GENERAL BIOLOGY

AND

PHILOSOPHY OF ORGANISM

Denique corporis atque animi vivata potestas
inter se coniuncta valent vitaque fruuntur;
nec sine corpore enim vitalis edere motus
sola potest animi per se natura nec autem
cassum anima corpus durare et sensibus uti.

—LUCRETIUS *De rerum natura* iii. 558

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PREFACE

THIS short book is an essay on theoretical biology. Although in the broad sense philosophical in its aim, it is essentially empirical and naturalistic in its treatment and outlook. To philosophical students it may seem too empirical; to biologists, too philosophical. But philosophy cannot dispense with empiricism any more than empiricism with philosophy.

To make the distinction between science and philosophy too sharp is unrealistic; a closer mutual approach is needed for the solution of modern problems. I have had to range over many fields, and I am well aware of the difficulty of attaining adequate knowledge in more than one field—indeed, even in one. The interdependence of different fields of investigation is nowhere more evident than in biology. In an era of specialism attempts at a synthesis of scientific and philosophical conceptions of nature are often discouraged, as tending to lead nowhere. Yet I believe such attempts at unification should be made: the specialist's close contemplation of trees should not obscure permanently his vision of the wood. The detail of nature has its setting in a whole; we acknowledge the essential unity of this whole when we call it "universe"; inevitably the naturalist has an interest in the whole as well as in the parts. Nature is the field of individuation; but what arises in this field depends not only on local conditions but also on the properties of the whole, in its character as a single being or permanent unity. As Whitehead expresses it, each instance of individuation is "a special strand of unity within the general unity of Nature."[1]

The transition from naturalism to philosophy is often made, and modern philosophy appears to be following a path that is increasingly naturalistic. Accordingly, a discussion by a biologist may not be out of place. If I were asked to define my outlook in a phrase, I should say it is "critical naturalism."

[1] A. N. Whitehead, *Adventures of Ideas* (New York: Macmillan, 1933), p. 241.

"Naturalism" is a term of comprehensive meaning; in my interpretation it would be the equivalent of realism. "Realism" is the knowledge, testable or verifiable as far as possible, of what in reality exists and acts; its field is not only all experience, actual or potential, but whatever lies behind and conditions experience.

The main results and theoretical conclusions in any field of knowledge should be communicable to those working in other fields without too much loss of accuracy. There are, of course, differences of conception and terminology, but a consistent terminology should be an aid to understanding, rather than the reverse. "Science" means understanding; it is an intellectual discipline, and its votaries are likely to consider exact knowledge as representing the most valuable part of experience. Scientific concepts and terminology aim at simplification; but the result is too often mystification, and the applications of science are not always fortunate in their outcome. We must remember that knowledge, while an important part of experience, is only a part. Science schematizes, epitomizes, and atomizes the world of nature, largely out of deference to human limitations. Because science is wedded to simplification as an aid to understanding ("entia non sunt multiplicanda praeter necessitatem!"), its tendency, when it turns philosophical, is often toward oversimplification.

Philosophical conceptions of the nature of scientific knowledge have been derived mainly from a consideration of physical, rather than of biological, science. For this reason the scientific view of nature has become predominantly analytical, in accordance with the prevailingly analytical character of physical science. Nature is resolved into a combination and interplay of invariant factors and conditions, and its mathematical characterization becomes the chief aim. This mode of consideration yields invaluable insight, but it should be supplemented by one that is also synthetic. Now it is a peculiarity of biology that it is a synthetic science, dealing with the most highly organized products of natural synthesis that come under our observation. Its endeavor is to "understand" the natural processes by which living organisms are brought into existence and maintained. When biology becomes too exclusively analytical, it misses its aim. While accepting the results of physicochemical analysis and applying them to the living organism, biology should not forget that its field extends beyond the mere physics of the organism. After all, the living being is not only a physical but a psychophysical entity (can any human being forget this?); the problem of the nature and role of the psychical in living organisms is as important as the problem of their physical constitution.

To the unprejudiced observer the vital synthesis appears as based on conditions and factors of both kinds; each living organism is to be regarded as a psychophysical unity. The separate consideration of its physical and psychical aspects may be compelled by the requirements of scientific observation and description; but this does not mean that the physical and the psychical in reality correspond to two distinct realms of existence, different in kind and capable of acting in entire independence of each other. Rather, they are to be regarded as existing and acting in an inseparable unity, although to our observation this unity may present a double aspect; this aspect may be either physical or psychical, as in ourselves, or only the physical may be directly observable, as in other organisms. The advantage of this general view is that the problem of how the physical and the psychical interact (the "mind-body problem") ceases to be in principle an insoluble one and remains open to investigation by scientific methods.

The following discussion is largely a recapitulation, continuation, and synthesis of contributions which I have made in past years to some of the philosophical problems of biology, in papers published chiefly in the *American Naturalist*, the *Journal of Philosophy*, and *Philosophy of Science*. In some chapters (especially chaps. i, ii, xii, and xiii) I have incorporated, with only slight alteration, considerable sections of these papers. I express my grateful acknowledgments to these journals.

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CHAPTER I

Living and Nonliving: Biological Evolution and Development

THE fundamental problem of general biology may be briefly described as the problem of the relation between the living and the nonliving. In physical nature we meet with material and "systems"—unified collocations of matter and energy—of both kinds, although by far the greater part of nature is nonliving, in the biological sense of the word. Experimentally we find that the living is dependent for its existence on the nonliving in a definite manner: each living organism incorporates material and energy from its nonliving environment, often by devious ways, and after certain internal changes returns the material and the energy (the latter now at a lower potential) to the environment; in this cycle the organism gains energy which it applies in a special way in furthering its existence and activities.

Considered as a physical system, the living organism represents a focal region to which matter and energy converge and from which later they diverge. In the interval they undergo chemical and physical transformations of a highly special kind, with consequences which are expressed in the characteristic structure and activity of the organism. Typically, this structure and activity are of a kind "adapted" to promote the persistence of the species in its environment, and both are dependent on chemical changes of a complex kind not found elsewhere in nature. We indicate the special importance of the internal chemical reactions of the organism when we speak of it as a "metabolizing system." Metabolism, especially constructive metabolism, is the primary physical activity of life.

When we consider the living organism physically, as an observable object in external nature, we find that it is a physicochemical transformation-product of a highly special kind. It comes into being and preserves stable existence under conditions which, when we consider physical nature as a whole, are undoubtedly very unusual. The evidence from natural science is that life appeared on the scene relatively late in the evolutionary history of nature, and only in certain restricted localities where the environmental conditions—e.g., temperature and the accessibility of chemically transformable material—were especially favorable. The living system thus appears to physical science as an evolutionary derivative of the nonliving; there was at some time in past history a transition, sudden or gradual, from the nonliving to the living. The evidence that living organisms may originate by "spontaneous generation" at the present time is inconclusive; but in any event, each organism now existing is of necessity continually engaged in transforming nonliving environmental materials and energy into its own living and complexly organized substance. This is the indispensable condition of its existence. We may say, then, that nonliving nature is potentially living and requires only a certain rearrangement or reorganization of components to become living. The general biological problem of organization has reference to the nature and conditions of this rearrangement.

Two chief questions arise at the outset. First, can we define clearly those general or universal characters of nature which underlie and have made possible so remarkable a development? And, second, what are the essential distinguishing characters of the living part of nature as contrasted with the nonliving? The first question relates to the general nature of the conditions required for any process of evolution; the second, to the special criteria of life as a part of nature.

With regard to the second question, unquestionably the fact of greatest general significance is that the living organism of which we know most—man himself—exhibits a double aspect. We know human beings not only objectively, as physical systems performing complicated evolutions in an external or public world, but also inwardly or subjectively, as individualized centers of experience from each of which the world is seen in perspective.[1] The world extends indefinitely in space and time outside each living and experiencing center. This central position determines the aspect which nature presents to our observation. The general theory of relativity in physics recognizes that the central status of the observer is always presupposed in the spatial or geometrical description of nature. This self-centeredness, or what may be called the "psychological isolation" or "inwardness" of each living organism, is a biological fact of the first importance which must be taken into account in every attempt at a comprehensive survey of the biological problem. Apparently it testifies to the special significance of internal, as distinguished from external, factors of determination in vital activity. In voluntary human action, especially, initiation seems to come from *within*, although external factors and restrictions, physiological and environmental, necessarily play their part in the total effect.

The other question, which is essentially the problem of the place of life in nature, may be approached from a purely scientific point of view, seeking inductively valid generalizations from facts of observation. A possible experimental side enters here: can living matter be produced artificially in the laboratory from nonliving matter? So far we have not succeeded in doing this, although we can synthesize biochemical compounds of all classes and can simulate by artificial models, often with surprising accuracy, many types of structure and activity which formerly were regarded as uniquely vital. Or the problem may be regarded as primarily a philosophical one, leading ultimately to considerations of the kind usually called "metaphysical," i.e., regarding the nature of existence itself, of which biological phenomena are one special manifestation. Our consideration in the present essay will be based, as far as possible, on tested scientific knowledge but will inevitably have its reference to the metaphysical problem also, since the problem of cosmology, i.e., of the factors underlying all natural

[1] In his *Analysis of the Sensations* (Chicago: Open Court Publishing Co., 1914) Ernst Mach gives a drawing showing the external world framed in a setting consisting of the nose and eyebrows of the observer.

creation and diversification, is one that lies behind the problem of evolution.

Physical science assumes, as an actuality, a nature or universe which is self-existent, i.e., has a reality and status which are independent of our apprehension. It regards the physical world as real and autonomous—as having an existence and activity of its own. The conceptions, scientific or other, which we form of this world may be more or less adequate and serviceable; but in any case the conception must not be confused with the natural reality as it is in itself. This reality is what it *is*—possesses its own being and characteristics—independently of mental representation, at least by the animal "mind." *Real* things (in the sense in which we are now using the word) have the same influence on the course of events whether we have any knowledge of them or not. In this sense all experience indicates that physical nature is real and that we "know" only a small part of it. The autonomy of nature, it may be said, is usually accepted without question by scientific men. But this autonomy implies a further background of reality which is the subject of philosophical consideration; and in this philosophical quest methods may be used, and used legitimately, which differ from scientific methods as ordinarily understood. This brief statement will require amplification later, but I make it now because I wish to be understood as favoring all methods of inquiry which further insight into our essential problem. Philosophical and scientific methods, when properly employed, do not contradict but supplement one another.

In considering scientifically the problem of evolution, a problem concerned with the progressive transformation of one kind of natural system into another, it is important that the most general characteristics of nature—and, indeed, of experience in its broadest sense—should be held in view as clearly as possible. The naturalist assumes that the evolution of the living from the nonliving began and came to its consummation in a world which already had certain stable properties and modes of action, i.e., features which are essential to natural existence as such and without which nature would not be nature. Can we define clearly these general features of natural existence? Such a question, at once scientific and philosophical, is not an easy one to answer, since existence is expansive and hard to pin down to any rigid scheme of definition; but certain broad statements may be made, in general agreement both with experience and with the scientific and philosophical traditions.

Briefly, the most fundamental general fact relating to the structure of natural existence appears to be as follows: Nature shows everywhere a combination of constancy and change. It exhibits (1) a conservative side, one consisting of constant elements, conditions, relations, and modes of action (invariants); and (2) an active, novelty-producing or originative side (variants), i.e., one consisting of *process*, as distinguished from static condition. Each of these appears integral to the other and presupposes the other. The two are interfused; apparently they represent parts of an indissociable unity; we distinguish them only by abstraction.

Without conservation there can be no change; i.e., certain constant or persistent conditions are required for the occurrence of any kind of event; without such constants no change could proceed for any time in a definite direction. The converse proposition is less evident; an unchanging existence seems conceivable and has, indeed, been believed in by many philosophers; but at least it may be said that without change, in the form of evolution, many of the constant conditions which we now find in nature could never have come into existence and established themselves as permanent factors.

Also, it is to be noted that, according to modern physics, the most constant property of a physical entity—mass—is not a simply static or inert character but is an active function or index of activity, i.e., a manifestation of energy. Experimentally mass appears associated with activity of a vibratory kind in the ultimate units of matter or radiation, i.e., with a regular periodicity of manifestation, as indicated, for example, by interference phenomena in protons and electrons. Physical evidence thus indicates that without change, in the form of continued activity, stations of constancy can neither be reached nor maintained; and this is especially true of living organisms.

In this sense, change would appear necessary to the existence of constant conditions—so far, at least, as these have a physical side, i.e., have the observed characteristics of natural reality. A further consideration, of special importance in relation to the evolutionary problem, should also be noted at this point. Change is the substance of creativity; it is the prerequisite for all novelty and synthesis. Whitehead's phrase, "Creativity is ultimate," expresses the fundamental status of creativity in nature. Creativity is the principle of novelty and lies behind evolution.[2]

Factors of stability and factors of change are thus both necessary to any kind of natural process. The general conditions just considered may be represented schematically thus:

NATURAL REALITY

A. *Conservative side.*—Factors of stability, including purely logical and mathematical factors and relations, space-time, natural constants (invariants, "steady states"), *structural* conditions in general—all forms of permanency and regularity

B. *Active side.*—Factors of change or activity, including both routine change and originative or novelty-producing change. The latter type of change comprises all factors of evolutionary advance, creativity, will, factors of "emergence" and synthesis, etc.

It may not be possible to make this division a hard and fast one, since many routine types of change belong in the class of constants or conservative conditions—e.g., the velocity of light, the reaction constants of chemistry, or other stable characters belonging to the various types of natural activity. But this difficulty illustrates again how closely interconnected stability and change are in natural events.

Following Whitehead, we may assume the conservative or stable conditions now existing in nature to be partly innate or primordial (i.e., nontemporal in origin) and partly derivative or consequent (i.e., of evolutionary or other historical origin). The natural world, when observed comprehensively and without prepossession, seems always to present the general appearance of a stable field, continuum, or matrix *within* which change occurs. We see this in everyday experience. When we

[2] Cf. A. N. Whitehead, *Process and Reality* (New York: Macmillan, 1929), esp. p. 31.

look out on the natural scene—a landscape, familiar streets, or the starry heavens—the attention can always distinguish these two complementary aspects. We observe that a large part of nature, perhaps the greater part, is permanent, stable, apparently unchanging; we receive this impression especially when we look at a distance. Another part, consisting especially of things close at hand and our own bodies (always part of the natural scene), is continually changing and active. If we apply the microscope, we observe the smallest loose particles of matter to be in a state of continual agitation—the Brownian movement, a manifestation of heat energy. Scientific analysis, if pursued in finer detail, brings into evidence the kinetic agitation of molecules and atoms and indicates that the ultimate physical units are fields of rhythmical or vibrational activity. Briefly, nature everywhere exhibits an unchanging background, on the one hand, combined with a constant undercurrent or inner process of change, on the other.

The general features of the visual field—a biologically important part of our experience, in which the psychophysical aspect is especially clear—are instructive. As a rule, most of the distinguishable objects in this field preserve their relative positions, and the field itself has its constant characters, geometrical and other. But inside it we observe changes: objects or colored patches corresponding to objects, having themselves greater or less persistence, shift their positions and vary in their size, shape, color, intensity, or contrast with their surroundings. In other words, we perceive change always as occurring within a setting or background which has a certain persistent identity or unchanging character. This combination of stability and change which we find in sense perception appears, so far as we can judge from experience, to be characteristic of all natural existence. Everywhere nature, whether observed externally or felt as inner experience, presents this closely interknit combination of conservative elements with changing or novel elements.

Let us now consider briefly *stability* itself, as a general fact or condition in nature, and try to indicate more definitely just what special part is to be assigned to it in the natural process.

First we note that stability and regularity (implying mathematical definability) are in essence one and the same, in the sense that order and recurrence in events always imply the existence of permanent or stable conditions underlying the events. Thus the regular alternation of day and night is based on the stability of several broad physical underlying conditions, viz., the speed of rotation of the earth, its distance from the sun, and the quantity of radiation received from the sun; if these constant factors are present or "given," the end-result is a regularly recurring cycle of change.

Now let us take a more complex case. The phonographic record of a symphony is intricate in the extreme, but the possibility of its regular reproduction on the instrument depends on certain clearly definable factors of stability. Some of these are: the shape and depth of the grooves cut in the disk; the special features of the mechanism for uniform rotation of the disk; the shape, material, and pressure of the needle; and the connections of the various parts of the loud speaker. Other extraneous but essential factors are the constant properties of the atmosphere, the structure and physiology of the human auditory apparatus, and the nervous organization of the listener. Given these various factors of stability plus a single factor of change, the uniform rotation of the disk, the whole cycle unfolds itself and may be repeated as often as desired.

Similarly, to give a still more complex illustration, this time biological: when we see the complexly organized human being developing with unfailing regularity from the egg—forty or fifty million times each year—we cannot help being impressed with the extraordinary stability of the vital process and of the structural and metabolic conditions that underlie its manifestations. What are the fundamental factors of stability in such a case? One answer, according to genetic theory, would be the *genes;* but it is evident that the stability of genes presupposes as its own basis a regularly repetitive and stable character in the process by which the genes are formed and reduplicated in each ontogeny. And this highly special process implies, still further, a stability in the chemical processes of specific metabolic synthesis—the fundamental physical process underlying all life. Again, the metabolic process implies another long series of stable factors, such as the properties of atoms and molecules and the elementary conditions of physical change in general. And in the last analysis it would seem necessary to assume an underlying or foundational stability which is ultimate or primordial and which is the necessary condition for any kind of natural happening.

It is especially important in considering our present problem to realize clearly that an active *process* or cycle, as well as a static condition or structural character, may have its own special type of stability, as shown by its exact reduplication under the appropriate conditions. To give a broad example, life, as a natural fact, is constituted by an integration of many active processes as well as of the structural conditions underlying these. Each living organism is a unified system having a definite "organization"; this organism maintains a definite kind of activity and reproduces itself with regularity. But, as just pointed out, such a combination of stability and change is not peculiar to living organisms; all natural facts and events have as their underlying condition and prerequisite some element of stability, regularity, and order. In scientific description this orderly element in phenomena is most adequately represented by the mathematical equations of physics.

It is evident, however, that stability by itself does not account for the fact of progressive change and the appearance of novelty in nature, as shown in evolutionary processes or the creative activities of human beings. Equally essential are the factors represented in the second group (B) of our scheme, which have as their common feature the natural property of change or activity, as shown physically in the various manifestations of energy. The general term "energy" refers to that property of nature which exhibits itself in activity of all kinds. But this activity requires a background of constant conditions. Briefly we may say that in nature stability is interwoven with change: the two form the warp and woof of the fabric.

We have indicated above that the factors of change may be of two kinds: (1) routine or regularly repetitive (cyclical) and (2) originative or novelty-producing. It seems necessary to make this distinction because of the fact that many forms of natural activity have the appearance of being in large part indeterminate or "spontaneous"; i.e., we cannot account for them completely on the basis of regular or physically identifiable causes and conditions. This inability may in some cases be due to ignorance; but such facts as the appearance of new forms of life in the evolutionary succession and creative originality in human beings seem to indicate that an element of real novelty is present in such activities; they cannot be accounted for solely on the basis of routine physical causation. In fact, we usually find in even the simplest natural event, if our examination is close enough, something (it may be a small detail) which is unforeseen and incalculable. Nevertheless, it is well known that many scientific men and philosophers have at times maintained that there is no real spontaneity in nature; that all events are determined completely and unequivocably by fixed conditions, i.e., by factors already in existence and uniformly operative. This view has found one expression in the "closed-universe" conception of certain philosophers: reality, as a whole, is unchanging and only appears to us to change because of the accident of our situation as finite beings set inside the universe and viewing it in a partial manner.[3]

Certain forms of scientific "materialism" have been similarly absolutistic, in the sense of asserting a rigid or invariant causal interconnection between all natural events. Such a view implies that there are never any alternative possibilities of outcome in any natural situation; each event presupposes all the others, past and future; the whole system of physical reality is tightly interlocked. It seems clear, however, that this conclusion has been reached by formal deduction rather than by impartial observation; it is logical, rather than empirical, in its derivation, and it does not appear consistent with what we know experimentally about physical nature at the present time. It seems to be more in accordance with scientific (as well as general) experience to hold that in any natural occurrence

[3] F. Bradley's position, at least in his *Appearance and Reality* (2d ed.; New York: Macmillan Co., 1902). In America, Josiah Royce has represented a similar view.

both kinds of factors—(1) law-abiding and (2) spontaneous (freely acting or physically indeterminate)—are always present, but in proportions which show extremely wide variations in different events and situations. According to this view, natural events are never completely predictable, i.e., in all of their detail; and on the whole this view appears to correspond more closely with our actual experience of nature than does the absolutistic conception.

The law-abiding factors determine the uniformity and regularity which we observe in natural events, while the indeterminate factors are responsible for a certain tendency to vary from fixed rule, and hence ultimately for the continual appearance of novelty in nature. The latter factors have a certain forward-tending quality and also a certain arbitrariness; they are responsible for that element in the future which is not unequivocally determined by the past. In the long run they determine the evolutionary trend. In living organisms they express themselves in spontaneous variation or in voluntary action.

It is true that these factors always act under restrictions set by the law-abiding factors, as well as by the actual state of nature at the particular place and time. The past is fixed and forms the necessary and inescapable condition of present action; but it is also to be noted that the conditions of natural action are not necessarily the same at all places and times. New rules are continually being made as new permanencies appear in nature. Some of these rules may be merely local and transitory, while others may have a wide application and a high degree of permanency. This subject will be considered later in more detail.[4] The essential point to be emphasized now is that certain factors of the second class (B in our scheme) are to be regarded as only partly determinate in the usual physical or causal sense of the term. These factors, acting in the present, i.e., in the transitional zone between the past (fixed) and the future ("not yet"), appear to have a certain range of indeterminacy; i.e., alternative possibilities exist with respect to the precise time and direction of their incidence. Although

[4] Chap. xi, p. 150.

this range may be small in the physical sense, being fixed (according to Heisenberg's principle of indeterminacy) for each electron event by the value of the quantum constant, it is sufficient to free natural events from the absolute invariance or fixity to which otherwise they would be held, and hence leaves room for a certain measure of spontaneity.

It is a part of the thesis of this essay that the essential peculiarity of the vital organization—as contrasted with the nonliving part of nature—is that these spontaneous or free factors, whose action is internally determined and largely independent of environmental and past conditions, are somehow enabled to assert themselves in a unified and effective manner. The directive and integrative features of vital activity, as well as the spontaneity and originativeness which it exhibits under certain conditions, are to be referred to this individually or inwardly conditioned determination with its partial independence of external control and of the past. Physical research has shown that single microphysical events have a certain degree of indeterminacy in the sense of not being completely calculable or predictable; thus, no one can predict when a single radium atom will shoot off an electron. Predictability enters only when large numbers of units are acting in concert; it is statistical predictability. In living organisms the indeterminate characteristic, which exhibits itself in single elementary physical events, appears to become in some manner an essential factor in the control of the whole complex system. Hence an internal determination, as distinguished from an external or environmental determination, may under appropriate circumstances assume the upper hand and guide the course of vital activity in a manner which is largely independent of environmental conditions. This integration and independence are most clearly seen in voluntary human action. They also appear to play a part in ontogenetic development, although this is largely a stereotyped process and dependent on the constancy of physical conditions, both internal and external. The incomplete character of the physical determination is also shown in the variability and spontaneity of living organisms, as exhibited in their genetic mutations and especially in their individual behavior. Here we touch on a fundamental biological problem, to be considered more fully later. It would appear that in the last analysis reference must be made to intra-atomic factors (and apparently beyond) if we are to account satisfactorily for this spontaneity and internal determination.

A further brief statement regarding some of the more general features of organized vital action, especially as seen in individual development, seems to be desirable at this point. We observe that each individual living organism is a temporary construction, complexly organized according to a constant pattern and built up out of materials originally distributed at random in the environment. On the whole, it is in its individual development (or ontogeny) that the organism shows most impressively its character as an integrating center. Materials and energies which previously were isolated and independent come into close association, under some kind of directive influence or compulsion, to form a characteristically organized unity. This is equally true whether we take as our example a bacterium or a yeast cell in a culture medium or a higher animal (such as man) in its complex environment. In either case development appears as essentially an integrative process, i.e., a process of concrescence in which a variety of materials come together to form a closely unified whole. For a time this unity, no matter how completely organized, has a stability which is automatically conserved, together with a correspondingly unified complex activity. After this period of maintained organization and activity, which varies greatly in length in different organisms, the system disintegrates; i.e., it loses its wholeness or unity and is again resolved into randomness and relative simplicity. Its materials are then again dispersed in the environment.

Such a general description would apply to any higher organic individual; a cycle of integration is followed by one of disintegration, the whole sequence constituting a coherent combination of processes which is the characteristic life-cycle of the organism under consideration. Some biologists might object here and might say that the lapsing into randomness at the end of life-cycle is an incidental, rather than a necessary, feature of the living organism—the protozoans and the germ cells are regarded as "immortal." Nevertheless, it seems generally true that any organization of the highest complexity carries with it certain factors and conditions which, in the long run, render maintenance difficult or impossible. Sooner or later, the integrative activity of the system declines; it appears as if the second law of thermodynamics were for a time successfully disregarded, only to resume its dominance later; the physical components of the organism then suffer dispersion.

This contrast between integrated activity, on the one hand, and undirected or random activity, on the other, always impresses us when we compare the living with the dead organism. As we shall indicate later, the contrast seems to correspond, in a broad way, to the essential contrast between the living and the nonliving systems of nature. The vital trend or impulse, to use Bergson's term, has as its natural tendency or effect the synthesis of beings or systems which combine with complex organization and activity a persistent and characteristic unity. No such integration is discernible in the materials before they are thus brought together to form the living system, although various fundamental elements of order are present, in correspondence with the prevalence of order in nature as a whole.

CHAPTER II

Living and Nonliving Systems

WE SHALL now try to describe more fully and concretely the essential differences between the living and the nonliving systems of nature. First of all, attention should be directed to certain general characteristics of the external world, i.e., of nature as we see it outside ourselves. Obviously, physical nature is highly diversified, but it also shows everywhere certain characteristics that appear simple and unvarying—or at least lend themselves to simple modes of description.

Of first importance is the fact that each distinguishable object is set in an environment and, at the same time, has its own interior. This interior is separated from the surroundings by a boundary which is sometimes well defined and sometimes fluctuating. Each object may thus be described as a local differentiation within the spatiotemporal continuum. Physical nature appears to the observer as a public spectacle or performance; it is an externality, something outside the experiencing center, resolvable into materials, systems, and activities distributed throughout an indefinitely extended space and time. Viewed comprehensively, the external world appears as a continuum. When so regarded, what impresses us chiefly is its *unity:* it is a single being, a cosmos; its diversity is detail set in a background which is continuous and largely homogeneous.

Everywhere, so far as we can observe, there is apparent a certain unchanging neutral or static property, furnishing uniform conditions for motion, radiation, electrical manifestations, gravitation, and the other fundamental types of physical action. The older concept of an ether had reference to this omnipresent physical condition. No physical entity is isolated; everything forms part of a larger system; if there were complete isolation for any entity, we could never be aware of its existence, since then it could not be a source of radiation or other action affecting the sense organs of an observer. The natural diversity has its place (and presumably had its origin) in a setting, medium, or matrix having properties which, broadly speaking, are stable and uniform. But such a comprehensive view neglects detail; in its more usual aspect nature is a manifold, a mosaic, a complex tissue of many separate systems and events. Multiplicity and diversification, rather than unity, are what chiefly impress the human observer or—I feel sure—the animal struggling for existence.

In the summary statement just made, I have spoken of nature as if it were primarily a physical system; biology, and especially physiology, have usually regarded the living organism as a purely physical object existing in a physical world. The question of how far the phenomena of life are representable in terms of physical models has been much debated. Undoubtedly, physical models and conceptions have proved of the greatest value to biology; recently, however, there have been many indications that the tide of scientific opinion is swinging away from an exclusively physical conception of the organism. An illustration is the rise of psychosomatic medicine, as a department of practice in which psychology and physiology are regarded as of equal importance; and certain departments of biology are now called "psychobiological." Physics is, in its nature, the *spatial* representation of phenomena; its subject matter is an external world, consisting of entities and factors with exclusively spatiotemporal interrelations. Physiology is also an "externoreferent" science; it conceives life as complex physics, as an externality which, however complex in kind, may be expected in the long run to yield its secrets to persistent physical and chemical analysis. But from the standpoint of a general biology it may be objected that this conception represents only a partial aspect of life; there is also its inner side, as felt in direct experience, and this experience, as immediate and undeniable, has its priority over the externalization and physical analysis of physiology. We are now referring to the physical, as distinguished from the physical, aspect of life.

It is unnecessary to enlarge on this at present; every man is aware that his inner life has features which are not spatially representable, or, indeed, representable (symbolizable) in any terms. No descriptive combination of concepts, however ingenious and exact, can be a substitute for any strongly felt immediate experience. A pain is what it *is*—pure affective experience; its scientific characterization is no consolation to the sufferer; in fact, we cannot describe it; we can only point to it and describe some of its conditions. Similarly, no one can describe the exertion of will; it has to be experienced directly and in the *present:* the willing agent is immediately aware of a kind of activity not representable in physical terms. All we can do is to call attention, verbally or otherwise, to the experiences themselves. These have terms or qualities common to all human beings—perhaps to all experiencing subjects other than human. There is a character of ultimacy about these elementary types of experience—pure feeling and pure volition; and certain ultimates seem unanalyzable, like the concept of energy in physics.

Nevertheless, it is often scientifically desirable to analyze complex experiences into their ultimate factors, as far as possible. In the case of the living organism, the best we can hope for is that both physiological and psychological analysis, if carried far enough, will converge to the same ultimates. As already indicated, the realistic approach to the fundamental problems of biology regards the organism as a psychophysical, rather than a purely physical, system and considers its problems, according to their special nature, from either the physiological or the psychological point of view—or from both.

First let us consider the biological problem in some of its more general aspects. Viewed from the purely physical or naturalistic point of view, as a phenomenon in external nature, life appears as a *process*, which differs in a striking manner from other natural processes in exhibiting a predominantly synthetic and integrative type of activity. Claude Bernard emphasizes this in his sentence (often quoted), "Life is creation."[1]

[1] *La Science expérimentale* (Paris: Baillière et Fils, 1878), p. 52: "La vie, c'est la création." For an account of Bernard's views on theoretical biology cf. the recent

The distinguishing physical feature of life is a complex type of material organization having constant and specific structural and chemical characters which are combined with constant metabolic activity; this organization is built up through the orderly association and transformation of materials and energy taken from the environment where they are distributed at random, i.e., in a manner which shows no relevance to the kind of system formed later by their association.

It is also highly important to note the "vortex-like" feature of the vital constitution. The living substance is continually changing; its stability is dynamic rather than static; "all living structure is actively maintained structure."[2] An old comparison is that with candle flames, vortexes, fountains, and other systems which preserve constant structural and active characters in spite of continual change of material. Such systems have been classed by Wilhelm Ostwald[3] as "stationary systems"; each represents not a static but a kinetic (or dynamic) equilibrium—what we now often call a "steady state"; there is a balance of constitutive and dissipative processes. In living organisms these processes consist essentially in chemical reactions of a complex kind; hence the designation "metabolizing system." Materials and energy converge to the living center; undergo there characteristic transformations, among which chemical and structural syntheses are conspicuous; and are again distributed at random to the surroundings. In exhibiting this special type of transformative cycle the living organism is unique among natural systems.

The most striking physical feature is the dependence of the whole system on organic syntheses of a highly complex kind, leading especially to the production of proteins, the chief characterizing compounds. Directly dependent on this chemical cycle is the integration, which is the other unique physical

article by W. Riese, "Claude Bernard in the Light of Modern Science," *Bulletin of the History of Medicine* (Johns Hopkins University), XIV (1943), 281. See also the biography by J. M. D. Olmsted, *Claude Bernard, Physiologist* (New York: Harper & Bros., 1938), esp. Part III (pp. 231 ff.).

[2] J. B. Haldane, *Mechanism, Life and Personality* (New York: E. P. Dutton & Co., 1914), p. 67.

[3] Wilhelm Ostwald, *Vorlesungen über Naturphilosophie* (Leipzig: Veit & Co., 1902).

feature. Although each organism has a great variety of distinguishable components, existing in constant structural and other associations, nevertheless the whole system holds together, maintains its identity, exhibits its characteristic behavior, grows, and reproduces. In its properties and activities it is sharply contrasted with its environment; yet it comes into existence through the orderly association and transformation of materials taken from this environment; and physiological research has been able to trace many of the transitional steps of the vital synthesis as this occurs in the interior of the organism. Nevertheless, from the physical point of view, it remains a continual source of astonishment that the composition and activity of the system—especially when we remember that it is a flux, not a static structure—should exhibit such remarkable constancy. What enters the system is unorganized; even carnivorous animals break down their food material into simple compounds before they incorporate it.

In the synthetic process which follows incorporation, these materials are recombined in accordance with a constant organizational pattern which is characteristic for each species. Each animal or plant organization, once it is synthesized, is maintained with an essential constancy of structure and activity throughout a certain limited period or lifetime, which varies greatly from species to species and is biologically predetermined, i.e., inherited. In this sense, each organic individual is transient, i.e., passes through a temporally limited life-cycle, usually divided into successive subcycles of development, level maintenance, and senescence, after which it dies or disintegrates. But before this stage is reached, certain special portions of the organism, usually germ cells, are detached and begin similar life-cycles; in this way the continuance of the species is assured. Apparently, the species itself has no such limited lifetime; the individuals of which it consists may be repeated through an indefinite number of generations with only slight variation from a constant norm. This norm represents the scientific conception of what is stable and characteristic for each species; it is a general picture or ideal, not an observed physical fact; what we actually find in nature is a genetically interconnected succession of similar individuals which die and are replaced.

We may sum up our general description briefly as follows: Each animal or plant is constituted by a synthetic process which, complex as it is, is stable—i.e., is regularly repeated in the single individuals as they appear in successive generations. Each of these individuals conforms to a definite biological type or pattern with constant spatial (structural or morphological) and temporal (developmental and behavioral) characters; if the biological individual were represented graphically by a geometrical diagram, it would require a four-dimensional type of construction. The vital synthesis is a process of concrescence[4] occurring within a larger spatiotemporal environment. Its special unitary character appears to physical analysis as a consequence of the orderly association and integration of a large number of materials, energies, and subprocesses.

We now come to a consideration of certain more special features of the organism. Since the living material is continually being oxidized and broken down to yield free energy, there is always the necessity of replacement; hence the problems of maintenance, growth, and reproduction are the most general biological problems. These processes are based on specific chemical syntheses, and they include chemical reactions of a highly special kind, which differ widely from those found in inorganic nature. Accordingly, much of the effort of physical biologists has been to show that the special processes of the organism do not vary in any fundamental way from those possible in the laboratory. In fact, modern biochemistry and biophysics have been astonishingly successful in their analysis of many vital processes into known processes of inorganic physics and chemistry. The purely chemical distinction between living and nonliving has largely been broken down; almost any biochemical compound can now be synthesized, including polymers (polypeptides) which have all the essential characters of the simpler proteins. No scientific man now doubts that for many scientific purposes living organisms are

[4] Whitehead's term in *Process and Reality.*

to be regarded simply as physicochemical systems of a special kind, to be investigated by the methods of physics and chemistry.

While the foregoing conclusion is amply justified experimentally, we must remember that it has reference to the organism in its character as a physical system only. It is true, of course, that the psychical characters of the organism are dependent on the physical characters, in the experimental sense that psychical phenomena are found to be constantly associated with physical changes in the brain and sense organs. But an exclusively physical outlook is required for many purposes of investigation, and a specialization or abstraction which provisionally ignores the psychical side of living organisms does not necessarily deny its biological importance. The physical characters of organisms are so remarkable and exceptional that their possession of other characters which are unique, including the psychical, does not seem altogether surprising; one might expect that a psychophysical system would show many differences from one which is exclusively physical.

As physical systems, living organisms present many curious and unique features, one of the most significant of which is the high degree of chemical and structural diversification which their material substratum exhibits on the microscopic scale of dimensions. Protoplasmic units (usually "cells") are small-scale units, subjects for microphysics and microchemistry. Fineness of physical subdivision and differentiation and a fine-grained heterogeneity of structure and composition are universal features of living protoplasm. Its chief biochemical constituents, the proteins, are correspondingly heterogeneous in their chemical structure and form large and diversified molecular complexes, sometimes having a molecular weight of some millions. These compounds consist chiefly of asymmetrical amino-acid groups or "residues" (R-groups), united by dehydration to form chemical structures of highly varied type. There may also be great morphological, as well as chemical, diversity within the small volume of a single cell, as is shown perhaps most strikingly in the protozoans. In addition, living protoplasm contains many compounds, like salts and sugars, which are of low molecular weight and present in simple aqueous solution; and it is remarkable that these also are distributed in a nonhomogeneous manner. Physical chemistry has shown that to build up and maintain such a state of nonhomogeneity requires work, since the automatic tendency of dissolved substances, in conformity with the second law of thermodynamics, is to distribute themselves uniformly by diffusion throughout the solvent. The work expended in opposing this dissipative tendency (called "concentration work" or "osmotic work") may become relatively large (in proportion to the total energy freed within the system) when the volumes are small, as in the cell, and the diffusion-gradients correspondingly steep. Accordingly, the characteristic heterogeneity of living protoplasm, existing as a stable condition during life, is possible only when there is a constant source of free energy within the system to perform this work; we know, however, that such energy is continually being furnished by metabolic oxidation or otherwise, e.g., by sunlight in green plants; and part of this energy forms what has been called the "energy of maintenance."[5]

In general, local inequalities of concentration in fluid systems are soon evened out automatically by diffusion—unless conditions are present which resist or compensate diffusion or unless the inequalities are maintained by the local addition or removal of dissolved substances. In systems having a solid structural framework, diffusion-proof partitions (membranes) may be present; and differences of composition or concentration across such partitions may be passively maintained, a condition frequent in living organisms. But local differentiation of structure and chemical composition may be highly developed within single cells not internally partitioned, as in many protozoans. And even where regions are delimited by membranes, the gradients must first be established by osmotic or other work.

From such general considerations it is clear that free energy is continually being applied within the living system in direc-

[5] Estimates of its magnitude have been made by A. V. Hill (*Adventures in Biophysics* [Philadelphia: University of Pennsylvania Press, 1931]), and by others.

tions opposed to the forces of diffusion. Diffusion is the manifestation or effect of the random thermal motions of molecules; therefore, it is always *down* a concentration gradient. It is a dissipative process, making for uniformity of distribution; hence it tends to break down any organization based on local differences of concentration or composition. As a constant factor, present in all fluid systems, it acts in opposition to what is perhaps the most characteristic physical activity of living protoplasm, the building-up of complexly differentiated structure from dissolved molecules. To give a concrete illustration: solid protein structures of specific constitution are continually being built up in growing cells from dissolved amino acids. The concentration of the amino-acid residues in the protein structure is much higher than in the fluid part of the protoplasm; hence, to form this structure the dissolved molecules must be moved up and placed in position against the resistance of diffusion.

