the practical intelligence in its beginnings (these goals will subsequently enlarge to include all knowledge), but it is the fundamental relationship peculiar to consciousness itself: the relationship of thought to things. The organism adapts itself by materially constructing new forms to fit them into those of the universe, whereas intelligence extends this creation by constructing mentally structures which can be applied to those of the environment. In one sense and at the beginning of mental evolution, intellectual adaptation is thus more restricted than biological adaptation, but in extending the latter, the former goes infinitely beyond it. If, from the biological point of view, intelligence is a particular instance of organic activity and if things perceived or known are a limited part of the environment to which the organism tends to adapt, a reversal of these relationships subsequently takes place. But this is in no way incompatible with the search for functional invariants.

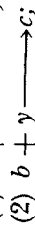
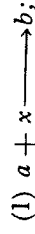
In fact there exists, in mental development, elements which are variable and others which are invariant. Thence stem the misunderstandings resulting from psychological terminology some of which lead to attributing higher qualities to the lower stages and others which lead to the annihilation of stages and operations. It is therefore fitting simultaneously to avoid both the preformism of intellectualistic psychology and the hypothesis of mental heterogeneities. The solution to this difficulty is precisely to be found in the distinction between variable structures and invariant functions. Just as the main functions of the living being are identical in all organisms but correspond to organs which are very different in different groups, so also between the child and the adult a continuous creation of varied structures may be observed although the main functions of thought remain constant.

These invariant operations exist within the framework of

the two most general biological functions: *organization* and *adaptation*. Let us begin with the latter, for if everyone recognizes that everything in intellectual development consists of adaptation, the vagueness of this concept can only be deplored.

Certain biologists define *adaptation* simply as preservation and survival, that is to say, the equilibrium between the organism and the environment. But then the concept loses all interest because it becomes confused with that of life itself. There are degrees of survival, and adaptation involves the greatest and the least. It is therefore necessary to distinguish between the state of adaptation and the process of adaptation. In the state, nothing is clear. In following the process, things are cleared up. There is adaptation when the organism is transformed by the environment and when this variation results in an increase in the interchanges between the environment and itself which are favorable to its preservation.

Let us try to be precise and state this in a formal way. The organism is a cycle of physicochemical and kinetic processes which, in constant relation to the environment, are engendered by each other. Let  $a$ ,  $b$ ,  $c$ , etc., be the elements of this organized totality and  $x$ ,  $y$ ,  $z$ , etc., the corresponding elements of the surrounding environment. The schema of organization is therefore the following:



The processes (1), (2), etc., may consist either of chemical reactions (when the organism ingests substances  $x$  which it will transform into substance  $b$  comprising part of its structure), or of any physical transformations whatsoever, or finally, in particular, of sensorimotor behavior (when a cycle of bodily movements  $a$  combined with external movements  $x$  result in  $b$  which itself enters the cycle of organization). The relationship which unites the organized elements  $a$ ,  $b$ ,  $c$ , etc., with the environmental elements  $x$ ,  $y$ ,  $z$ , etc., is therefore a relationship of *assimilation*, that is to say, the functioning of the organism does not destroy it but conserves the cycle of organization and coordinates the given

data of the environment in such a way as to incorporate them in that cycle. Let us therefore suppose that, in the environment, a variation is produced which transforms  $x$  into  $x'$ . Either the organism does not adapt and the cycle ruptures, or else adaptation takes place, which means that the organized cycle has been modified by closing up on itself:

$$\begin{aligned} (1) \quad & a + x' \longrightarrow b'; \\ (2) \quad & b' + y \longrightarrow c; \\ (3) \quad & c + z \longrightarrow a. \end{aligned}$$

If we call this result of the pressures exerted by the environment *accommodation* (transformation of  $b$  into  $b'$ ), we can accordingly say that *adaptation is an equilibrium between assimilation and accommodation*.