Just how energy is applied in moving the molecules against concentration, or in sorting molecules of different species so as to get the observed fine-grained differentiation, is a problem as yet unsolved. But processes of this kind are universal in living systems; a specialization of this kind of selective action is seen in the process of secretion which is universal in living organisms. The factors involved have been described collectively as "antidiffusion factors," but their physical nature is obscure. It is conceivable that electric forces might be concerned in the case of charged bodies, like ions or colloidal particles; but in such a case the distribution of the potentials would have to correspond to the distribution of the particles thus guided—a problem in itself—and the case of uncharged molecules would remain. Short-range forces like those concerned in crystal formation have also been regarded as acting; and since crystallization is a highly selective process—e.g., a growing tartrate crystal will distinguish between right- and left-handed molecules—some of the specific features of protein synthesis might conceivably thus be explained. But, in general, crystallization requires supersaturation, and the problem would then arise of accounting for a supersaturated layer of amino acids in contact with the growing protein structure. A closely related general problem of physical biology is seen in the fact that many cells assemble their nutritive and other supply from highly dilute solution, as seen, for example, in the growth of molds or bacteria in weak solutions of organic compounds.

In addition to the physical problem of the factors underlying this universal ability of living organisms to perform selective work of concentration, there are the special biochemical problems presented by the metabolic transformation of the materials thus assembled. The general process to be accounted for is the transformation of a dilute aqueous solution of nutrients and salts into the organized living protoplasm. The essential physical prerequisites are: (1) an increase in the concentration of dissolved substances and (2) a selective distribution or sorting-out of molecules in accordance with a definite spatiotemporal (four-dimensional) scheme or pattern. These changes are preliminary to the special chemical working-over or rearrangement constituting the metabolic cycle of the system, through which its materials are transformed specifically so as to produce and maintain the characteristic chemical organization. The chemical reactions of this cycle are extremely diverse and complex; they consist essentially in biochemical sequences ("chain reactions") interrelated in a manner which is constant within narrow limits, as is shown by the constancy of the biological outcome in growth and development. It must always be remembered that vital organization is a product of metabolism, especially synthetic metabolism; this metabolism, however, is controlled by physical and other conditions of a kind only partly understood at present.

A fundamental biological fact is that the synthesis of the vital organization occurs only under the direct influence of a pre-existent organization of the same kind—*omne vivum ex vivo*. In all species of animals and plants the factors of organization preserve a stable existence from generation to generation; this is the general biological condition to which the term "heredity" has reference; and a chief aim of the modern science of genetics is to specify these factors exactly. Here, again, it is to be noted that the essential factors are *small-scale* in their physical dimensions and incidence.

Cytological investigation, in correlation with experimental genetics and biochemistry, gives ample evidence that the specific molecular configuration of special nuclear proteins, which form an essential part of the biological units called "genes," is a fundamental factor in the determination of the detailed course followed by the developmental synthesis. The growth and maintenance of single cells, as well as the development of the organism as a whole, are also dependent on nuclear conditions, as is shown experimentally by the effects following the removal of nuclei from cells. There is a large body of experimental evidence supporting the conclusion that in each protoplasmic unit an essential part of the organizing control emanates from the nucleus; this structure is a centrally placed aggregate of specifically constituted materials which are reduplicated exactly in mitotic cell division. Later we shall discuss in more detail the possible biological significance of nuclear control in metabolism and development.

The foregoing brief description describes in broad outline our present conceptions regarding some of the more fundamental physical factors concerned in the vital synthesis. The essential activities, while conceived as physical, are recognized as being selective, or directive, in a highly special sense. We know that the compounds present in a typical cell, such as a yeast cell, when mixed at random in a test tube, interact chemically in a manner very different from that which they show inside the cell while it is living. Experimental proof of this is seen in the different course taken by the intracellular reactions after the death of the cell, as in self-digestion or autolysis. What is most striking in this difference is the cessation of the synthetic reactions, especially the formation of proteins, on which maintenance and growth depend; chemical reactions continue in the dead cell, but they are now predominantly hydrolytic and disintegrative. It is reasonable to infer that the autolytic breakdown represents, in large part, a consequence of the substitution of random molecular motions for the directed motions which are normal during life. If this is true, it would seem that the synthetic reactions of the cell must depend in some way on special directive factors which control the motions of molecules. According to this view, the synthetic activity and integration so characteristic of vital processes are the manifestation of some factor or factors whose effect is to limit or counteract the purely random molecular motions and impart to these motions a directed character. Such a factor would be closely related to the "antidiffusion factor."

Let us now consider in somewhat more detail, at first in terms of a purely physical analysis, what is implied in the existence of such a selective control of molecular motion, with the dependent differentiation and integration. In the growing or developing organism we observe the building-up of an organization; there is a steady progress from a less ordered to a more ordered arrangement of components. Whitehead's term "concrescence" may be used to describe the assembling and rearrangement of materials to form this organized whole.

Now processes of this general kind, leading to the production of more highly organized systems from randomly distributed components, need not be confined to living systems; such a change may occur in nonliving systems, even as the result of random or undirected activity, but (it is important to note) only as an exceptional occurrence—the probabilities are against it. Typically, the transformation of a complex ordered system subjected to random agitation is in the direction of *decreased* order: it is easier to destroy than to build up. In physics the second law of thermodynamics is regarded as the general expression of this automatic tendency in nature at large—an incidental result of its composition out of actively moving molecules.

The general nature of the foregoing conditions may be indicated by a simple type of model. Take an ordered pack of cards, with the suits separate and consecutively arranged, and shuffle them again and again. According to the theory of probability (a branch of science which describes mathematically the observed behavior of such collections of freely mobile units), a sufficiently large number of shufflings and reshufflings will arrange the cards in their original order. The implication is that the ordered arrangement represents merely one out of a large number of possibilities, all of which have equal chances of being realized; experimentally, this means equal frequencies of occurrence when the number of cases is large, implying that mechanically one arrangement is as easily produced as another. Yet to produce any particular arrangement at will requires a highly selective course of action—if the desired order is to be produced with constancy and within a reasonable time. Such a course of action must be controlled by a definite purpose or plan. Now this plan represents a special condition, existing in advance, which *persists* throughout the entire process of rearrangement and determines its course; expressed somewhat differently, it is a stable factor, whose presence insures that the succession of activities will lead to a definite final result. This end-stage has a unitary character corresponding to the plan; i.e., the plan is an integrating factor, which unifies the series of actions. The sequence which it governs is of the kind generally called "teleological," illustrating what some biologists have called "finalism."

An imaginary experiment, which could easily be performed, may indicate more clearly the requirements for such a finalism. Let us place our sorted pack of cards on the floor of a glass chamber (so that they can all be seen) and then make a moving picture of them while they are being scattered at random by a strong current of air. The picture will show a succession of casual or unco-ordinated events transforming the ordered state into one of disorder. The individual events are entirely incoherent: what happens to one card of the collection has no constant relation to what happens to another. There is no single type of behavior uniquely characteristic of the scattered collection as a whole. If it can be spoken of at all as integrated, the state of integration is a very loose one—the system is "unorganized." We then run the same film backward; this gives a picture showing the reverse kind of change, a progress from disorder to order. At the end of a series of movements, at first apparently quite irregular, a definitely ordered system emerges. In spite of the casual nature of many movements, we see on reviewing the sequence as a whole a steady progress toward the definite order which is finally attained. No matter how often we repeat the experiment, we get the same result; the random arrangements with which the various sequences begin are all different, yet in the picture they all transform themselves by a series of rearrangements into the same ordered end-stage. If we watch the sequence closely as it unfolds, we observe the units forming, apparently spontaneously, combinations which become more and more "improbable," until in due course the final stage is reached with the suits all in order. A persistent directive or controlling influence seems to be asserting itself throughout the whole process.

Such a picture may be regarded as a model showing the difference between a guided and an unguided sequence of events, i.e., a model of a teleological process. It is true that in the reversed film the appearance of teleology is in one sense an illusion, since the end-stage of the sequence is already laid down at the outset; its successive stages are merely brought into appearance in an order which is artificially made the reverse of the natural order. The completely organized end-stage was originally chosen consciously by the experimenter and realized concretely through his voluntary action; the integrative activity of his mind was an essential factor. But, although such a model may not "explain" the process by which a yeast cell or bacterium transforms the randomly distributed molecules of the culture medium into its own specifically organized living protoplasm, yet in certain aspects there is a significant resemblance between the two kinds of transformation. If we regard the cards in the reversed film as corresponding in their behavior to molecules, the picture would correspond to a local physical process associated with a *decrease* of entropy, instead of the increase which is the usual course of change in an isolated physical system.

Processes of this kind are by no means infrequent in physical nature, but they always require the addition of free energy to the local system; this energy is taken directly or indirectly from the surroundings. As already pointed out, such addition is a constant feature of living organisms: in green plants the energy required for growth and differentiation comes from the absorbed sunlight; in animals, from the oxidation of food materials. It is clear, however, that the special features of the final organization cannot be accounted for as the effect of a simple increment of energy (although this is essential); a complete explanation would include an account of how the energy is applied directively within the living system so as to give rise to the characteristic differentiation. The existence of the living state is dependent on a *directed* (ordered or integrated), as contrasted with a random, application of energy. Any random application of energy is disorganizing in its effect; this is illustrated, for example, in an explosion or in the process of autolysis in the dead cell, as well as in mixing and shuffling processes in general.

So far we have been considering only the physical aspects of vital action. Let us now consider an integrative process occurring in a living organism where both physical and psychical aspects are open to observation. Such an organism is one's own self. Take the simple act of writing a sentence with a pen on paper. As the words flow through the mind of the writer, there is a corresponding flow of ink from the pen to the paper. We know from experiment that the physical processes by which the ink is deposited on the paper, is adsorbed by the fabric, is fixed and dried there, and so on, are scientifically definable with a high degree of precision as phenomena of capillarity, adsorption, evaporation, etc. What happens physically is the same at every point traversed by the pen; a purely physical analysis would give a sufficient account of the process as it occurs locally; each local event is a simple instance of physical cause and effect.

But there is one feature in the writing which it would be difficult or impossible to explain physically, and that is the precise direction of motion taken by the pen at each point in its course. This direction determines what words are formed, and is itself determined by the voluntary control of the writer as the words come into his mind. At the same time, the act of writing is itself largely automatic; and scientific investigation shows that, in addition to the physical events just mentioned, there is a highly complex succession of physiological events, occurring chiefly in the neuromuscular system of the writer. Let us suppose that we analyze this physiological sequence into its physical and chemical components as completely as possible. All the analytically distinguishable materials and events making up the sequence would appear as having constant characters conforming to definite scientific conceptions. As we continue to resolve the single events into their finer small-scale components—ultimately with the aid of the electron microscope—limits would eventually be reached to further physical analysis. The reason for this limitation, according to our modern conceptions, is that in the smallest observable physical field the events occurring in each minute element of volume would depend for their special direction and character upon energy exchanges determined by quantum leaps, whose "causes" could not be specified in the individual cases. It is true that on close examination uniformities would be found, showing a correlation with the large-scale uniformities; but these would be scientifically characterized in terms of probabilities rather than of fixed quantities which are assignable to all the individual events. A large number of single observations and a statistical analysis would be required in order to define the uniformities exactly, i.e., to determine the mathematical conditions (algebraic formulas, curves, or geometrical constructions) to which they would most closely conform.

It is to be noted especially that these submicroscopic physical factors would show a parallelism with the psychical controlling factors, since both series of events have experientially their constant characters and proceed side by side. The special part played by the mental factors, as mental, would then have to be determined if the investigation is to be complete.

Now the chief peculiarity of mental processes is that they have a comprehensive or integrative quality; it is the nature of "mind" to embrace the details of an experience and gather them together into a unity. Apparently, it is just this unifying activity, characteristic of the psychical as psychical, which determines what occurs in the large-scale action (the writing of the sentence) considered as a single integrated event; this remains true even though the neuromuscular act of writing is subject in all of its details to strict physical causation. This physical exactitude is an indispensable feature of the whole process; clearly, without such exactitude and dependability the writing of a sentence would not be possible. The precision with which the physical events are determined thus appears as a necessary *condition* of the writing; but this physical regularity by itself cannot be regarded as the final determinant of the process, considered in its unified aspect as the expression of a thought on paper. A sentence is a mental (psychical) occurrence; the separate words are held together in consciousness as a single experience or prehension through the integrative ("apperceptive") activity of the mind. A certain mental grasp is required to synthesize or understand ("comprehend") a sentence; this means, among other things, to respond to it in a coördinated or biologically effective manner. The same is true of other experiences which involve a temporal or spatiotemporal span of consciousness, such as listening to a piece of music or looking at a picture. Such acts illustrate the psychophysical characteristic of the organism; both mental and physical factors are involved, and both are indispensable; but the act of integration appears in itself as psychical rather than physical, no matter how dependent it may be upon physical factors for its execution.

A general characteristic of vital action is seen here; namely, the presence of an integrative control which is made effective through the intermediary of exact physical causation. This conclusion is not modern; it is clearly and convincingly set forth in the writings of the great biologist and philosopher Aristotle. His distinction between final causes and efficient or motor causes and his discussion of their biological interrelations in his books *On the Vital Principle* (*De anima*) and *On Parts of Animals* (*De partibus animalium*) are well known to many biologists.[6] The fact that a complex process may be analyzed into simpler, physically constant component processes is no proof that factors other than physical do not play an essential part in its determination.

[6] Cf. the admirable discussion of Aristotle's biology in L. J. Henderson's *The Order of Nature* (Cambridge, Mass.: Harvard University Press, 1917).

We have just considered an instance of voluntary activity, the act of writing, as an example of a synthetic biological process. Among other biological phenomena the synthesis of a complex integrated whole is best illustrated in such processes as embryonic development and growth; either is a good example of a finalistic sequence, and it may be of advantage at this point to consider such a sequence in some detail. Let us begin with a simple physical model, as before:

An experimenter makes a stiff foam or emulsion of oil, soap, and water (Bütschli's model of protoplasm) and then molds it with his hands into the shape of a rabbit. If we examine microscopically what is happening at any region of the plastic mass as it takes form, we find, for example, that each droplet of emulsion is determined in its shape, position, and motions by a variety of local physical factors; these include flowing movements, pressure of adjacent droplets, conditions of surface tension, viscosity, electrokinetic potential, and so on. All these factors influence one another mutually and are dependent on the special composition, state of subdivision, phase relations, and temperature, etc., of the system at the region under observation. By careful observation and experiment we satisfy ourselves that these local processes are physically constant and determinate in the exact sense of mathematical physics. We then discard the microscope and consider the formative sequence as its appears on a large scale. We observe that the plastic mass takes on by progressive steps the shape of a rabbit. If we try to account for this, we find that it is not necessary to consider in detail all the single physical processes; the special course followed by the process as a whole is determined by a single comprehensive factor of a nonphysical type, namely, the image, conception, or Gestalt in the mind of the molder. His muscles furnish the physical energy for the process; but the exact manner in which this energy is applied depends on his purpose, artistic imagination, and will. These, however, are psychical, not physical, qualities. The sequence of physical processes culminating in the production of the model rabbit is open to external observation by anyone; but their physical character is not in the least altered by the fact that this sequence is under the mental control of the molder. The essential integrative factor is psychical, namely, the image, plan, or Gestalt in his "mind"; this is a stable condition which, without in any way infringing the physical conditions—which, indeed, are utilized and conformed to throughout—determines why the plastic mass assumes one final shape rather than another.

It should be emphasized that the purely physical analysis of the process, if carried out in sufficient detail and completeness, would also account satisfactorily, in terms of physical cause and effect, for the production of the rabbit. The formation of a foot or ear would be preceded by the outflow of a protuberance ("limb bud") in the appropriate place; here the lines of flow, while conditioned by physical factors, would have a definite relation to the formative process as a whole. The physical description would give a consistent explanation, sufficient up to a certain point, of "why" the mass of jelly took on this special shape. But so also would the psychological description of the image and motivation in the mind of the agent. Either description, physical or psychological, would be "true" —conformable to testable fact—so far as it went; but each would be incomplete without the other. For a complete scientific account of the process, including *all* observable factors, both kinds of description would be needed. No one could make a mass of plastic jelly into the form of a rabbit unless the material possessed certain physical properties—of consistency, tenacity, and so on—determined by its special physical and chemical composition. But, equally, the mass would not take on this form of its own accord without the directive control of a conscious agent with a comprehensive survey of the process and the end desired. It is clear that, if all the observable factors contributing to the morphogenetic process were considered and properly characterized scientifically, some would be classed as physical and others as psychical. If the whole combination of factors were regarded as constituting a single system, this would be more accurately described as *psychophysical* rather than as merely physical or merely psychical.

How far can the consideration of such a model be regarded as throwing light on actual cases of development in animals or plants? This is a difficult question. In any case, constancy in the physical factors of development must be assumed, since normally the whole developmental sequence is constant for each species; and physical analysis shows that the component materials and processes are also constant, within a certain slight range of variation. The simplest case of development would be, for example, the reproduction of a bacterium in a culture medium (unless a virus particle in its host protoplasm is living); the most complex, that of a human being from a fertilized ovum. Especially significant is the fact that development is a specific process; each animal or plant reproduces its own kind.

Briefly we may say that modern biology regards specificity in development as a character which is based on constancy and specificity in the chemical processes of metabolic synthesis; in other words, the structural and physiological specificities are based on chemical specificities. We find that a universal biochemical character of living organisms is the chemical specificity—in the sense of uniqueness of structural configuration as indicated by serological tests—of their chief protoplasmic compounds, the proteins. Modern theories of heredity regard the constancy in the course of development as determined by the structural and chemical constancy of the genes; these units are the specific stable factors underlying the stability of development; and the specific properties of genes are regarded as based upon the chemical specificity of their constituent proteins.

The modern physiological conception of development may be briefly outlined as follows: The complete organism, with its specific structural and physiological characters, is synthesized from unorganized materials (food, water, salts) collected from the environment. Each individual development, or ontogeny, represents a stable biological sequence or cycle; this cycle is associated with, and dependent on, a similarly stable set of physical and chemical factors and conditions which are partly internal, partly external. The developmental cycle shows great complexity of detail, increasing progressively as development advances toward its final stage; but the single details are found experimentally to be subject to definite physical determination and to have their regularly repeated and scientifically definable characters. Certain nuclear structures, which remain essentially unchanged in character throughout the whole of development (although increasing greatly in number), appear to have a special determinative relation to the whole process. These are the chromosomes, each of which contains its definitely ordered serial array of genes. The special determinative relations of the genes to the specific biological characters of the organism form an essential part of the modern biological science of genetics. The chief proteins of the genes belong in the class of nucleoproteins and are specific in their structural constitution; according to all the available evidence, the same genes (i.e., nucleoproteins) are present not only in the germ cells but in all the nuclei of the organism at all stages of development.

This presence of the same set of specific biochemical compounds distributed throughout the whole cellular organization of the animal indicates some definite relation to integration. Such a constant condition must mean something; what we observe is a widely distributed and uniform biochemical character having a correlation with the prevailing biological character or unity of the organism. Apparently the genes exercise a determinative control over the special processes of constructive metabolism by which the organism is built up and maintained. We have also experimental evidence that an important part of this control consists in promoting (possibly in the sense of catalyzing) the production of special biochemical compounds; thus the synthesis of certain enzymes or hormones has been found to depend on definite genes, and hormones are known to determine various special features of the adult organization—e.g., whether the structural and psychophysical characters are of the male or female type.[7]

The foregoing analysis is purely physical; and, in general, modern biologists regard development as a purely physical or

[7] A recent review of physiological genetics, with special reference to the gene, will be found in the article by Sewall Wright, "The Physiology of the Gene," *Physiological Reviews*, XXI (1941), 487. See also Richard Goldschmidt's *Physiological Genetics* (New York: McGraw-Hill Co., 1938).

physiological process the special course and integration of which depend on biochemical and structural factors. But we have already seen that not all cases of integration can be accounted for in purely physical terms. In the adult animal (e.g., a man) the functioning of the whole organism as a biologically well-adapted unity is well known to be largely dependent on psychological factors. It is true that these have their physiological correlates; e.g., a pain may have a definite symptomatic significance in the purely physical sense. Nevertheless, the obvious fact of psychical control reminds us, whenever we are disposed to forget, of the special character of the living organism as not merely a physical but a psychophysical system, and it shows the scientific insufficiency of a purely physical conception of the living organism.

We know that in the postnatal development of the child psychological factors play an essential part, as seen in the formation of habits, with their correlated physical characters. There is, however, no direct scientific evidence that psychical factors play any part in prenatal development. In general, biological theory regards the vegetative and routine functions of the organism as purely physical; thus, in the activity of the kidney or liver or in the development of the ovum, psychic factors are considered to take no part whatever; at least there is no evidence of their presence. The mechanist regards such processes as examples of organic machinery, analogous to the machines of human construction (like Paley's watch) which carry out their activities automatically and unconsciously. But such reasoning is scarcely conclusive, for we know that in the case of an artificial machine the imagination of the designer is indispensable to its production—at least in the first instance—although, once the machine is constructed and put in operation, mental factors may play no further part, unless occasionally, when repair or special adjustment is needed. Even the construction of a machine may be automatic, as illustrated in a well-designed assembly line, although even here there is always a certain minimum of mental supervision and control. The fact that psychic factors may now play no part in the production or activity of a mechanical system is no proof that such factors were never of importance.

Here we come to a problem which will be considered in more detail later, namely, what special features in the control of vital processes are attributable to psychical factors, and in what respect a psychical control differs from a physical control. What are the criteria of conscious intelligent actions, as distinguished from actions which have the appearance of being intelligent but are known to be purely mechanical—like the activity of a sorting machine or calculator?

We know that, in the highly trained human being, acts of the greatest complexity may be carried out unconsciously; but we also know that such acts are typically of a stereotyped kind, i.e., they are habitual or routine in nature. In the *origination* of such habitual activities, psychic factors may have played an essential part; but, once an action becomes well established, the conscious control lapses or disappears. The same is true of many familiar activities, such as writing, talking, or even walking; they have to be learned, and in the learning process psychical activity is indispensable; later they become automatic. Is it possible that the ancestral kidney or liver had first to *learn*, through an effort which had in it something of the psychical, to perform its function, now apparently purely automatic and mechanical? An alternative hypothesis is that the evolution of such a function occurred under the control of some more comprehensive psychical direction, producing its effect cumulatively through a series of generations. Such an idea would correspond, in some respects, to the older biological conception of orthogenesis.

If we combine this idea with modern genetic theory, the inference would be that the factors leading to evolution were variations or mutations originating under some kind of directive control which had its application in the gene system of the organism. The factors of evolutionary diversification still remain essentially unknown, but the selection of purely fortuitous variations does not seem to be a sufficient explanation for the origin of the more complex adaptive characters. The entrance of some directive or integrative factor seems to be required; and we are led to consider the manner in which factors of this kind act in our own experience where, as pointed out above, both physical and psychical factors can be directly observed.

Integration is a fundamental biological fact, and every synthesis is within its range an act of integration. We know that the integration of activity in higher organisms is in large part a matter of inherited physical organization; but we also know from human experience that many unified actions, especially those having in them an element of novelty or initiative, require the participation of psychic factors; i.e., they cannot possibly be carried out in the absence of attention and volitional control. In such instances the "mind" is intent, and accidental or other deviations interfering with the end-in-view are corrected by conscious acts of will. Both physical and psychical factors are present and open to observation; a performance like playing a game of tennis is full of actions which are automatic and purely mechanical; but the integrative control of these—whether they are permitted, repressed, or reinforced—depends on the mind of the player. His immediate field of consciousness is concerned; he is "interested," must act here and now; his psyche is strongly activated.

In general, what we recognize as the distinguishing property of the mental is its special quality of *unity;* a conscious field seems always to correspond to an integrative field. The separate items are held together in a unity of awareness; this is perhaps seen most readily in vision, with its predominantly spatial character, although temporal integration seems more definite in the auditory field, as in speech or music. The psychical control over activity is typically selective and directive, in the sense of aiming at conformity with some "purpose," i.e., some integrated image or conception which is held in mind and depends for its realization on future voluntary action.

In purposive action, integration is clearly dependent on psychical factors; the psychophysical character of the living organism is then most directly in evidence. But the degree to which the psychic factor is appreciable and enters as an effective factor in the behavior of living organisms appears to vary greatly; not only is this true of the same living organism at different times, as seen in human experience, but it seems especially true when we compare the different species of animals. In organisms other than one's own self the psychical is not directly observable, but its presence or absence can apparently be estimated by using certain criteria of comparative psychology, such as the ability to learn. This ability is based on memory, a general psychobiological character which seems to be correlated with the degree of neural integration and is chiefly developed in higher animals.

The physical side of living organisms is constantly present and is a condition of their stability of structure and function. Now, in general the distinguishing characteristics of the physical, as physical, are considered to be conservation, regularity, and quantitative constancy; the physical corresponds to the stable or routine side of natural process. On the other hand, the special adjustment of the organism to novel conditions seems to depend mainly on psychical qualities. In contrast to the physical, the psychical factors (if we may judge from our own experience) are evanescent and fluctuating; they act only in the present and are characteristically *lacking* in conservation. Consciousness appears and disappears (as shown in sleep and anesthesia), varies in intensity, is qualitative and immediate in its character, and is associated with pleasure and pain. In these respects it is strongly contrasted with the physical, where energy takes different forms but in its sum-total remains constant. Human experience indicates that consciousness is not always a factor in the physical activities of the organism. Apparently, it is aroused and becomes effective as a directive and integrative agency chiefly when the originative or nonroutine side of activity becomes important, as when there is some new demand on the response of the organism or when a situation has to be met which calls for some departure from routine—in brief, whenever the activity of the organism is of a kind in which integration is combined with *novelty* in action or adjustment. In our own experience, originative activity, initiative, and invention seem always to require psychical, as distinguished from merely physical, activity, as illustrated above in the instance of writing a sentence.

The general conclusion to which we are led by these considerations is that in living organisms physical integration and psychical integration represent two aspects, corresponding to two mutually complementary sets of factors, of one and the same fundamental biological process. It is this close interfusion of psychical and physical characters which gives living organisms their unique status in the natural world. In later chapters we shall consider in more detail some of the presuppositions and implications of this view.

CHAPTER III

Philosophical Aspects of General Biology

IN GENERAL, our discussion in the two preceding chapters has been scientific rather than philosophical and has had reference chiefly to the observed constant characters of living organisms and of the natural world in which they are set—and with which they are continually exchanging material and energy. But a consideration of constancies leads inevitably to problems of a kind usually regarded as philosophical rather than scientific.

The distinction between science and philosophy is not a hard and fast one and has reference to procedure rather than to final aim. Science aims mainly at tested knowledge, exactly formulated, of the actualities of experience, and especially of the permanent and continually recurrent features of that experience. But science has found that a mere description or tabulation of events as they are directly experienced[1] is not a sufficient or even a feasible aim. By a process of abstraction, combined with intellectual and imaginative reconstruction, it has built up a picture of nature which has reference not only to the experiential world of human beings but also to a world conceived as existing independently, i.e., as lying behind experience and forming the condition of that experience. And since human experience is always bound up with the processes occurring in a living organism, the relations between fundamental biological problems and the general problems of philosophy must be regarded as very intimate. When we consider the conditions and factors involved in any conscious experience, the border line between biology and philosophy tends to disappear. The living organism, viewed objectively as a part of external nature, appears as a natural system of a

[1] This would correspond to the program of positivism and is only partly realizable.

special kind, set in a physical or spatiotemporal environment. On the other hand, when regarded as a center of experience, or "subjectively," it is the seat of feelings, perception, and volition; and the environment appears as something of a different and strongly contrasted kind. But the two aspects cannot be separated from each other, and often a single item of experience is regarded as either objective or subjective, according to our special purpose and point of view; for example, this may be true of a colored object which an artist is thinking of inserting in his landscape.

It is not my intention to enter on a philosophical discussion of how the distinction between objective (which, for the present, we may identify with physical) and subjective (psychical) has come to be made. This problem is a difficult and complex one and is perhaps not susceptible of a complete scientific "solution." At least we have, as "given," the two sides of experience; and the universal human testimony to this effect undoubtedly has its scientific, as well as philosophical, significance. It does not seem possible to identify experience—the consciously felt or "lived-through"—with nature or cosmos, since immediate experience (our own, at least) reflects only a very small part of what we find nature to be when examined closely and over long periods of time. Recently there has been a tendency to denounce the term "experience," used as a part of the philosophical vocabulary, as being both vague and unscientific; yet this seems hardly justifiable. The boundaries of experience cannot be "defined" rigidly (defining is assigning boundaries!) because of its fluid and expansive character; and there is the further difficulty that, when attention is directed to its general features, it seems to merge into an extra-experiential background. But if we abandon this term, ill-defined as it is, we shall certainly be compelled to find a substitute, since the actuality to which it has reference is permanently present and undeniable; after all, as Descartes said, we exist and are. If any meaning is to be attached to the phrase "philosophy of organism," some attempt should be made to make clear just what permanent and demonstrable features in our experience—i.e., features that would usually be called "facts"—we have in mind when, as above, we characterize the living organism as a "psychophysical system."

When I use this term, I mean simply that we *observe* the characters and activities of living organisms to be both physical and psychical. The meaning of this statement seems clear: every human being will, I think, subscribe to it when he reflects on the main features of his own experience. To illustrate: a man is using his physical hands in driving his automobile, a physical construction, along a road, also physical; and at the same time he is receiving an impression of beauty from the landscape. The permanency of the physical machine and roadway are contrasted with the inwardly felt and transient aesthetic impression. There is a conviction of something external and permanent, which remains the same whether we are conscious of it or not, and also of something whose existence consists in its being inwardly or immediately felt ("lived-through") in the present.

In general, it is to these two sides of experience that we refer, respectively, when we use the terms "physical" and "psychical." The Cartesian dualism distinguishes between the extended substance without and the thinking substance within. Nevertheless, it is important to recognize that this traditional bifurcation of physical and mental is, in a certain very definite sense, an artificiality, as many philosophers have maintained, especially in modern times.[2] This time-honored distinction or duality, so sharply defined and unambiguous to the unsophisticated human being, is one which is made within experience itself. In a broad sense, experience is a unity; it is immediate,

[2] Among modern philosophers a notable example is William James; see especially his *Essays in Radical Empiricism* (New York: Longmans, Green & Co., 1943) (including "A World of Pure Experience" and other important papers). See, also, John Dewey's recent papers, "The Vanishing Subject in the Psychology of James," *Journal of Philosophy*, XXXVII (1940), 549, and "How Is Mind To Be Known?" *ibid.*, XXXIX (1942), 29; also his *Experience and Nature* (Chicago: Open Court Publishing Co., 1925) and *Logic: The Theory of Inquiry* (New York: Henry Holt & Co., 1938). Also, Whitehead, *Adventures of Ideas*, esp. chap. xv, "Philosophic Method." Recently, among biologists, Professor C. Judson Herrick, in a discussion of the mind-body problem, has expressed a similar view. He refers to "this clear-cut polarization of subject and object" as being "perhaps a methodological artifact arising from the radical difference in the use we make of introspective and extraspective experience. It seems to appear rather late in psychogenesis" ("The Natural History of Experience," *Philosophy of Science*, XII [1945], 68, footnote).

"phenomenological." As such, it forms the subject matter of the important philosophical field now called "phenomenology."[3] Evidently, we know the physical world only as it is experienced, i.e., as it becomes an "object" for the "mind"; the phenomenological is prior to the distinctions made within it.

At the same time, the scientific observer can have no doubt that the physical world—external nature, as we perceive it through our senses and intellect—has an existence which is independent of the individual perceiver; this independence is unquestioned by physical science, not merely as an article of faith, but for the reason that no other assumption is consistent with the range and character of scientific knowledge. Science therefore assumes the existence of an independent and autonomous reality, existing in its own right—the natural world or cosmos. Our experience is based on the sensory impressions and intellect of an animal perceiver and gives us only a limited representation of this cosmos. Yet this representation, such as it is, has a sufficient correspondence with the external reality to serve effectively the practical "purposes" of animal existence, such as individual survival and the perpetuation of the species. Science is a development, expansion, and tested codification of this type of knowledge, which is representative or symbolic rather than literal. We must acknowledge that the scientific view of nature is incomplete; that the self-existent reality or independent existence of which science is a partial representation is many-sided; and that not all sides of nature come under scientific review. In one of its aspects, science is an abstraction from the manifold of experience; in another aspect, it is a construction based on the data thus abstracted. But although we must accept the phenomenological view of the essential unity of experience, it remains true that an unavoidable distinction is made between the extended independent world "out there" and the feeling, willing, thinking world within; in the main, this distinction corresponds to the distinction between physical and psychical.

We observe, also, that the psychical world is attached to a

[3] For a recent extended review and criticism cf. Marvin Farber, *The Foundation of Phenomenology* (Cambridge, Mass.: Harvard University Press, 1943).

persistent experiencing center with a conscious (and unconscious) background of memory, and this center appears physically as a living organism. Scientific investigation may direct its attention to either world alone or to the interrelations which it finds between them. But for biology the all-important fact is that the physical object which is nearest to the perceiver and always forms the center of the perspective in which other objects are perceived is the observer's own organism.

In this sense the living organism is a center of experience. We have already reviewed the general physical characteristics of the organism. Its psychical side, of which the higher developments, as experienced directly in ourselves, constitute what we call "mind," is something which is not observed physically, i.e., through the sense organs of an observer with attention directed to objects in the external world. The external world is "public," open to the observation of many observers; the psychical world, as psychical, is individual or private. The psychical differs from the physical in being felt directly, not observed from without; it has the character of immediacy, and it should again be noted that as a correlate of this character the psychical (as existent) is always *in the present*.

The concept of present time, as distinguished from past and future, has its origin in this immediate quality of psychical experience. The physical world, on the contrary, is regarded as having the same kind of existence in the past as it has in the present. Psychical origination, e.g., in volition, is usually regarded as being in its nature *internal* rather than external. The very word "external" implies the existence of a correlative internal or central station of observation; it is in relation to this experiencing center that the physical or spatial world is *external*. We see things in perspective; each psychical center is insulated; in Leibnitz' terminology each is a "windowless monad," the term "windowless" referring to the universal fact of psychical isolation or selfhood. Similar considerations apply to modes of perception other than the visual; tactile, auditory, and other sensations require as their condition the physical impact of external objects or energies on the central perceiving organism, which, accordingly, is spoken of as "one's own."

Although the generalizations just cited are derived from human personal experience, they undoubtedly apply to experience as centered in other (at least the higher) animals. The conclusion seems justified that each living organism, in addition to being a product of physical concrescence, has a special kind of inner directly experienced unity, to which we apply the term "psychical." To regard psychical as the antithesis of physical, and completely different from it, would be inconsistent with the observed close association of psychical and physical. Nevertheless, psychical characters, as an expression of this self-centered character, have their peculiar qualities different from the physical. It is in its aspect as psychical that the living organism exhibits the properties of feeling and passive perception, combined with inwardly determined activity or conation (will). Physical causation consists in the transfer of energy from one physical entity to another entity which is *external* to it, i.e., has a different position in space. In what we may call "psychical causation" (determined by "will") certain features of the transfer of energy appear to be *inwardly* determined; they also have the characters of directiveness and purpose. These characters are not dissociated from the physical but occur in intimate union with it; nevertheless, in the vital directiveness there seems to be present a source of determination which is not derived from the world external to the active center but has its origination within the center itself. According to modern physics, each atom represents a large internal store of energy (rest-mass energy), the greater part of which is self-contained and nontransferable. In the living organism, which consists physically of a concrescence of atoms, the same must be true; and it seems reasonable to assume that in some way this internal energy serves as a source of the energy exhibited in psychical activity.[4]

In its situation as central or inclosed, i.e., as immersed in its natural setting, each living organism is acted upon by the converging forces of its environment; and in turn it acts or reacts upon that environment. *Direct* physical interaction between organism and environment is restricted to the immediately

[4] Cf. chap. iv.

adjacent, i.e., contiguous, regions of both; from this region of contact (and to it), influence is transmitted to (and from) more distant regions. In physical causation temporal and spatial contiguity between "cause" and "effect" is always required. If a distant event influences one near at hand, it is always through the intermediary of radiation or some other kind of physical connection (mechanical, electrical, gravitational, etc.) which establishes continuity between the events. In the interaction between organism and environment the same rule holds.[5]

The close biological interdependence between physical and psychical is shown by the physiological observation that an essential determining condition of the psychical immediacy is physical activity occurring in certain definite regions of the organism; for example, in the human being such a region is the retina or the cerebral cortex. We have seen that the physical origin of the organism is traceable to materials and energy taken from the environment. As a physical system the organism is a product of past physical activity; it has its definite historical origin and background; and its physical characters have the persistence, stability, and regularity that we associate with the physical. Its development in the evolutionary history of nature has been a gradual process, apparently because slowness of change in evolution is a consequence of the general natural requirement that any orderly activity must have a foundation of stable (or near-stable) conditions.

To the naturalist, observing nature as an external system, the essential factors of evolution appear as physical factors, acting under physical conditions. Many of these conditions appear to observation as fixed or permanent ("endurants");[6] either they are primordial—without assignable origin in past time—or they are the persistent results of activity which has occurred in the past and has completed itself, leaving a stable product or residue which continues into the present and deter-

[5] For fuller discussion cf. my paper, "Biological Causation," *Philosophy of Science*, VII (1940), 314.

[6] Professor Roy Sellar's term; see his *Philosophy of Physical Realism* (New York: Macmillan, 1932).

mines (or limits) the nature of activity in the present. Note that this statement emphasizes the fundamental importance of *conservation* in physical nature. The conservation of energy, of mass, and of spatiotemporal and other conditions is a cardinal doctrine in theoretical physics; physical nature is regarded as extending continuously and uninterruptedly through time as well as through an indefinitely extended volume of space.[7] These stable physical characters form the substratum or matrix within which the psychical, with its immediacy and transient quality, makes its appearance. It is in this sense that the psychical appears as a general character of living organisms. This contrasted, yet mutually complementary, character of physical and psychical must always be borne in mind in considering the general characters of living organisms.