This definition applies to intelligence as well. Intelligence is *assimilation* to the extent that it incorporates all the given data of experience within its framework. Whether it is a question of thought which, due to judgment, brings the new into the known and thus reduces the universe to its own terms or whether it is a question of sensorimotor intelligence which also structures things perceived by bringing them into its schemata, in every case intellectual adaptation involves an element of assimilation, that is to say, of structuring through incorporation of external reality into forms due to the subject's activity. Whatever the differences in nature may be which separate organic life (which materially elaborates forms and assimilates to them the substances and energies of the environment) from practical or sensorimotor intelligence (which organizes acts and assimilates to the schemata of motor behavior the various situations offered by the environment) and separate them also from reflective or gnostic intelligence (which is satisfied with thinking of forms or constructing them internally in order to assimilate to them the contents of experience)—all of these adapt by assimilating objects to the subject.

There can be no doubt either, that mental life is also *accommodation* to the environment. Assimilation can never be pure because by incorporating new elements into its earlier schemata the intelligence constantly modifies the latter in order

to adjust them to new elements. Conversely, things are never known by themselves, since this work of accommodation is only possible as a function of the inverse process of assimilation. We shall thus see how the very concept of the object is far from being innate and necessitates a construction which is simultaneously assimilatory and accommodating.

In short, intellectual adaptation, like every other kind, consists of putting an assimilatory mechanism and a complementary accommodation into progressive equilibrium. The mind can only be adapted to a reality if perfect accommodation exists, that is to say, if nothing, in that reality, intervenes to modify the subject's schemata. But, inversely, adaptation does not exist if the new reality has imposed motor or mental attitudes contrary to those which were adopted on contact with other earlier given data: adaptation only exists if there is coherence, hence assimilation. Of course, on the motor level, coherence presents quite a different structure than on the reflective or organic level, and every systematization is possible. But always and everywhere adaptation is only accomplished when it results in a stable system, that is to say, when there is equilibrium between accommodation and assimilation.

This leads us to the function of *organization*. From the biological point of view, organization is inseparable from adaptation: They are two complementary processes of a single mechanism, the first being the internal aspect of the cycle of which adaptation constitutes the external aspect. With regard to intelligence, in its reflective as well as in its practical form, this dual phenomenon of functional totality and interdependence between organization and adaptation is again found. Concerning the relationships between the parts and the whole which determine the organization, it is sufficiently well known that every intellectual operation is always related to all the others and that its own elements are controlled by the same law. Every schema is thus coordinated with all the other schemata and itself constitutes a totality with differentiated parts. Every act of intelligence presupposes a system of mutual implications and interconnected meanings. The relationships between this organization and adaptation are consequently the same as on the organic level.

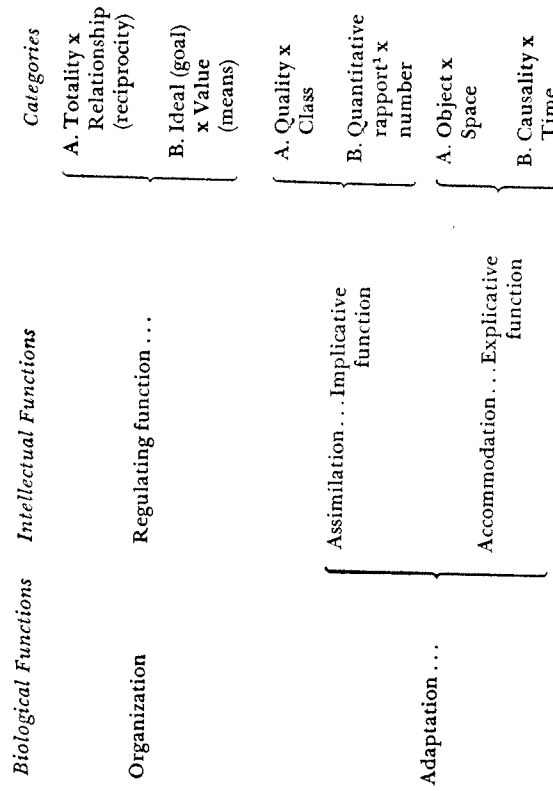
The principal "categories" which intelligence uses to adapt to the external world—space and time, causality and substance, classification and number, etc.—each of these corresponds to an aspect of reality, just as each organ of the body is related to a special quality of the environment but, besides their adaptation to things, they are involved in each other to such a degree that it is impossible to isolate them logically. The "accord of thought with things" and the "accord of thought with itself" express this dual functional invariant of adaptation and organization. These two aspects of thought are indissociable: It is by adapting to things that thought organizes itself and it is by organizing itself that it structures things.