There is some danger of misunderstanding when "physical" and "psychical" are used as if they referred to entities or realms of being which are in their nature disparate and discontinuous—corresponding, as it were, to two separate fields which come into interaction in some way which is quite incomprehensible. To avoid this misunderstanding, I wish expressly to disclaim a dualistic view; the two fields, physical and psychical, are rather to be regarded as grounded in the same foundational reality and as representing different aspects of that reality. Such a view corresponds to the "double-aspect" view of psychology, which is essentially monistic. As a physical system, which at the same time is a center of psychical activity, the organism partakes of characters belonging to both fields. When we consider it as physical, we visualize it as a local volume of organized matter and energy which is continuous with a more inclusive or enveloping world (environment) from which it receives, and to which it transmits, activity and

[7] This does not necessarily mean *infinite*, in the sense of unlimited magnitude, but rather without assignable boundaries, resembling in this respect a closed surface like that of a sphere. Using this model, physicists have reached the conception that the universe may be "finite yet unbounded," an idea which may have important theoretical consequences; thus, on a spherical surface a straight line (great circle), indefinitely prolonged, returns to its source, and, analogously, we may regard as possible a re-entrant distribution of energy rather than a permanent dissipation into an infinitely large volume of empty space. Such a conception of world geometry would support the principle of conservation, which otherwise seems to meet with difficulties.

influence. Apparently, this influence may be physical or psychical, or both; experientially, the two fields, physical and psychical, appear as separate and yet as influencing each other directly; there is no scientific ground for denying the reciprocal nature of this interaction.

The appearance in consciousness of a constant sensory quality—e.g., a definite color sensation like blue—is not to be accounted for by physics alone, with its methodical abstraction from the felt or qualitative in experience. This or any other sense experience may appear to the experient subject only under definite physical conditions. But the experience itself is psychical, and it may with equal justification be regarded as demonstrating the natural existence of constant properties or universals of a psychical kind. These, however, become evident only under definite physical conditions. In the case of the blue sensation, we find experimentally that these conditions are furnished (in human beings) by excitation of the retina (assuming its properties and connections intact) by light of a constant physical wave length (about 470 mμ). But we also observe that the same blue sensation may arise in consciousness independently of external stimulation by light—for example, in dreams or imagination or under the influence of drugs. Such facts are a small part of the evidence showing that the psychical comes into present experience—its own kind of existence—only under definite physical conditions.

Although the physical and the psychical activities of the natural systems, living organisms, which we are considering, are usually thought of as quite different in their nature, this difference in mode of conception means only that the two kinds of activity are represented intellectually in different terms. Our present view regards them as forming together a natural unity which we call "psychophysical"; they are not to be regarded as separable or capable of independent existence in the strictly realistic or existential sense. If we adopt the view of panpsychism, this would also be true of other natural systems and of nature as a whole. All psychical activity would be psychophysical; the disembodied psyche would not be capable of existence, or at least of making itself a factor in the natural world. An implication would be that the physical side of natural systems corresponds essentially to the stable or conservative side of nature, represented under Group A in our scheme above.

In psychical existence, on the other hand, there are certain characteristic features which are usually regarded as entirely absent from the physical, as physical; these are the conscious phenomena of animal (human) life called "feeling," "motivation," and "will." Physical events, as science now conceives them, are characterized, above all, by regularity, constancy, and spatiotemporal continuity with their surroundings. Continuity is an aspect of conservation; what one physical entity gains in energy, another loses. These characteristics are perhaps best expressed by saying that the physical order is a strictly mathematical order, which means a permanent order. No one regards a purely physical event as actuated by desire and motivation; its cause is determined by conservative conditions into which no element of the psychical enters. Thus we often speak of the impartiality or cold-bloodedness of physical events. In contrast, psychical events have an element of preference or selection; this seems connected with a certain property of novelty which they possess as part of their nature; and this, again, is related to their evanescence and lack of continuity. A psychical experience, e.g., a sensation or a volitional impulse to action, often seems to issue from nowhere; its appearance in consciousness may have no discernible psychical antecedents of a similar kind. Psychical events are transitory, and in their volitional aspect they are not impartial but preferential.

Preferential implies valuational; and it seems relevant at this stage in our discussion to indicate briefly the role which the feature of experience called "value" may be conceived as playing in the psychical life of organisms. The philosophical theory of value is a large and important field of study and inquiry on which I am not competent to enter in detail; yet no naturalist can doubt that elementary feelings of value are present as factors in the psychical life of many animals, especially the higher. In science it is customary to dissociate considerations of value from the representation of physical reality; this, however, is to be regarded as an abstractional procedure which does not at all imply that value and fact can be entirely separated from one another.[8] All observation indicates that motivation plays its part in animal behavior; and while this motivation has its physical side (as in any psychophysical system), there is also the psychical side in the estimation of which considerations of value cannot be excluded. E. S. Russell uses the term "valence"[9] in reference to the elementary values which external objects, such as food, the other sex, materials for nests, etc., may have for animals; these valences determine the motivation which, from analogy, we assume to underlie their voluntary behavior To regard will and motivation as not real factors in animal behavior would imply that they are not real factors in human behavior—surely an unrealistic position to take; and while at times scientific men may have held this view, it seems at the present time to be outdated. On the other hand, no impartial observer can deny the importance of physical factors in behavior.

The evanescent character and untraceable origin of many conscious experiences often give an impression of arbitrariness (especially in dreams), and the belief in the "free" character of voluntary action has no doubt arisen in this way. The initiatory and spontaneous actions of human beings share this quality of the psychical; they have in them something which is unpredictable. At the same time, biological experiment shows that they are limited by physical conditions; according to physiological psychology, all psychical processes have their definite physical antecedents and accompaniments, consisting chiefly in processes occurring in the nervous system. In this empirical sense, physiological conditions may be regarded as the foundation on which the regular or repeated psychical qualities (the "immediates") are based. Any test that can be applied shows that a man's brain preserves its uninterrupted existence and its constancy of physical characters whether he

[8] Cf. the recent discussion by W. Köhler, "Value and Fact," *Journal of Philosophy*, XLI (1944), 197; also his *The Place of Value in a World of Fact* (New York: Liveright Publishing Corp., 1938).

[9] E. S. Russell, *The Behaviour of Animals* (2d ed.; London: Edwin Arnold & Co., 1938).

is awake or asleep, somnolent or intensely interested. The normal physical functioning of this organ is necessary to a normal psychical life. At the same time, a large part of the psychical, as psychical, is nothing if not variable; and scientific psychology is largely concerned with specifying the stable physical conditions or physiological background under which the variable and transient psychical characters emerge.

This is by no means the whole of psychology; the regular characters of the psychical, considered as psychical alone, in provisional disregard of the physical accompaniments, also form an important part of its subject matter, as in the experimental study of Gestalt phenomena, sensory discrimination, contrast, pain, pleasure, and other purely psychical processes; such investigations yield descriptive results from which definite conclusions and generalizations are reached. But, as remarked earlier, elementary psychical characters, like feeling and will, cannot be described; they can only be experienced. In general, description applies only to those items of experience which are composite, in the sense of being analyzable into combinations of stable, simpler elements or factors. The ultimates or unanalyzables, such as simple sensations of sound, color, or feeling, are not describable, although they have their constant qualitative and other characters, as is shown by the usages of language, which applies constant terms (loud, shrill, blue, hot, cold, etc.) to those psychical characters which recur continually and are easily discriminated.

In the traditional classificatory triad of psychology—feeling, will, and intellect—the terms "feeling" and "will" have reference to immediately present psychical qualities or events; their "immediacy," i.e., felt property or givenness, is what constitutes their character as psychical. "Intellect," on the other hand, has its application not so much to single experiences as to the general, repeated, or universal characters which appear constantly in association with experience and qualify or condition its single events. It seems clear that the classifying activity of intellect is a reflection or expression of the orderly and repetitive features of experience; these features coexist with and apparently underlie the novel features which also form part of experience.

When experience is surveyed, either immediately or in memory, the attention readily singles out a variety of components which are either constant or recur from time to time in the same form; these constants give a special form and character to the individual events as they occur. In other words, objects and events fall into classes. What seems especially striking to the biologist is that many of these stable characters are psychical, rather than physical, in their nature; yet their biological importance is on the same level as that of the physical. The visual field is a good illustration. This has its constant features which form a stable setting for the events continually occurring within it;[10] these events, although psychical, are an index of the spatial position, movements, and physical properties of external objects, many of which are of special interest (or valence) to the perceiving animal. In this respect, psychical events have their definite biological significance; they play a part in the life of the organism similar to that played by its physical activities. In both cases the fundamental biological importance of the activity, whether physical or psychical (or both), consists in its being a factor in the survival of the individual or species. Obviously, the persistence of a species in an environment implies the persistence or regular repetition of the physiological conditions and activities upon which its existence depends. It also implies the persistence of correlative constant conditions in the environment; i.e., regularity, both in the organism and in the environment, is a necessary condition for organic survival.

It seems clear that intellect, as a biological attribute or activity, is based upon this universal natural fact of regularity and recurrence. Repetition—spatial or temporal, or both—is universal in the natural world; and no one need be surprised that the whole organization of animals and plants bears witness to this fact and is based on it. As has long been recognized, at least since Plato, repetition is an aspect of constancy; it im-

[10] Cf. above, p. 17.

plies the presence of stable conditioning factors which impart constant characters to the single facts or events as they occur, although each single event is itself individual and transient. We may assume that primitive man was well aware practically (even if his knowledge was not formulated) that many of the numerous objects and events in both his inner and his outer experience resemble one another and fall naturally into groups, i.e., the collections of similars which we now call "classes." This is perhaps sufficiently proved by the general characteristics of language, based, as it is, on the permanent or recurrent facts of experience.

Considerations of a similar kind apply to animals lower in the scale than man; in general, the biologist observes that all animals are adapted or "keyed" to respond to special natural objects or conditions which are of importance to them. This responsiveness has its basis in certain definite active and structural features of their organization; and in each species these biological characters have a correspondence with certain stable or recurrent features of the environment. If, for example, an animal exhibits special structural characters which protect it against attack, such as spines or defensive armor, their existence shows that such attacks are of frequent occurrence in its normal life. In general, the special organization of the living organism is a testimony and index to the existence of correlative conditions in the environment—in the case just cited, the activities of predatory animals. Similar considerations apply to all forms of interaction between organism and environment, from the simplest to the highly developed. To quote from an earlier paper: "The intellectual apparatus of conceptual reasoning must be regarded as having a correlative physiological apparatus consisting of permanent organic predispositions and adjustments of various kinds; these adjustments correspond to the various continually recurring situations which the organism must be prepared to meet in its normal life."[11]

It is not possible to discuss here the philosophical signifi-

[11] "What Is Purposive and Intelligent Behaviour from the Physiological Point of View?" *Journal of Philosophy, Psychology and Scientific Methods*, XII (1915), 589; cf. p. 609.

cance of this repetitive structure which apparently pervades all physical nature as well as its psychical correlative, the conscious experience of living beings; for the present we simply accept it as a fact. Generalizing broadly, we may assume that behind this natural system of recurrent events and phenomena, physical and psychical, there exists a correspondingly large and diversified assortment of stable factors which furnish their necessary foundation. These factors correspond to the "eternal objects" of Whitehead (alternatively called "forms of definiteness"); and their relations to nature, as experienced, will be considered more fully below.[12]

[12] See Whitehead, *Process and Reality*, *passim*. An excellent discussion from the standpoint of a biologist will be found in the paper by W. E. Agar, "Whitehead's Philosophy of Organism: An Introduction for Biologists," *Quarterly Review of Biology*, XI (1936), 16; see also his later paper, "The Concept of Purpose in Biology," *ibid.*, XIII (1938), 255, and his *A Contribution to the Theory of the Living Organism* (New York: Oxford University Press, 1943; also Melbourne University Press). A general discussion of Whitehead's philosophy of organism has recently been published by Sydney Hooper in *Philosophy*, XVI (1941), 285; XVII (1942), 47; XVIII (1943), 204; XIX (1944), 136; XX (1945), 59. See also Dorothy M. Emmet, *Whitehead's Philosophy of Organism* (London: Macmillan & Co., 1932).

CHAPTER IV

Physical and Psychical

ONE task of a scientific psychology is to determine, and to define clearly, the constant conditions under which psychical qualities come into existence, i.e., "emerge" into consciousness. Another task, equally important, is to determine the conditions under which effective influence is transferred, in either direction, between the physical and the psychical fields of the organism. We have seen that psychical qualities, as such, have the character of immediacy; they are psychical only while they are being experienced, i.e., in the present. This statement may sound like "psychical only while they are psychical," but just now my aim is to contrast, as sharply as possible, the sphere of reality called "psychical" with that called "physical"; and for this purpose it is necessary to emphasize differences rather than resemblances.

Obviously, our knowledge of the physical world has its basis in personal experience, which, as immediate and in that sense subjective, is psychical; but many features of that experience are scientifically unintelligible except on the assumption that a permanent and independent realm of being exists, continuous in space and time and having regular "causal" interconnection between its separate events; this realm is the *physical*. It is in its character of permanent or uninterrupted existence that the physical is here contrasted with the psychical; thus, to physics, objects which are distant in space or time and unperceived are no less real than those which are immediate objects of perception. In contrast, the psychical, in its character as psychical, is real only in the present; and its existence is correspondingly transient.

This transiency imposes limitations on scientific description as applied to the psychical field, i.e., considered purely as psychical and untranslated into its physical equivalent. The psychical, since its character is immediacy, is evanescent; it exists only in the temporal span of the present. On the other hand, that which *remains* in existence as the result of psychical activity (e.g., an exertion of will resulting in muscular action) is physical and has the property of conservation characteristic of the physical. Present events—and psychical events are always present events—have permanent results. This transiency of single present events, as contrasted with the permanency of their results, is often dwelt on in literature, as in the sundial motto quoted by Whitehead, "Pereunt et imputantur," and is a favorite theme with poets.[1] Accordingly, psychical action may (and often does) provide, directly or indirectly, the permanent physical conditions which determine the special character of many succeeding events, both physical and psychical.

It is true that psychical facts, in so far as they are constant or regularly recurrent, are also recognized (when reviewed in memory) as belonging in definite or stable categories; accordingly, they can be and are designated in language by constant signs or words; i.e., language has its basis in the recurrent character of psychical, as well as physical, events. "Blue" refers to a definite class of psychical event, although each instance of its occurrence is an immediate personal experience. But since this experience emerges with perfect constancy under certain physical conditions, namely, the human (one's own) neurosensory organization activated by radiation of 470 $m\mu$ wave length, the problem of defining its conditions of emergence becomes a purely scientific one, to be solved by empirical investigation.

[1] See, e.g., Tennyson's "Lotos-eaters":

"All things are taken from us and become
Portions and parcels of the dreadful past."

Fitzgerald's stanza in Omar Khayyam is familiar:

"The moving finger writes and having writ,
Moves on. . . . ."

Recently a well-known critic of literature, referring to Proust's description of how, for example, old memories are revived by odors (in his novel, *A la recherche du temps perdu*), has given an admirably clear expression of this general fact: "In our lives the past is that which has ceased to act but has not ceased to exist" (Mary Colum, *From These Roots* [New York: Charles Scribner's Sons, 1937], p. 352). Proust was influenced by Bergson: memories survive in the unconscious and have the potentiality of rising again into consciousness. "Time the destroyer is time the preserver" (T. S. Eliot, in *Four Quartets* [New York: Harcourt, Brace & Co., 1943], p. 24). See also the discussion of C. D. Broad in his *Scientific Thought* (New York: Harcourt, Brace & Co., 1923), pp. 66 ff.

Similar considerations apply to other regular psychical facts; as psychical, they appear, disappear, and vary in intensity and quality; obviously, they lack the kind of stability or conservation which we ascribe to physical facts. Yet their recurrence is subject to stable rule; their special *quality* is constant, and this constancy is found experimentally to be associated with constancy in the physical determining conditions. Both psychical and physical events, considered singly, show the usual combination of generic and individual characters, but in the psychical the element of individuality and uniqueness asserts itself with greater distinctness; this is the feature of novelty always present in the psychical, as contrasted with the conservation which is the characteristic feature of the physical.

It is important to bear in mind that the characteristic of *presentness* (which means "novelty") is an essential peculiarity of psychical facts; this characteristic is of the greatest importance in relation to the part which they play in the life of the organism. Life is based on present activity; and this activity cannot be long interrupted without permanent physical injury or breakdown, as shown, for example, in the effects of depriving nerve cells of oxygen. Purely static or conservative (structural) conditions, however important they may be, are not in themselves sufficient for the stability of the living system. The biophysicist might object here that the dependence of life on a routine of active processes need not imply the presence of special psychic factors; there are many automatic routines in nature which are governed by constants of a kinetic kind; life might consist entirely in an organization of such routine processes. These processes, like other physical processes, have the same character in the past as in the present. This may be granted; but what I am now emphasizing as important is merely that whenever the psychic factor does play a part in a natural process, its participation is necessarily in *present* time and has in it an element of novelty. This condition is emphasized now because of its importance in our later discussion.

The fact that many psychical events (sensory thresholds, etc.) conform exactly to quantitative rule is evidence that conservative conditions are a constant factor in psychical, as well as physical, activities; the chief reason why these constant conditions are usually conceived by psychologists as physical (or physiological) is that conservation is recognized by science as the essential distinguishing feature of the physical. Accordingly, there is a strong tendency for modern psychology to become predominantly physiological; apparently it cannot be purely phenomenological and retain the accepted characteristics of natural science. As science, psychology aims at the discovery and clear formulation of *all* the factors underlying psychical events and furnishing the constant conditions necessary for their occurrence. Like other sciences, it is concerned with observable facts and conditions which have the empirical properties of constancy and reproducibility; these properties imply quantitative character—measurability and amenability to mathematical treatment. Such characters are typically regarded in science as belonging to the objective and physical and are contrasted with the subjective and transient property peculiar to the psychical as such. Hence, physical conditions, especially organized structural and physiological arrangements of a constant kind, are assumed to be the "objective" counterpart of the psychical; and observation bears out this assumption.

Although in strict realism the living organism must be regarded as a psychophysical rather than a purely physical system, its physical characters, because of their permanence and demonstrability, have often been regarded as having a superior title to reality or even as being the only reality. Such claims have a certain plausibility, since all experience confirms the view that the physical world is a stable world with an uninterrupted existence, differing from the psychical world in being independent of the experiencing subject's attention or state of awareness: a man's organism persists in all its physical character during his unconscious, as well as his conscious, states. This permanent physical organism is the seat of the stable factors and conditions which underlie the psychical events; "consciousness" has even been regarded by some extremists as an unreal and scientifically negligible by-product or epiphenomenon. Physiological psychology has discovered and measured many of the physiological factors concerned in psychical processes, and its progress has strengthened the tendency to regard physical factors as the necessary foundation and essential determinant of psychical events. This belief is now widespread not only among scientific men but among educated persons in general.

The progress of physiological psychology is, however, no justification for ascribing an exclusive reality to the physical factors in vital phenomena. The belief that the "soul" (psyche) influences the body is an ancient and empirically well-grounded belief; and many parallels between the stable features of a man's psychical character—moral quality, talents, will, temper, and so on—and the physical features of his bodily organism have been well known to physiognomists and students of human nature from time immemorial. A psychosomatic medicine, not entirely rudimentary, was practiced by the ancients and is now a recognized field of practice, with a large literature and its special journals.[2]

The importance of the psychic factor is now recognized in many fields of pure and applied biology. Certain modern schools of psychology may even overemphasize the autonomy of the psychical and its independence of the physical. They regard the unconscious background of psychic life as consisting largely of factors which in their primary nature are psychical rather than physical. According to Freud, the determining conditions of the psychical cannot be adequately represented by purely physical models. He believes that the conscious characters of a human personality have an unconscious foundation consisting of a complex of conditions which are psychical, rather than physical, in their essential nature; these constitute the stable core of personality and persist throughout the individual life. A conservation is ascribed to them which parallels the physical (or physiological) conservation while not identical with it; the stability of the fundamental psychical qualities and propensities of a personality (which remain constant

[2] See the American quarterly *Psychosomatic Medicine.*

in spite of continual physical change) is pointed to in support of this contention.

The whole modern psychosomatic movement shows the difficulty of any strict separation of psychical and physical. To some biologists there may seem to be an inconsistency in assigning stable characters, i.e., characters enduring through time in the same sense as physical characters, to psychical factors qua psychical, since the experienced character of the psychical is immediacy and transiency, not permanency. Yet this apparent inconsistency need not be real, since direct personal experience, as distinguished from scientific abstraction and schematization, shows clearly the psychophysical character of the organism. Also, there is ample evidence, which no one seriously doubts, that psychical characters have a real existence in innumerable fields of which the individual subject is completely unconscious, namely, the "minds" of other subjects—each mind being attached (as one's own is) to a physical organism.

It might be assumed that the "unconscious" psychical factors underlying the conscious life of any one person have a status, in relation to his whole or integrated consciousness, analogous to that which *another* person's conscious life has to the life of the social group to which he and many others belong. This is not a perfect analogy, since the consciousness of a human group is not integrated in the same sense as the personal consciousness of a single individual. The single individual, however, is not directly conscious of the psychic life of his separate cells and tissues, supposing this to exist. A possible view is that immediate consciousness in the mind of any single person is an indication that certain subthreshold psychical conditions, which nevertheless have a real existence as psychical, have reached a certain critical level of intensity, or have effected certain combinations or interactions necessary for the emergence of the superthreshold consciousness. Such a view would seem to imply the existence of a permanent psychical substratum or background, which is united in some way with the physical and reaches the level of personal consciousness only under certain physical conditions. Without passing judgment on this question we may say that to the general biologist one of the chief features of the Freudian conception is its insistence that the living system is a psychophysical rather than a merely physical system. This, of course, was the ancient conception and may be found clearly set forth in the work of that great naturalist Aristotle.

The concepts "purely psychical" and "purely physical" are to be regarded as abstractions, taken from a total reality which combines characters of both kinds. Undoubtedly, there are great difficulties in approaching scientifically the problem of the final origin to be assigned to the psychical qualities of the organism, so highly developed in man and higher animals; but experiment leaves no doubt of their close and constant association with the physical. Such a conclusion has implications of a general or metaphysical character; if we extrapolate beyond the level of animal existence to the general background of nature, the conception of the living organism as psychophysical would seem to require logically a conception of the whole natural world as also psychophysical in its essential constitution—a view related to the widely entertained philosophical doctrine of panpsychism. This view is a monistic rather than a dualistic one; it regards existential nature as combining characters of both kinds, physical and psychical, grounded in a single unity which in reality cannot be so subdivided in any strict sense, although abstractly and for certain purposes we may consider single natural factors as belonging to one or the other of these two classes.[3]

We have now to consider in somewhat more detail the nature of the interrelations between physical and psychical. Some remarks of an abstract and general kind may first be made. Physical science traces the spatial and temporal con-

[3] The conception of an all-pervading or "cosmic" reservoir of psychical characters and qualities—the psychical counterpart of physical nature—which manifests itself in the individual consciousness only partially and under certain physical conditions is one that has been widely held. Recently among physical scientists the astronomer Gustav Strömberg has given clear and striking expression to this view; see his paper, "The Physical and the Non-physical Worlds and Their Intermediate Elements," *Scientific Monthly*, LIV (1942), 71; also for a more speculative consideration, chap. ix of his book, *The Soul of the Universe* (Philadelphia: David McKay Co., 1940). A modern view of panpsychism is found in the recent book of Charles Hartshorne, *The Philosophy and Psychology of Sensation* (Chicago: University of Chicago Press, 1934); see esp. chap. viii.

tinuity and the functional (or "causal") connections between the separate phenomena of the external world. It regards all physical entities and activities as contained within the same space-time continuum, which is, or includes, physical nature; and the causal relation, qua physical, is confined within this continuum.[4] Hence there is always the possibility of accounting more or less completely for an event's happening in one region of external nature by tracing its connections with events and conditions in other regions. Apparently there cannot be more than one such continuum, since the very expression "more than one," signifying plurality, implies separate positions within a single continuous field. If objects are to be recognized as *separate*, there must be something "in between," even if only empty space or time.

Observation shows that wherever the space-time co-ordinates of previously separated events intersect, i.e., where the events come into contact, there is always mutual influence, or "causation." It is a truism that two physical objects cannot occupy the same space at the same time; and this general observation implies that physical interference—implying the persistence of a certain individuality in single objects and events—is a fundamental fact of nature. Many of the physical relations between separate objects can be defined with quantitative exactitude because of the uniform nature of the medium, space-time, by which they are connected. Geometrical and mathematical relations are universal; natural events are always a certain distance apart in space or time, or both; and physical influence between separate events is largely dependent on this distance.

Such other general scientific facts as the conservation of energy and mass, the constant transmission-velocity of radiation, the constancy of energy units, and the regular repetition of physical events and cycles, all point to the existence of an all-inclusive physical field with uniform and stable properties, which is the seat of the observed physical diversity. It is be-

[4] This is the extensive continuum, corresponding to the general scheme of relatedness within the universe. For a discussion by a biologist cf. Agar's paper, "Whitehead's Philosophy of Organism," *Quarterly Review of Biology*, XI (1936), 16; see p. 23 of this paper.

cause we can proceed on this assumption—the ultimate basis of which is simple observation—that the phenomena of physical nature are so largely describable in logical or mathematical terms, i.e., in terms of invariants and constants and their interrelations.

Single physical objects and events appear as discrete areas or differentiations within the spatiotemporal continuum, and local changes appear as in continuity with other local changes in their immediate vicinity; every physical object has a physical environment and a physical interior. This leads to a further consideration, of special importance for biology, which is as follows: Because of the continuity of geometrical space (as assumed in mathematics), any spatial volume is regarded as subdivisible without limit. Each element of volume is regarded as *real;* accordingly, the possibility of magnification enters, i.e., of bringing any such element, no matter how small, within the range of perception by imagining it as sufficiently enlarged; and it has long been known that the physical properties of radiation, as influenced by refraction, can be utilized so as to make the minute inner detail of small-scale objects visible to observation. This circumstance enhances enormously the possibilities of physical analysis and explanation; detail within detail can be perceived almost without limit, and the art of microscopy is still advancing, especially since the invention of the electron microscope. No one need be reminded how greatly indebted biology is to magnified images for its conceptions of living structure and constitution. Where would this science be without the microscope?

The eye is the chief, though not the only, organ of physical observation; and in forming our conceptions of the fundamental structure of natural objects we must make allowance for the irresistible psychological tendency to identify physical things with their visual images. These images, made usually by lenses, form the chief means by which the higher organisms, including ourselves, adjust themselves to their physical environment; the eye has evolved because such images are a reliable index of the direction, size, distance, and movements of objects within the organism's field of action.

It must be remembered, however, that at the smaller end of the scale of physical dimensions the properties of radiation themselves limit the possibilities of further optical discrimination. Accordingly, it becomes unrealistic to form imaginary visual images of physical objects and conditions as they exist below a certain degree of spatial subdivision and then to regard these images as giving true representations of the actual structure and behavior of objects. Radiation has a resolving-power giving evidence of spatial separation of component units down to a certain limit, but not beyond.

What lies beyond that limit? We can scarcely hold that reality ceases where physical observability ceases; and if there is a more intimate reality of objects, access to this reality must be sought by other methods than the physical. Is it an extravagance to suppose that introspective (immediate or psychical) observation may furnish one such method, affording further and equally valuable insight into the real nature of the living organism? We know from experience that certain vital phenomena may be experienced directly even when they cannot be physically observed; no one can observe a feeling, in its quality as feeling, by physical methods, although its physiological accompaniments and conditions may be observed by these methods to any required detail, presumably down to the limits just indicated. The feeling is a psychical, not a physical entity; observation from both sides, physical and psychical, is required if we are to gain the fullest possible insight into its nature and conditions as a special biological fact. This is recognized in practical life, as in the case of the philosopher's toothache (a favorite illustration);[5] his pain is used by the dentist, a physical manipulator, as a means of physical diagnosis, for the simple reason that observation shows the physical and the psychical facts to be interconnected in a constant way. In many other instances the same biological condition or event may be observed either from the outside as physical (i.e., part of the spatial world) or from the inside (introspectively) as psychical.

[5] "For there was never yet philosopher
That could endure the toothache patiently."
—*As You Like It.*

This characteristic dual property of vital phenomena has received its special formulation in the so-called "double aspect theory" of psychology.[6] The term "double aspect" implies the existence of an actuality that is unitary in character but can be observed from two quite different points of view. There is, perhaps, a difficulty in understanding how one and the same natural process can be both physical and psychical at the same time. But it may be a mistake to regard this difficulty as presenting a "problem," since the dual property appears rather to be a fundamental condition which has to be accepted as part of the innate constitution of nature. The living organism is psychophysical because it is a development from a nature which is psychophysical. To search for a "solution" may not be the proper method of consideration or approach; the traditional bifurcation may be an artificiality, as indicated already (p. 53).

In any case, an essential scientific requirement is that whatever is actual or forms a part of real nature shall be represented (where representable) *consistently* by the conceptions of physical science, so far as these are "true." In physics *energy* is regarded as the ultimate natural reality, conserved in all processes. Any act of visual observation requires transfer of energy from the observed object to the eye of the observer. But if we identify physical reality with energy—as the factor manifesting itself in all physical events—the *whole* reality of any physical object can be only partly indicated by the small fraction of energy which it emits or reflects in the form of radiation and by which it is made visible to an observer. Mass (m), the most general property of physical objects, is, according to Einstein, a manifestation of energy (E) according to the formula $E = mc^2$, where c represents the velocity of light. This theory recognizes that the intrinsic or "rest-mass" energy of any body or physical unit (such as an atom) is vastly superior in quantity to the energy which it exchanges with other bodies interacting with it mechanically or by radiation. The greater part of this in-

[6] An excellent discussion of this theory is given in the presidential address of Professor H. C. Warren before the American Psychological Association, at the New Haven meeting, in 1913: "The Mental and the Physical" (*Psychological Review*, XXI [1914], 79).

ternal energy is not transferable but remains bound to, or an integral part of, the physical unit.

The experience which is centered in each psychical unit (such as one's self) appears to be inseparably attached to a single physical organism; and it may not be merely fanciful to suppose that in the immediate experience of the psyche certain real inner properties which are in some way bound up with the physical rest-mass energy come under direct observation as immediately given or felt. Such a view is consistent with the general conception of panpsychism, the chief philosophical form of which is the monadism of Leibnitz and his successors. Although panpsychism can hardly be regarded as a scientific theory, it offers no conflict with physical or biological science, even though it is not open to any general observational test. On the other hand, if the living organism is acknowledged to be a psychophysical system, the consistent evolutionist would find it difficult to avoid ascribing a similar character to nature as a whole.

To derive psychical qualities from exclusively physical factors, or the reverse, does not appear scientifically possible. In experience they are conjoined; and to regard either as having an existence of its own, entirely independent of the other, is a feat of abstraction which does violence to the experienced reality. The manner in which logical and scientific concepts have been derived by a process of intellectual refinement from common human experience is open to investigation, and this investigation may be essentially factual and historical.[7] The regularity and repetition found in nature are facts of experience and do not become less so when formulated in logical, mathematical, and scientific terms. The traditional bifurcation of physical and mental has led to much confusion, and this seems to be especially true with regard to the physical nature of space and time.

To refer again to magnification: If the independently existent or "real" character of the external "public" space in which physical objects are set corresponds in all respects to

[7] John Dewey's recent *Logic: The Theory of Inquiry* is an example of such investigation.

conceptual or mathematical space, it would seem that the process of visual magnification could—theoretically, at least—be continued without limit. Already the electron microscope magnifies 25,000 diameters or more, and even at this magnification it furnishes evidence of inner structural differentiation in many physical objects. There is a tendency, especially strong among biologists, to seek fuller insight into the constitution of nature by increasing still further the scale of physical magnification. Many persons besides Jonathan Swift have speculated on the appearance which the world would present if it were perceived on a spatial scale much larger than that to which human beings are physiologically adjusted—or, somewhat analogously, on an expanded time-scale, like that realized in slow-motion moving pictures.

It is true that microscopic study has vastly enlarged our knowledge of organic structures and processes; the activities of large-scale units like the whole organism are observed to be regularly dependent on the activities of smaller component units (cells) which become visible only under high magnification. Undoubtedly, actual physical origins can thus be traced; larger processes are seen to be in direct continuity with, and "caused by," smaller processes, either in the sense of being summations of such processes or in the characteristically biological sense of receiving their special impulses to action from them, as in stimulation and response. The control of large-scale physiological processes by activities originating in microscopic units, like the neurones of higher animals, is a universal feature of living organisms; and the remarkable properties of transmission, amplification, and integration presented by the nervous system furnish the physical basis for almost everything that is unique in the behavior of animals.[8] In this highly important sense microscopic activities may truly be said to lie at the basis of the large-scale activities of organisms.

Similarly, we are justified in referring many properties of living cells to the properties of their component structural

[8] See my paper "Physical Indeterminism and Vital Action," *Science*, LXVI (1927), 139. The general integrative role of the nervous system is discussed in Sir Charles Scott Sherrington's classical book, *The Integrative Action of the Nervous System* (New York: Charles Scribner's Sons, 1906).

units, and these again to the properties of molecules and atoms. But to continue without limit this process of accounting for larger processes by reference to component smaller processes does not seem either justifiable or possible. It may be that the physical subdivision of nature into elementary units has already reached its limits. There is danger of misunderstanding the possibilities of such "subdivisional analysis" (as I have called it in a recent paper).[9] Space is not to be regarded as a physical entity or existent which is infinitely subdivisible. Physical objects are spatial; and they are surrounded by, and inclose, other physical objects; but to infer from this fact of experience the real existence of a pure "empty" space having properties like those of abstract geometrical space, and correspondingly capable of being the seat of physical differentiation at any degree of subdivision, is a fallacy which, if entertained seriously, is more likely to hinder than help the scientific understanding of nature.

I have already pointed out, in discussing the possible origin of the psychical qualities in experience, that they cannot be referred to pre-existing psychical qualities; psychical events have a novel quality and at times seem to emerge into consciousness from nowhere. Similarly, we cannot regard them as composites of smaller psychical units, such as the hypothetical units of psychological atomism. It is not possible to trace psychical events to their origin in the same way as we trace the origin of physical events, by reference to stable factors acting in a continuous spatiotemporal field extending indefinitely into past history. This difference is part of the characteristic contrast between psychical and physical. Although there may be demonstrable physical antecedents to the sudden appearance of a sensation in consciousness, e.g., a pain or a flash of light, there are no constant *psychical* antecedents. When the physiological psychologist accounts for the appearance of a blue sensation, he does so by reference to constant physical and physiological factors; the continuity required for the scientific explanation is sought in the physical realm. The same is true for a nonspatial sensation such as a musical tone; observation

[9] "Directive Action and Life," *Philosophy of Science*, IV (1937), 202; cf. p. 220

does not give the origin of the tone in its character as felt sensation, but only the physical conditions under which it emerges into consciousness. These conditions, however, may be observed by physical methods to any degree of completeness possible with the available apparatus.

Hume's demonstration of the lack of necessary connection between successive sense experiences is classical. The origin of the psychical is not given by investigation of the physical, but only some of its *conditions*. As we have just seen, physical investigation cannot be extended beyond a certain well-defined limit of spatial subdivision. The limits of exact physical observation are defined by Heisenberg's principle of uncertainty, which has also been called the principle of limited measurability, as by Max Born.[10]

If we try to go *behind* the limits of physical observability, we enter a region of speculation rather than of critical scientific discussion. Experiment indicates that the constant physical factors which determine the limits of optical discrimination or visibility are not themselves indefinitely subdivisible, since radiation is transmitted in units, or quanta, having discontinuous or atomistic properties. The question if, supposing a quantum to be a spatial (or spatiotemporal) unit (and, as such, occupying volume), it is theoretically possible to regard it as subdivisible into smaller subquantal units, and these into sub-subquantal units, and so on, again raises the question as to how far the formal geometrical conception of space can be regarded as an exact model of "real" space, i.e., of spatial conditions as existent in an independent extended world, in the sense of Descartes. The objectivity of space, as conceived by Newton and other physicists, was denied by the great philosophers Leibnitz and Kant; but the real existence of some general condition, or *principium individuationis*, which underlies the fact of separateness, repetition, or plurality in natural objects and events, is hardly open to doubt.

[10] Since measurability implies *stability*, both of the measuring instrument or scale and of the thing measured (at least during the time occupied by the measurement), this principle might also be called the "principle of limited stability," a characterization which would be in conformity with the conception of reality as process rather than as static.

The question may be put thus: Is it possible to ascribe reality (existentiality) to this natural space in the precise form in which space is conceived in geometry or in which it was conceived by Newton? The answer, from the modern philosophical point of view, seems clear. Historically, the mathematical conception of a continuum, perfectly uniform and hence infinitely divisible, is an invention of the human mind, i.e., a construct. If we admit this, the *real* natural condition, which is the counterpart of space as mathematically conceived and which forms the condition of the plurality, separability, and (with time) motion of objects, would have only a partial correspondence with the mathematical model, in accordance with the recognized scientific principle that reality and model are never completely identifiable. We may note that such an answer corresponds in substance to the position adopted by Leibnitz in his discussion of the problem of spatiality, where he concludes[11] that "in bodily mass or in constituting corporal things we must recur to indivisible unities as prime constituents." Indivisible can only mean nonspatial, nonextended.[12] Leibnitz' statement is a denial of unlimited physical subdivisibility and is consistent with his psychical (or psychophysical) conception of the ultimate natural units or "monads." Similarly, in our own time, Whitehead has ascribed an inner quasi-psychical quality which he calls "feeling" (appetition) to the ultimate elements. Both philosophers regard psychical property as ultimate, i.e., as not derived *from* the physical but as expressing itself *through* the physical, or as forming a unity in close conjunction with it or internal to it (nonspatial).

A similar position is taken by Carr[13] in his commentary on Leibnitz's monadology. His discussion may be paraphrased as follows: Elements which are spatial or physical cannot be ulti-

[11] Translation on p. 242 of Bertrand Russell's *A Critical Exposition of the Philosophy of Leibniz* (2d ed.; London: George Allen & Unwin, 1937).

[12] It may be said that modern physics also rejects the "space-filling property" of the ultimate elements of matter. These are treated as having mass, motion, and position but not necessarily as occupying volume. Of course it is a question of what model, mathematical or other, corresponds most satisfactorily to the properties which, on experimental grounds, are assigned to these elements.

[13] Wildon Carr, *The Monadology of Leibniz* (London: Favil Press, 1930), p. 117.

mate, if only because by virtue of being spatial they are still further subdivisible. Being spatial, i.e., occupying volume, implies having something *within*, i.e., some internal principle of existence or activity which ultimately must be nonspatial. But nonspatial (nonextended) is equivalent to nonmaterial (since matter occupies space), and a nonmaterial principle of existence or activity which nevertheless is real can only be regarded as spiritual or psychical.

We are thus brought by a logical sequence of reasoning to the conception of the psychical as being something innate (or at least potential) in the physical but as having its own different and special properties. Of these the novel activity, or "presentness," discussed above, would appear to be the most important from the biological point of view, since it implies actual or potential creativity (see below, pp. 161 ff.).

CHAPTER V

Randomness and Directiveness in Living Organisms

WE NOW come to consider some of the more general natural conditions which underlie the vital activities of synthesis and integration. We have seen that the materials from which the living organism is synthesized are originally distributed at random in the environment; i.e., they are unorganized in the biological sense of the word. In the living center they are combined in a manner which is directive, i.e., follows a special course of a definite and integrated kind corresponding to a constant biological scheme or pattern; the result is the specifically organized animal or plant. An essential part of the contrast between vital and nonvital activities consists in this contrast between randomness and directiveness.

Let us first try to define clearly what we mean by "directiveness," as opposed to "randomness." In general, directiveness presupposes the existence of an end in view, i.e., a foreseen and aimed-at termination of a course of action; accordingly, directive action is also called "teleological" or "finalistic." Randomness is a negative concept, meaning simply the *absence* of directiveness; random events occur without any guidance or control uniting them into a larger unity; they are haphazard or casual. Hence random events tend toward no definitely integrated conclusion or final state.

Experimentally we find that long-continued random agitation of a freely mobile collection of objects leads to their uniform or equally spaced distribution; this is seen, for example, when we shake otherwise similar red and blue balls in a container or mix mutually soluble materials like salt and water. In all such cases the random action is *symmetrical* in its incidence, in the sense of acting equally in the different directions of space. In contrast, an asymmetrical force acts unequally; for example, gravity has a selective effect on objects of different specific gravities, as is seen when we shake together lead balls and wooden balls. It is characteristic of a purely random force, like an explosion, that it mixes objects together indiscriminately; it opposes or destroys any settled arrangement or organization. Correspondingly, a randomly assorted collection of objects shows an absence of local differentiation; there is no definite contrast or asymmetry between any circumscribed region of the collection and the surroundings; the mixture, as a whole, is uniform in its distribution of components. This is the familiar effect seen in mixing, stirring, or shuffling operations; in physics the second law of thermodynamics is regarded as the expression of a similar randomness in the thermal motions of molecules.

Vital action, on the contrary, is typically asymmetrical and selective; accordingly, it always leads to, or involves, some ordered arrangement, or organization, of components and activities. This asymmetry shows itself even on the smallest scale of physical dimensions. Louis Pasteur, the discoverer of stereoisomerism, was greatly impressed by this fact; in 1860 he referred to "the molecular asymmetry of natural organic products as the great characteristic which establishes perhaps the only well marked line of demarcation which can be drawn between the chemistry of dead matter and that of living matter."[1] According to this view, the fact that only one of the two possible stereoisomers of each asymmetric carbon compound occurring in the living organism is usually found—and this is especially true of the amino acids constituting the proteins—is to be regarded as evidence of a special kind of directive activity which is intimately bound up with the vital process.

Perhaps the best way of demonstrating the vital directiveness is to place a living microörganism, such as a bacterium or yeast, in a sterile culture medium. We then observe that the materials of the previously homogeneous or randomly assorted mixture are transformed in a specific manner, the change being from a state of uniform distribution and relatively simple

[1] Cited in the presidential address of Professor F. R. Japp before the British Association in 1898: "Stereochemistry and Vitalism" (published in *Nature*, CVIII [1898], 452). Cf., for a fuller discussion, my paper "The Directive Influence in Living Organisms," *Journal of Philosophy*, XXIX (1932), 477.

composition into a contrasted state in which the materials are completely made over chemically and segregated in discrete units (cells) having a complex structural and chemical organization similar to that of the introduced organism. The inoculation sets in motion a sequence of processes having a definite trend or direction and leading to the synthesis of active systems with a highly special constitution and activity. Their substance (protoplasm) is heterogeneous or highly differentiated, in contrast with the undifferentiated state of the surroundings from which its materials are taken; an evident feature of the living organism is that it is always sharply contrasted with its environment, both in physical composition and activity.[2]

In general, observation shows that unguided natural processes tend automatically toward simplicity and uniformity rather than toward complexity and diversity. Nature, however, is in fact highly diversified; and this diversity has been achieved in spite of the omnipresence of casual conditions, including the second law of thermodynamics, which favor uniformity.

The second law, or law of entropy, describes a universal natural condition whose prevailing influence is opposed to diversification; this influence is in the general direction of equalizing potentials, while diversification requires a nonuniform distribution of both energy and matter. One expression of this equalizing influence of casual factors is seen in the general instability of highly complex material constructions,[3] especially those which, like the living cell, are characterized by the nonuniform distribution of mobile components within a small volume. Physically considered, the usual living cell is a minute droplet of solution separated by a diffusion-proof membrane from another solution, the aqueous environment, such as the lymph in higher animals. Its chemical and structural elements are arranged in a constant manner which is highly "improbable" in the physical sense of the word; correspondingly, the cell is an unstable system which is enabled to preserve its special organization only by the continual expenditure of free en-

[2] For a fuller discussion cf. my paper "Directive Action and Life," *Philosophy of Science*, IV (1937), 202.

[3] For further discussion see below, pp. 176 ff.

ergy, this energy being largely directed toward the maintenance of its peculiar heterogeneous arrangement of components.[4] There is here illustrated a general natural condition, namely, a tendency for complex types of order to pass automatically into a less ordered state—*unless* some active counterprocess is maintained which prevents or compensates this tendency.

Apparently, all physical systems show this tendency in greater or less degree; for example, any complicated construction, such as a machine, a work of art, a delicate piece of scientific apparatus, falls into ruin through neglect. In order to preserve the normal state of such systems, accidental losses and displacements must be prevented or restored, accidental accretions must be removed, and this can be done only by action which is selective or purposive in its application. The natural physical trend toward disorganization is especially evident in living organisms, as is seen in the rapid disintegration which they undergo when constructive metabolism ceases, as at death. One of the chief tasks of a theoretical biology is to give a scientific account of these directive counterprocesses which preserve the integrity of the living organism in the face of general conditions, both internal and environmental, which work toward its disintegration.

These biological counterprocesses are constructive and integrative in their final effect, but they appear to scientific observation as consisting of combinations and sequences of physical and chemical processes which have the same regularity and stability as the disintegrative (largely energy-yielding) processes which are always associated with them. Their physics, however, is of a highly special kind, as is shown by the wide divergence of biophysics and biochemistry from the other divisions of physical science. Precision of detail and quantitative exactitude are fully as evident—if not more so—in living organisms as in nonliving systems; but the general trend of the vital processes, as we observe them in their total effect, is in the direction of *increasing*, rather than of decreasing, heterogeneity and complexity. The vital activity is synthetic; hence,

[4] See above, p. 32.

the quantity of highly organized material tends to increase in the presence of living organisms, as is shown by their automatic growth and reproduction under normal conditions.

The astonishing precision of action which living organisms display does not prove them to be purely physical systems and nothing more; a similar exactitude of repetition is shown by the nonliving and casual activities of nature—in fact, is characteristic of physical action everywhere. The random activities of nature are far from being lawless; it is well to remember that the mathematics of "chance" events, i.e., the theory of probability, is a highly exact science. In fact, probability represents a form of constancy; the constancy of physical action is now regarded as based ultimately on the stability of probability conditions.

The difference between living systems—the most highly ordered systems found in nature—and nonliving systems is not that physical action is exact in the one case and not in the other; it consists rather in the fact that in the living system the physical and chemical processes are so combined and coordinated that they lead to the production of an ordered and integrated product of a special and unique type. As we have seen, the high development of synthetic chemical reactions is the most characteristic physical expression of this "creative" character which so impressed Claude Bernard and Pasteur; and it is because of this unique constructive ability of living organisms that they are able to build up and maintain their complex organizations, which are contrasted so sharply with the comparative uniformity of their environments. Upon this synthesizing property depend all the special vital activities with which we are familiar. What is most remarkable is that in living organisms many processes of the most complicated nature, sometimes requiring years for the building-up of their necessary conditions, are carried out with unfailing regularity and precision. The presence of some special regulative factor, nonphysical in the sense of being directive and synthetic rather than dissipative, appears to be thus indicated, since, as we have just seen, unguided physical processes tend toward uniformity rather than toward increasing differentiation.

The term "directive" may seem ambiguous to many; and a chemist may well inquire whether the morphogenetic action shown, for example, in the formation of a snow crystal is not directive in exactly the same sense as organic growth or any other vital constructive process is directive. There is some justice in such a criticism, since directiveness, in the sense of ordered character or precision of action, is a feature of physical processes in all fields. But the use of the term in biology has reference to something of an essentially different kind. Undoubtedly, biological directiveness requires physical regularity as a necessary *condition;* but it also includes factors which are specifically vital, in which a psychical element appears always to enter or to have entered. This psychical factor may be a matter of immediate experience, as in present voluntary action; or it may have played its part in the past—for example, in the invention of a useful tool which is used in the present but is now purely physical in its action. It is not inconceivable that the complex physical arrangements of the animal body may belong in the latter category.

The comparison of organic development with crystallization has often been made; a crystal is often described as growing from a "mother-liquor." But, while it is probably true that the finer elements of organic structure are structural in the crystallographic sense, as is indicated by the fact that many proteins like haemoglobin form crystalline aggregates having a definite morphology, this fact would not in itself justify the biologist in referring *all* the structure-forming activities of the organism to crystallogenesis.

The case of the ultramicroscopic pathogenic agents known as "viruses" has recently attracted much attention. These can be isolated in crystalline form, and the inoculation of these crystals will cause infection in a susceptible organism in very much the same way as inoculation by bacteria. But the conclusion need not be drawn that the viruses are themselves living organisms, or that the fact of their crystallizability throws any special light on the problem of vital morphogenesis. The fact that they multiply automatically in the host protoplasm does not prove them to be independently living; a similar increase in quantity occurs in the proteins of all normal cells during growth and is especially evident in the nucleoproteins (to which class viruses belong) during cell division. All organic growth involves specific synthesis. Viruses are peculiar among foreign proteins in being synthesized in the cells which they infect, just as are the proteins normally present; it is because they are foreign to the normal organization that they produce pathological effects.

In living organisms the presence of special directive factors having a psychical, as well as physical, character is shown in many synthetic activities besides development. This is obvious in human life; it is a commonplace that most of the permanent physical arrangements on which we depend in daily routine have come into existence under psychical direction; tools, apparatus, and utilities are now purely physical and act automatically, but originally they had to be invented. Many animals besides man build nests, snares, burrows, and other structures adapted to their special biological requirements. Even plants show many structures and activities that impress us by their apparent foresight and ingenuity. If such physical constructions and arrangements owe their origin to psychical directiveness, we are led to inquire whether directiveness of a similar kind may not be a fundamental factor in the natural process in general, especially on its creative or synthetic side. This factor would supplement the purely physical and random factors also present.

The problem may be put in the form of alternatives, as follows: Is directive activity an ultimate or primordial factor of nature—one whose existence long preceded the evolution of living organisms? In other words, does it represent a special kind of agency continually active in nature and contrasted in its essential nature with the random factor? Or are the random and undirected activities of nature—those based on the "fortuitous concourse of atoms"—the primary ones and themselves capable of giving rise to the existing diversification without any teleological guidance? Is the teleological prior to the casual? Or the casual prior to the teleological? Or are both always present, in proportions which vary widely in different natural processes?

To decide such general questions by purely scientific methods seems hardly possible, since they cannot be settled by observation or experiment. Moreover, the very question at issue is whether or not a novel or nonregular factor or group of factors enters constantly in the natural process; and such a factor, as lacking constancy, could not be "defined" scientifically. But in the existing state of nature—highly diversified as it is, and partly living—the existence of both kinds of activity, casual and teleological, seems an obvious fact. It is true that they occur in close association and are often most difficult to distinguish. Many times we are hard put to it to decide whether what happens is accidental or intentional; disputes of this kind are common with children, in courts of law, in worldly affairs; they have even led to war ("Remember the Maine!").

To primitive man whatever happens is teleological, his view of nature is animistic; while to modern sophisticated man everything—ultimately, at least—may seem casual.[5] Anyone who considers this problem is well aware of the fact that actions originally purposive always have their unforeseen casual consequences; also, attentive examination invariably shows a large admixture of the casual in the inner detail of any purposive activity. In normal experience we find that purpose, as purpose, has immediate reference only to certain selected aspects of the total situation; we pursue our objectives in the midst of conditions which, for the most part, are indifferent, if not antagonistic. This is the reason why if we leave things to chance they usually go wrong. When we examine closely the detail of single events belonging to the two classes, random and directed, a purely physical analysis may show no difference. The ultimate components (atoms, molecules, electrical units, quanta), the single events and their causal interconnections, the dependence on environmental conditions—in

[5] E. G. Spaulding's *A World of Chance* (New York: Macmillan, 1936) emphasizes the predominance of casual factors in natural events. An exactly opposite conviction is expressed in Alexander Pope's couplet in his "Essay on Man":

> "All Nature is but art, unknown to thee;
> All Chance, direction which thou canst not see. . . ."

general, the purely physical features of composition and activity—may be indistinguishable in the two cases. Typically, a purposive action aims at some end-result corresponding to the desire of a conscious agent. Yet a pure accident may have the same aspect of malice or of benevolence as a deliberately purposive action. In folklore the agencies of good and bad luck are personified; in the present war small spiteful happenings, otherwise inexplicable, are attributed to "gremlins." The distinction does not seem to be based on merely physical differences.

Apparently, there is no unequivocal way of characterizing the directive factor in events, as distinguished from the random factor, except in terms of ends foreseen and acted on, i.e., in psychical terms. Purposive action can be defined only as an expression of the conscious and conative factors characteristic of the psychical as such. In voluntary human action the guiding or controlling influence which holds a train of events to a constant direction is psychical; it involves a persistent awareness of the end in view; a more or less definite image (Gestalt) of this end precedes and directs the effort toward its attainment. We find that purpose varies greatly in its definiteness and intensity. The conscious aim may be well defined from the start, or it may become clear by degrees—as in trial and error—as the action proceeds. The essential feature is that *some* plan, image, or conception persists for a greater or less time in the mind of the agent and plays in his activity the part of a stabilizing and integrative factor. Voluntary action, directed by this conscious intention, intervenes at certain selected places and times, with the result that the current of events is steered in the desired direction.

Teleological activity, as we observe it in nature, always consists in a combination of directive and nondirective processes. Observation shows that purely physical and random events always form a large part of what is actually happening and demonstrable in any instance of purposive action. If a driver relaxes his control too long, the car runs off the road; usually in any undertaking, direct voluntary effort is not continuous, and in the intervals of the volitional intervention events take a course determined by the regularly acting factors which are always independently present and active. "Man shifts things about and nature does the rest."[6]

Obviously, we have no direct control over molecular motion. But even in cases where direct control is possible, it is applied intermittently. Thus, when the rider controls the action of his horse, he does so by occasional pulls on the bridle; or, to give a more complex instance, when a commander controls the action of his army, it is by orders which are issued at intervals, but not too frequently. In both cases the purposive agent relies on the constancy and predictability of the intermediate events, and these are determined by factors independent of his immediate will. This statement describes a condition which is universal in purposive action. The conscious integration has reference to a larger whole, which is conceived in advance more or less clearly; but while some parts of the teleological sequence may receive special attention, most of the inner detail is disregarded, since its constancy is taken for granted. Yet without the constancy of this inner detail—which may be physical or psychical, or both—effective action with reference to the larger whole would not be possible. Such considerations show that regularity and predictability in the character and interconnection of events is an indispensable condition of any teleological action.

On the other hand, this ever present physical subcurrent of events represents only one necessary condition or prerequisite of the teleological action. It would be a mistake to regard it as a *complete* determinant of the action, considered in its special character as an integrated whole, since the directive part played by the psychic factor is the really decisive one. Apparently, if we may judge from our own experience, the psychic factor acts by preventing, compensating, or supplementing

[6] Quoted in the interesting paper entitled "Method" by Heath Bawden, *Journal of Philosophy*, XLI (1944), 477. Compare Hans Driesch's discussion of "the moment of regulation" in his *Science and Philosophy of the Organism* (London: A. and C. Black, 1908); the entelechy is conceived as exerting its regulative influence intermittently, not continuously. For example, he writes (II, 237): "In adaptation especially it would seem to be quite sufficient if entelechy were to break the inorganic chain of events at one special point, the rest being inorganic becoming again. In restitution and acting something very similar may happen" (see n. 7 below).

the casual actions whenever these interfere with the desired course of events.

The correction of such accidental deviations, in the interest of the end in view, is a necessary part of any conscious teleological action; hence, corrective activities of this kind are of fundamental biological importance. The human organism furnishes many illustrations. In addition to those controls of which we are immediately conscious, there is also the large group of physiological activities, called "regulations," by which deviations from the normal biological conditions are automatically corrected. Such activities are adaptive and in this sense have every appearance of being teleological, but they are usually regarded by the biologist as purely physical. In higher animals they include the regulation of body temperature, of blood pressure, of muscular and nervous adjustment, of the alkalinity and osmotic pressure of the blood, and many others; and their investigation forms an important division of physiological science.[7] In consciously purposive actions it seems clear that the psychic factor controls the course of events, and evidently it can do this only by virtue of its being at the same time physical. The case is not one of "either-or"; physical and psychical factors are both present in intimate union and act in concert. The physical effect is to be regarded as the expression of one group of factors which forms only a part of the whole complex psychophysical system. But the psychic factor, at the same time as it is directive and integrative, is also physical, since it is not in reality—i.e., existentially as distinguished from ab-

[7] For a recent comprehensive study cf. E. F. Adolph's *Physiological Regulations* (Lancaster, Pa.: Jaques Cattell Press, 1943). Hans Driesch's *Organische Regulationen* (Leipzig: Engelmann, 1901) considers the subject from a philosophical, as well as naturalistic, point of view. Driesch's conception of regulation is not purely physiological; he ascribes certain kinds of regulation (e.g., form regulation) to a psychic (psychoid) factor, which is a manifestation of the "entelechy" innate in the organism; this "inserts" its directive and integrative influence at certain places and times in the physiological nexus of events, thus modifying in a teleological way the physical routine otherwise characteristic of the organism. See *Organische Regulationen*, p. 128 ("Regulationsmoment"); also his Gifford Lectures, *Science and Philosophy of the Organism*, esp. II, 237; *Die Maschine und der Organismus* ("Abhandlungen zur theoretischen Biologie" [Leipzig: J. A. Barth, 1935]), IV, 45; and elsewhere in his writings. Driesch is in disfavor with present-day biologists, largely because of misunderstanding. He was, in fact, a stubborn realist, but felt impelled to fit his biological facts into a comprehensive philosophical synthesis.

stract or scientific representation—dissociable from the physical.

It may be of interest, at this point, to examine in some detail the difference between a nonteleological sequence of events and a physically similar sequence which is at the same time teleological. When by some happy accident the bungler scores a brilliant shot in billiards, the physical sequence of events, as viewed by an external observer, presents exactly the same appearance as in the similar shot made by a skilled and deliberate player who estimates his stroke to a nicety and foresees every motion of the balls. In both cases each separate event of the physical nexus fits regularly into the other events spatio-temporally adjacent to it in the definite manner which we describe as "causal." The special features of the sequence, in its character as a connected process terminating in a desired result, depend on the direction and force of the original impact of the cue, as well as on the stable conditions present in the cue-ball and its environment,—e.g., the position and properties of the other balls (roundness, size, weight) and the special physical features of the table (quality of cushions, levelness, etc.). But, preceding the deliberate shot, there is in the mind of the skilled player a conscious unified image (Gestalt) of the external situation and of the result aimed at, and he adjusts voluntarily his action to the consequences which are foreseen to follow. The estimate of these consequences is based on previous knowledge, gained experimentally, of the factors controlling the motions of billiard balls. The sequence of physical events following the initial stroke is determined by the stable physical features of the external situation; but the special outcome depends on the original "sizing-up," or psychical integration, made by the player before he hits the ball.

This example shows again that it may be impossible to tell from a purely external examination whether an apparently directive action is consciously so or not. So far as the single physical events and the manner of their interconnection are concerned, there is no appreciable difference between the "fluke" shot and the skilled shot. What is peculiar to the latter cannot be defined *physically;* it consists in the entrance of a psychic factor which is at once directive and integrative. But this factor by itself is not sufficient to control the course of events; constancy and stability in the external conditions are also necessary. The conclusion is unavoidable that in any teleological action both physical and psychical factors are present and that both kinds are equally indispensable. This coincides with Aristotle's view, recently paraphrased by Woodbridge in the remark: "Teleology and mechanism are correlative rather than opposed."[8] Professor E. G. Conklin has made a similar remark in a recent address: ". . . . there may be good grounds for holding that mechanism and teleology are complementary views of nature, neither excluding the other."[9]

The various physical factors which determine the outcome of the billiard shot include physiological events occurring in the neuromuscular system of the player and culminating in the selective act of innervation, upon which the rest follows automatically. The initiation of the physiological sequence is usually referred by the physiologist to some critical or decisive event having its locus in the cerebral cortex. It is clear from experiment that physical and physiological regularity, implying stability of both organized structure and activity, is necessary to the performance of the skilled act; the processes in the visual and motor areas of the cortex and elsewhere must occur with precision if the final outcome is to have the constancy and reliability required to meet the situation. We conclude again that, while a purely physical examination might disclose no difference between the skilled and the casual action, the former has a special character which is determined by the physically unobservable psychical integration preceding the decisive event of the physiological sequence and determining the force and direction of the stroke. Any experienced player is conscious of the difference between an accidentally successful shot and one which is a real feat of skill. But the difference is not externally evident; to an observer viewing the neuromuscular

[8] Frederick J. E. Woodbridge, *An Essay on Nature* (New York: Columbia University Press, 1940), p. 196.

[9] Address before the Joint Sections of Biology and Psychology, *Transactions of New York Academy of Sciences*, Ser. 2, VI, 132.

events with a perfected apparatus the two physical sequences might be indistinguishable. The real criterion of the teleological action is the psychical integration, which includes the subjective aim (to use Whitehead's expression) reflected or registered in a special manner in the player's consciousness. What distinguishes the conscious act from the unconscious one which effects the same result is just this physically unobservable, inwardly felt process of unification which is so characteristically psychical. But the physical factors are also inseparable from the action, which in its totality is neither purely physical nor purely psychical but psychophysical.

Physical and psychical thus appear as two aspects of a unity which combines within itself factors of both kinds. The intimacy of the connection between the two fields is further shown by the familiar fact that a control which is originally conscious may later become unconscious, as the conditions become physically stabilized by repetition; thus a difficult passage on the violin becomes automatic by repeated performance. Many kinds of physiological regulation, such as the control of posture and other routine adjustments and habits, may be acquired during the lifetime of the individual; others, as we have seen, are inherited in a finished state.

Physiological acquirements which require conscious personal experience as a prerequisite illustrate the physical side of the general biological processes of learning, memory, and habit. Apparently, the psychophysical action leaves behind it in the nervous system some special chemical or structural modification which has the characteristic physical property of persistence or conservation; and this stable impress, or engram, in some way makes easier the later repetition of the action. All physiological theories of memory, a universal psychobiological character, refer the retentive and canalizing effect to this general physical characteristic of conservation. The psychical event leaves a lasting physical impression; and this impression determines the repetition of the event, very much as a stamp or die, originally made with care and attention by an artist, makes possible the indefinite multiplication of the design or as a phonographic disk reproduces an oration or piece of music.

The persistency of the physical, as contrasted with the transiency of the psychical, is well illustrated in such phenomena as the foregoing. In general, physical conservation is recognized by science as the basis of the regularity which is so characteristic of natural events and which makes them subject to prediction and calculation. The mnemonic impression in the living organism is a regularizing condition; in its physical character it represents a stable factor which enters determinatively in later physiological events occurring at the same locus. What should especially be noted at this point is that the element of novelty or origination in voluntary action is typically a contribution of the psychic factor in its quality as psychical and is directly connected with the special psychical property of present "feltness" or immediacy, while later repetitions of the action depend on stable conditions which have arisen in the physical field in consequence of the psychical innovation.[10]

This contrast in the characters of physical and psychical is closely related to the contrast between the casual and the teleological. The designation "chance" or "casual" is anthropomorphic; it refers simply to the lack of connection with human intention, not to any real lack of regular causation. As just shown, analytical study may disclose no physical difference between chance events and purposive events. The contrast between the casual and the directive factors in the natural world is often illustrated by the difference between shuffling a pack of cards and sorting them in regular order. The sorted arrangement may also be reached by casual shuffling in rare instances, whose frequency is subject to calculation; incidentally, this very fact shows the stability and uniformity of the probability factors. But under psychical direction any desired arrangement may be made at will with perfect constancy; here the critical determinative factor is conscious purpose. We have already seen that "chance" events occur with the same exact conformity to physical rule (but no more!) as events which are teleologically determined; the difference has no reference to the purely physical conditions of actuation. What is peculiar to teleological action and absent from random action is the ele-

[10] See also below, chap. xii.

ment of psychical directiveness or choice; this characteristically psychical factor is made effective by physical action, which is applied intermittently at certain selected places and times in the causal nexus.

The question of what determines the selection of these points of application can apparently not be answered in purely physical terms, i.e., terms which disregard the possible entrance of a directive psychic factor. We may assume that a microphysical analysis of the train of events composing the teleological action would lead ultimately to quantum factors, at which limit the possibility of further physical observation apparently ceases. To refer the special vector property expressed in a conscious choice to these purely physical factors does not, however, offer any solution of the problem. In any case, these factors are always present; they are constants in all physical action, random and directive alike. Empirically, the only deciding factor to which we can point is psychical choice or volition, observation of which, however, is not external (physical) but internal (introspective). How the psychic factor can change the physical conditions is the crucial problem, for which at present there appears to be no final scientific solution; but the fact itself must be accepted as experimentally well established, since it is a universal human experience.[11]

Summing up, we may say that the guiding or controlling influence in a consciously teleological action consists essentially in a persistent awareness of the desired end; some conception, image, or diagram of this end precedes and directs the effort toward its attainment. We are here speaking of the action in its consciously purposive aspect, before it has been "mechanized" by repetition and its conditions rendered unconscious and purely physical. Voluntary action, under the guidance of this intention, or motivation, intervenes at selected places and times in the causal nexus, with the result that the course of events is steered (so to speak) in the desired direction.

The dependence on images (Gestalt) shows that the psychical unification is essentially a summarizing or epitomizing procedure. It always has reference to a larger whole, and typi-

[11] This problem is further discussed in chap. ix, pp. 129 ff.

cally without being aware of more than a small part of the detail disclosed by analysis as making up that whole. This is perhaps best seen in works of art, which always have a synthetic and teleological quality. At the same time, the very possibility of teleological control presupposes the constancy of the disregarded inner detail, which is assumed to have the stable or invariant quality characteristic of the physical as such; without this physical reliability no voluntary control over the process as a whole would be possible.[12]

Science takes it for granted that the regular causal interconnection of the physical detail is an existential character, constantly present and effective whether it is under observation or not. This view seems sufficiently justified by the fact that the living organism, conscious or unconscious, preserves a stable existence and acts in the regular manner determined by its physiology. But, taken by itself, this regularity does not account for the teleological character of vital action; it is a condition or prerequisite rather than a determinant in the comprehensive sense of the word. As we have just indicated, a conscious teleological action always involves a *prehension* (to use Whitehead's term), i.e., a unification of details under a coherent mental grasp or conception, which, in general, is of a simplifying kind. But the concrete realization of this conception in the external world depends on physical factors; and of these factors, some of the more intimate and critical appear to be under direct psychical control. Such critical events would be the key events to which Sir Arthur Eddington refers in his *Science and the External World*;[13] they are volitional at the same time as they are physical and physiological. If we could observe them physically, we should find only physical conditions; to the external observer they would appear the same, whether or not controlling purpose was behind them. Apparently, the purposive and directive factor has its local habitation and place in the internal or psychical field of the organism, and some ultimate origin other than physical must be assigned to it.

[12] A classical statement of the connection between the mechanical and the teleological in voluntary action is given by Socrates in Plato's *Phaedo*.

[13] (New York: Macmillan, 1928), p. 312.

CHAPTER VI

General Characters and Interconnections of Psychical and Physical

WE HAVE already briefly indicated the nature and origin of the dualistic distinction between the physical and the psychical—"matter" and "mind." While we may assign a common foundation to both, there is no doubt that they correspond to clearly distinguishable, or even strongly contrasted, aspects of nature as presented in experience. But just how or why they have diverged so sharply from a common background is not easy to understand; and for the sake of clearness some further consideration of physical and psychical, especially in their biological interrelations, seems required at this point. Since we have described the living organism as a "psychophysical system," i.e., as a natural entity or existent in which physical and psychical characters coexist in intimate union, it is important to define as clearly as we can the general properties which are to be regarded as specifically characteristic of each. What are the distinguishing characters of the field called "physical," as contrasted with that called "psychical"?

We have already seen that *conservation*, i.e., the permanent retention of a certain constant state or property, is considered by science to be a primary and fundamental attribute of physical nature. The conservation of energy is a condition which limits all physical change; perpetual motion has been found experimentally impossible; and various all-pervasive physical constants are well known and have been given exact quantitative representation. On the other hand, what we call the "psychical," the conscious experience as such, has the quality of being always in the present and of being correspondingly transient in character; in itself, qua psychical, it *lacks* conservation. As Professor Sellars has put it recently: "The mode of being of consciousness is participial rather than substantive.

The principle of conservation, or intrinsic endurance, does not apply to it."[1] A similar characterization is made by Whitehead, in reference to what he calls "presentational immediacy": "Percepts are distinct, definite, controllable, apt for immediate enjoyment and containing the minimum of reference to past and future."[2]

But any attempt to make the simple distinction between transiency and permanency equivalent to that between the psychical and the physical lands us in difficulties. Obviously, many single physical events are transitory; the conservation has reference to their whole natural setting and conditions, within which we find abundant activity and differentiation. The essential point now to be emphasized, however, is that the two fields now contrasted as psychical and physical form originally parts of a single experiential or phenomenological field (assumed to have its relation to the whole system of reality) in the consideration of which the two are separated by a process of abstraction. In this sense the psychophysical dualism is an artificiality.[3] Yet, further reflection reminds us that this distinction would never have been made by human beings—typical living organisms—if it did not correspond to something fundamental and permanent in their experience. There *is* a physical nature "out there"; and a psychical nature "within," which is regarded as "subjective," in contrast to the permanent "objective" world surrounding.

The mode of description now universal in natural science implies that the physical world, as physical, is in its essential nature permanent, fixed, or established. It is a system of events which happen in the same way at one time as at another; i.e., in their physical character present events are not regarded as different from past events or future events. With psychical events, on the other hand, the difference is profound: we have

[1] Roy W. Sellars, "Reformed Materialism and Intrinsic Endurance," *Philosophical Review*, LIII (1944), 259; cf. p. 270.

[2] Quoted from the article by Sydney Hooper in *Philosophy*, XIX (1944), 136. Causal efficacy and presentational immediacy are being contrasted. Causal efficacy is a character of the physical, while presentational immediacy is a character of the conscious psychical.

[3] See above, p. 53.

only to contrast a present pain or enjoyment with one past. Representation by permanent mathematical symbols or expressions (equations, formulas, geometrical constructions), the preferred method of physics, refers to that which is invariant, which persists through time, which has stability or endurance. This stability may, of course, refer to a mode of change, i.e., a constant type of process, as well as to a static endurance or equilibrium. It is also true that each physical event, considered as a single entity or existent, has its own individuality, uniqueness, or transiency; but when it is considered as an object of physical science, it is represented as forming a part of, and as constituted by, a permanent and independent (objective) system of external factors and relationships by which alone its special character is determined.

It must be remembered, however, that many of these physical factors and relationships, now apparently quite constant, represent the persistent result, or residue, left over from special activities and events which have occurred at definite times in the past; i.e., they are products of temporal process (which may be either single events or evolutionary sequences of events) rather than permanently unchanging (primordial) conditions. Examples of such historically determined constants are innumerable; they include such natural conditions as the constitution of special isolated parts of nature (such as the solar system, fixed stars, galaxies), the mass and physical structure of the earth or moon, the periodic system of elements, and so on—in brief, all permanent natural conditions which have a secondary, consequent, or derived character; these conditions include the constant characters of living organisms. In addition, there are countless permanencies which are the results of the past voluntary activities of living beings: London city, the pyramids, the Suez Canal, and the Atlantic cable may serve as examples.

Let us consider again the case of a voluntary human action. While the event is in the process of happening (in the present), the psychic factor plays a decisive part; but this factor, as psychical, vanishes with the accomplishment of the event; accordingly, the event may appear on subsequent consideration to be purely physical. The physical leaves permanent evidence (to which we can return) of its existence, while the psychical is perceived only during its passage.

It is a peculiarity of the psychical that it is always on a level with the present. Most natural events are usually regarded as being quite devoid of psychical factors—or at least such factors are considered negligible; this is especially the case with physical or mechanical occurrences which are instances of routine or automaticity and have in them no appreciable element of novelty. On the other hand, in voluntary action the psychical is the dominant or deciding factor; consider, for example, the human being struggling against adversity. In either case—purely physical action or voluntary action—the result, once it has been achieved, becomes part of an unchanging system of reality, existing permanently, i.e., the *past*. This feature of the past, as conservation, is a constant and inescapable factor in the determination of what happens in the present. Here we have the general natural fact known as *causation;* present events are determined largely or mainly by past events and conditions. But our immediate experience of voluntary action warns us that the past is not the *exclusive* determinant of the present; in natural events of the volitional class the psychic factor enters also, *but only in the present;* as psychical, it vanishes with the accomplishment of the event, as the completed event recedes into the past.

The point we are now discussing is difficult to express clearly and unambiguously (the scientific ideal of expression), and the metaphorical nature of so much abstract formulation renders misunderstanding easy. The temporal present, as felt or given in immediate experience, might be defined as real existence or actuality *plus* the psychic factor; the past, as real existence which has shed that factor. The purely physical, as it exists in the present, would then be largely or mainly a residue from past activity: it would correspond to stable process which has shed subjective aim, or, as Sydney Hooper has expressed it recently, to "completed process when the subject has perished."[4] Such expressions are a paraphrase of Whitehead's

[4] Cf. his article on Whitehead's philosophy in *Philosophy*, XVII (1942), 47.

doctrine of events, as summarized in his sundial motto, "Pereunt et imputantur."

No one need suppose that *all* present events have in them a psychic factor which is capable (on occasion) of novel action. Many natural conditions which have had their origin in psychical action maintain themselves as purely physical routines or static factors through long periods of time, continuing into the present. Once the psychic factor has played its part, the events become purely physical and automatic; the phonographic record is a good example (see p. 162). But psychical events, when they happen, are always novel and in the present. This is the main reason why the philosophy of organism regards them as the primary source of novelty in an evolving world.

Referring again to concrete facts of experience, we observe that when the psychic factor vanishes from consciousness, as in sleep or anesthesia, the sense of time vanishes also; i.e., the consciousness of intervals between successive events disappears —last night's events and this morning's may seem only a few minutes apart instead of hours. "Time," using the word in Bergson's sense of consciously experienced duration, is the general term for the experienced sense of change or activity; existence is regarded as *in* time because present or immediate existence is continually changing.

The application of exact time measurements to past events, as in the dates of history, is analogous to the application of a foot rule to an unchanging spatial system; the relative temporal positions of events—before, after, simultaneous—are fixed because the past is fixed. Such measurements are in physical or Newtonian time, with its equability or even spacing. But time in Bergson's sense, as change, lapse, or passage, occurring in the present, is something which is immediately experienced. On the other hand, since conscious experience has its foundation in conservative physical or physiological processes, present or passing time is also subject to physical measurement, i.e., by regularly acting mechanisms (clocks). We have here a fact indicating the existence of a certain uniform or homogeneous property in what we call "physical time," considered as the natural condition common to all instances of change; a similar uniformity is attributed to physical space; both are now united in the modern relativistic conception of space-time, the regular isometric four-dimensional geometrical framework within which events happen. Correspondingly, there is a physical or measurable character in both space and time. The connection of uniform time measurement with uniform space measurement is perhaps best shown in the regularly undulating tracing made by a vibrating tuning fork upon a uniformly moving smoked surface, i.e., the kymograph tracing used in all physiological laboratories for the measurement of brief time intervals. A clock or watch, where the uniform tension of a weight or spring gives rise to uniform spatial motion, illustrates a similar condition.

The fact that a "mental" experience (e.g., a visual or other sensation) has in it features which are subject to physical measurement illustrates again the unity and inseparability of psychical and physical. The traditional dualistic view expressed by Descartes, that conscious world and extended physical world correspond to separate and disparate realms of being, has brought much confusion into philosophical discussion and has introduced an artificial difficulty into the problem of how their interaction is possible. The causal determination of the physical by the mental has been regarded as an impossibility because it has seemed to imply that physical action, which is action in space, can be determined by factors which are nonphysical (i.e., nonspatial) and hence to contravene the rule that nothing can happen without a cause.

The nature of physical causation is now better understood than formerly, largely because of modern experimental physics; and our ideas of what is to be included under the concept of causation are clearer. Activity and change are now recognized to be an essential part of all natural existence; and the special features found in each instance of change are regarded as being determined by factors which are both external to *and* internal to the entity undergoing change. These factors have permanent characteristics which exhibit themselves in each instance of change; i.e., the factors fall into regular classes, and the events accordingly appear as subject to fixed rules which are called "rules of causation."

Experiment has shown, however, that the absoluteness of these rules has been exaggerated; the notion of a completely fixed and predetermined universe is inconsistent with a feature which we find in all natural events, namely, a certain variability shown by each event in its finer detail, which renders it incompletely predictable. This lack of complete predictability is a character of individuality. Indeterminacy (under different names) has long been regarded as a special peculiarity of the behavior of living organisms; other animals besides ourselves, and even plants, have been credited with "free will." This expression (if it means anything) would seem to mean a determination which has a part of its source in present and internal conditions and is not completely fixed by external conditions and the past. In the strictly physical sense such determination would be *acausal;* in fact, the phrase "decline of determinism" has been used in recent years by physicists to describe certain tendencies in their science.[5] But, of course, the rigor of causation in large-scale events remains unaffected by this change in the theoretical point of view; the mechanics of daily life are the same as before, and modern technology illustrates the degree to which regular causation can be relied upon in the activity of complex physical systems—no more convincingly, however, than the facts of physiology.

If an "indeterminacy" of the above-defined kind, i.e., a factor of determination which is independent of past conditions or acausal in the physical sense, does in fact exist in living organisms, its ultimate locus of action would seem to be intra-atomic—or even intraelectronic. In accordance with the considerations brought forward on page 81, this would mean nonspatial, in the last analysis; and, in fact, the ultimate

[5] Cf. Sir Arthur Eddington, "The Decline of Determinism," *Nature,* CXXIX (1932), 233. Eddington speaks here of a body's "un-get-at-able inner nature which is beyond the scope of physics." See also the chapter on causation in his *The Nature of the Physical World* (New York: Macmillan Co., 1929), p. 293. In a review entitled "Causality or Indeterminism," by the physicist H. T. R. Piaggio (*Nature,* CLV [March 10, 1945], 289), the author, after discussing the part played by probability factors in physical action, concludes that "the balance of the present evidence is rather against complete causality, but that the question is still unsettled."

physical elements need not be regarded as being spatial in the space-filling Newtonian sense, i.e., as having actual or possible *parts;* they are rather units of action, having position but not necessarily occupying volume.