§2. FUNCTIONAL INVARIANTS AND THE CATEGORIES OF REASON.—The problem now is to ascertain how these functional invariants will determine the categories of reason, in other words, the main forms of intellectual activity which are found at all stages of mental development and whose first structural crystallizations in the sensorimotor intelligence we shall now try to describe.

It is not a matter of reducing the higher to the lower. The history of science shows that every attempt at deduction to establish continuity between one discipline and another results not in a reduction of the higher to the lower but in creating a reciprocal relationship between the two terms which does not at all destroy the originality of the higher term. So it is that the functional relations which can exist between intellect and biological organization can in no way diminish the value of reason but on the contrary lead to extending the concept of vital adaptation. It is self-evident that if the categories of reason are in a sense performed in biological functioning, they are not contained in it either in the form of conscious or even unconscious structures. If biological adaptation is a sort of material understanding of the environments, a series of later structures would be necessary in order that conscious and gnostic image may emerge from this purely active mechanism. As we have already said, it is therefore at the end and not at the point of departure of intellectual evolution that one must expect to encounter rational concepts

really expressing functioning as such, in contrast to the initial structures which remain on the surface of the organism and of the environment and only express the superficial relationships of these two terms to each other. But in order to facilitate analysis of the lower stages which we shall attempt in this work it can be shown how the biological invariants just mentioned, once they have been reflected upon and elaborated by consciousness during the great stages of mental development, give rise to a sort of functional *a priori* of reason.

Here, it seems to us, is the picture thus obtained:



The categories related to the function of organization constitute what Hoeffding calls the "fundamental" or regulative

<sup>1</sup> In this diagram we distinguish between "relationships" in the most general sense of the word and "quantitative rapport" which corresponds to what is called, on the level of thought, the "logic of relationships." The relations which the latter envisages in contradiction to the logic of classes are always quantitative, regardless of whether they interpret "more" or "less" as comparisons (for example, "more or less dark," etc.), or whether they simply imply ideas of category or of series (for example, family relationships such as "brother of" etc.), which presuppose quantity. On the contrary, the relationships on a par with the idea of totality surpass the quantitative and only imply a general relativity in the widest sense of the term (reciprocity between the elements of a totality).

"categories," that is to say, they combine with all the others and are found again in every psychic operation. It seems to us that these categories can be defined, from the static point of view, by the concepts of *totality* and *relationship* and, from the dynamic point of view, by those of *ideal* and *value*.

The concept of *totality* expresses the interdependence inherent in every organization, intelligent as well as biological. Even though behavior patterns and consciousness seem to arise in the most uncoordinated manner in the first weeks of existence, they extend a physiological organization which antedates them and they crystallize from the outset into systems whose coherence becomes clarified little by little. For example, what is the concept of "displacement groups," which is essential to the formation of space, if not the idea of organized totality making itself manifest in movements? So also are the schemata belonging to sensorimotor intelligence controlled from the very beginning by the law of totality, within themselves and in their interrelationships. So too, every causal relation transforms an incoherent datum into an organized environment, etc.

The correlative of the idea of totality is, as Hoeffding has shown, the idea of *relationship*. Relationship is also a fundamental category, inasmuch as it is immanent in all psychic activity and combines with all the other concepts. This is because every totality is a system of relationships just as every relationship is a segment of totality. In this capacity the relationship manifests itself from the advent of the purely physiological activities and is again found at all levels. The most elementary perceptions (as shown by Köhler with regard to the color perception of chickens) are simultaneously related to each other and structured into organized totalities. It is useless to emphasize analogous facts that one finds on the level of reflective thought.

The categories of *ideal* and of *value* express the same function, but in its dynamic aspect. We shall call "ideal" every system of values which constitutes a whole, hence every final goal of actions; and we shall call "values" the particular values related to this whole or the means making it possible to attain this goal. The relations of ideal and value are therefore the same as those of totality and relation. These ideals or value of every category

are only totalities in process of formation, value only being the expression of desirability at all levels. Desirability is the indication of a rupture in equilibrium or of an uncompleted totality to whose formation some element is lacking and which tends toward this element in order to realize its equilibrium. The relations between ideal and value are therefore of the same category as those of totality and of relations which is self-evident, since the ideal is only the as yet incomplete form of equilibrium between real totalities and values are none other than the relations of means to ends subordinated to this system. Finality is thus to be conceived not as a special category, but as the subjective translation of a process of putting into equilibrium which itself does not imply finality but simply the general distinction between real equilibria and the idea equilibrium. A good example is that of the norms of coherence and unity of logical thought which translate this perpetual effort of intellectual totalities toward equilibrium, and which therefore define the ideal equilibrium never attained by intelligence and regulate the particular values of judgment. This is why we call the operations relating to totality and to values "regulative function," in contradistinction to the explicative and implicative functions.<sup>2</sup>

How are we to consider the categories connected with adaptation, that is to say, with assimilation and accommodation? Among the categories of thought there are some, as Hoeffding says, which are more "real" (those which, besides the activity of reason, imply a *hic* and a *nunc* inherent in experience such as causality, substance or object, space and time, each of which operates an indissoluble synthesis of "datum" and deduction) and some which are more "formal" (those which, without being less adapted, can nevertheless give rise to an unlimited deductive elaboration, such as logical and mathematical relations). Hence it is the former which express more the centrifugal process of explication and accommodation and the latter which make pos-

<sup>2</sup> In *The Language and Thought of the Child*, London, Routledge, 1932, p. 236, we called "mixed function" this synthesis of implication and explication which at the present time we connect with the idea of organization. But this amounts to the same thing since the latter presupposes a synthesis of assimilation and accommodation.

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sible the assimilation of things to intellectual organization and the construction of implications.

The implicative function comprises two functional invariants which are found again at all stages, the one corresponding to the synthesis of *qualities*, that is to say, *classes* (concepts or schemata), the other to that of *quantitative relations* or *numbers*. Ever since the formation of the sensorimotor schemata the elementary instruments of intelligence reveal their mutual dependence. With regard to the explicative function, it concerns the ensemble of operations which makes it possible to deduce reality, in other words to confer a certain permanence upon it while supplying the reason for its transformations. From this point of view two complementary aspects can be distinguished in every explication, one relating to the elaboration of *objects*, the other relating to *causality*; the former is simultaneously the product of the latter and conditions its development. Whence the circle object x *space* and causality x *time* in which the interdependence of functions is complicated by a reciprocal relation of matter to form.

We see the extent to which the functional categories of knowledge constitute a real whole which is modeled on the system of the functions of intelligence. This correlation becomes still more clear on analysis of the interrelations of organization and adaptation, on the one hand, and assimilation and accommodation, on the other.

As we have seen, organization is the internal aspect of adaptation, when the interdependence of already adapted elements and not the adaptational process in action is under consideration. Moreover, adaptation is only organization grappling with the actions of the environment. Now this mutual dependence is found again, on the level of intelligence, not only in the interaction of rational activity (organization) and of experience (adaptation) which the whole history of scientific thought reveals are inseparable but also in the correlation of the functional categories: Any objective or causal spatial-temporal structure is only possible with logical-mathematical deduction, these two kinds of reality thus forming mutually interconnected systems of totalities and relations. With regard to the circle of accommoda-

tion and assimilation—that is to say, of explication and implication—the question raised by Hume concerning causality illustrates it clearly. How can the concept of cause be simultaneously rational and experimental? If one puts causality in a purely formal category reality escapes it (as E. Meyerson has admirably shown) and if one reduces it to the level of a simple empirical sequence, necessity vanishes. Whence the Kantian solution taken up by Brunschvicg according to which it is an “analogy of experience,” an irreducible interaction between the relation of implication and the spatial-temporal known data. The same can be said of the other “real” categories: They all presuppose implication although constituting accommodations to external known data. Inversely, classes and numbers could not be constructed without connection with the spatial-temporal series inherent in objects and their causal relations.