In all causal fields of a higher order open to observation, regular physical causation is demonstrable. On the other hand, in electronic or quantal phenomena no complete determination of the individual event, as individual, seems to be possible. Nevertheless, a regularity does appear in these phenomena if a sufficient number of observations are made, as seen, for example, in the regular curves of radioactive decay, which are constant for each element, or in the photoelectric effect and other phenomena of microphysics. This regularity must be based on some permanent feature of internal constitution or condition. The indeterminacy has reference only to certain characters of the individual event; in our general experience of single events close observation always shows some element (it may be small) of uniqueness.

We may reconcile causal determination (which we may call *past-determined*) with "free" determination (*present-determined*) by assuming that each individual action has a certain internal or autonomic character but that this action is carried out under external restrictive conditions which are constant and largely fixed by the past. The constant influence of these conditions is shown in the constancy of the statistical result when sufficient numbers are taken into account, as seen not only in intra-atomic events like those just cited but also in the statistics of casual events in general—e.g., dice-casting, card-shuffling, accidents, suicides, and many other events each of which has its individual, as well as its external, determination. According to the present view, some element of indeterminacy—in the sense of present determination, or internal determination, or what may be called "spontaneity"—is always present in a natural event, but to a degree which varies greatly in the different instances. Within the vital organization this internal determination is apparently able to express itself in a way which is not possible in nonliving systems; the latter are more directly dependent for their determination on factors external to themselves. Such a conclusion has the advantage of not dividing living systems sharply from nonliving systems, and is consistent both with physics and with the theory of organic evolution. I may add that I do not underrate the difficulty of understanding how a present activity can have a property which is independent of past conditions. But equally I do not "understand" the natural characteristic of creativity, which, nevertheless, is an undeniable fact, as human experience and evolution both show. This characteristic is ultimate, as Whitehead insists; and on the basis of immediate experience, as well as of our scientific knowledge, it seems justifiable to refer it to psychical rather than purely physical factors, since psychical events are, in a sense peculiar to themselves, a manifestation of novelty or spontaneity, as well as of the individuation which is a main characteristic of nature.

CHAPTER VII

Interrelations of Directive and Nondirective Factors in Nature

IN THE present chapter we come again to considerations of a more concrete kind. As already indicated, the presence of casual or random events distributed everywhere throughout the detail of any purposive action is readily seen by inspection. But the action as a whole remains directive, in spite of the nondirective detail; and we have the problem of accounting scientifically for this directive quality and the unity which it implies. Observation shows that, when a plan is carried into effect, the unification of the various events composing the whole purposive sequence depends on the directive and integrative control exercised by the conscious mind of the agent. To secure this unity, the psychic factor intervenes in the physical stream of events, as a rule not continuously but at intervals, when and where it sees that something "ought" to be done—otherwise things will "get out of hand." Through this psychical intervention, occurring at special places and times, the casual and undesired deviations are continually being compensated and further actions are interpolated—all in the interest of the wished-for termination or the end in view. In this way the stream of events is given a course which, in spite of accidental side currents and external interference, leads eventually to the end desired.

This is familiar enough in human affairs; but something of the same kind should be recognized as a constant feature of all teleological action and hence as a general biological characteristic. In living organisms the various automatic compensatory activities or "regulations" which keep vital processes on their normal level are open to physiological analysis. Many of these are general protoplasmic activities, while others are based on the functions of special organs; thus the concentration of the blood plasma is kept constant by the kidney, the constancy of the blood-sugar level by the pancreas, and so on. Where additional energy is required, as in regulations requiring muscular work (control of posture, of blood pressure, etc.), this is typically furnished by increased oxidative metabolism. In general, the rate of metabolism is under exact regulative control, as is shown by the normal constancy in oxygen consumption and by the general facts of bodily maintenance, growth, and repair. But it must be remembered that the present existence of these regulations presupposes some earlier process of development and integration by which they originated in the course of evolution. Unless we accept the thesis that evolution is based solely on random variations, there seems to be here implied the continued presence of natural factors of another kind, having the quality of directiveness; and ultimately biological evolution would be referred largely or mainly to such factors.

If we extend this principle to the natural world in general, the logical conclusion would be that the differentiation and individuation everywhere found in nature is largely or mainly the expression of some nonrandom or directive agency which is a universal factor in natural process. We observe that nature is far from being uniform in its composition; its matter is distributed in a complex and apparently arbitrary manner, and the same is true of its energy. Random activity, if left to itself, would be expected to have a very different kind of effect, leading toward an eventual uniformity of distribution and hence of thermodynamic potential, corresponding to the so-called "heat-death" of Clausius—a state of things which does not now exist and which there is no good reason to expect.

The essential problem with which we are now concerned has reference to the general factors and conditions of natural diversification, creation, and evolution. The synthesis of complex systems by the concrescence of simpler systems appears to be a constant feature of the natural process as a whole; it is important to note that evolution is not confined to living organisms. In general, synthesis requires the convergence and close association of a variety of diverse elements. This is seen most clearly in living organisms, and in this case (as already indicated)[1] the free energy required for this convergence is derived from more elementary physical processes and has the appearance of being applied directively. A nondirective application of free energy, as in an explosion, leads typically to a more uniform, as well as scattered (i.e., nonconvergent), distribution of components; the great example of this tendency on the cosmic scale is the nondirective dissipation of energy described in the second law of thermodynamics and illustrated concretely by such processes as the automatic cooling of bodies or diffusion in gases or solutions. In many departments of physical theory randomness in the motion of ultimate particles is presupposed in the mathematical treatment; this is the case, for example, in the kinetic theory of gases, and calculations so based lead to results in close conformity with experience. The continual random motions of the molecules are the condition for the uniform and stable properties shown by all gases and formulated in the gas laws.

But random action alone can hardly account for the evolutionary diversification of nature. Randomness should not be identified with capriciousness; it corresponds to a very definite type of lawfulness, formulated in the mathematical theory of probability. In some forms of scientific procedure randomness is, in fact, relied upon to give a certain type of regularity, one free from the element of conscious choice or bias, as in the random sampling of statistics. But the kind of regularity observed in the integrative processes of living organisms is of a strongly contrasted type; we realize this when, for instance, we see the animal in its embryonic development building up a complex organization out of randomly distributed materials taken from its environment and then maintaining this organization throughout a long life. An even greater contrast is seen in consciously purposive behavior, as when a human being carries into effect a complex plan of action.

Taking our ground on simple observation and generalizing broadly, the conclusion seems to be forced upon us that natural activity has two contrasted forms or tendencies, which reach their extremes at the opposite ends of a scale containing

[1] Chap. ii, p. 33.

many intermediates: these may be designated as (*a*) random or undirected and (*b*) teleological or directed. As already pointed out, any teleological process includes in its inner detail both types of activity, in close association and interdependence. Careful examination of a directed process invariably discloses the presence of random subprocesses which occur with the same regularity and precision as the directed process; indeed, without this nondirective and purely physical regularity any effective direction would not be possible. We may put the matter briefly as follows: All local natural occurrences, both directed and undirected, prove on analysis to be composites in which the single event-components show definite characters conforming to quantitative rule. But in the directed occurrence there is, in addition, a comprehensive controlling factor which overrules or subordinates the undirected processes in such a manner that these do not prevent the attainment of a definite final end (end in view).

To give a simple physiological illustration of the above: the adaptive character of the vasomotor reaction determining the blood supply of an organ is not affected by the innumerable random motions of the corpuscles carried along in the blood stream. Similarly, when a man rises in the morning to greet the world, the random motions of his bath towel and garments do not prevent him from accomplishing his purpose. In the former instance, the motion of the blood stream as a whole is integrated by the walls of the vessels and the other special structural and physiological features of the circulation; in the latter the essential integrating factor appears to observation as psychical, consisting in the simple intention to rise. In both cases the directive and the nondirective factors act together and play into one another's hands; the uniform distribution of the corpuscles and hence of the oxygen in the blood depends on random (stirring) factors; in fact, many familiar purposive actions rely on such random factors, as when one washes one's hands or stirs a cup of tea; "trivial" examples are best, since they illustrate the universality of this condition. Often, in order to make a mechanical process teleological, only a single purposive intervention may be required, such as the turning of a key. Simple dichotomies of this kind, as when we decide whether to lock or unlock a door, underlie many important decisions. When I press a button or turn a key, this may be the only directly purposive act in the whole sequence; the other events all happen in accordance with probabilities which are fixed by the arrangements and configurations already existing in the system: "nature does the rest!"

Instances such as the foregoing show how inseparable teleological actions are from the presence of random, mechanical or unguided processes in the inner detail; and they illustrate a condition which is fundamental in the natural world. Accordingly, whenever we disclose by analysis the physical factors making up a complex process (biological or other), we do not disprove the possibility that the process as a whole may, nevertheless, be teleological. This constant presence of the casual element in events is seen in the simplest voluntary actions, as when we set down an object on the table; there is always some accidental vibration before it comes to rest, conforming to the well-known "die-away" curve.[2] Both the presence of the casual ingredient in common events and the dependence of regular physical conditions on casual events are thus illustrated, as well as the special particularity or individuality of the action, which depends on the intention of the conscious agent.

Analogous considerations hold for integrative processes on the higher psychical plane, such as the painting of an imaginative picture by a human artist. If the process of artistic creation were observed as a purely physical sequence by an external observer, like Laplace's ideal physicist, able to observe the motions of the single molecules and to represent the whole process as the effect of their summation and combination, the final physical result would correspond to the making of the picture. All physical and physiological subprocesses would be found compatible with, and many contributing directly toward, the creative end-result.

[2] The curve which represents graphically Newton's law of cooling, the discharge of a condenser against resistance, osmotic transfer, and many other physical processes.

But can anyone suppose that such an analytical description as the foregoing would give a complete explanation of the unification or creative synthesis which is the distinguishing feature of the process considered as a whole? For the guidance and integration of the innumerable physical subprocesses the ideal, image, or Gestalt in the mind of the artist is all-essential; this constitutes a stable directive and unifying factor which controls the manipulation of material and determines the exact shape taken by the final product. We see by this example that analysis by itself is insufficient for the complete description of any synthetic process which leads to a predetermined end. So far as any scientific description is possible of such processes, it would also require a science of synthetic procedure; and, in fact, highly developed sciences of this kind already exist in all the fine arts, as well as in other synthetic arts, such as engineering, medicine, and the various fields of applied science. What is especially to be noted is that no purely physical or physiological analysis, however detailed and exact, can account for the feature of originality or novelty, which, combined with integration, is the essential fact in any creative process.

It should not be overlooked, however, that the actual presence of a conscious plan, image, or Gestalt, existing in advance as a directive and integrative factor, is not necessary in every individual instance of synthetic action. Synthetic processes may become routinized or stereotyped, like many other sequences of nature; and this is continually illustrated in biological processes.

In living organisms many adaptive activities may in their origination have been consciously teleological, but they have since become fixed by habit or heredity and are now carried out unconsciously and automatically. There is also the further class of animal activities which are consciously conative but are now pursued without any knowledge of their biological or other ends, simply because they are pleasurable, i.e., have psychical valence.[2] Their teleological character has been established at an early stage of evolution, and the physical conse-

[2] Cf. W. E. Agar's book (cited p. 65) under "hormic goal."

quences of the present action—which are often far in the future—may be quite unknown to the agent or indifferent to him. Here Goethe's expression is classical:

> Solange nicht den Bau der Welt
> Philosophie zusammenhält,
> Erhält sie die Getriebe
> Durch Hunger und durch Liebe.

The Trobriand Islanders, according to Malinowski, are ignorant of the biological significance of sexual intercourse.

There is a fundamental biological problem here of how so many organic activities, essentially finalistic and teleological, have come to be so completely dependent on routines in which there is a closely unified interplay of physiological and psychological factors. Hunger is a case in point; the interdependence of the two conditions—(1) depleted food reserves in the physical organism and (2) the peculiar psychical affection of hunger—is as familiar as any other instance of psychosomatic integration. Hunger is a partly sensory, partly emotional state, arousing strong impulses to purposive action. It is found to be regularly associated with special physiological processes, including muscular contractions in the wall of the stomach; and because of this constant physical association the physiologist is likely to conclude that the last word on hunger is said when the physiological description is complete. The starving man would dispute this; but the illustration may serve to make clear the difference between the pure physiologist and the psychosomatologist, e.g., of the Freudian school.

Both the physical and the psychological descriptions may be quite true, so far as they go, but either is incomplete by itself; partisanship is out of place, since what science demands is openmindedness in the face of *all* the experimental facts. The scientific observer, if he is candid, is aware that behind the consciously observed phenomena of experience lie many other conditions, some of which may in their very nature be unobservable. No one can doubt the existence (or "subsistence") of certain constant natural conditions which are essential to the process of observation itself, as a general psychobiological activity; and we may further assume that there are in nature even more general underlying conditions, which are foundational to natural reality itself but for the present are beyond human observation. We may acknowledge this frankly without any discredit to science, realizing that the mystery of existence is not dispelled by the advance of purely scientific knowledge.

CHAPTER VIII

Natural Reality, Symbolization, and Scientific Method

BEFORE considering teleology in more detail it seems necessary to review briefly certain general characteristics of scientific description and symbolization[1]—now perhaps the chief means of representing nature to our minds and making it comprehensible. Our purpose as scientists is to reach an intellectual understanding of certain types of natural activity; and a first step is to form as clear a conception as possible of the relations existing between the special body of doctrine called "science" and the natural reality as it is in itself, i.e., nature as a field of existence independent of human knowledge.

Science is a representation of nature by symbols and their combinations, and special care is taken to make the realistic and experiential significance of these symbols as clear and unambiguous as possible. Natural science is a realism. Its essential presupposition is that reality is one thing, symbolization is another;[2] science never doubts that the natural world has a real existence in its own right, independent of any representations which the human mind may make of it or about it. Accordingly, science makes a sharp distinction between the "universe of nature" and the "universe of discourse," considering the latter to be something secondary to and contained within the former, which is the independently existing real world with all its properties and activities.

[1] For a general descriptive and theoretical account of symbolization, scientific and other, see the article "Foundations of the Theory of Signs" by C. W. Morris in *International Encyclopedia of Unified Sciences* (Chicago: University of Chicago Press, 1938), Vol. I, No. 2. C. K. Ogden and I. A. Richards' *The Meaning of Meaning* (4th ed.; London: G. Routledge & Sons, 1936) is a well-known modern book in this field.

[2] "There is the name and the thing; the name is a voice which denotes and signifies the thing; the name is no part of the thing, nor of the substance; 'tis a foreign piece joined to the thing and outside it" (Montaigne, essay *Of Glory* [Cotton's translation]).

Reality, actual existence, is assumed to be something which is unequivocal—is what it *is;* while language and other symbolisms may be (and often are) highly equivocal, indefinite, and misleading. In our everyday experience nature exhibits itself as a refractory and (so to speak) self-willed medium within which there are many elements and conditions which we cannot change and about which it is impossible, in the long run, to deceive ourselves. These elements are insistently *there;* and it is futile, or worse, to use symbolism in such a way as to misrepresent or "deny" their actuality. The disastrous results following the obstinately unrealistic use of symbols are well illustrated by the present war; an opposite form of unrealism (which may be equally disastrous) is to ignore the existence of anything that is not freely talked about or otherwise represented. The only satisfactory recourse is a direct appeal to experience itself—which is the method of science. To give a simple biological illustration: we always find, whatever we may say or wish, that a man or other living organism soon dies if deprived of food. Such an unequivocal natural fact which regularly repeats itself is called a "law of nature"; nature is like the Medes and Persians in allowing no exceptions to certain laws.

It is a peculiarity of science, as a realistic mode of description, that it stresses the *lawfulness* of natural events. But nature, according to our present survey, also includes in its composition an initiatory, novelty-producing, or teleological element or ingredient, one not bound by pre-existing rule. Nature is not a closed system. Such novel factors are especially evident in living organisms, and the not infrequent disregard of precedent which they show is difficult to reconcile entirely with fixed law. To many scientific men the concept of teleological seems to conflict with the belief in a universal natural law-abidingness admitting no departure from rule. Apparently, the only way out of this difficulty is to recognize frankly that scientific representation does not consist in simply copying nature as we find it, but involves a special kind of selectiveness or abstraction; science is, in fact, a mode of singling out and representing accurately the constant, stable, recurrent, and therefore verifiable features of experience and of the natural world. It explains the changing aspects of nature by reference to the unchanging;[3] hence arises the scientific preference for mathematical models or methods of description.

But the final basis of science always remains observation; and this observation, besides being painstaking and exact, must be impersonal, implying co-operative, since a further essential requirement is agreement between different observers. Thomas Huxley recognized this in describing science as organized common sense. Accordingly, the type of descriptive symbolization which it has developed aims at conformity with the constant or verifiable features of the real world, as this is given in the experience of all competent observers. Nevertheless, it must not be forgotten that science is a *symbolization* of reality, not reality in itself; if its representation of nature is regarded as corresponding completely to the actuality, an element of misunderstanding, illusion, or unrealism may enter into the conclusions drawn.[4]

In any symbolism used for purposes of human communication, such as language, certain special items of experience, which are chosen for their definite and unmistakable character and reproducibility at will—in this case vocal sounds or writing—are agreed upon to represent or indicate certain other items of experience; the latter may include anything that has constant or stable features or recurs with sufficient frequency. The symbolic item—word, sentence, formula, diagram—then stands as a sign, index, or serviceable substitute in discourse for the indicated item or "referent."

Language has developed so many words and expressions which signify *absence* of law—lawless, random, haphazard, fortuitous, indeterminate, unpredictable, and so on—that we may be sure that human experience contains much that corresponds to this description. The scientific question is whether what is true of our conscious experience may be regarded as

[3] Bergson emphasizes (perhaps overemphasizes) this feature of science in his *Creative Evolution* (New York: Henry Holt & Co., 1911).

[4] The dangers of confusing or "identifying" symbol and reality are discussed at length in Alfred Korzybski's *Science and Sanity* (Lancaster, Pa.: Science Press Printing Co., 1933; 2d ed., 1941).

also true of the real independent world of nature which is partially reflected in that experience and represented secondarily in the language or other symbolism with which we picture experience. To many reflective persons the advance of science has seemed to show that the conception of certain occurrences as lawless or indeterminate is based on imperfect knowledge. "Lawless" is a negative concept; all apparently random or casual actions, when examined by science, are found to be not entirely lawless but to illustrate certain types of law, even though in many instances an irreducible or "not understood" residue may also be found. The circumstance, however, that factors of law and constancy are found in any single object or event which comes under scientific scrutiny does not prove it to be entirely law-abiding and nothing more. There is also the fact of individuality to be taken into account. Indeed, any distinguishable natural entity or individual, even the simplest, appears on close examination to have in it some element of constitution or behavior which is not entirely law-abiding or predictable.

On the philosophic view, some measure of uniqueness or autonomy belongs to each natural individual; each has its own "singularity"; as a real existent having its own separateness or special station in nature, it is not repeated, and therefore it contains factors and qualities which are not repeated. Any action which depends on such individual or intrinsic factors is to that extent "free" action; and in this sense any natural individual has a greater or less degree of freedom—definable here as determination by internal factors forming a part of its particularity, i.e., by factors which have a special relation to its isolation as an individual entity, or what might be called its "monadic character." A scientific definition of individuality and freedom would be based on considerations of this kind, but both the degree of individuation and the freedom would be recognized as varying widely in their development and expression.

The older physical conception of natural processes as *completely* determined by invariant factors or conditions is characteristic of the scientific point of view predominating in the eighteenth and nineteenth centuries. Historically this conception appears to have been based on the assumption (largely unconscious) that repetition in the natural world is of the same exact kind as repetition in the abstract symbolic worlds of human invention, such as logic and mathematics. Such a conception assumes, in other words, that the real or existential universe and the universe of discourse and description may be regarded as having (potentially at least) a complete one-to-one correspondence with each other. The disclosure of this correspondence would then be the main task of science.

The question whether this view is justified has been the object of endless discussion, but it cannot be denied that a very close correspondence does exist in many cases. This is shown not only by the very evident success of science but also by the simplest facts of experience. Take the highly practical operation of *counting:* An arithmetical statement, like $2 + 2 = 4$, is usually regarded as expressing an incontrovertible truth. Yet we must note that it belongs in the general logical class of analytic statements and that its apodictic character depends on an abstraction from the natural fact of individuality. Any careful observer can convince himself that repetition and summation in the natural world, and the same processes in the conceptual world, are not to be completely identified, although they are undoubtedly closely correlated and apparently are to be referred ultimately to the same natural foundation.

In our experience of physical nature the conjunction of two individuals produces a result which is determined by their characters as individuals; their special properties and the special manner of their conjunction are factors to be considered, besides their mere number, in predicting the experiential outcome. At the same time it is true that a consideration of the invariant, repeated, or uniform characters of natural objects and events is often sufficient for scientific or practical purposes. But while experience shows that all natural processes have their invariant conditions and factors, this circumstance does not commit us to the belief that other characters, having the special feature of novelty—i.e., nonderivation from the past or nonrepeatedness—are not *also* present as determining factors in single events. Individuation, evolution, and creation are also features of the natural process. The invariant, regular, or constant characters of nature are, however, the ones on which science, as science, fixes its interest.

Experience shows that there are many close parallels between the behavior of physical objects in the external world and the behavior of symbols as manipulated by the mathematician in accordance with strict logical rule. For example, the physical summation of weights on a balance and the arithmetical summation in the mind of the experimenter agree closely. But the two processes are not identical; and in nature there is always some margin of uncertainty—of plus or minus—no matter how close the correspondence may be. It is upon the general fact of correspondence between logical processes and experience that the possibility of scientific prediction is based. The logical and mathematical order corresponds to the stable order of nature; in modern times the term "isomorphism" is often used to indicate the essential feature of the correspondence between mathematical order and natural order.

The word "order" implies stability, or something stable, existing as a determinative condition. What should be noted at this point is that only in so far as things are orderly are they representable mathematically. In its very nature such representation has reference to the invariant, constant, recurrent factors and ignores the individual or arbitrary ("free") factors in objects and events. Every time a given mathematical operation is performed, the result is the same, because the terms and the procedures are by definition constant. But close observation shows that every time a natural event repeats itself there is some variation—it may be slight—hence the mathematical description is always an approximation. There is an interesting parallel in the representation of a musical composition by notation, a mathematical scheme which, as such, is constant, although the individual performances may vary widely.

The conceptual world, or universe of discourse, is a human creation and is subject to the rules of logic, also a human creation. The world of external nature also conforms to the rules of logic and mathematics, but only in so far as its entities and processes contain factors of stability which correspond in their invariance with the invariance assigned by the arts of logic and mathematics to their special terms and procedures. Mathematical physics is the standing proof of this "logical" quality in nature; its success justifies the belief that there actually exist in natural conditions and processes stable factors and elements which conform closely—even if not "absolutely"—to the invariant features of logical and mathematical procedure. Many natural events repeat themselves with astonishing exactitude.

Nevertheless, a thesis long familiar to philosophers is that the description of a particular event or situation in generic terms—a necessary feature of description in its abstracting and classifying character—inevitably omits what is unique or peculiar to the special individuality of the thing described. Since any natural object or event, considered as an isolable entity or individual, always shows some quality of uniqueness, fallacies may enter when scientific descriptions of natural regularities are regarded as giving a complete account of nature as it is in itself, i.e., existentially.

The naturalist can never doubt that the existing world has a character and an activity of its own which are independent of human conception; nature, as a sequence of events which occurred in past history, had its existence long before human beings were evolved. In so far as nature is the field of individuation, we may be sure that it will always exhibit many features of manifestation and behavior which, although governed in part or even mainly by regular conditions, also show unpredictable characters of their own, having their basis in a natural tendency of all individualized existents to transcend established rule. Rules are equivalent to stable conditions already laid down, but it can scarcely be held that all possible rules have already been made in nature—unless we hold that individual nonconformity is itself a rule! Whenever a description (a formulation in conceptual terms) is regarded as a complete representation of a natural reality, there is this risk of fallacy.

Observation shows quite convincingly that nature is a highly diversified and individualized field of activity and creation, and much of what has occurred and is now occurring within it could never have been predicted on scientific grounds. At the same time it is a matter of experience that many events occurring under broad and stable natural conditions, especially of the kind known as "formal," can be predicted with remarkable exactitude; of this general fact eclipses are perhaps the most impressive illustration. But sweeping conclusions with regard to the *complete* causal determinateness of nature—past, present, and future—including human behavior, should not be drawn from such correspondences between natural events and their scientific representation. If we accept the evidence of experience, it seems clear that *both* regularity (formal stability) and individual uniqueness (implying a measure of unpredictable or "free" activity) are actualities in all natural existents; also, that they occur in intimate association and interdependence. There is here a close parallelism with the association of randomness and directiveness in certain events, as already discussed; this, again, is related to the association of physical and psychical in living organisms. These general characteristics of nature should be borne in mind in considering the problem of teleology, to which we shall now turn.

CHAPTER IX

Teleology

THE tendency, which still lingers in scientific circles, to deny that teleology exists as an effective factor in nature or to subordinate it completely to purely physical factors, is largely a survival of the Laplacean or Victorian belief in the completeness and all-sufficiency of physical methods of explanation. Actually this belief was (and still is) confined to a small and specialized group consisting chiefly of learned men; as a rule, human beings who form plans and carry them out, using physical means whenever necessary, never dream of regarding the *whole* of purposive activity as mechanistically determined. The Aristotelian conception, concisely expressed in Woodbridge's phrase, "Teleology and mechanism are correlative rather than opposed," is more in accordance with the accumulated experience or common sense of mankind, and there is no sound reason for regarding it as conflicting with scientific fact or principle. This is now recognized by many scientific men and has been well expressed recently by Sir D'Arcy Thompson in his book *Growth and Form*. He speaks of the insuperable difficulty of determining final causes, while granting that teleology and mechanism are inseparably conjoined in living organisms: "Still, all the while, like warp and woof, mechanism and teleology are interwoven together . . . . their union is rooted in the very nature of totality."[1]

The fact that the physiological side of human purposive activity shows such complete physical regularity and determination remains a serious difficulty to many scientific men who might otherwise reject the purely mechanistic view of human behavior, now so widely and demoralizingly popular. No biologist will deny that any voluntary train of behavior can be shown by analysis to consist of interconnected physical activ-

[1] Sir D'Arcy Thompson, *Growth and Form* (2d ed.; Cambridge: University Press, 1942), p. 7.

ities which show complete regularity, precision, and determination in the scientific sense of these words. While this is undoubtedly true, nevertheless the exact course followed by the physical train of events may still be under psychical control.

We have already shown that in the teleological guidance of any purposive sequence the direct voluntary interposition is not continuous but intermittent and is applied at selected places and times where a definite trend has to be imparted to events or some correction made for random activities; in the intervals of this directive action the events follow their own physically determined or routine course. A game shows this as well as anything; it is a combination of causal and purposive actions, with the interest derived largely from their interplay; when the tennis ball is struck, its course, until it is struck again, is determined solely by physical factors; the directive influence of the player is interposed only when he serves or makes his return. This example may be taken as a model of teleological action in general: "man shifts things about and nature does the rest."

A large preponderance of mechanical or physically determined regularity appears to be a constant feature of every teleological situation—at least in nature as we now find it. Whatever is physically observable appears to external observation as physical. At the same time, certain determinative or critical features of the inner physical detail may receive their special direction from psychic factors, as we saw in our earlier illustration of writing a letter; and this direction may determine the whole course of events.

In general, we conclude that physical stability and physical automaticity (i.e., stability in modes of action), so far from conflicting with directive action, are, in reality, necessary conditions and prerequisites of such action. In order to make any kind of guidance effective, the purposive agent must be aware of the regular and reliable features always present in any natural situation and must act with continual reference to these. Usually such features are the physical features (which include formal conditions like space and time); accordingly, the whole natural sequence may appear to scientific analysis "as if" it consisted of "nothing but" rigidly determinate physical factors. Even where "irregular" factors are also recognized as forming part of the total situation, they are usually assumed to vary in accordance with definite rules, e.g., of probability; in other words, the variants can, in a well-understood situation, be treated as manifestations of underlying invariants. In cases where we find individual behavior to be hopelessly unpredictable, we usually fall back on considerations of probability, as the best we can do under the circumstances.

In all scientific prediction of events, from astronomy to sociology and current history, principles based on knowledge of the stable features of constitution or activity are applied; for example, in civilized countries the size and racial composition of the population at a future date are regarded as largely determined by factors known to be already in existence which act in definite ways. Such factors are treated as invariants—at least provisionally—and their time relations may be represented graphically by curves of known type; prediction then becomes a matter of extrapolation. In the most uncertain cases, as in forecasting the actions of a particular human being, such prediction as is possible is based on the known stable facts of his or her mental and physical constitution, as well as of the external circumstances. But if we are dealing with a complex personal character, it is more than likely that novelty will assert itself unexpectedly and confound all prophecy. Often the only possible prediction regarding personal actions is that they will remain capricious and unpredictable.[2]

Conscious directive activity requires the ability to foresee or predict, and this ability is based on knowledge of stable factors—i.e., factors which can be relied on to remain the same in the future as in the past. To a person armed with such knowledge, all that may be required to modify the course of events in the way desired is temporary intervention at certain critical points in the causal nexus. Control of what happens at these points then becomes the key to the whole situation—provided always the intermediate events run true to form. Certain events may

[2] ". . . . varium et mutabile semper Femina . . . ." (Virgil *Aeneid* iv. 569–70).

thus be recognized as "key events"; and it is conceivable that in some actions of living organisms, including human beings, these may be events limited to a few atoms in the central nervous system, as Eddington imagines in his conception of "key atoms."[3] But the proviso that the intermediate events remain constant in their character is essential; and, in fact, such constancy is taken for granted, usually unconsciously, in all purposive activity; this is illustrated in games, war, scientific and other arts, and the pursuits of ordinary life.

We have seen that a purposive control which is conscious presupposes some mental image, conception, or plan of the end desired. If this integrating psychic factor is absent or fails to be acted upon, the sequence of events follows a course which is completely determined by the physical factors[4] present in the situation. But even a slight voluntary modification of these factors, at times and places chosen in conformity with the plan, may insure that events move in the preconceived direction and terminate in the way desired. To a purely external examination the whole sequence may then appear as physically determined, in the sense that the energy transfers and the other efficient causes everywhere conform to exact physical rule. But if a conscious plan, constituting the psychic factor in the activity of the agent, is present and acted on throughout the situation, the whole physical sequence of events takes on a unitary character corresponding to the requirements of the plan. The physical sequence then shows a coherence and integration similar to that of the plan. It must always be remembered, however, that what the mental factor is responsible for is the *integration*, not the physical detail of the sequence: it corresponds to Aristotle's "final cause"; the efficient causes remain purely physical.

This general description applies to any consciously teleological sequence of events. It is only when we can rely on the stability and uniformity of the physical factors present that we

[3] Sir Arthur Eddington, *The Nature of the Physical World*, esp. p. 313.

[4] These include all factors independent of the will of the particular agent; and some of them may, of course, have their origin in the purposes of other agents. But to the first agent these will appear as events external to him and in this sense as physical (behavioristic or physicalistic view).

can modify a natural situation in correspondence with our intention. But to do this means introducing voluntarily, at the appropriate times and places, physical factors having the necessary conformity with the plan. If the plan is a novel one, the physical factors thus introduced partake of this novelty, and the course of events takes on a direction which it would never have had in the absence of the plan. The final result may then be novel or creative, as seen, for example, in an original work of art.

But in order that any preconceived plan, having at first only a mental existence, should have this result, two conditions are required. First, the plan itself must have a sufficient definiteness and persistence; and, second, its presence must in some way influence the course of the physical action without infringing the general physical conditions always present, such as those defined in the laws of energy. The first requirement is the general one of stable factors in all events (p. 16). The second requirement presents an especially difficult problem, i.e., of how psychical factors can have a directive influence on physical events; here we have the essential problem of teleology, and I know of no way to make this problem entirely simple or easy.

It seems possible, however, that a general solution consistent with the modern scientific outlook may be sought along the following lines. If we accept the prevailing view that the course of physical action, especially on the micro-scale, is governed ultimately by conditions of probability, all that the psychic factor can consistently be regarded as doing is to make it *more probable* that the critically determinative physical events ("key events") will show a preponderance in one direction rather than in another, i.e., will have an asymmetrical and directed, rather than a random, incidence. The question is *how* does the psychic factor effect this modification?—since there seems to be no doubt that it does so. The only consistent hypothesis known to me is that the ultimate *locus* of psychical control, in the psychophysical system which is the living organism, is situated *internally to* or behind the elementary physical events (ultimately quantum transfers) which determine the direction of action in the physical field. This hypothesis implies that the final elements or factors underlying psychical action have a certain *inner* or nonspatial quality which places them on a different plane from the plane of purely physical action, meaning here by "physical action" any action forming part of an external or spatial world and describable in terms of external observation. Psychical factors, according to this view, would have a nonspatial, or form part of a nonspatial, mode of existence.[5] However, when the psychical influence expresses itself in the physical world—apparently by some process of transformation and transmission associated with physical amplification[6]—whatever happens becomes necessarily subject to the special conditions and restrictions (e.g., laws of conservation) which form a constant part of that world.

Two questions require further consideration at this point: first, with regard to the part played by probability conditions in natural events and, second, with regard to the manner in which the internally active psychical factors can modify these conditions. In modern physics probability conditions are regarded as having a maximum of stability and as underlying the stability of physical action in general.[7] For example, the preservation of its constant properties by a gas is referred ultimately to such conditions (conditions of statistical mechanics), and quantum theory is based on probability theory.

To many it may seem strange that random events, rather than psychically guided events, should be the ones which are most completely subject to physical regularity; but the strangeness largely disappears when we consider that in the absence of guidance there is nothing to make the necessary motions or

[5] Cf. the discussion above, p. 80.

[6] Cf. my paper "Physical Indetermination and Vital Action," *Science*, LXVI (1927), 139, for a fuller discussion.

[7] For a summary account of the applications of probability theory in physics cf., for example, Lindsay and Margenau, *Foundations of Physics* (New York: Wiley & Sons, 1936), especially chaps. iv and v. For more general discussions cf. Eddington, *The Nature of the Physical World*, chap. x; also his *New Pathways in Science* (New York: Macmillan Co., 1935), chap. vi, and *The Philosophy of Physical Science* (New York: Macmillan Co., 1939); also, Sir James Jeans, *Physics and Philosophy* (New York: Macmillan Co., 1943), chap. v. For more technical aspects and detail, reference must be made to special memoirs and treatises.

transfers of energy occur in one direction rather than in another. Purely spatial conditions are equal or symmetrical in all directions; hence, without guidance, disconnected events of the same kind tend to distribute themselves without preference, or symmetrically—e.g., about some central position or line of reference, as illustrated in probability curves.

This condition is amply exemplified in general human experience. We observe that casual, disconnected events of any kind, if sufficiently numerous, fall into stable groupings or patterns; this is seen equally in dice-casting and in vital statistics; and the patterns are found conformable to the rules of probability. Similarly in genetics, the laws of Mendelian inheritance are regarded as depending for their constancy on probability factors. In the long run there is nothing quite so regular as chance—as is well understood in Monte Carlo.

In psychically guided events, on the other hand, there is always a quality of individuality, uniqueness, and unpredictability. This statement is not inconsistent with the fact that the arbitrary actions of single persons may, if the number of instances is large, fall into regular statistical patterns, as is seen, for instance, in the statistics of divorces and suicides. In this case, however, the separate events of the assemblage, although each one is psychically determined, are quite disconnected, so that their *distribution* becomes a matter of chance and shows a corresponding regularity. Our present problem has reference to the psychically determined actions of single biological individuals. How is the psychic factor to be conceived as influencing the elementary physical events which underlie and determine such actions?

Apparently, if we are to avoid conflict with the requirements of physical conservation, the ultimate source of directive quality in vital action must be referred to factors which act intra-atomically,[8] since in the interior of atoms the elements of action are regarded as asserting themselves under conditions of determination quite different from those of large-scale phe-

[8] Here I find myself in agreement with a leading atomic physicist, Niels Bohr; cf. his paper, "Causality and Complementarity," *Philosophy of Science*, IV (1937), 289, esp. p. 295.

nomena. I have already expressed this point of view in an earlier paper,[9] which may be paraphrased here with some slight modification, realizing that any conception which is too specific may be open to criticism in detail. Consider a single atomic unit, corresponding, for example, to one of Eddington's key atoms. Such a unit is a store of energy; physically this means that under certain conditions it may transfer one or more quanta of energy to some other unit or units in its environment and so transmit activity or influence. Any such single transmission has a directive (vector) character, since it occurs between definite units having definite spatial positions. If the unit is conceived as having no spatially fixed internal differentiation, such a transmitted action, if determined solely from within, could equally well be in *any* direction. That is, the direction, if determined by solely physical conditions, would be a matter of chance. No internal impulse to action would necessarily act in one direction rather than in another, since any such physically determined action would imply the existence of one part acting upon another along definite lines of contact or interconnection, as in large-scale mechanical transmission; and such definitely situated separate parts are here absent. We may thus conceive of the possibility of an intra-atomic directive action which is quite independent of the classical laws of energy; these laws relate solely to the behavior of systems consisting of *many* atomic units. If a single atom is considered, uninfluenced by others (i.e., from outside), it seems that a quantum transfer *from* this atom might be in any direction (i.e., *to* any other atom) without any infringement of physical laws. The same conclusion would apply to groups of atoms acting in concert—e.g., under some unifying influence of a psychical kind.

The foregoing view is based on the assumption, well supported by observation, that any repeated local activity which is aimless and is carried on over a sufficient length of time has an incidence which is equal in the different directions of space (i.e., is symmetrical), as we see in dice-shaking or shuffling. In

[9] "Types of Physical Determination and the Activities of Living Organisms," *Journal of Philosophy*, XXVIII (1931), 561.

such a case there is no preponderance of motions or energy transfers in a single preferred direction.

In order that such asymmetry should prevail, *aim* is required—i.e., using the terms of ordinary language, some bias, preference, directiveness, or purpose. Each *single* element of motion or action in a spatial world must have, while it lasts, some direction in space; but in a random succession of many such motions the total or summated effect will show no preponderance in any one direction, since action in a single direction is sooner or later counterbalanced by action in the opposite direction. What is required to give a preponderance in one direction is, according to our present view, some persistent individual or integrated influence favoring action in a definite direction. This is furnished in living organisms by the internal psychic factor, acting under the influence of its subjective aim, appetition, or motivation. A pattern of directive activity is thus provided, corresponding to a "field" with stable and integrated characters (see below, p. 183).[10] This general conception defines the elementary condition, which permits of further complication and lends itself to the formation of more highly organized combinations.

Broadly speaking, such a model seems consistent with the present physical conceptions of intra-atomic conditions. What is to be noted is that the view of a completely rigid and unequivocal physical determination in all vital processes had its historical origin in, and support from, classical physics, whose laws were based on the observation of large-scale phenomena. At the present time the recognition that other sources of determination, including the psychical, may play their part in vital action is no longer inconsistent with prevailing physical theory. The deviation of natural events from strict symmetry, as a consequence of some internal directive action, is a natural possibility which does not conflict with the conception of math-

[10] A quotation from Whitehead is apposite here: "It seems that, in bodies that are obviously living, a coördination has been achieved that raises into prominence some functionings inherent in the ultimate occasions. For lifeless matter these functionings thwart each other and average out so as to produce a negligible total effect. In the case of living bodies the coördination intervenes, and the average effect of these intimate functionings has to be taken into account . . . ." (Whitehead, *Adventures of Ideas*, p. 266).

ematical exactitude in single physical events. The asymmetry (temporal as well as spatial) which underlies all vital action manifests itself in many ways besides conscious teleological action—for example (as already pointed out), in the asymmetry of metabolic syntheses, the fact which so impressed Pasteur; this asymmetry is shown especially in the asymmetrical structure of the amino acids, which form the building-stones of proteins. Asymmetric syntheses underlie all vital action; this general biological fact justifies the conclusion that the directive factor in the growth and development of living organisms is referable ultimately to conditions of the same kind as those underlying other forms of directive action. We shall return later to this topic,[11] after considering more fully the special nature of the physical factors in vital processes.

[11] See chap. xiii.

CHAPTER X

Stable Conditions in Living Organisms and the Distinction between Living and Nonliving

DURING the normal lifetime of the living organism its varied and complex functions are carried out with remarkable exactitude, each function maintaining its unity and its correlation with the whole vital economy.[1] This fact seems especially impressive when we reflect how subject to derangement are the complex physical systems of our own contrivance.

What kind of factors determine this combination of unity and stability? The word "integration" points to the fact without explaining it; similarly, the statement that the organism is an automatically self-regulating system is a description rather than an explanation. There is no doubt that one chief source of this constancy is to be sought in the constancy of the component physical and chemical processes; i.e., the stability of living organisms is to be referred in large part to conditions of the same general kind as those determining the stability of other processes in nature. Just why natural processes should be ordered rather than chaotic—i.e., should repeat themselves with such exactitude—is a philosophical rather than a scientific question; science observes this fact of regular repetition, especially in the elementary events and aspects of nature, without, as a rule, troubling itself about its ultimate significance.

As already pointed out, one source of constancy in larger natural events is the statistical summation of the simpler events composing them. Individually considered, these may be highly variable; but if many are taken into account, they are usually found to conform to some definite law. Many natural regularities have their basis in such statistical summation,

[1] This is the *homoeostasis* discussed with knowledge and insight by W. B. Cannon in his *The Wisdom of the Body* (New York: W. W. Norton & Co., 1932).

and many routine physiological processes owe their stability to such conditions; thus the cells composing the liver or kidney may vary widely in their physical state and activity at any given time, but their collective activity remains constant within narrow limits. Such statistically constant physical routines may also enter as components in actions occurring under psychical direction, as in voluntary muscular movement; in any such action observation shows that rhythmical nervous or bioelectric oscillations of a well-defined frequency are initiated in the cerebral cortex and pass along the nerves to the muscles. The initiation of these impulses is "determined" by the act of will, but the study of isolated nerve-muscle preparations shows that their propagation and motor influence are determined by nonteleological factors having definite physical characters; and these characters owe their constancy to statistical summations of still more elementary processes. In general, physical reproducibility depends on the physically based automaticity of simpler component processes, and ultimately these include atomic processes. In any instance of voluntary action this physical precision of the elementary processes is counted on or presupposed; obviously, anyone would be unable to walk or swallow if he had to attend to all the physical details of these acts.

The conclusion follows that repetitive, automatic, and individually unguided factors enter as components in all natural events, whether they are purely physical and random or vital and teleological. The constancy with which fundamental natural conditions and events repeat themselves is shown by their calculability; as already pointed out, this fact implies that the constancy in the behavior of natural units and systems has a correspondence with the constancy assigned by definition to the mathematical symbols and procedures employed in the calculation. The accuracy of the algebraic or graphic representation of a phenomenon is like the accuracy of a map which portrays the stable features of a locality. In simple natural events, e.g., the motions of astronomical masses, this correspondence is astonishingly close; but observation shows that natural events of almost any kind, including the biological, show a similar conformity to mathematical rule if the observation is exact and the number of individual cases sufficiently large.[2]

Here we touch on a fundamental philosophical question having reference to the nature of the ultimate existential conditions which make scientific generalization possible. This is the problem of induction, with which in its philosophical aspect the scientific investigator is usually little concerned. But we may accept the fact that induction is empirically a valid procedure without understanding why. In actual scientific investigation, the more frequently single events of a recurrent and recognizable kind are found to occur in nature, the more certain do we become that there exist definite and stable physical conditions underlying and determining them. Frequency of repetition then becomes the basis of generalizations or predictions which have reference to all the events included in the assemblage under consideration.

In scientific description these events are assigned to definite classes, and all members of each class are assumed to have uniform "class characters." Hence is derived the general principle, implicit in all scientific reasoning, that repetition of events is based on stability of underlying conditions. To illustrate: the daily repetition of sunrise is based on the continued existence of the sun and the regular rotation of the earth. This principle may be extended to include the case of logical induction in general, regarding the foundations of which there is not yet perfect agreement among philosophers. But from the empirical point of view, induction, as a scientific procedure, owes its validity to the simple fact that natural processes repeat themselves. Natural science aims at forming clear conceptions of the stable properties, active or static, which belong to all the individuals of the group considered; it also aims at assigning a common foundation to these properties. From the family resemblances shown by the single members of the group the general characters of the family, as a natural unit, as well as the constant conditions underlying these characters, are

[2] Outside the field of vital statistics, the work of Nicholas Rashevsky well illustrates this mathematical conformability of vital processes; cf. his *Mathematical Biophysics* (Chicago: University of Chicago Press, 1938).

inferred. Since induction is primarily a procedure based on observation, it forms the characteristic mode of reasoning used in the natural sciences and particularly in biology. Evidently induction implies the existence of stable and pervasive systematic conditions in nature.

Living organisms are self-regulating systems which conserve automatically their special organization and modes of behavior; and biological science consists largely in a description of the physical and chemical conditions on which the autonomy, coherence, and stability of the organism are based. In physical biology the organism is considered primarily in its character as a physical system existing in a physical environment, and experimentally its properties are found to depend on the constancy of the physical and metabolic processes which build up its special organization and furnish the energy required for its activities. Individuals of the same species of animal or plant are closely similar in their inherited characters, even though there is evidence that in their fundamental chemical composition individuals of the same species differ slightly but significantly from one another.[3]

According to modern genetics, this uniformity of organization is based ultimately on the constancy of the physical and chemical properties possessed by the centrally placed protoplasmic aggregates, or *nuclei*, of the cells composing the organism. The nuclei contain the *genes*, which are regarded as determining the fixity of hereditary characters; and the special biological properties (or specificity) of the genes are referred secondarily to the biochemical specificity of their chief constituent proteins, the nucleoproteins. Microscopic and other evidence indicates that the same group of genes is present not only in the nuclei of the germ cells but in all the nuclei of the developing and adult organism. This is an especially interesting condition; apparently, an essential physical requirement, if the whole organism is to retain constant character, is

[3] Our knowledge of this "individuality differential" is based chiefly on the work of Leo Loeb, summarized in his recent book, *The Biological Basis of Individuality* (Springfield, Ill.: Charles C. Thomas, 1945). The experimental evidence points to the conclusion that as a physiological character the individuality differential is based on the specific biochemical constitution of certain proteins.

that its nuclear compounds, the "key" compounds in its constructive metabolism, should have constant character throughout the entire organism. The stability of the organism as an integrated whole would then depend on the stability of the genes; hence, upon the exactitude with which the nuclear or gene proteins are synthesized in mitotic cell division depends the constancy of the special organization characteristic of the species.

According to this physical conception, a constant biochemical character pervading the entire organism forms the basis of its constant character as a biological species. It is especially to be noted that the stability of the individual characters from generation to generation (heredity) is based on the exact reduplication or resynthesis of the specific nuclear proteins in cell division and development.[4] These proteins are regarded as regulating the fundamental constructive metabolism of the organism; and they themselves are notable examples of the exact regulation of structure and composition. The factors determining this regulation therefore require consideration.

The ancient philosophical question of form and substance enters at this point. What is especially to be noted is the fact that, although the specific proteins on which, according to present physiological conceptions, the specific biological characters of the animal or plant depend are in a state of continual metabolic flux (as shown by the facts of nitrogen metabolism), the stability of their complex chemical configuration is quite unaffected by this circumstance. The recent method of tracing the course of atoms through the animal body by the use of readily identifiable isotopes (radioactive or "tagged" atoms) has confirmed this conception of constant flux, even in the case of the nuclear proteins determining the specificity of the genes. To quote from a recent volume on cellular chemistry: "Schoenheimer fed isotopic ammonium salts to normal animals and found that the nitrogen of the thymonucleic acid

[4] The reduplication is sometimes referred to as "autocatalysis"; but this designation is inexact, since the directive application of free energy is required in the building-up of these compounds from the originally separate amino acids and other components. Catalysis simply facilitates a reaction without adding any energy.

rapidly undergoes a partial replacement by isotopic nitrogen from the ingested ammonium."[5] What proves to be stable is not the actual material substance of the genes but their form, pattern, or constitution. From a general point of view, there is nothing unexpected or novel in this conclusion. The problem of the stability of form in the objects and events of nature, as contrasted with the transiency of their material, is at least as old as Plato. In physiology the living organism is regarded as an example of a dynamic or stationary equilibrium, i.e., an equilibrium of physicochemical processes.

It may be questioned, however, whether this physical conception is sufficient by itself to account fully for the organismic constancy. This constancy is a physical character; but, after all, the organism is not a merely physical but a psychophysical system. Accordingly, we ask the question: Can uniformly constituted physical units (genes), distributed at frequent intervals throughout the organism, furnish by themselves a sufficient basis for the organismic coherence and unity? Physiology regards the genes as the physical basis of integration. But this special biological property of integration is exhibited on the psychical no less than on the physical plane; and it is natural to inquire as to which of these planes is primary and which secondary or whether either, considered alone, can be regarded as primary. We grant that the physical coherence is indispensable; and, according to the present biological evidence, this is based on uniformity of nuclear characters throughout the organism. But the question remains as to how this physical uniformity was attained in evolution, as well as how it is maintained in the present; also, what its final significance may be, and what (if any) special determinative role is to be assigned to the psychical factors as distinguished from the purely physical ones.

This brings us back to the fundamental problem discussed in our first chapter. The essential question may be put thus: What are the distinguishing characters of the living systems of nature, as contrasted with the nonliving? The belief that some

[5] "Frontiers in Cytochemistry," *Biological Symposia* (Lancaster, Pa.: Jaques Cattell Press), X (1943), 182.

ultimate or irreducible distinction exists between the living and the nonliving has, for the most part, disappeared from modern biology, mainly because of the success of biophysics and biochemistry in tracing the transitions between the two classes of system and in bringing to light the physical factors always involved in vital activity. Nevertheless, the apparent dominance of the psychical element in living organisms, as seen in directive and voluntary behavior, inevitably brings sharply to the fore the traditional problem of the interrelations between the psychical and the physical—the "mind-body problem." In a broad philosophical interpretation this problem has reference not only to living organisms but to nature in general: panpsychism has been a widely entertained doctrine among philosophers.[6] Living organisms, however, are peculiar among natural systems in exhibiting a unity and integration of structure and activity which are unique in their kind; these properties are associated with structural and chemical complexity and with the further special property called "finalism" or "teleology," as illustrated in the adaptive and purposive activities of man and animals and in developmental processes of all types.

All these vital sequences have an especially close-knit or coherent quality and appear directed toward definite ends. The general concept of directive activity, as contrasted with random activity, had its origin in the observation of animal activity; and from analogy with human behavior such activity has usually been regarded as implying a control by volitional or psychical factors. The intimate union of physical and psychical in the determination of human behavior is a familiar fact; what is true for human beings is undoubtedly true for higher animals, and a similar inference may be extended to other animals, and even to lower organisms, including plants, although with increasing uncertainty as we descend the biological scale.

The problem of the special status of the psychophysical, as distinguished from the purely physical, in the natural world may be approached both scientifically and philosophically. If it

[6] Cf. above, p. 72.

is not exclusively a problem for biology, it is evidently one of special importance to that science, particularly in its psychological aspects. The distinction between physical and psychical is deeply rooted in human experience. In the normal field of interest and activity of any human being he is accustomed to distinguish—usually without special reflection—between two broad classes of natural facts and events: (1) those which are physical, automatic or apparently casual, which he cannot do anything about, like the weather or the permanent properties of ordinary objects; and (2) those which are subject more or less fully to his voluntary direction and control and for that reason are of special interest to him. He observes early in life that his own organism furnishes examples of both classes: as a physical system it exhibits many properties and activities which are "given" and unalterable (its curious and intricate organization is a natural fact which he simply has to accept); and as a psychical system it has its special sensations, its thoughts and memories, its volitional impulses to action, and the other characteristic features of conscious life. Some physical actions of his body, especially muscular movements, are early discovered to be subject to his will, while others, like digestion or the heartbeat, are not, but proceed automatically. When he turns his attention to the external world—which is in close contact and interchange with his body, but for the most part goes its own way independently—many events appear as purely physical (casual or random) in their complete lack of relation to any imaginable purpose; while others, especially certain actions of other human beings and of animals, give every impression of being under a purposive control similar to that of which he is conscious in his own life. Between these two classes there is a border line of cases which seem ambiguous, especially to primitive man, by whom they are sometimes referred, more or less vaguely, to psychical agencies of an unknown kind, often conceived as supernatural.

For the purposes of the present discussion we may disregard the doubtful cases and make, as before, a broad division of the events of nature into the two classes: (*a*) purely physical (automatic, random, or casual) and (*b*) psychically directed or teleological. Experience shows that the two are not independent, and it may not be possible to maintain this distinction in any ultimate sense. Nevertheless, many natural events have all the appearance of being purely physical, i.e., without psychical guidance or admixture of any kind.

Usually the distinction between physically determined events and purposive or intended (teleological) events is perfectly clear, and the distinction has always been recognized. The chief, if not the only, demonstrable examples of the teleological class are to be found in the actions of living beings; on the whole, nonliving nature appears as undirected or nonteleological. Undoubtedly, this contrast is a real one, and it appears to be an essential feature in the contrast between living and nonliving systems; the indifference ("cold-bloodedness") of purely physical events is instinctively regarded as a nonvital or antivital character. We may consider nature, then, as including both undirected events (casual, random, fortuitous) and events directed toward special ends, the latter owing their character (ultimately, at least) to agencies or factors having some inner aim, direction, or purpose—i.e., psychically actuated.

Randomness is a negative conception, signifying *absence* of direction; and scientific observation indicates that fortuitous (undirected) activity pervades all parts of the natural world. As already pointed out, it forms the basis of many physical regularities, including the thermodynamic and other statistically based laws. The motions of single molecules are casual or mainly so; single atomic and molecular units are regarded as not identical in their behavior but as having a certain range of variation, grouped regularly around a stable value or mean. In physical law this mean corresponds to a natural constant of fundamental importance, one manifestation of which is the gas constant.[7] Like many other scientific constants, this one is not an immediately observed datum or natural individual but an intellectual product or "construct," derived by applying a

[7] Represented by R in the general gas-law equation, $PV = RT$, where P = pressure, V = volume, and T = absolute temperature.

standard mathematical treatment to a collection of measured data.

The validity of statistical method in its application to natural phenomena has been thoroughly tested and confirmed experimentally in many fields; Willard Gibbs's work on statistical mechanics is a classic example. The important conclusion follows that the mathematical science of probability has an entirely empirical basis, grounded on certain universal features of natural activity, even though in its finished form it is an artificial creation, representing an abstraction from the individual characters of observed events. As Born has recently remarked, "the laws of probability are valid just as any other physical law in virtue of the agreement of their consequences with experience."[8] Probability is a type of constancy.

The most significant characteristic of living organisms is the high degree of individuation which they exhibit, as illustrated especially in the higher animals and man. It should be noted that this individual quality is shared, in greater or less degree, by all natural objects and entities. Nature is a composite of individual events; i.e., each single object or occurrence, psychical or physical, has its own uniqueness or particularity; by implication, even each atom has its "own" internal constitution, just as it has its own unique activity and its special position in an environment. Each atom retains its individuality ("selfhood") and occupies unequivocally a certain portion of space at a given time; two colliding atoms displace each other, just as do two larger material objects or two electrons: interference is a fundamental fact of physical nature.[9]

But, complementary to this recognition of uniqueness in each single object or event there is the further recognition—of limitless antiquity, as the existence of language shows—that the events of nature repeat themselves, that they fall into

[8] Max Born, *Experiment and Theory in Physics* (Cambridge: University Press, 1943), p. 26.

[9] This is an exclusion principle, having its relations to the physical exclusion principle of Pauli, which is too technical for consideration here; it is sufficient to note that it is also an individuality principle. For a discussion of the philosophical significance of the exclusion principle cf. the recent article of Henry Margenau, "The Exclusion Principle and Its Philosophical Importance," *Philosophy of Science*, XI (1944), 187.

classes or "tropes,"[10] i.e., into definite forms or categories. This state of things is also an empirical fact, the implication of which is that nature contains a variety of permanent factors or conditions making possible the recurrence of objects or events with fixed properties. In Whitehead's terminology, these permanent conditions are partly "primordial," i.e., without assignable temporal origin, and partly "consequent," i.e., products of past activity or evolution.[11] Undoubtedly, it was through reflection on this universal repetitiveness of nature that Plato was led to the conclusion that stable forms or similitudes, and not individual entities as such, constitute the fundamental realities of existence. The problem of the origin of natural species applies not only to the biological field but to nature in general and has its origin in this universal natural fact of repetition. Individuals are transient, while forms are permanent;[12] and in modern times Whitehead has introduced the term "eternal objects"[13] to designate the ultimate stable factors which underlie and condition the repeated occurrence of similar events in nature.

The scientific interpretation of this natural tendency to recurrence is somewhat different; the repetition of similar objects or phenomena is usually regarded as indicating the existence of constant physical determining conditions; and this principle, long acted on, has its general logical application in inductive reasoning. As already pointed out, induction recognizes that the continual recurrence of natural individuals of the same type implies the existence of stable determining conditions of a more inclusive kind, the nature of which may be inferred from the study and comparison of the single individuals. In general, the conditions determining the recurrences of nature appear to have a greater stability than the individual events, although there are exceptions to this rule; a mold may

[10] George Santayana's expression in *The Realm of Matter* (New York: Scribner's, 1930), Vol. II, chap. vi.

[11] *Process and Reality, passim.*

[12] Cf. Plato's cosmology—e.g., in the *Timaeus.*

[13] *Process and Reality, passim.* "Forms of definiteness" is an alternative expression.

be broken, or printing plates melted down, or works of art may outlast the artist who created them. Nevertheless, exemplifications of this rule are innumerable; an unlimited number of impressions may be made from a single die, or hundreds of performances from a single movie film or phonograph record; a stalagmometer delivers drops of uniform weight an unlimited number of times, illustrating both its own stability and the stability of the laws of surface tension; countless individuals of *Lingula* have lived and died since the Paleozoic age.

Belief in the real existence of eternal objects, constituting the ultimate factors of stability which underlie and condition all natural recurrences, may be justified as an extension of the experimentally well-founded scientific principle that repetition of events implies the stability of their conditions. As Whitehead has expressed it, "cause, repetition, habit are all in the same boat." A watch spring or pendulum shows the connection between constancy of static properties (such as tension or weight) and the constancy of the dependent activity. Similarly with the case of rhythm in general: the evidence from astronomy indicates that the physical characteristics of radiation (a rhythmical activity pervading all nature and associated with rapid transfer of energy) have remained unchanged during many millions of years;[14] the same may be said of many other physical conditions, such as gravitation, on which, for example, the stability of the solar system with its regular cycles depends. From such natural constancies it is a short step to infer the existence of underlying stable conditions which form the necessary foundation of *all* constant types of activity. On such a view, all natural recurrences, including the biological, are assumed to have a foundation of permanent or unchanging conditions; and the term "eternal objects" may well be used as having reference to these conditions. The word "object" implies a status like that of other natural existents, while the word "eternal" implies an extreme or exceptional degree of stability, as well as pervasiveness.

At the same time it should be recognized that many special

[14] For a recent discussion cf. the paper by Gustav Strömberg, "Coherence in the Physical World," *Philosophy of Science*, IX (1942), 323.

recurrences have their basis in conditions which are far from being eternal; thus the automatic or habitual actions of a particular human being depend on definite features of his personal organism, and the latter, as a physical system, is only temporarily stable. It seems clear that any natural system or condition which preserves its stability for a certain period of time may during that period furnish the determining conditions for a succession of single events having a special and uniform character dependent on that stability, even though its own lifetime, and hence that of the dependent events, may be strictly limited. The general natural fact of causation is to be understood on this basis; what it implies is that each single instance of physical activity occurs under certain more or less stable physical restrictions imposed by environmental conditions, which determine, largely even if not completely, its special character as an individual occurrence. Uniformity of conditions implies uniformity of change or activity.[15]

This dependence of likeness, both in static facts and in active events, on the permanence of determining conditions is a familiar fact to the naturalist and is illustrated impressively in the facts of biological inheritance. In this process, according to present theoretical conceptions (briefly reviewed above), the required conditioning permanency is the physical constitution of the germ plasm (now conceived as a group of genes), which is handed on in an essentially unaltered state from parents to offspring in the succession of generations. All individuals developing from similar germs under similar external conditions are similar. This case again illustrates the general principle (just cited) that the permanency required to serve as the condition under which similar events are repeated, or similar physical systems come into existence, may be only relative. A special generating condition or set of factors may last for only a limited time, and yet during that time it may furnish the

[15] For the case of biological causation cf. my paper in *Philosophy of Science*, VII (1940), 314; cf. also Whitehead, *Adventures of Ideas*, chap. xii, Sec. III, p. 250; also Whitehead, *Symbolism, Its Meaning and Effect* (New York: Macmillan Co., 1927); here he describes the cause-effect relationship as consisting essentially in *conformation:* in each instance of causation we see "the overwhelming conformation of fact, in present action, to antecedent settled fact" (p. 41).

origin for a long series of events reflecting its temporary constancy; these events will have a class similarity or "family resemblance," but this will vanish when the condition in question is altered or destroyed.

Such a special temporary condition, which acts during its lifetime as a conditioning or causative factor, illustrates also the property of individuality or special uniqueness possessed by all single events. A single event, regardless of whether it is casual, voluntary, or repeated, may under favorable circumstances establish conditions having a high degree of permanency. Not all natural events are of a repetitive kind; many appear to be completely individual, unique, and transient; they never attain the stable properties and connections which are necessary if they are to be the determining source of numerous events of a definite kind. Many occurrences in the history of nature or mankind illustrate this condition; such a unique occurrence or individual is "in a class by itself"; the distinction between class and individual disappears. As Whitehead has pointed out, an event, as individual event, is not repeated;[16] it is what it *is*, then and there; its likeness to other events of the same class depends on the existence of other conditions, i.e., permanencies of some kind (including eternal objects), which determine its occurrence and its special peculiarities. These conditions are the stable factors which are responsible for the likenesses between single events of the same class.

Since, then, the single historical individual or event is just itself and is nonrepeated, there seems to be a certain naïveté in assigning stereotyped class characters or applying fixed formulas—as is often done—to highly individualized events, facts, or persons and then considering the latter as completely characterized. While such a procedure may often be practically useful or necessary, it is at best an approximation and, when employed without judgment, may give deceptive or unrealistic results. Whitehead's "fallacy of the perfect dictionary"[17] has

[16] A. N. Whitehead, *An Enquiry concerning the Principles of Natural Knowledge* (Cambridge: University Press, 1925), sec. 14, p. 61; also *The Concept of Nature* (Cambridge: University Press, 1930), chap. vii.

[17] A. N. Whitehead, *Modes of Thought* (New York: Macmillan Co., 1938), p. 235; cf. the discussion of language throughout this book.

reference to unrealism of this kind. The natural process, with its inherent creativity and impulse toward novelty, never repeats itself exactly in the single objects and events which it brings into existence.

This last statement requires a certain qualification. Observation shows that it is true of the more complex products of evolution, such as the higher animals. But in the elementary natural units of structure and action what impresses us chiefly is their uniformity: all electrons are alike, all molecules of the same composition and structure have the same properties. The units apparently repeat themselves with perfect exactitude, as well as in numbers which appear unlimited. In strict theory, however, the uniformity of (for example) all carbon atoms is statistical, and single atoms have a limited range of variation. At the same time, the uniformity of atomic properties must be very great; otherwise complex groups could not unite to form higher systems having constant properties. In a fluxlike system like the living organism all atoms of the same kind must be perfectly substitutable for one another; life depends on this substitutability, which insures the stable properties of the metabolic flux. Similar considerations apply (*mutatis mutandis*) to all natural processes which are regularly repeated. Apparently evolution requires a combination of stability in the foundational units with a certain novelty of action in the higher synthesized individuals. The stability of units, however, is relative to the stability of the cosmos as a whole at the particular stage of cosmic history. This stability may be very great, but evolution shows that it is not absolute.

CHAPTER XI

Stability, Equilibrium, Change, and Novelty

IN NATURE we meet with all conditions ranging from extreme transiency to extreme permanency; so long, however, as any object or condition has a local existence and a sufficient degree of endurance, it may act as a generating center in the manner indicated above and give rise to a succession of events or objects with uniform characters. An important general fact is that single events which appear to be entirely arbitrary or fortuitious may, under favorable circumstances, establish conditions having a high degree of endurance; and these may secondarily determine the character of many succeeding events. Both the special nature of the conditions and the events resulting may be quite unforeseeable; for example, according to the tidal hypothesis, the solar system had its origin in the chance mutual approach of two stars; and the irreparable consequences of accident in human affairs are all too familiar. Innumerable instances of this kind are afforded by human and natural history. What is true of casual actions may also be true of the voluntary actions of human or other living beings. In general, we may say that the effects resulting from the conjunction of highly individualized systems or events can be predicted only in part, if at all; something novel or "unprecedented" is sure to happen. This is the case of "emergence," which is considered later in this chapter.

It may be questioned whether the conception of absolute stability can apply in strict realism to any condition which forms part of an evolving universe; it is even possible that the most fundamental laws of nature may vary at different widely separated periods of time, as Whitehead has indicated in his conception of cosmic epochs.[1] Yet there can be no doubt that many conditions deeply rooted in nature (like the law of

[1] *Process and Reality*, esp. p. 139.

gravitation), if they change at all, do so with extreme slowness. Such permanent conditions would correspond to eternal objects; their stability would be as complete as it is possible for stability to be.

Complete stability would seem to require a very special kind of natural setting; if nature is a single whole, the essential requirement would be a certain conformity, fitness, or harmony in relation to the *whole* system of reality. Experiment shows that the special character and behavior of any single physical system or event depend primarily—apart from its own intrinsic constitution and properties—on its relations with the *immediate* surroundings, i.e., on that region of physical nature with which it is in direct contact or continuity: these relations would include influences, like radiation, reaching it from a distance. If the system is a perfectly stable one, the system and its contiguous environment would exemplify the reciprocal relation called "equilibrium," in which equal, oppositely directed influences balance one another, producing a stationary state; such a condition would be illustrated by the phase-rule or similar instances of heterogeneous equilibrium, like the equilibrium of ice with liquid water at 0° and 760 mm. pressure.

But the immediate environment of the system under consideration has its own larger or inclosing environment with which, under the assumed conditions of complete stability, it also is in equilibrium; hence the stability of the original system will depend secondarily on the stability of this larger environment; and in a similar manner we may proceed to include more and more comprehensive environmental conditions, until ultimately they come to be all-inclusive. Whether nature actually does include any conditions exemplifying a stability which is complete in this physical sense may perhaps be doubted; but an all-pervasive medium which is perfectly homogeneous and uniform in properties, like the ether as formerly conceived, would correspond closely to this condition.

In fact, the existence of certain all-pervasive stable natural conditions is assumed as a general postulate in the fundamental departments of theoretical physics. Nature as a whole does persist, and this general fact of unlimited durability would seem to presuppose the existence of certain ultimate characters which are invariant and foundational; these would constitute the fundamental natural constants underlying *all* kinds of regular activity. Examples of such constant conditions and factors, experientially well attested, may be cited briefly as follows: (1) the general homogeneity of space-time (i.e., geometrical) conditions; (2) the rectilinear propagation of radiation *in vacuo* at constant velocity; (3) the uniform rectilinear motion of bodies in free ("empty") space (Newton's first law); (4) the gravitational and inertial constants; (5) the electrostatic constant; (6) the quantum constant; (7) the unit electric charge (electronic charge); and (8) other general conditions partly derivative from those just cited, such as the conservation of energy and mass and such closely related phenomena as centrifugal force, the Foucault experiment, and the stable setting (i.e., constant relative positions) of the stars and nebulae—a fact indicating a fixed orientation of spatial co-ordinates and stability of the general space-time field. All these facts imply that the general continuum within which events happen has certain uniform physical properties of a definite kind—"definite" here meaning stable and measurable.

A certain unitary, coherent, and integrated property, of which these uniformities are the physical expression, must apparently be ascribed to nature as a whole. In this broad sense nature corresponds to a single being, or cosmos, *within* which the observed diversification occurs; and the extent and variety of this diversification appear to have increased in the course of time, as an expression or consequence of the historical process which we call "evolution." On the whole, allowing for local side-currents and setbacks, evolution has been diversifying or creative in its trend. We are thus brought back to a consideration of the conditions making for differentiation and progressive evolution within this cosmos. These conditions exist side by side with others, such as those just cited and the laws based on inertia (like the laws of thermodynamics), which apparently make for uniformity.

It is perhaps worth while here to point out that scientific extrapolations like the prediction of an eventual thermodynamic equilibrium throughout nature (the "heat death" of Clausius) are based on the consideration of single physical factors, abstracted from the remainder of natural activity; they further assume the invariance of these factors throughout the whole history of nature. Hence it is not surprising that they appear incompatible with the creativity which is regarded by Bergson and Whitehead as an ultimate property of nature. Of course, if there were nothing but random activity in the universe, Clausius' prediction might very well turn out to be true. But all reasonings based on the assumption of a complete uniformity in the fundamental processes of nature must be taken with reservation; they ignore or "reason away" the unpredictability in detail which is also a feature of nature, especially its living part; this feature seems to be inseparable from nature's character as the field of individuation.

Any natural process which leads to novel differentiation and evolution requires a combination of diverse factors, and these may be divided (as indicated in chap. i) into the two broad classes: (1) stable and routine factors and (2) initiatory, novelty-producing, or creative factors. Considered in its most general aspect, as an evolving nexus of events, nature appears as a system in which conservative and anticonservative factors coexist and play equally indispensable parts.

Factors belonging to these two groups are closely interdependent and at times are difficult to distinguish. Many natural systems appear stable, and yet close observation shows them to be slowly changing in directions for which no external determination can be seen; this is notably the case with living organisms, each of which, according to present biological conceptions, represents a stage in an evolutionary line of descent. Biologists regard animal and plant species as stable, within narrow limits of variation, yet at the same time as subject to evolutionary change, although at very different rates. The stability of species varies from organism to organism, and this variability appears to have some correlation with environmental conditions. Yet it is still a vexed problem as to how environmental changes affect the germinal constitution; and certain variations are classed as "spontaneous," implying an internal rather than an environmental determination. Many instances of mutation belong in this class.

We may now consider these factors, especially the second group, in somewhat more detail. We are considering evolution in its synthetic or creative aspect; this restriction is necessary because evolution is at times regressive. The naturalist observes that part of the activity of nature expresses itself, in the long run, in the creation of novel systems and organisms; these are products of synthesis and appear as resulting from the concrescence or rearrangement of already differentiated simpler elements or systems. Evolution requires persistent and progressive change, asserting itself in the midst of conditions having a certain degree of stability, sufficient to enable the anticonservative (including creative) factors to assert themselves continuously and unidirectionally. In considering the factors of change which underlie evolution, a distinction must be made between (*a*) routine types of change, including uniform change and regularly recurrent (cyclical) change, and (*b*) nonroutine types of change; the latter appear largely to be individually determined or "spontaneous," i.e., are examples of change having its origin within the changing system itself rather than in its environment.

The conception of spontaneous change is a difficult one. Complete isolation of any system, like the isolation assumed in the "windowless" character ascribed by Leibnitz to his monads, can hardly be regarded as existing in nature, since every natural system appears as in contact and communication with its environment. Yet it is undeniable that certain systems attain a high degree of autonomy, and such highly individualized systems are especially likely to be the source of novel activities leading to new creation. These systems would exemplify the condition which we call "freedom"; among human beings, creative persons, such as men of genius, would be examples.

Individual uniqueness and evolutionary progress are closely related facts, although they are not incompatible with a close dependence on the environment which incloses each single entity. According to this conception, some degree of autonomy must be ascribed to each natural entity; i.e., the recognition of a thing as unique, different from all others, implies that its determination—in part, at least—is unique, which means individually conditioned or "free." A further implication would be that the more highly individualized a thing is, the freer it becomes; in other words, in the more highly organized and integrated systems determination becomes to a greater degree internal and independent of external conditions. At the present time creative processes appear to be largely centered in human beings as the most advanced products of animal evolution. But this statement is only meant to describe what we observe in our present situation and has no reference to the ultimate source of creativity, which may very well have little respect for human pretensions.

King Solomon is related to have said, "There is no new thing under the sun," a statement difficult to ascribe to a wise man and realist (such as he is reputed to have been), since it would deny the existence of nonroutine activities in nature. The similar denial made by Lucretius in the *De rerum natura* ("Eadem sunt omnia semper")[2] is qualified by him in another passage, as has been pointed out by Sir d'Arcy Thompson,[3] who remarks on

> a strange point in the Lucretian doctrine, that "exiguum clinamen" (Book 2, 292) by which the atoms swerve ever so little, and only now and then, from the straight determined path and so are brought into collision, which collisions are the starting point of a new order of things. Thus a certain freedom of action is possessed even by the atom and is the first adumbration of our own soul's free will—"unde haec est nobis innata potestas" (Book 2, 286). Here Lucretius qualified the more relentless materialism of Democritus. . . . . It reminds us of Newton's famous scholium: "a caeca necessitate, quae eadem est semper et ubique, nulla oritur rerum variatio."[4]

[2] iii. 945.

[3] *Nature*, CXXI (1928), 565.

[4] There is a modern echo of this in C. S. Peirce: "Mechanical law can never produce diversification" (*Collected Papers of Charles Sanders Peirce* [Cambridge, Mass.: Harvard University Press, 1931], Vol. I, par. 174). Cf. also Whitehead, *Process and Reality*, pp. 139–40. The foregoing citations are from my paper "The Directive Influence in Living Organisms," *Journal of Philosophy*, XXIX (1932), 477.

Routine types of change are those which are continually being repeated in phenomena; there is nothing new in them; they represent stable conditions of a spatiotemporal or four-dimensional kind and are illustrated in the countless regular processes, cycles, and rhythms of nature. When measured, such activities may show a constant quantitative character or invariance equal (as regards stability) to the invariance of purely static conditions, like the mass of an isolated solid object or the properties of a gravitational field; for example, the velocity of light *in vacuo* is the same whenever and wherever measured, and the wave lengths of light are regarded as the most exact natural units of space measurement that we possess. Similarly, the speed of sound in a given gas at constant pressure and temperature is constant and characteristic of the gas, an experimental fact implying that in each region traversed by a sound wave the molecules pass through a regular and perfectly reversible cycle of displacement.

Innumerable processes based on fixed physical routines are well known; of special biological interest are chemical reactions occurring under standard conditions of concentration, temperature, environing medium (solvent), and catalysts; each reaction has its characteristic speed or tempo ("velocity constant"). More complex types of active change are based on such regularities; and of these types, living organisms furnish the best examples; they are stable systems (during their lifetimes) in which the component units (cells and tissues) are highly organized centers of activity. Physiological processes like the heartbeat are repeated regularly with only slight variation throughout a long lifetime; and the complex cycle of embryonic development repeats itself from generation to generation with unfailing exactitude. These examples illustrate how stable elementary processes may give rise, when combined in an organization, to stable types of activity of a higher order. It is evident that a fundamental condition of these higher types of synthesis is the constancy of the elementary component activities.

The natural fact which has to be accounted for on other grounds than constancy is the not infrequent departure from routine, i.e., the initiation of activities leading to novel and unprecedented developments and ultimately to creation and evolution. Observation indicates that such novel conditions may originate in two ways. One mode of origin is through pure "chance." Chance is a real factor; the detail of nature is only partially integrated, and unforeseen conjunctions are sure to happen. We have already referred to the fundamental part played by probability conditions in physical action. Some have doubted whether there is such a thing as pure chance (chance is "direction which thou canst not see"); but in the sense of activity uncontrolled by teleological aim, all observation indicates that it is an omnipresent factor in natural events. Apparently, it is more pervasive than the directive factor; the latter appears to intervene not continuously but intermittently and only at special places and times.

In general, the conjunction of previously separated elements, factors, or systems has consequences that could never have been predicted from a knowledge of the single items before their conjunction. We are referring to the universal natural condition now called "emergence." As a general natural fact it is discussed briefly by Aristotle,[5] and Morgan considers it fully in its relation to biological problems in his book *Emergent Evolution.*[6] Whether the components are brought together by accident or design makes no difference in the final outcome; the first combination of hydrogen and oxygen gave a product—

[5] *Metaphysics* vii. 17.

[6] Lloyd Morgan, *Emergent Evolution* (Gifford Lectures, 1922) (New York: Henry Holt & Co., 1926). For other recent discussions of emergence cf. H. S. Jennings, "Diverse Doctrines of Evolution," *Science*, LXV (1927), 17; W. M. Malisoff, "Emergence without Mystery," *Philosophy of Science*, VI (1939), 17, and "Chemistry: Emergence without Mystification," *ibid.*, VIII (1941), 39; R. Ablowitz, "The Theory of Emergence," *Philosophy of Science*, VI (1939), 1; E. G. Spaulding, *A World of Chance;* W. E. Ritter, *The Unity of the Organism* (Boston: R. G. Badger, 1919).

The Hegelian dialectic, as applied to nature in general, is a doctrine of emergence. It may be noted, however, that the number of opposites (or concrescents) uniting to effect the synthesis need not be limited to *two;* many factors are concerned in each emergence or instance of creation; the logical division into A and not-A is too bare for most scientific purposes. Nevertheless, the division of the factors of a phenomenon into two opposing groups is a general feature of scientific method, as we see in the concept of physical equilibrium, as well as in the general use of equations to describe the quantitative aspects of phenomena. There is a certain relation here to the general property of existence called "diadism" by C. S. Peirce.

water—which had not previously existed and which had properties different from those of either component in isolation. Random conjunctions of a similar kind may be assumed to have been responsible for part of the existing diversity of nature; the possible origin of the solar system from the casual encounter of two stars has already been cited, and other instances readily come to mind, as, for example, geological events, or (in the biological field) the chance meetings of human beings, or, more generally, the curious structural and physiological makeshifts often found in animals and plants.