Finally, it remains for us to note that, if every organ of a living body is organized, so also every element of an intellectual organization also constitutes an organization. Consequently the functional categories of intelligence, while developing along the major lines of the essential mechanisms of organization, assimilation and accommodation, themselves comprise aspects corresponding to those three functions, the more so since the latter are certainly vicarious and so constantly change in point of application. The manner in which the functions which thus characterize the chief categories of the mind create their own organs and crystallize into structures is another question which we shall not take up in this introduction since this whole work is devoted to study of the beginnings of this construction. To prepare for this analysis it is simply fitting to say a few more words about the hereditary structures which make this mental structuring possible.

§8. HEREDITARY STRUCTURES AND THEORIES OF ADAPTATION.—Two kinds of hereditary realities exist, as we have seen, which affect the development of human reason: the functional invariants connected with the general heredity of the living substance, and certain structural organs or qualities, connected with man's particular heredity and serving as elementary instruments for intellectual adaptation. It is therefore fitting to



examine how the hereditary structures prepare the latter and how biological theories of adaptation are able to cast light on the theory of intelligence.

The reflexes and the very morphology of the organs with which they are connected constitute a sort of anticipatory knowledge of the external environment, an unconscious and entirely material knowledge but essential to the later development of real knowledge. How is such an adaptation of hereditary structures possible?

This biological problem is insoluble at present, but a brief summary of the discussions to which it has given and still gives rise seems useful to us, for the different solutions supplied are parallel to the various theories of intelligence and can thus illuminate the latter by setting off the generality of their mechanism. Five principal points of view exist concerning adaptation and each one corresponds, *mutatis mutandis*, to one of the interpretations of intelligence as such. Of course this does not mean that if a certain author chooses one of the five characteristic doctrines that can be discerned in biology he is forced by this to adopt the corresponding attitude in psychology; but whatever the possible combinations with regard to the opinions of the writers themselves may be, "common mechanisms" undeniably exist between biological and psychological explanations of general and intellectual adaptation.

The first solution is that of Lamarckism according to which the organism is fashioned from the outside by the environment which, by its constraints, trains the formation of individual habits or accommodations which, becoming hereditarily fixed, fashion the organs. There corresponds to this biological hypothesis of the primacy of habit *associationism* in psychology according to which knowledge also results from acquired habits without there being any internal activity which would constitute intelligence as such to condition those acquisitions.

*Vitalism*, on the other hand, interprets adaptation by attributing to the living being a special power to construct useful organs. So also *intellectualism* explains intelligence by itself by endowing it with an innate faculty for knowing and by consider-

ing its activity as a primary fact whence everything on the psychic plane derives.

With regard to *preformism*, the structures have a purely endogenous origin, virtual variations being made up-to-date simply by contact with the environment which thus only plays a role of "detector." It is through the same sort of reasoning that various epistemological and psychological doctrines that can be labeled *apriorism* consider mental structures as being anterior to experience which simply gives them the opportunity to manifest themselves without explaining them in any respect. Whether structures are considered to be psychologically innate, as they are thought to be by the classic proponents of innate ideas, or merely as logically eternal, "subsisting" in an intelligible world in which reason participates, is of little importance. They are preformed in the subject and not elaborated by him as a function of his experience. The most parallel excesses in this respect were committed in biology and in logic. Just as a hypothesis was made of a preformation of all the "genes" which were made manifest in the course of evolution—including genes injurious to the species—so also Russell came to allege that all the ideas germinating in our brains have existed for all eternity, including false ideas!

A separate place could be set aside for the biological doctrine of "emergent evolution," according to which structures appear as irreducible syntheses succeeding each other in a sort of continuous creation, parallel to the theory of "shapes" or "Gestalt" in psychology. But actually only a more dynamic apriorism of intention is involved which, in its particular explanations, only amounts to apriorism properly so called to the extent that it is not frankly directed toward the fifth solution.