The second and perhaps the chief source of novelty in nature is conscious (and perhaps also subconscious) aim and effort—the teleological factor; this, of course, is especially conspicuous in human affairs. The modern philosophers who have considered teleology most fully in relation to general biological conditions are Bergson and Whitehead. According to Whitehead, "subjective aim"—rudimentary or potential purpose—is a characteristic of all actuality; he holds that there is present throughout nature an innate tendency ("appetition") toward diversification and synthesis: "creativity is ultimate." The presence of subjective aim is a direct fact of experience in higher animals (man); obviously, most of the permanent conditions peculiar to human society are the direct or indirect result of the purposive activity of past and present generations of men. But even here, chance and conscious purpose are closely interwoven and often difficult to disentangle; it is familiar that opportunity may come by chance and then be seized upon by purpose. Just now we are merely calling attention to these general conditions without entering into detail.

The fact of present interest is that in human beings the nature and consequences of purposive action are in large part observable and open to scientific study. In other organisms, however, the attempt to account for behavior in terms of subjective aim and other psychical factors meets with the insurmountable difficulty that such factors are not accessible to external observation. Psychical isolation seems to be the inevitable correlate of individuation: the monads are "windowless." As Thomas Huxley remarked in his monograph on the crayfish, "nothing short of being a crayfish would give us positive assurance that such an animal possesses consciousness." External observation, on the other hand, is always possible; accordingly, he recommends concentration on the physical aspects of animal behavior as alone being capable of giving true scientific knowledge in this field. It is needless to emphasize this at the present time, when behaviorism has attained the status of a special technique or cult, though now apparently declining in influence. Work in this field has shown that there is no limit to the analysis of behavior in terms of physical and physiological detail; and such an analysis, if purely objective, disregards the possible presence of controlling psychic factors.

Nevertheless, there remains the problem of the existence and range of activity of such factors and of how they are enabled to intervene effectively in the determination of vital activity; and our present scientific concern becomes one regarding the possible valid methods of approach to this problem. At the present time, many comparative psychologists recognize that psychical factors such as motivation and purpose must be considered, in addition to physiological factors, as real determinants in animal behavior. The essential problem is: What observable criteria are peculiar to activity occurring under psychical control, as distinguished from activity determined by purely physiological conditions?

We come again to the fundamental biological problem of the interrelations between psychical and physical. In our preceding discussion the chief emphasis has been placed on the view that physical and psychical are not separate and independent factors but different aspects of a unity described as "psychophysical" (psychobiological). Can valid inferences be drawn from the external or physical manifestations of living organisms as to what is occurring in the physically unobservable psychical field? Apparently the answer is partly "yes" and partly "no." In the intercourse between human beings such inferences are continually being made. Each person can observe both aspects of his own behavior, and he finds that certain physical actions are an infallible index of consciousness and purpose; general rules derived from such observation (which we are assuming to be scientific in method and purpose) can then be applied to his fellow-men. Such empirical methods are based on the correlation of external and introspective observation; they include as a chief object of study the part played by language in the communication of feelings and ideas.[7] Here only brief reference can be made to such methods of approach to the psychobiological problem in human beings. On the other hand, in those cases where observation is confined to the physical, as in nonhuman organisms, any inferences regarding the psychic factors at work become doubtful, even in closely related animals like the primates, and the more so the greater the difference from human beings. The general question may perhaps be better put in another form: Can we account for all that occurs physically in living organisms without reference to the possible influence of psychical factors? If not, what are the externally observable criteria of the psychical, and what special role in vital action is to be ascribed to such factors?

[7] There are also such facts as the "intuitive" awareness of other persons' feelings, thoughts, and intentions. This is also a part of communication, and we may assume it to be based on sensitive observation and quickness of interpretation, long cultivated in human relationships.

CHAPTER XII

The Special Role of the Psychic Factor in Living Organisms

IN GENERAL, observation indicates that the primary biological role of the psychical is integrative, in correspondence with the unitary character which is the essential feature of the psychical in our immediate experience. As integrative, the psychic factor might be expected to have a special relation to the synthetic activity so highly developed in living organisms, since synthesis is by its nature integration or whole-formation; and the general evidence seems to support this view. Originative or novelty-producing activity appears to be a special prerogative of the psychical, rather than mere repetition or routine; constancy and routine, as exemplifying the conservative or stable side of nature, belong rather in the field of the physical. Psychical existence is in present time and carries with it a quality of novelty; the past is left behind, and there is an advance into the future. According to our present conception, the psychical is the source of initiative when action takes on a novel, unforeseen, or creative form, as in purposive activity or (in a broader sense) in natural creative action in general. For example, in animal life (including our own) most of the vegetative and routine processes appear to be purely physiological and unconscious, while actions requiring special initiative or innovation demand conscious effort and attention.

In human beings we know that some actions (like writing a letter) presuppose consciousness and purpose, while others, perhaps equally complex, are unconscious. Both kinds are alike in requiring a complex physiological apparatus. Biologists of the mechanistic school may point to the fact that those forms of human behavior which seem the most intimately dependent on psychical activity may nevertheless be duplicated by mechanism. Machines can carry out complicated calculations; we are accustomed to hearing them deliver passionate orations or perform elaborate symphonies. Yet these actions are determined by purely physical conditions; no one supposes the phonograph to be conscious of what it is doing. Such cases are instructive as illustrating the possibilities of regularly acting mechanism; such mechanisms are omnipresent in the natural world, and there seems to be no limit to the complexity of the results which may be achieved through their combination. Similarly, the air is not conscious of carrying the sounds of a voice; nor the ether of transmitting the intricate pattern of radiation that forms the condition of a radio broadcast or a motion picture.

Obviously, all such performances are dependent on the precision of physical conditions and factors; yet the recognition of this undeniable truth does not touch the essential difficulty in the problem of the psychophysical interrelationship. Everyone acknowledges the dependence of human mental activity on physiological conditions; but the problem of the special "volitional" relationship through which psychical factors influence physiological action has seemed to many an insoluble one, mainly because such an influence seems to imply that physical nature—a closed system in space-time characterized by conservation and regular repetition—can be altered by factors which have no place in that system. How can a condition which is not physical effect physical change?

There is undoubtedly a scientific difficulty here; but this difficulty becomes less formidable when we recognize that the concepts "purely physical" and "purely psychical" are artificial ones and, as such, incomplete in their realistic reference, being, in fact, abstractions from an experience which combines both aspects. If either aspect, psychical *or* physical, represents only part of a reality which in its actual or existential character includes factors of both kinds—hence better called "psychophysical"—the problem appears in a different and clearer light and need no longer be considered "insoluble." According to the "double-aspect" conception, psychical activity cannot be isolated, as an independent agency, from other kinds of natural existence but is always associated with physical activity; hence, no one need be surprised that it has physical effects. A man is not directly conscious of the underlying physiological and neural processes accompanying his thoughts and feelings, which may (or may not) lead to voluntary action; nevertheless, these physical processes are existentially present as part of the associated activity of his organism and, in their character as physical, have their effects in the physical field pervading and inclosing them. The psychical action may appear to have physical effects of its own; but in reality this action is not purely psychical but psychophysical, and only its physical moment is physically effective.

The term "psychical" is used here as designating the immediate conscious experience or awareness; inner qualities of feeling and conation, not physically observable, are its criteria. What have these to do with the performance of the phonograph delivering the oration? To the scientific observer the answer seems clear enough: the initiation, the original making of the record—as well as the original invention of the instrument itself—necessarily require psychical activity. Such activity, as an emergent, consciously present and immediate, always has the quality of something new or unprecedented; as such it may be novelty-producing or creative. But the subsequent repetitions of the oration by the machine are purely physical or routine, and this distinction at once indicates where the special property of the psychical, as psychical, enters as a determinant in the situation.

As already indicated (chaps. iv and vi), something of novelty is always present in psychical activity per se; its antecedents cannot be traced (as Hume recognized); as psychical it occupies the present exclusively; at the same time it merges with the past (completed actuality) and the future (not yet actualized). In Whitehead's phrase, the psychical is a part of the creative advance into novelty. As conscious and immediate, it always contains something not existing before: the term "emergence" has reference to this novel quality. At the same time it always has definite connections with the physical; in the absence of stable physical conditions established in the past (in this case the neuromuscular system of the orator) the psychical does not emerge. But the present origination, the invention, the appearance of essential novelty, seem always[1] to require psychical quality, over and above the physical. The immediate experience, the conscious aim and effort, and the presently felt action are necessary to the delivery of the oration.

All these, however, since at the same time they include the physical as an inseparable correlate, leave their impress on the associated physical; and this impress, by virtue of the conservation which is the characteristic feature of the physical, persists in the shape of modified physical conditions at the site of the action. This physical (or physiological) modification, in so far as it is permanent, forms the basis of memory, a psychobiological effect always associated with a conscious experience.[2] In addition to this effect, which leaves its record in the nervous system of the orator, there is also produced, through his vocal apparatus, a physical effect in the external world, in the form of a pattern of sound waves; these lay down another record in the instrument (the phonograph) devised for the purpose. Both records, as physical configurations, have the characteristic physical quality of persistence or conservation; and by using the phonographic record as a means of reproducing the pattern of sound waves the original performance, in so far as it is physical, may be repeated (in replica) an indefinite number of times. Apparently anything repetitive or routine can be done by mechanism.

This example shows that, while the *original* production or creation of the special physical pattern of events requires psychical—or rather psychophysical—action, the formation and preservation of the record are purely physical. The repeated performances of the phonograph require only physical, i.e., permanent or conserved, factors; but the first performance of the series requires action which has also the special quality of the psychical, i.e., the quality of experiential immediacy, involving at least some measure of innovation or creation. A

[1] Or, bearing in mind the possibilities of casual conjunction (p. 150), perhaps we had better say *nearly* always—although in such a case as that considered exceptions can hardly be imagined.

[2] All learning appears to involve conscious experience. Attention is especially important.

writer or composer has an inspiration, an intensely felt immediate experience which, as psychical, is in the present and evanescent; but if the result is to be made permanent and transmitted to posterity, a physical record is required. Formerly this was made by writing; but now it can also be made by taking advantage of the permanent properties of air waves, rigid mechanism, and plastic surface, on which a pattern is cut by a needle attached to a sympathetically vibrating diaphragm. These activities are physical, but it is clear that such unique and highly integrated types of physical configuration could never come into existence except as the physical expression of a psychical activity, which in its nature is both integrative and creative.

The case of the living organism has many close analogies; memory requires a physical record or engram; and the analogy of heredity to memory has been emphasized by Hering, Semon, and other biologists—although as an instructive comparison rather than as a theory. Yet it remains true that the characters of the organism are permanently recorded in the germ, which has stable properties in very much the same sense as a phonographic record has stable properties. Hence either system—germ or record—may, under appropriate circumstances, initiate a complex sequence of physical change which can be reduplicated an indefinite number of times—i.e., so long as the germ, or the record, preserves its special physical configuration and is exposed to the right environmental conditions.

The biological theory of how the germ attained its present constitution and properties forms part of the general theory of organic evolution and is far from complete at present; in any case, it can hardly be summarized adequately in a brief chapter. We have already seen that in modern genetics the special structural and chemical properties possessed by the complex of specifically organized hereditary determinants called "genes" are regarded as determining the development of the constant characters and activities exhibited by the organism during its lifetime. It should be noted that these characters include not only the adult characters but all those which make a regular appearance at any time during the entire life-history, from germ to senescence. Together these form a unified sequence or cycle, upon the exact repetition of which in the single individuals depends the ability of the species to maintain itself in its environment.

Biologists regard these characters as in some way physically represented in the germ at the beginning of development, and the variations shown by individuals are referred chiefly to variations in the germinal material or germ plasm. The theory of germinal variation includes the theory of mutations, the suddenly appearing heritable modifications now regarded as furnishing the chief material of evolution. That the essential germinal substance (the gene complex) has a remarkably stable constitution under the usual conditions is shown by the constancy in the specific characters of the organism; this constitution is maintained in spite of the indefinite increase in quantity which occurs in growth and reproduction.

Experimentally we find it difficult to modify the properties of the genes, while leaving unimpaired the ability of the germ to give rise to a complete organism capable of independent life. Artificially induced mutations are usually nonviable or "lethal." This general fact, well established by a large body of evidence, apparently explains why the course of evolution has been so slow. The characters of the adult organism, maintaining its precarious equilibrium with an environment, cannot deviate far from a constant norm without imperiling survival. Darwin pointed this out in his account of the struggle for existence; he also showed that the heritable characters (an index or correlate of the germinal characters) of a species do fluctuate slightly and that the selection and propagation of individuals showing the appropriate variations can modify permanently these characters, as seen most clearly in domesticated species. On the basis of these facts he developed his theory of evolution by natural selection.

Germinal stability is thus a necessary condition for the organismic stability, while germinal variation is required for evolution. Germ and adult are integral parts of a single organic cycle or life-history; hence favorable organization in the adult implies favorable organization in the germ. The unsolved problems in the theory of evolution have reference primarily to the conditions determining germinal variation. The germ is a single protoplasmic mass or cell with a single (usually bisexual) nucleus, and apparently it is in this nucleus that the inherited variations have their origin. In the evolutionary process, as in other natural processes, there enter both factors of conservation and factors of change. Now conservation, as already indicated, is a characteristic of the physical as physical; this is recognized in all modern physical science, with its ideal of mathematical representation, which defines physical conditions in terms of constants (static and kinetic) and their combinations. The conservation of germinal properties is an example of this general physical character of stability or conservation, and it is largely to such physical factors that we must refer the stability of species.

The question as to the origin of variations is a more difficult one. Some measure of casual or random variation is to be expected, in view of the general presence of randomness throughout nature; and this expectation is confirmed by the apparently casual characters of so many living animals and plants. Every niche of the habitable world seems to have developed its appropriate living organism. The prevalence of parasites and other maleficent organisms ("nature red in tooth and claw . . . .") has disconcerted many believers in a divinely ordained world; conscious design, based on any kind of valuation, could hardly have produced the tapeworm or the chigger or the streptococcus. We may regard such biological facts as pointing to a casual or nonteleological determination for certain variations and their evolutionary consequences. Random variation, however, seems insufficient to account for the chief facts of evolution; and the entrance of teleological factors seems a more likely origin for many kinds of variation, especially the highly adaptive.

Human beings are directly aware in their daily experience of purposive activities which give rise to complex and highly integrated changes in the surroundings; hence the possibility can hardly be ignored that factors of the same general kind may be present and active in other fields of nature and that psychical origination, with its character of teleological aim and integration, may be a general source of natural variation, especially biological variation. To the realist it seems unlikely that teleology, so conspicuous a fact in human affairs, is without its counterpart in the rest of nature.

In the historical development of human society changes and innovations directed by psychic aim have been the dominant factor. Undoubtedly, this development has had its biological background and undercurrent in the biological characteristics of man and his constant need for physical survival, and many significant parallels have been drawn between the social organizations of human beings and those of lower animals like the social insects.[3] Yet no candid observer can deny that the sciences, the arts, religions, and social institutions in general have reached their present forms through the conscious aims and creative efforts of human beings, acting singly or in collaboration. In these efforts the psychophysical character of the determinative activity is always apparent; psychical origination, in the form of imagination, has contributed the element of novelty or departure from routine; while constant physical factors, acting as efficient causes, have played their indispensable part in the process of actualization. The survival of the products of creative effort illustrates the conservation characteristic of physical conditions; cities, writings, works of art, and the results of science are all embodied in physical materials. The same is true of the biological characteristics and conditions on which society is based; conservative physiological needs and factors provide the background of custom and habit under which the same forms of activity are continually being repeated; to this degree the physical—or "materialistic"—interpretation of society has its realistic justification

Nevertheless, the partial character of this physical interpretation should be clear from what has already been said. "Persistence," "conservation," and "stability" are different names for the property of endurance or constancy shown by all estab-

[3] For a recent discussion cf. Alfred Emerson, "Basic Comparisons of Human and Insect Societies," *Biological Symposia* (Lancaster, Pa.), VIII (1942), 163.

lished reality; and such reality appears to external observation as physical reality. In scientific analysis most of the conditions now found existing in physical nature are explained by reference to pre-existing physical conditions; there is always a temporal or causal background furnished by the past; and the past is contrasted with the present by its special character of unalterability Such past conditions, persisting into the present (which is the field of change and activity), are usually regarded by science as determining mainly, if not entirely, the special features of present activity. Causation is determination of present conditions by past conditions.

But at this point the question arises again whether present conditions are determined *exclusively* by the past. Is there no room for novelty? Or is it possible for novel factors, originating "spontaneously" in the present, to play a decisive part? What the pure mechanist contends is that past conditions determine present conditions completely and unconditionally, and he extends this kind of determinism to human behavior. The unprejudiced realist, however, cannot help doubting the realism of this position, because he is always conscious of the part played by present conscious origination in his own behavior. To give a crucial example, the strict mechanist or behaviorist is bound to hold that the originality of the creative artist is determined completely by his special physiology (a product of the past), acting under the play of environmental factors. But to the realist it seems clear that such a contention is a theoretical simplification, based on a type of abstraction which rejects as illusory the fact of psychical origination because of a supposed inconsistency with the facts of physics. The realist appeals to direct experience for his evidence and insists that the conscious immediacy, always present in voluntary action, includes in its very nature some element of the novel and that this novelty always has in it something at least potentially creative. The present is a part of the general creative advance of nature.

It is true that the range of this creativity may vary within wide extremes; thus, a simple sensation follows with apparently perfect constancy upon the stimulation of a sense organ, and its novelty may be overlooked, although it is an emergent having its insistently *present* quality and may arise in consciousness without any conscious antecedents of its own kind—one may never before have felt a certain pleasure or pain. At the other extreme, we find acts of intellectual or artistic creation; sometimes these may be completely unexpected and surprising to their originators—hence called "inspirations." Between the two are the ordinary conscious acts of daily life, requiring some degree of innovation but having, in most cases, the character of slightly modified routine. Nevertheless, even here there is always some element of novelty.

While historians are well aware of the importance of psychical innovation in social evolution, few biologists are ready to acknowledge it as a factor in the evolution of lower animals or in the evolutionary process in general (using here the term "evolution" in the sense of the progressive appearance of novelty and diversity in nature, nonliving as well as living). An unwillingness to encroach on the field of cosmological or theological speculation may be partly responsible for this, but the chief difficulty is the almost complete lack of tangible scientific evidence. The process of learning by mental effort is familiar to everyone; special habits and modes of behavior, with their somatic and physiological accompaniments, are readily acquired in education and persist throughout life. But the earlier belief that such voluntarily induced characters are heritable, at least in part, and might therefore be important factors in evolution, has not stood the test of investigation and has been generally abandoned. Undoubtedly, the failure of Lamarckianism as a biological doctrine has had much to do with the unwillingness of biologists to believe that psychical factors play any important part in evolution. On the other hand, no such doubt is possible with regard to physical factors; experimental evolution is a recognized field of research which is limited to the physical and physiological fields, and its results have been highly important for science.

It must be admitted that the incidence of a psychic factor in germinal variation—supposing it to be a real factor—cannot be demonstrated, and scientific methods of approach to the problem are not easy to imagine. The methods of psychoanalysis have been extended to the early years of childhood; but they can be applied only doubtfully (if at all) to prenatal life,[4] and no one (so far as I know) has seriously considered applying them to the undeveloped germ, where the heritable variations are usually regarded as having their origin. Psychoanalysis presents a paradox to the theoretical biologist; it refers the origin of certain physiological modifications to psychical factors, but a large part of these are regarded as "unconscious." Is there a contradiction here? Or is the demarcation between the conscious psychical and the unconscious psychical an undefined one, as it certainly seems to be in dreams? A related question is whether there is actually or existentially a psychical element or factor present in elementary cellular or neural processes? If this is in fact the case, the higher processes, with their accompaniment of vivid consciousness, might be a composite or summation of elementary psychical processes.[5] But answers to such questions are purely conjectural and based on considerations of a vague and inconclusive kind.

The related problem of the possible influence of psychical factors in the development of the individual organism requires some special consideration. It seems clear that the typical ontogeny, especially in its early stages, is very completely stereotyped or mechanistically determined, and scientific analysis resolves it into purely physicochemical factors; here we have the field of *Entwicklungsmechanik* (experimental embryology or experimental morphogenesis), which has its background of biophysics and biochemistry.[6] The whole regular and closely integrated process is found to be a composite of physicochemical regularities; yet when it comes to the question of the evolutionary origin of these regularities, with all their delicately adjusted balance and interplay, the possibility

[4] Note, e.g., the controversial status of "birth trauma" and similar conceptions of psychoanalysis. There is, at present, no scientific method of determining whether, or at what time, conscious psychic factors assert themselves in prenatal development. (But see Luke 1:41–44.)

[5] See above, p. 71.

[6] The recent book of Joseph Needham, *Biochemistry and Morphogenesis* (Cambridge: University Press, 1942), gives a full account of physical investigations in this field.

that the psychic factor has played a directive part at critical stages cannot be ignored, any more than in the case of the oration which the phonograph repeats with equal exactitude. In both cases the original initiation and certain special features, such as the coherence and co-ordination of the highly organized train of events, may quite reasonably be attributed to an integrative psychic factor; indeed, we know of the existence of this factor in the case of the oration. On the other hand, the persistence and the stable routine of the organic regularities, once they have originated, are to be referred mainly to physical conditions; only physical processes have the precision and reliability required for the execution of such complex sequences.

Development has been compared with instinctive activity by many biologists, and instincts have their close affinities with conscious behavior. The development of an egg into the adult animal is a sequence of biological activity which has much in common with such an instinctive performance as the building of a nest; in both cases there is an integrated sequence of morphogenetic or structure-forming activity.[7] Nest-building is largely a stereotyped activity, just as development is; yet one finds it hard to believe, when watching a bird or even a spider, that this activity is unaccompanied by conscious aim and effort. We also have such examples of concerted morphogenetic behavioral activity as the construction of definitely patterned and complex nest structures by the blind, sterile, and perhaps individually unconscious workers of certain termite communities. Here we observe a co-operative activity which reminds one of such histogenetic processes as the united activity of osteoblasts in building up a bone of a definite size, shape, and structure or of feather-germ cells in shaping an elaborate plume.[8] Are such integrated activities purely physical?

To ascribe such unification to a "field" influence gives a

[7] For a recent discussion of this parallel see the paper by E. S. Russell, "Instinctive Behaviour and Bodily Development," *Folia Biotheoretica*, II (1937), 17; also, his *The Behaviour of Animals*.

[8] For the physiology of the feather germ see the series of studies of F. R. Lillie in *Physiological Zoölogy*, Vols. XI–XVII (1938–44). For the case of bone see E. S. Russell, *The Directiveness of Organic Activities* (Cambridge: Cambridge University Press, 1945), pp. 165 ff.

name to the unifying factor—the term "group soul" is also a name—but is not very illuminating as a scientific explanation. On the other hand, all such activities, when viewed externally, appear as definitely physicochemical and mechanical; this is why the mechanist or behaviorist often seems to have made out such a strong case; if mechanism is sufficient, why drag in the psychic factor? In our own experience a well-learned routine is often hindered rather than helped by psychical interference, such as too close attention.[9]

The physiologist is aware of such facts, but also of many others which seem to have a directly contrary significance. The individual characteristics of human beings are a case in point. Obviously, many of these represent the permanent residue left in the organism by actions which in their initiation and immediate experience were psychically directed and controlled. Voluntary actions become the origin of permanent physical and psychical conditions by which later actions, with their structural and physiological correlates, are determined. Evidently, the processes of training and education depend on the persistent results, physical as well as mental, of psychical effort and activity. It is familiar that the play of the muscles of the human countenance may be a sensitive index of the underlying thoughts and feelings:

> Your face, my thane, is as a book where men
> May read strange matters. . . . .

And in the course of a lifetime the form and expression of a face become physically set in a manner which is in correspondence with the prevailing psychical character of a person; beauty of character often reveals itself in beauty of expression: "the spirit shines through. . . . ." Such facts show how unrealistic it may be to regard physical or psychical factors as if either were free to act independently of the other; the two kinds interpenetrate each other and their influence is mutual.

With regard to the possible teleological factor in evolution, somewhat similar inferences may be drawn. The concept of organic evolution has reference to the course of transformation

[9] Attention brings in an element of novelty which conflicts with stability.

followed by animal and plant species in past history. The species, however, is a group of single individuals, and what applies to the individuals applies (with some modification) also to the group. The chief implications of the present discussion would then be, first, that the decisive or critical events in the evolutionary process—those involving innovation or departure from routine—are attributable primarily to the psychic factor always latent, if not actual, in each organic event as it is happening; second, that the persistence of the results of such novelty-producing events is a part of the general physical persistence or conservation—foundations are thus laid furnishing the conditions for further advance.

According to the foregoing view, evolutionary advances having special importance or value would be chiefly the outcome of psychical innovation—unless something equally fortunate happens by mere chance! But apparently all regularly repeated or routine processes are, or tend to become, purely physical; i.e., they dispense more or less completely with the psychic factor. Their essential character then becomes stability—the preservation of constant character, independent of the lapse of time; this is a feature corresponding to inertia, a universal property of physical objects. Apparently, in the evolutionary process factors both of inertia and of innovation play their parts. Biological evolution shows that well-established natural conditions or processes which receive at intervals slight increments of novelty (i.e., through variation) may in the course of time achieve an indefinitely high degree of stable complexity or "organization." Such organization is the distinguishing character of living beings, as we find them in existing nature; they represent the end-result of innumerable successive acts of innovation or creation, each in itself minute but capable, together, of producing the observed cumulative effect because of the physical consequences of the creative action; these, as physical, have the property of persistence or conservation which is necessary for summation, progress, or evolution of any kind.

It is a part of scientific caution to call attention to possibilities but not to claim them as actualities until there has been sufficient experimental or other support. In the case of evolution the general position outlined above may be difficult to substantiate in the usual experimental sense, except possibly in the case of domesticated animals and plants—Darwin's first line of evidence—where the psychic factor has been furnished by human selection. Perhaps its chief support is to be derived from the analogy, or parallel, between the evolution of human social and other conditions, as observed historically, and the evolution of living organisms, as this is conceived to have occurred in prehuman periods of time. We can hardly doubt the reality of this evolution, although it is now removed from the possibility of direct observation; and we may assume that factors known to be effective in the one case have played their part in the other.

CHAPTER XIII

Vital Organization and the Psychic Factor

OUR earlier review in chapter v indicated that the general tendency of random or unguided activity is opposed to the development of complex organization and favorable to structural simplicity– in the sense of uniform distribution of components. This antiorganizing trend of purely physical processes is illustrated in ordinary large-scale mixing and stirring operations, as well as in the automatic increase of entropy with time in systems subject to the laws of thermodynamics (material or molecular systems in general). Recently Eddington has given the whole matter an admirably clear expression: "Entropy may most conveniently be described as a measure of the disorganization of a system . . . .; we can see chance creeping in where formerly it was excluded."[1]

Unless counteracted by directive action the casual or random element in nature tends to increase. If things are left to chance, not only does organization of any high degree of complexity fail to develop, but what organization there is tends to lapse or disappear. Hence in those cases, such as living organisms, where the existence and activity of the system depend on a special and complex organization, it appears necessary to assume the continued operation of a stable directive influence or factor which pervades the whole system and excludes or compensates casual factors whenever these conflict with the special vital requirements. The presence of this factor is what makes possible the development and maintenance of the type of organization required for vital activity. A peculiarity of the

[1] *New Pathways in Science,* p. 55. A fuller discussion of the relations between thermodynamics and biology is found in the essay of Joseph Needham, "Evolution and Thermodynamics," in his recent book, *Time, the Refreshing River* (London: G. Allen & Unwin, 1943), p. 207. Cf. also the paper by Alfred Lotka under the same title, in *Science and Society,* VIII (1944), 161 (here the relations between will and physical action are discussed in a highly interesting manner), and his *Elements of Physical Biology* (Baltimore: Williams & Wilkins Co., 1925).

vital process is that it offsets, for a time at least, the inevitable drift toward physical equilibrium.

From these general considerations we may conclude that in any highly organized and physically active system a perfect balance or equilibrium (such that the system retains its characters for an indefinite time) which depends solely on random factors and their interplay is not physically possible. In the normal living system we see free energy directively applied in such a way as to further the increased concentration of the materials incorporated from the surroundings, together with their transformation and distribution in correspondence with a definite type of organization.[2] This is true not only with regard to the synthesis of the system in development and growth but also with regard to its maintenance: both equally require directive action.

A similar need exists in the maintenance of complex artificial machines, and not only in their construction; in all systems of this type various safeguards and regulative devices are introduced by the designer, their purpose being to promote stability and to prevent casual (and hence disorganizing) conditions from gaining the upper hand; such are the automatic controls of boiler pressure, speed, temperature, electrical potential, lubrication, and so on. But all these devices, although they may work well for a certain time without special attention, require sooner or later to be adjusted or repaired; and this can be done only by conscious directive action. The psychic factor must enter correctively, now and then, otherwise the special properties of the system are lost.

The analogy of the machine with the living organism is clear enough in some ways while unclear in others; thus, in the normal living organism automatic self-maintenance is complete (or nearly so) during the greater part of a lifetime, while in an artificial machine it is never more than partial. The living organism is sometimes described as an automatically self-regulating piece of mechanism[3]—a verbal formula which states

[2] See above, chap. ii.

[3] Cf. Jacques Loeb's definition of living organisms: "chemical machines consisting essentially of colloidal material, which possess the peculiarities of auto-

accurately some of the conditions of vital activity but hardly "solves" the essential biological problem. What is self-regulation, and what are its factors? The regulative devices in a piece of machinery may be made as automatic as possible; nevertheless, not only is the original construction of the system the outcome of conscious intelligence, but its activity, smooth-running as it may be for a time, is always subject to derangement by the inevitable random factors; hence there is always the need of supplementation by directive factors.

In addition to regulative devices, many complex mechanical or electrical installations are furnished with a system of automatic signals which call "attention" to local conditions like overheating, leakage, mechanical breakdown, cross-circuiting, etc., which can be corrected only by purposive action. These may be compared with the psychical danger signals in the animal organism, like pain, which call forth conscious corrective effort. Random or unguided factors are based, like all purely physical action, on probability factors; and such factors cannot by themselves—except occasionally by rare good luck—correct the deviations of organized systems from their normal state; such correction can be accomplished only by activity which is directive; i.e., controlled by psychic aim or purpose. Activity of this kind has the special quality of not being stereotyped, like purely physical action; it is individual in its nature and can adjust itself to nonroutine or novel situations as they arise.

It is agreed that all physical action contains within itself an element of randomness, in correspondence with the part played in such action by statistical or probability conditions, as contrasted with directive or individually controlled (i.e., integrated) factors. In any system consisting of material parts (parts having inertia) the general effect of random agitation, if uncompensated, is to distribute *more uniformly* the movable components which at the outset have their definite places in the system; this effect is equivalent to a decrease of the spatial differentiation which is the essential feature of any physical or-

matically developing, preserving and reproducing themselves" (*The Dynamics of Living Matter* [New York: Columbia University Press, 1906], p. 1).

ganization. A simple experiment will illustrate: If we place a layer of pure water above a strong sugar solution in a vessel, the two layers remain distinguishable for a long time, provided the system is not agitated; but stirring soon destroys this differentiation, and the sooner the more rapidly the system is stirred; the effect is characteristically irreversible. Similarly, the effect of introducing sand into the bearings of a machine is slight if the system is at rest; but if it is in motion, injury (i.e., disorganization) soon follows, at a rate depending on activity. The disorganizing effects of "wear and tear" are seen wherever there is prolonged activity. Such examples show that a disorganization resulting from chance factors is more likely to occur in a system which is active than in one which is at rest.

In the living system a high degree of physical and chemical activity is the normal state; the continued existence of the system is directly dependent on a flux of material and energy, and this flux must be a stable one—giving a balanced condition or steady state—if the vital organization and activity are to be preserved. The effects of physical randomness must not be allowed to accumulate; chance deviations from the normal must be corrected before they reach the stage of deranging the system. We have already seen that automatic regulations of this kind are a universal feature of living organisms. Take, for example, the ability of living cells and tissues to repair mechanical injury (wound-healing, regeneration); one of the effects of the injury is to set in motion counterprocesses of reconstruction which under favorable conditions restore the normal state. But if this regulative effort is insufficient, disorganization becomes progressive; and this is more likely to happen if the organism maintains or increases its activity than if it remains at rest. Hence the importance of rest in medical or surgical treatment: the *vis medicatrix naturae* is then less effectively opposed by random or other antiorganizing factors. These include purely physical factors, which typically have a nondirective quality in correspondence with their dependence on probability factors or statistical conditions.

In accordance with this general natural condition, we find that in many animals, especially the less prolific, the process of development is carried out under conditions of isolation (e.g., egg cases, nests, uterine development) where random interference from the surroundings is reduced to a minimum; the importance of freedom from casual interference is here illustrated. In general, we may say that casual and vital activities are opposed to one another in their essential nature and tendency, and this opposition expresses itself in many features of vital organization. This is seen, for example, in the tenacity with which the vital organization maintains itself against disturbing influences. It is remarkable how difficult it is to break down the physical organization of a living cell—for example, the sea-urchin egg (on which much of the experimental work has been done)—by stirring or mixing procedures, such as centrifuging, mechanical shaking, or microdissection. Such resistance to disorganizing action is usually regarded as an example of "regulation," but it well illustrates the stability of the organizing factors which maintain constant the structural and physiological state of the system in spite of its being in a continual state of physical and metabolic flux. A further experimental fact of fundamental importance is that this regulative and regenerative capacity of cells typically disappears with the removal of the nucleus; indicating that the regulative influence is internal or central in its origin. The possible significance of this association of directive activity with nuclear activity will be considered more fully later.[4]

The building-up of a complex organization in the development of an animal or plant is a process of concrescence, combined with integration. The considerations brought forward in the preceding paragraph indicate that development, as well as the maintenance of organization, once it is synthesized, is itself evidence of the existence of some specifically biological condition or activity which automatically corrects or compensates the disorganizing influence of random physical factors. At the same time, all the externally visible activities of the organism appear to the observer as physical; the fundamental activities of growth and maintenance are the result of special chemical transformations and shiftings of materials, and these processes

[4] Chap. xiv; cf. the general discussion on pp. 34–35 above.

occur in accordance with physical and chemical law, as experiment shows. The material which is synthesized and deposited in definite places to form organized structure has the same general physical properties as material which is "nonliving." But this physical character does not prevent it from exhibiting also those special properties which it possesses by virtue of being also "living"—i.e., of having its unique place and activity in the vital organization. Above all, the entire organism, besides exhibiting these physical characters, acts as if it were the field of some specifically vital unifying agency or factor, which also has constant properties but whose activity is directive and synthetic in its essential nature. Apparently, this factor pervades the living system in all of its parts and in some way counteracts the purely physical tendency to disorganization.[4a] The possible nature of this factor may now be considered in more detail.

In our experience of natural processes, the presence of an integrative and directive factor, having control over an extensive field of physical activity, is most readily observed in voluntary action carried out in pursuit of a purpose. Here "psychic aim" becomes dominant and determines the special direction of what happens in the physical field. Obviously, voluntary action is not independent of physical factors but is carried out in intimate conjunction with them; the normally acting neuromuscular system is a physical system having definite and constant properties without which the action would not be possible. The significant fact, however, is that the precise form which this action takes is dependent not only on this physical organization but also on the motivation and aim in the conscious mind of the agent. In some unknown manner the psychic aim determines that events take a special and definite course, rather than one of many others which are possible in the physical sense; there is a selection out of a wide range of possibilities.

[4a] As a concrete example consider a typical vital organization like that of the heart, which maintains for years a nearly constant form, weight, structure, and activity, although its source of supply and most of its internal substance consist of aqueous solution, subject to continual stirring by the mechanical action of the organ. The essence of life is directed flow; in contrast, in a physical machine the parts and connections are typically made as rigid as possible.

We have no physical observation of how this selection is made, but certain general conditions may be assumed. In order that the psychic aim should have this effect, it must be persistent, and it must modify in some asymmetrical manner the field in which the physical action is taking place. The association of asymmetrical action with vital action, particularly in the fundamental chemical syntheses, has already been discussed. To indicate the general importance of asymmetry, the analogy of a gravitational field may be helpful; in the absence of such a field bodies free in empty space pursue straight paths; and a casual assemblage of such bodies, differing in their velocity and direction of path, is soon dissipated. But inside a sufficient gravitational field (arising, for instance, from the preponderant mass of one body) the path of each body becomes curved, i.e., asymmetrical in relation to the whole volume occupied by the field; and under certain conditions—as of not too high relative velocities—the whole group forms a coherent and stable system, as illustrated, for example, by the solar system. In the living system the conditions are widely different, both in detail and as a whole; but for the purpose of the present comparison we may regard the gravitational integration as a simplified model of the more complex vital integration, where, as illustrated in voluntary action, it is effected under the influence of psychic aim and effort. At least such a comparison of the simple with the complex illustrates how a nonmaterial, formal, or structural condition pervading all parts of a system may modify in a directive and integrative manner the total course of activity within the system.

The stability of the living organism is known to be determined largely or mainly by physical (i.e., physiological) conditions; even the duration of the individual lifetime is inherited. But in the human being we observe that the physical stability is paralleled by another kind of stability: this is the psychical stability, as expressed in the fundamental psychological character of the person. A large part of the coherence and integration shown by the human individual, even regarded solely in his aspect as a physical system, is demonstrably a function of this psychical character; and the relations of the psychical to the physical character are largely open to scientific investigation. The general biological problem is: how are we to conceive scientifically the nature of the psychical field and its relations to the physical field?

The concept of *field* has recently assumed in biology an importance comparable to that which it has long held in physics. In both sciences it is used in the general sense of an area or volume pervaded by a single unifying influence of some kind—gravitational, magnetic, electrical, chemical, developmental; in its biological application the term has reference chiefly to the pervasive unifying factor in developmental processes.[5] The developmental field has been regarded by Child as consisting essentially of a system of metabolic gradients; evidently the organized structure arising in development is a product of metabolism, and this metabolism proceeds under physical conditions in which gradients (e.g., of oxygen consumption, resistance to injury, electrical potential) are clearly demonstrable. According to Child, the developmental fields "in their simplest and most general form are gradient systems; the gradients are the vectors of the field and determine its extent and the orderly relations within it."[6]

The experimental evidence for this view is extensive and convincing, and the fundamental importance of metabolic and physiological gradients in development must be recognized. Broad structural characters, such as axes and polarities, are early established in most cases of development and have their basis in metabolic gradients with definite orientation. But the general problem of the biological field has other than physiological aspects; and if we regard the organism as a psychophysical system, the possible part played by psychical, as well as physical, factors must be considered. The problem of how a particular field came into existence in evolution and of how it is maintained during the individual lifetime is only partially solved by analyzing it into a system of physical gradients,

[5] For a general discussion and references to the earlier literature cf. the recent book of Paul Weiss, *Principles of Development* (New York: Henry Holt & Co., 1939), esp. Part III.