The fourth point of view which we shall call *mutationalism* is held by biologists who, without believing in preformation, also believe that structures appear in a purely endogenous way but then consider them as arising by chance from internal transformations and adapting to the environment due to a selection after the event. Now, if one transposes this method of interpretation to the level of nonhereditary adaptations one finds it is parallel to the schema of "trials and errors" belonging to *pragmatism* or

to *conventionalism*: according to this schema, the adjustment of behavior patterns is also explained by selection after the event of behavior arising by chance in relation to the external environment. For example, according to conventionalism Euclidean space with three dimensions seems to us more "true" than the other kinds of space because of the structure of our organs of perception, and is simply more "convenient" because it permits a better adjustment of those organs to the known data of the external world.

Finally, according to a fifth solution, the organism and the environment form an indissoluble entity, that is to say, beside chance mutations there are adaptional variations simultaneously involving a structuring of the organism and an action of the environment, the two being inseparable from each other. From the point of view of awareness, that means that the subject's activity is related to the constitution of the object, just as the latter involves the former. This is the affirmation of an irreducible interdependence between experience and reasoning. Biological *relativity* is thus extended into the doctrine of the interdependence of subject and object, of assimilation of the object by the subject and of the accommodation of the latter to the former.

The parallel between the theories of adaptation and those of intelligence having been outlined, study of the development of the latter will of course determine the choice it is fitting to make between those different possible hypotheses. However, in order to prepare for this choice and primarily in order to expand our concept of adaptation—given the continuity of the biological processes and the analogy of the solutions that an attempt has been made to supply on the different planes on which this problem is encountered—we have analyzed on the plane of the hereditary morphology of the organism a case of "kinetogenesis" suitable for illustrating the different solutions we have just catalogued.<sup>3</sup>

<sup>3</sup> For details, see our two articles: 'Les races lacustres de la Limnaea stagnalis' and 'Recherches sur les rapports de l'adaptation héréditaire avec le milieu', *Bulletin biologique de la France et de la Belgique*, LXII, 1929, pp. 424-455; and 2. 'Adaptation de la Limnaea stagnalis aux milieux lacustres de la Suisse romande', *Revue Suisse de Zoologie*, XXXVI, pp. 263-331.

There is found in almost all European and Asian marshes an aquatic mollusc, the *Limnaea stagnalis* (L.) which is typically elongated in shape. Now in the great lakes of Switzerland, Sweden, etc., this species is of a lacustrine variety, shortened and globular, whose form can easily be explained by the animal's motor accommodation, during growth, to the waves and movement of the water. After having verified this explanation experimentally, we succeeded in proving, by means of many breedings in the aquarium, that this shortened variety whose geological history can be followed from the paleolithic age to our own, became hereditary and perfectly stable (those genotypes obey in particular the laws of Mendelian segregation) in the places most exposed to the winds in the lakes of Neuchâtel and Geneva.

Thus it appears at first glance as though the Lamarckian solution fits such a case: The habits of contraction acquired under the influence of waves would have ended by transmitting themselves hereditarily in a morphologico-reflex ensemble constituting a new race. In other words, the phenotype would be imperceptibly transformed into a genotype by the lasting action of the environment. Unfortunately, in the case of the *Limnaea* as in all others, the laboratory experiment (breeding in an agitator producing an experimental contraction) does not show a trace of the hereditary transmission of acquired characteristics. Moreover the lakes of medium size do not have all the shortened varieties. If there is an influence of the environment in the constitution of hereditary contraction this influence is subjected to thresholds (of intensity, duration, etc.) and the organism, far from suffering it passively, reacts actively by an adaptation which transcends simple imposed habits.

Regarding the second solution, vitalism would not be able to explain the particulars of any adaptation. Why does the unconscious intelligence of the species, if it exists, not intervene everywhere it could be useful? Why did contraction take centuries to appear after the post glacial stocking of the lakes and why does it not yet exist in all the lakes?

The same objections apply to the solution of the problem in accordance with the theory of preformation.

On the other hand, the fourth solution appears to be im-

pregnable to attack. According to the theory of mutation the hereditary shortened structures would be due to chance endogenous variations (that is to say, with no relation to the environment nor with the phenotypic individual adaptations) and it would only be after the event that these forms, better preadapted than the others to the rough zones of the lakes, would multiply in the very places from which the elongated shapes would be excluded by natural selection. Chance and selection after the event would thus account for adaptation without any mysterious action of the environment on hereditary transmission, whereas the adaptation of non-hereditary individual variations would remain connected with the environmental action. But, in the case of our Limnaea, two strong objections to such an interpretation can be made. In the first place, if the elongated forms of the species could not endure as such in the parts of the lakes where the water is roughest, on the other hand the shortened genotypes can live in all the environments in which the species is represented, and we have introduced some to a new climate years ago, in a stagnant pond in the Swiss Plateau. If it were, therefore, a question of chance mutations, those genotypes should be scattered everywhere; but, in fact, they only appeared in lacustrine environments and moreover in those most exposed to the wind, precisely where the individual or phenotypic adaptation to the waves is most evident! In the second place, selection after the event is, in the case of the Limnaea, useless and impossible, for the elongated forms can themselves give rise to shortened variations which are not or not yet hereditary. One cannot therefore speak of chance mutations or of selection after the event to explain such adaptation.

Therefore only a fifth and last solution remains: This is to admit the possibility of hereditary adaptations simultaneously presupposing an action of the environment and a reaction of the organism other than the simple fixation of habits. As early as the morphologico-reflex level there exist interactions between the environment and the organism which are such that the latter, without passively enduring the constraint of the former, nor limiting itself on contact with it to manifesting already performed structures, reacts by an active differentiation of reflexes (in the

particular case by a development of the reflexes of pedal adherence and of contraction) and by a correlative morphogenesis. In other words, the hereditary fixation of phenotypes or individual adaptations is not due to the simple repetition of habits which gave rise to them but to a mechanism *sui generis* which, through recurrence or anticipation, leads to the same result on the morphologico-reflex level.

Concerning the problem of intelligence, the lessons furnished by such an example seem to us to be the following. From its beginnings, due to the hereditary adaptations of the organism, intelligence finds itself entangled in a network of relations between the organism and the environment. Intelligence does not therefore appear as a power of reflection independent of the particular position which the organism occupies in the universe but is linked, from the very outset, by biological apriorities. It is not at all an independent absolute, but is a relationship among others, between the organism and things. If intelligence thus extends an organic adaptation which is anterior to it, the progress of reason doubtless consists in an increasingly advanced acquisition of awareness of the organizing activity inherent in life itself, and the primitive stages of psychological development only constitute the most superficial acquisitions of awareness of this work of organization. *A fortiori* the morphologico-reflex structures manifested by the living body, and the biological assimilation which is at the point of departure of the elementary forms of psychic assimilation would be nothing other than the most external and material outline of the adaptation whose profound nature the higher forms of intellectual activity would express increasingly well. One can therefore believe that intellectual activity, departing from a relation of interdependence between organism and environment, or lack of differentiation between subject and object, progresses simultaneously in the conquest of things and reflection on itself, these two processes of inverse direction being correlative. From this point of view, physiological and anatomical organization gradually appears to consciousness as being external to it and intelligent activity is revealed for that reason as being the very essence of the existence of our subjects. Whence the reversal which is at work in perspectives as

mental development progresses and which explains why the power of reason, while extending the most central biological mechanisms, ends by surpassing them at the same time in complementary externalization and internalization.

## *PART I*

### Elementary Sensorimotor Adaptations

Intelligence does not by any means appear at once derived from mental development, like a higher mechanism, and radically distinct from those which have preceded it. Intelligence presents, on the contrary, a remarkable continuity with the acquired or even inborn processes on which it depends and at the same times makes use of. Thus, it is appropriate, before analyzing intelligence as such, to find out how the formation of habits and even the exercise of the reflex prepare its appearance. This is what we are going to do in the first part, dedicating one chapter to the reflex and to the psychological questions that it raises, and a second chapter to the various acquired associations or elementary habits.