[6] C. M. Child, *Patterns and Problems of Development* (Chicago: University of Chicago Press, 1941), p. 278.

which, in the Aristotelian sense, are efficient rather than final causes. The special peculiarity of the field as an integrating condition pervading the whole organism—holding the latter true to form in spite of disturbing conditions—suggests the participation of a psychical factor with persistent aim, which in some way is superposed on the physical conditions.

Modern theories of genetics refer the stability of an organic species primarily to the stability of its germinal determinants or genes; the special properties of these units are again referred to special stable features of physical and chemical constitution. Given a constancy in the character and interrelations of these units, constancy in the transformations occurring under their influence is to be expected, according to the accepted scientific principle of uniformity of process under uniformity of causal and other conditions.

Nevertheless, the observer cannot help being profoundly impressed with the exactitude of hereditary repetition in pure genetic strains of animals and plants developing under normal conditions, especially when he bears in mind the extreme complexity of the physical detail. In human strains this exactitude is most striking in persons of similar genetic constitution, such as identical twins or quintuplets; in these cases the psychical uniformity is as remarkable as the physical uniformity. In general we observe that the psychical characteristics of a person show the same stability as his physical characteristics, with which they are in close correlation. Mutuality of psychical and physical influence appears to be a general biological fact or condition; in human beings this is well shown in the familiar effects of habit, education, and practice, which modify simultaneously the psychical and the physical characters. Psychical factors are observed to act as partial determinants of physical characters during a man's personal lifetime; modern genetics, however, tends to restrict this psychical determination to the fully developed individual and does not admit psychical factors as playing any part in embryonic development.[7] Yet it is well known that in the postnatal development of the child

[7] See above, p. 171. In other words, observational evidence of such influence is lacking. If the existence of Lamarckian influence is admitted at all by the modern geneticist, it is in a highly attenuated form.

hereditary psychological traits, often asserting themselves in very early years—such as special talents, interests, or aptitudes—play an essential determinative part.[8] In this sense the psychical influence is a demonstrable factor in physical as well as in psychical development.

The organismic constancy, as maintained, for example, in a human being during the greater part of a long lifetime, is clear evidence of the presence of a stable directive and unifying factor or influence which pervades all parts of the organism and keeps its characters and activities, physical and psychical, integrated and true to form. This factor not only corrects chance deviations from the physical norm characteristic of the species and individual, but it also expresses itself in the consistency of psychical character exhibited throughout life. Yet the nature of this unifying influence is conceived by most biologists as purely physical.

There is a scientific impasse here, and the problem is how to overcome it in a manner which is consistent both with scientific principle and with the special facts of the case. The only concrete model or analogy which seems at all serviceable is that of the complex artificial machine, already discussed in part. The machine, however, is itself a product of pre-existing vital activity and organization. We regard any machine in its present existence as a purely physical system; yet, to account for its origin and its stability of operation during the period of use, unavoidable reference must be made to psychical factors. A system of mass production, once brought into existence, may act automatically for a considerable time, but only provided a certain intelligent supervision and control are exercised. All existing systems of this kind have reached their present state of development through a process of evolution, initiated and guided by inventive intelligence and continually tested by trial and error.

The parallel to biological evolution appears complete, except that modern physical biology seems committed to ruling out, as unimportant or nonexistent, any factors of psychical

[8] The evidence for this general statement is familiar to all observers of family traits. Sir Francis Galton's *Hereditary Genius* (New York: Appleton Co., 1887) gives many examples from biography and history.

control in the processes of development and evolution. It regards the variations which provide the material for evolution as chance variations determined by purely physical (or physiological) conditions. Many biologists feel the insufficiency of this conception; but so long as it seems consistent with the prevailing state of knowledge and criticism, it is likely to hold its own; there is always the hope that further advances in experiment and analysis will remove the chief difficulties. Obviously, any criticism must be based on realistic grounds, i.e., on direct observation and experiment as far as possible; but nothing is to be gained by a refusal to regard other than physical factors as effective in the activities of the organism when all observation shows the latter to be a psychophysical system.

In our human experience we find that, whenever novel or difficult situations have to be met, physical routine is insufficient; only the psychic factor is capable of furnishing the required novelty of action, and such action may, on occasion, be both unifying and creative. Under the psychical influence special direction is imparted to activities which otherwise would be determined by purely physical conditions, subject, in the long run, to statistical or probability factors rather than individual (integrated) factors. The contrast between a consciously voluntary action and an action determined by unconscious habit brings out clearly the special part played by the psychic factor. In the fully conscious human being the presence of this factor is felt as a pervasive controlling influence which supplements, reinforces, and at times counteracts the constantly present physical (physiological) factors whenever these, acting by themselves, are insufficient to meet the novel demands of a situation.

In those natural systems which we recognize as "living," the physical and the psychical factors are to be regarded as continually influencing one another reciprocally in this manner; as biological factors they are mutually supplementary. Routine, a universal fact of nature, is physical in its basis and character; this physical side of vital activity is shown in the ordinary automatic functions and habits of the organism. When the psychical influence intervenes, as a factor modifying the physical, the intervention is typically in the interest of novelty, integration, or creation. It is true that the adult animal or man is subject to psychical, as well as physical, habit; but experiment shows this to be based on physical (physiological) conditions. The constancy of psychical character shown by a human being during his lifetime has its correlate in a constancy of physical character, as seen in his anatomical structure, physiological "temperament," facial expression, habits, and so on. Many such characters, although now physically stable and externally visible, are the index of an inner psychical control, exercised constantly or intermittently over long periods of time.

It is, in fact, well known that in many cases a large part of the physical constancy of the adult animal requires for its maintenance the activity of a directive psychic factor; this is best seen in any highly developed human skill or aptitude; without conscious attention and practice the powers needed for any difficult accomplishment—physical or mental—soon decline; they are kept at a high level only through continual psychical activity. Mere physical practice is not enough, although it may be essential; a creative worker or artist in any field requires to be vividly conscious of what he is doing, otherwise his work loses originality and what we call "vitality." Any such accomplishment presupposes a complex physical structure of habit; but this can be built up only by conscious direction during the period of training or education, and its maintenance requires constant attention and exercise. If the psychical direction lapses, the correlative physical substructure, regarded as having its chief seat in the nervous system, lapses also; the closely integrated psychophysical organization suffers decline. Facts of this kind are a well-known part of the general psychophysiology of learning, but their fundamental biological significance is not always recognized.

The living body is a deposit from the past; observation shows it to be produced by the accumulation of materials which originally were distributed at random in the environment. In each life-history this accumulation begins at an organizing center, or germ, which physically is part of the parent-body; in most animals the fertilized egg is the earliest stage of the developmental cycle, but a similar selective accumulation and working-over of materials into an organization are necessary activities at all stages. Since the organism is a physical aggregate, in this general sense, it has physicochemical properties of a kind common to all such aggregates; hence, whatever happens within it is subject to physical control and physical restriction.

To the physiologist this omnipresence of physical determination may seem to offer a complete explanation of vital activity; and this impression needs to be corrected by a study of the psychical influence, as it expresses itself in voluntary and other activity—especially activity of a creative or integrative kind. While it is apparent that the psychic factor always acts in association with physical factors, its special property of selection and directiveness, or opposition to merely random action, gives it a natural status which is definitely contrasted with that of the purely physical. A complete science of animal behavior will draw its facts from the observable psychical, as well as physical, activities of the organism; both kinds, together with their interrelations, are to be taken equally into account in forming its theoretical conceptions. The same may be said of general biology, an observational natural science having special reference to the characters common to all living organisms.

Another consideration of a more philosophical nature needs emphasis at this point. The observed efficacy of the psychical in the determination of human and animal behavior shows that factors derived from the *past* are not the only ones to be considered in accounting for natural activity *in the present*.[9] There exist also natural factors which have their origination and effective existence only in the present, and unique among these are the psychical factors. No one need deny the existence of nonpsychical factors which also have their existence and activity in the present; these would be the stable or routine factors which have passed unchanged from the past into the present—in other words, the purely physical factors.

Apart from the general interdependence known as "causa-

[9] See above, pp. 102 ff.

tion," there is a special relation (or contrast) between the past and the present which may be briefly expressed as follows: The present differs from the past in being that part of the temporal field of nature in which its freely active and originative side is able to assert itself; to paraphrase Whitehead, we may say that the present has its existence on the fringe or border line of the natural advance into novelty. Spontaneous or novel action derives its special character from present rather than past conditions, and the chief[10] source of novelty or creative activity in the present is the psychic factor. Whatever causal independence the present is capable of achieving comes from the psychic factor working within it; only this factor can overcome the incubus of the past. This metaphor, of incubus, emphasizes the *inertia* of past conditions; inertia is primarily a physical property, a correlate of the conservation which is a recognized character of the physical as physical. In contrast, the psychical, being a factor of novelty, is the *anticonservative* property in nature—to use another metaphor: it leavens the lump.[11] Leaven, it will be noted, is a living organism; in all living organisms the element of novelty or origination, which always enters in some degree into present activity, is indispensable, even if it exhibits itself only in preventing the physical tendency of the highly differentiated (yet largely fluid) living system to lapse by diffusion into a less differentiated state.

We may note that this conception of the significance of present activity in natural process is in general agreement with the philosophical doctrine that reality is only partly contained in history.[12] Whitehead remarks, in reference to the activity of the living being in present time, "The data appropriated are provided by the antecedent functioning of the universe . . . . ," but "how it deals with its data is to be understood without reference to any other concurrent occasion. Thus the occasion, in reference to its internal process, requires no contemporary

[10] I say "chief" here rather than "only," because chance factors can never be completely excluded in natural events and may themselves lead to novel conjunctions. There *are* such things as strokes of good luck (cf. p. 157).

[11] I Cor. 5:6.

[12] In J. E. Boodin's recent paper, "Analysis and Wholism," *Philosophy of Science*, X (1943), 213, he makes brief allusion to this doctrine.

process in order to exist."[13] This is in agreement with the relativistic doctrine that strictly contemporary separate physical events do not influence one another. Each event, as individual, has a certain inner or independent source of determination; i.e., the spontaneous side of vital action has a basis of inwardly determined or "free" natural action in the present.[14]

The general evidence indicates that the constant entrance of this anticonservative factor as an effective determinant in present activity is the essential feature distinguishing the living from the nonliving systems of nature. For the continued existence of living organisms it is not sufficient that there should have been constructive activity in the past; such activity must also be continued in the present, otherwise the vital organization breaks down—as seen, for example, in the rapid disorganization of brain cells when deprived of oxygen. Of course, there are structural parts of the organism, like the skeleton, which in their finished state have a stability independent of immediate metabolism (the same is true of buildings and birds' nests); but the living protoplasm is dependent for its continued existence on active metabolism in the present; and an essential part of this metabolism includes the synthetic biochemical reactions, which apparently include the synthesis of proteins peculiar to the individual.[15] Synthesis, in its general character, is activity leading to novel production or emergence, and in general we find that originative (as contrasted with routine) action assumes greater and greater importance in the organism as the psychic factor enters more completely into control.

It may sound like a truism to say that the psychic factor—

[13] A. N. Whitehead, *Nature and Life* (Chicago: University of Chicago Press, 1934), p. 26. This essay is reprinted in his *Modes of Thought*, p. 173; cf. p. 206.

[14] In *Adventures of Ideas*, chap. xii, Whitehead discusses at some length this "causal independence of contemporary occasions" (p. 251): "Nature does provide a field for independent activities . . . ."; "The immediate activity of self-creation is separate and private, so far as contemporaries are concerned" (pp. 251–52). On the side of theoretical biology, the late eminent neurologist, G. E. Coghill, has expressed a similar general view: "The antecedent tells a part of the story about the present, but not all of it; for within the present are events that have behavioral significance only in that which follows" ("The Neuro-embryologic Study of Behavior," *Science*, LXXVIII [1933], 135).

[15] Cf. Leo Loeb, *op. cit.*

the special factor associated with immediate consciousness—has its activity and influence only in the present; but if we regard that part of nature which is in past time as having a real existence, this distinction seems both necessary and important.[16] Present time would then be defined as the time occupied by that part of the natural process which is (or may be) the seat of novel or originative activity, as distinguished from simple persistence, routine, or inertia. Routine and inertia are closely similar, if not identical, features of natural action, as may be appreciated if we consider the motion of a body in empty space free from gravitational or other influence; its state of motion at any instant is unequivocally determined by (quantitatively the same as) its motion at the preceding instant, and so back into the past; there is nothing *physically* peculiar about the present as present. The past corresponds to the fixed or permanent (established) part of nature; and since it is continuous with the present, it furnishes a large part, *but not all*, of the conditions determining activity in the present. The future (not yet existent nature) is shaped not only by past and conservative conditions but also by whatever conditions may originate in the present, and unique among these latter conditions is psychical action.

The general point of view outlined in the present chapter may be summarized briefly as follows: In the living organism those factors which were either originally (primordially) stable or have achieved physical stability as the result of past activity (completed or constant factors) act in close association with psychical factors which have their existence and activity in the present. In these psychical factors there is always some element of physical indetermination or spontaneity; under the control of psychic aim this spontaneity may become directive and achieve novel or creative results. Apparently, this is what has happened in the development of vital organization. In the absence of this directiveness the automatic trend of natural processes is typically toward a less differentiated or structurally more uniform state; this is the trend seen in the general effects of random or casual activity, as illustrated in stirring or mix-

[16] See above, chap. vi.

ing operations—molar as well as molecular. Accordingly, in the long run any complex physical system which is psychically uncontrolled suffers a decline or loss of organization. The permanent natural condition known as the "law of dissipation" (second law of thermodynamics), is an example, on the cosmic scale, of this effect, which always results from long-continued unguided activity.

In the natural world we observe a widespread counteraction of the purely physical tendency toward uniform distribution of matter and energy; even nonliving nature is highly diversified. But this counteraction is most completely exemplified in living organisms; here it is effected through the intermediary of an organization of highly special type, the product of long-continued evolution. There are, of course, limits to what vital activity can accomplish in building up and maintaining an organization.

Nature, however, has taken good care that we do not forget the dependence of life on material and physical conditions. The living organism, as a deposit from the past to which continual additions are being made, experiences during its individual lifetime a progressive alteration of physical properties. Part of the inert material incorporated in the organism appears to resist removal by the excretory processes or destruction by oxidative or other metabolism and remains within the system as foreign or otherwise refractory substance; as a consequence, the organism undergoes a gradual decline in its ability to preserve its normal physiological balance and its adjustment to its environment. By degrees a larger and larger part of its organization takes on the character of a purely physical or routinized system, which accordingly becomes less and less responsive to the integrative psychic factor. This is the process known as "senescence." In the course of time the psychic factor finds itself less capable of modifying and controlling to its purposes the structure of routine and habit which has been built up during the physical lifetime. Eventually the purely physical processes, including especially the random processes which make for decline of organization (disintegration), gain the upper hand, and the organism dies. Its materials then come under the control of purely physical factors; and these effect a random redistribution of its components—one, that is, occurring in accordance with simple probability factors, such as those which express themselves in the law of entropy. The nondirective element, always present in a physical system, is no longer adequately compensated by the directive and integrative psychical element; and vital integration is no longer possible.[17]

[17] It is evident that the psychophysical conception of the organism has its general implications for pathology. The decline of integration just described shows itself in a decline of control in the processes of growth, repair, and maintenance, as well as in other psychical and physiological activities. For example, tumor formation has its physical basis; but another factor in this process, according to the present conception, is a weakening or withdrawal of the directive and integrative influence normally present. This deficiency shows itself, for example, in the disorderly character of malignant proliferation. Obviously, a psychosomatic biology must consider physical pathology and psychopathology as closely interdependent.

CHAPTER XIV

Summary and Review

THROUGHOUT the present essay we have emphasized the conception of the living organism as a natural system in which factors of stability and factors of activity are combined in a special kind of synthesis. This synthesis has an aspect of novelty, shown both in individual development and in evolutionary advance: life is creation. We regard the source of this novelty as essentially psychical in its nature; at the same time the organism is a stable and orderly physical system and as such is subject to scientific description and analysis. Science, as science, is concerned primarily with the regular and constant aspects of nature and experience; its field is the permanent, recurrent, measurable, it aims at valid generalization.

Yet the fact of evolution shows that nature is not entirely stable; and science has the further responsibility of giving some account of the diversifying and synthesizing principle which brings into existence such a variety of forms, systems, and activities. Evolution implies that all these at some time in the past were *new*. Individuation, diversity, and novelty are primary facts of nature, as well as stability and regularity. The recognition that a substratum of energy or activity underlies all natural existence and process is not sufficient; many routine forms of activity (kinetic constants) exist which have the same stability as static facts like gravitation, yet are equally incapable (by themselves) of producing novelty. Our present interest is in the nonroutine activities which are the source of natural creation. What "causes" or conditions the departure from routine, the appearance of genuine novelty in nature?

In life-processes, as experienced in ourselves, we find a foundation of stable conditions and processes which are *physical;* superposed on these we find also the immediately felt quality or property which we call *psychical*. The latter is a matter of direct experience and is active in the present; and since present time is *new* (not previously existent), the psychical would appear to provide the required source of novelty. Woodbridge remarks in his *An Essay on Nature:* "Man is a sample of nature and just as good a sample as a solar system or an atom."[1] If this statement is accepted, the conclusion would follow that the psychical qualities, so highly developed in man and higher animals, are an evolution from properties and conditions which are general or universal in nature. Apparently, the physical and the psychical interpenetrate each other; and it is their united action which is responsible for the diversification of nature, including the evolution of living organisms.

"Mind," the psychical, is in our observation always associated with a physical organism. The question of why the body has a mind (or the mind a body) receives a partial answer from the considerations reviewed in our first chapter. The essential property of matter is stability, conservation; traditionally the atoms are indivisible and indestructible, and this still remains true in general;[2] the living system is an organization of atoms, and its stable properties are described in terms of physics and chemistry. Like other natural systems, the organism is a composite of stability and activity. Physiology describes its physical properties; these, as physical, are stable and routine. Within this framework of constancy appear the factors and elements of novelty; but these, if really novel, appear as psychical rather than physical in their origin and essential character. The physical complexity of the organism may be accounted for on the principle that complex modes of activity require a correspondingly complex foundation of stable conditions; this principle appears to be universal in physical nature and is illustrated in artificial machines as well as in living organisms. Whenever, therefore, we wonder at the physical intricacy of the animal organization, we may also reflect that without this intricacy the complex and versatile activities—

[1] P. 237.

[2] I.e., leaving out of account, provisionally, the facts of radioactivity and atomic transformation.

whether physical or psychical—so characteristic of life would not be possible.

The living organism, then, is not merely physical in its constitution but psychophysical; the psychical reacts on the physical, and vice versa: there is an observed reciprocality of influence. But the psychical influence is of a special kind and differs characteristically from that of the physical; it is the fundamental source of the selective, innovational, and integrative property of the organism; its essential quality may be described briefly as direction, aim, purpose—in a word, the teleological. There exists in the psychical a property of spontaneity; part of its determination is in the present and independent of the past, and also independent of present conditions external to itself; this independence is a character of individuality; it is a monadic property in the Leibnitzian sense. Accordingly, novelty and creativity (including "free will") have their origin in that part of the organismic activity which is psychical rather than physical. The physical is routine, and its characters have been fixed by conditions which are now past. Novel activity, in contrast, implies some departure from past-determined and conservative modes of action, although these latter are always present and necessarily have their effect in the total behavior of the system. Again, if any instance of vital activity is to eventuate in consequences that are creative (or will contribute to evolutionary advance), it must bring a sufficient variety of factors under a common influence and must maintain a certain consistency of direction (or trend) for a sufficient time. In other words, the activity as a whole must be unified, i.e., have a quality of coherence or integration.

In voluntary human activity such integration is normally effected by what we call "purpose"; this is a psychical activity, maintaining itself through time, which guides, controls, and unifies a course of action. Conscious purpose, however, as it exists in ourselves, is to be regarded as a highly evolved derivative of a more widely diffused natural condition or property, which we may call "directiveness" or (after Whitehead) "subjective aim." This is the property which underlies the teleological manifestations of nature. In teleological activity there is a participation of the psychical (in some form) in superposition on the physical or already established part of nature. In novel forms of natural action the selective or preferential property (aim) of the psychical dominates over the nonselective or random property of the physical and imparts a corresponding direction to events.

We have emphasized that conservation and regularity are the distinguishing features of physical reality; hence is derived the preference for mathematical representation in the physical sciences and a large part of biology. In one sense the inertia of the physical is an obstacle to the development of vital organization; in another sense it is a necessary precondition, since both the attainment and the maintenance of an organization depend in large part on the regularity of physical factors. Underlying any synthetic process there must be a foundation of order.[3] Living organisms are subject, like other natural systems, to the general laws of physics and chemistry, at the same time as they exhibit activities of a kind not found in nonliving systems and largely novel and unpredictable.

Observation indicates that nature is a combination of random and directed activities; randomness (probability distribution) furnishes the basis for uniformity and stability in physical processes; and, conversely, we may regard the existing diversification of nature, nonliving as well as living, as evidence of directiveness. The reason why random activities tend toward stability is not difficult to see. When chance events are repeated a sufficient number of times, they distribute themselves equally or symmetrically in all possible directions. Action in one direction is just as "probable" as action in another direction; hence, in any active group of particles an impulse in one direction is sooner or later compensated or reversed by an impulse in the opposite direction. Accordingly, chance activities cancel one another out and cannot by themselves lead to progressive differentiation, evolution, or complex organization.

[3] Joseph Needham, as a motto for his Terry Lectures on development (*Order and Life* [New Haven, Conn.: Yale University Press, 1936]), quotes Sir Thomas Browne: "All things began in Order, so shall they end and so shall they begin again; according to the Ordainer of Order, and the mystical Mathematicks of the City of Heaven" (*The Garden of Cyrus* [1658]).

It is because of their long-range uniformity that they constitute the factors of stability in physical processes. The molecules of a gas behave in accordance with probability patterns similar to those exhibited by other casual motions (like the shaking of dice); and the same is apparently true of the subatomic processes governing the emission of electrons from radioactive atoms, and similar processes of microphysics. In contrast, synthetic natural processes which are in any way complex require, in addition to such stable activities, the presence of some influence or factor which is directive and unifying and also sustains its directiveness for a sufficient time.

This contrast of casual and directive in nature has its close parallel in the contrast between physical and psychical in the animal organism. Purely physical activities, being based on random factors, are unguided; to give them a definite direction and a persistence in that direction, there is required either a psychical control which is applied in the present *or* a physical control based on some condition which had its origin in a psychical control applied in the past.[4] The resulting structure or condition persists and "canalizes" the present activity, very much as a stream bed canalizes the flow or a track directs a railway car.

Apparently, every present action leaves its permanent impress in nature; this physical property of conservation is what makes it possible for psychical action (acting always in the present) to achieve results which are stable and furnish a secure basis for further advance. Accordingly, under psychical guidance it becomes possible for physically stable organized systems to be built up step by step and ultimately to attain almost any degree of complexity—which means improbability in the purely physical sense. Of these systems, living organisms are the chief examples in existing nature. Such systems may be maintained in all their complexity if the psychical factor retains its directiveness; efficient purposiveness requires that this factor should interfere correctively whenever required in

[4] Here we are leaving out of account provisionally the case of casual single events, which, as pointed out above, may sometimes give rise to special persistent conditions—but never, it should be noted, to conditions having a high degree of organization.

such a way as to counteract the ever present physical tendency toward randomness and disorganization. So long as the psychical factor holds its control, the casual factors are thus prevented from disorganizing the system, which continues living until random factors again assume dominance within it or until some disorganizing influence enters from outside.

According to our present conception, it is in this step-by-step manner, under a steadily persistent directiveness, psychical in its essential nature, that living organisms have come into existence in the course of evolutionary history and attained their present characters. The contrast of randomness and directiveness appears to pervade all nature but is especially evident in living beings. We have seen that any effective teleological activity requires that the directive influence should be applied at certain critical places and times in the causal nexus but that its intervention need not be continuous. Intermittent direction is sufficient if properly localized in space and time; in the intervals, regular physical factors—static and active—keep events in their determinate course; they provide the stability which the process requires, as well as its energy.

If in such a teleologically controlled sequence the directive interventions occupy only a brief time and are confined to spatially minute regions (like groups of key atoms situated, for example, in nuclei), they may escape direct observation, and the whole process may then appear completely physical in its determination. Nevertheless, its special course and outcome will be determined by the teleological factor; without this factor physical processes can achieve nothing creative in any complex sense. Any progressive human undertaking illustrates such a state of things; special tasks are left over until next day; orders are given at intervals; repairs and adjustments are made when required. Temporary interventions of this kind are sufficient to insure the desired outcome. But unless the teleological control asserts itself, the random factors sooner or later become dominant; "we see chance creeping in where formerly it was excluded"; and progressive disorganization follows.

In general, we conclude that probability factors, although they furnish the conditions of stability in purely physical processes, cannot by themselves be depended on for the development or maintenance of highly organized and active systems, such as living organisms. Where no sustained directiveness is present, any system of events consisting of many active components tends toward a state in which the components are distributed according to the conditions of probability; this means, if mechanical restrictions are absent, a state of uniform distribution. When such a state has been reached, the system as a whole, if left to itself, remains static.[5] On the other hand, if through creative action a complex organization has once been synthesized, it may be preserved by a directive control which intervenes only occasionally—just how often will depend on conditions—and a stability thus maintained may be secure and may form the foundation for further advance.

In the highest known products of natural evolution, living organisms, we have the apparent paradox that, although they consist of synthesized materials and processes of the utmost complexity, they nevertheless maintain, both in detail and as wholes, the most exact regularity, precision of action, and coherence. Until the normal life-cycle nears its close, they resist successfully the automatic physical tendency toward disintegration. As we have seen, a prerequisite for this physical coherence is the physical stability of the component structures and processes; yet to account for the coherence and regular interaction of such a diversity of factors, it seems necessary to recognize the existence of another kind of stability, one based on psychical integration. This is a stability which in our human experience we find necessary in any kind of constructive or synthetic undertaking. Its nature is indicated by the terms "apperception," "comprehension," "mental grasp," and "sustained purpose": a variety of details are held together in the unity of a psychical field.

This psychical integration, so characteristic of the living organism on its conscious side, implies the existence of a parallel physical integration, the two forming together a psycho-

[5] Note Milton's description of Chaos in the passage quoted by Whitehead (*Process and Reality*, p. 146): ". . . . and by confusion stand."

physical unity. The concept of the organismic "field" corresponds closely; such a field is to be regarded as including biological factors which have a psychical (or quasi-psychical), as well as a physical, character; that is, in the characteristic unification of the organism an integrative principle or property is acting which is similar in its essential nature to that of which we are conscious in mental life. In this psychical unification, aim and directiveness, together with selective quality, are constant features. "Aim" implies reference to the future, a teleological property; the existence of effective teleological factors in living organisms is sufficiently shown by the part which purpose plays in our own activity. Conscious purpose, however, is to be regarded as only one form of biological integration; the integration shown in embryonic development is apparently unconscious, and the same appears to be true of most physiological regulations. Such biological facts point to the existence of a more general integrative property or activity of a fundamental kind which is universally present in living organisms, from amoeba to man; and if we acknowledge the existence of this factor, the problem of its special nature arises.

This problem has its philosophical aspects, but the more special biological problem of where and how the directive control which underlies integration is applied in the organism may be approached by scientific methods. In higher animals the nervous system is regarded as the chief organ of integration; but the essential physiological problem is of a more general kind and has reference equally to lower animals and plants. Hence the most important facts are the most general ones.

Of special significance is the fact that living organisms consist of structural units, "cells," whose activities are under nuclear control. In both physics and biology a "nuclear" influence is generally conceived as one which originates in a small, centrally situated area and controls processes in the immediate surroundings. One of the chief results of modern cytology is the demonstration that in the multicellular animal or plant, both during development and in the adult stage, the nuclei in all parts of the organism have the same physical constitution, as shown by the number and structural peculiarities of the chromosomes in mitosis. The chromosomes contain the genes, and the conclusion follows that the same group of genes is repeated regularly throughout the organism, at brief spatial intervals corresponding (in general) to the dimensions of the cells. Experiment shows that the general biological function of nuclei has reference to the synthetic and integrative side of cellular processes;[6] if the nucleus is removed from a cell, there is no nuclear regeneration and the cell later disintegrates.

A corresponding integrative function is to be ascribed to the totality of nuclei in the whole multicellular organism, if the gene theory of heredity is true; the difference between the single-celled and the many-celled organism is simply that in the latter the nuclei are multiple instead of single. Apparently, each nucleus has its limited sphere of influence, i.e., controls directly the special character of metabolism[7] throughout a certain small element of volume. In addition, there is the whole field of the organism, in its character as a unity; this corresponds to the field over which the whole nuclear aggregate (considered as a unit) exerts its control. The essential fact is that, scattered throughout the whole highly differentiated organism, wherever there is active metabolism, the same small compact packet of genes is found. This condition is undoubtedly a primary factor in the organismic integration.[8]

An unsolved problem, however, is why, although the genes in all regions of the organism appear to be identical in character, there should be such diversity in the developmental and other physiological processes in the different regions. The uniformity of gene character throughout the organism has a correspondence with the biological uniformity shown by all the individuals of a given species; but it does not account for the progressive differentiation which occurs in each individual as

[6] The basis for this general conclusion is the large body of experimental work upon protozoans and other single cells (e.g., egg cells), where nuclei can be removed or transplanted by operation.

[7] The view is widely held that the genes determine primarily the protein specificities.

[8] For the evidence connecting single gene characters with special somatic characters the reader is referred to the work of the geneticists, especially T. H. Morgan and his successors, as reviewed in all recent textbooks on genetics.

it develops. Here we have a problem of a peculiarly biological kind, and one upon which physical methods of analysis do not seem to throw much light. It is evident that in the organism there is both a unifying influence and a differentiating influence.

Much of the unity of the organism is plainly based on stereotyped physical conditions. The whole organismic "field" corresponds closely (in the spatial sense) to the volume occupied by the complex of nuclei, i.e., the genes. The gene system thus appears as the all-pervasive factor of stability; its presence confines the course of the organismic synthesis within definite bounds. Apparently, the reason why the genes are distributed in multiple groups (nuclei) is because physical conditions limit the direct influence of a single group to a small volume; hence the united influence of many similar groups is required to create a constant field character permeating the whole organism. Throughout the organism the stabilizing influence of physical conditions is everywhere apparent; evidently, for any ordered differentiation such as we find in the organism a foundation of stability comprehending the whole system is required. The structural and physiological characters of the adult are built up gradually in development; each stage, as it is reached, is temporarily stabilized by the formation of definite structure. This structure represents the physical foundation required to insure the constancy of the next step; and by such successive steps the constructive process continues until the adult stage is reached.

At any time and place there is a definite physical set of factors within which the other biological factors can act in a dependable manner. This dependence of local development (i.e., of special parts and organs) on local physical conditions is an intimate one, and experimental alteration of these conditions (by excision or displacement of parts, chemical influence, transplantation, etc.) produces correspondingly constant changes in development. Hence to the experimenter development may have the appearance of being nothing but a complex physical cycle, which, like other physical processes, is altered in a definite manner by physical interference.

Differentiation, however, while requiring this basis of physical conditions, appears to have its ultimate origin in conditions where psychical factors also play a fundamental part. What constitutes the real biological problem is not the mere physical regularity of the organism, but rather the tendency toward novelty, synthesis and higher organization, as seen both in individual development and in evolution. According to our present interpretation, this diversifying tendency is the expression of a directive and integrative factor which is psychical in its essential nature, although acting within or through the physical. This psychical factor offsets the physical tendency toward uniformity and dissipation; and under its directive influence, essentially teleological, the routine physicochemical processes are guided and co-ordinated in such a way as to build up and maintain the special biological organization—which in the purely physical sense is so completely "improbable."

It is clear that within the organismic field there are diversifying influences at work which are directive and vary in different spatial regions, at the same time as a unifying control is maintained over the whole; in these general respects the conditions are similar to those present in any other orderly and complex synthetic process, such as the construction of a building or the composition of a work of art. In all such cases the components are placed in position through a combination of physical and directive factors. An essential requirement is that the elements should hold together at every stage so as to produce a physical concretion having the character of stability, at least temporarily, i.e., for a time sufficient to insure the constancy of the next step. Further additions can then be made, and by such steps steady progress is made until the final stage is reached. Many structures laid down in such a synthetic process may be temporary or of a "scaffolding" nature; such conditions are frequent in living organisms and may be even elaborate, as seen in the amnion and allantois of mammalian development. In the organism what is essential is that the regularizing physical and the directive psychical should maintain effective co-ordination throughout the whole ontogenetic process, as well as later in adult life.

Why is it so difficult to demonstrate scientifically the presence of such directive factors? And why are so many biologists frankly skeptical regarding their existence? Throughout our discussion we have ascribed to these factors a psychical or quasi-psychical quality. As psychical, their action is in the present; something interferes with, or is added to, the simple probability conditions which determine the purely physical course of events, and this something has a selective or preferential, as contrasted with a random, character. Just what it selects is determined by the internal factor, called by Whitehead "subjective aim," which is of the same essential nature as the purpose of higher animals and man. As subjective, this is not open to external observation, and here is where the chief difficulty lies. All the externally demonstrable conditions and processes in the organism are physical (physicochemical) or physically conditioned; they exhibit the same precision, causal dependence, and regularity as other physical processes. The functional intricacy of the organism is based on a corresponding physical intricacy; indeed, to many biologists the physicochemical processes of the organism appear quite sufficient to account for even its most complex activities, including the psychical. Such men are likely to believe that with the advance of science all vital activities will be "explained" in terms of physics and chemistry.

Undoubtedly, the realistic approach to the problems of the living organism has this "materialistic" side; but, if entirely realistic, it is not materialistic alone. The dilemma is in large part resolved when we remember that the teleological guidance of a physical sequence requires only an occasional directive intervention; there is no need of a continually active psychical influence which is at variance with the laws of physics. In the physical structure of the organism we find ample evidence that the directive control is frequently, if not always, localized in spatially minute regions, where it acts intermittently and from which it spreads to larger areas; the activity of the nervous system is a familiar instance of this; and many other critical forms of physiological control are local and intermittent in their action. The fundamental nucleated structure of the organism appears itself to illustrate this condition. We may assume that the directive intervention which guides and integrates the organic processes is applied, when needed, at these scattered focal areas. In this way the varied physicochemical activities are given a unity and a direction which otherwise they would not have, and it becomes possible for them (acting as efficient causes) to carry out constructive or other processes having almost any degree of complexity.

The general biological evidence indicates that the fundamental integrative influence in cellular organisms is exerted chiefly, if not exclusively, through the nuclei. These constitute a relatively small part of the total living material; but their chemical and structural complexity is great, and this complexity of structure implies that they are the seat of correspondingly complex activity. One might picture the directive psychical influence as playing upon this structure very much as a musician plays upon his instrument. The amino-acid residues in the protein structure have graded properties which may be compared with the gradation of the notes. The possibilities of varied activity based upon the combinations of such units are unlimited; and on such a conception the association of life with protein structure becomes easier to understand. At present little may be gained by speculating on the possible biological significance of the special chemical configuration of nucleic acid, that remarkable substance which is universal in cell-nuclei and other proliferative forms of living matter, including bacteria and viruses. Apparently, this compound has some intimate relation to the synthesis of other protoplasmic compounds, especially proteins. In conformity with our psychophysical conception we may assume that the directive influence of the general organismic field asserts itself at certain points in the nuclear structure as required, and that the regular physicochemical factors always present complete the biological process through their automatic activity. Similarly, in carrying out an organic synthesis in the laboratory, the chemist makes certain adjustments in his apparatus and reagents and leaves the rest to nature, with the assurance, based on repeated experience, that events will turn out as he expects.

I am not prepared to offer any more concrete suggestions regarding the nature of the general organismic field influence—*et hypotheses non fingo.* All that can be said, on the evidence, is that it is a unifying principle and that it pervades all parts of the organism while the latter remains alive. It is a principle of coherence, of harmonious activity—apparently four-dimensional. Applying such a term as "field," "psyche," "vital principle," "anima," or "entelechy" is merely giving a general name to a natural condition which apparently exists in every living organism. What the existence of this condition means in an ultimate sense is a metaphysical question. The properties of living organisms (including man) are in part general, in part individual. Our chief hope of attaining adequate biological conceptions lies in the extension of valid knowledge and insight, but in this enterprise no aspect of the organism should be overlooked. It should never be forgotten that the living organism is both physical and psychical, the two aspects being grounded in a unity.

In conclusion, some brief reflections on the relations of the biological philosophy of organism to human life seem relevant. While the possibilities of science are unlimited, it should by now be obvious that mere knowledge, scientific or other, is not sufficient to insure the good life. Creative activity, directed toward worthy aims—ideal and practical—is even more important. The world is suffering from maladjustment, and to the biologist maladjustment in a conscious organism is equivalent to unrealism in outlook and response. In nature no system can maintain itself or expand its existence if it is out of conformity with its environment, i.e., with reality as its exists and acts outside the system itself. Realism and sound morality must be regarded as synonymous.[9] "Environment" means nature in general; but what nature is in *all* its reality is a question that goes beyond science. At least we may be sure that, if the human race persistently flouts this reality, the consequences cannot fail to be disastrous. George Meredith's great philosophical poem, "Earth and Man," begins:

[9] A thesis that might be expanded without limit in its implications for civilization.

On her great venture, Man,
Earth gazes while her fingers dint the breast . . . . .

The biologist may also at times doubt the capacity of the human race for survival. Yet Meredith's final judgment is hopeful, even optimistic.

When science offers recommendations to humanity, these should be forward-looking, temperate, and critical—at once imaginative and realistic. Man is a product of nature and lives immersed in nature. But science cannot foresee in detail the course of natural creative action. Nature, as it exists in the present, offers to our observation a highly diversified array of stable (hence scientifically definable) conditions, systems, and processes. Present nature must be regarded as similar in essential respects to nature as it is (or has been) in the past—at least during the period covered by organic evolution. The natural creativity, building on stable foundations, laid historically or otherwise, has achieved its results by slow degrees; and, if we may judge from the outcome, many of its activities give evidence of being tentative, experimental, and at times mistaken.

Nevertheless, much of the outcome has a value which justifies optimism for the future. Here science may take encouragement from a position well known in philosophy; a property of the *good* (in the universal or Platonic sense) is that conscious effort tends to be directed toward its continuance, since it is the object of desire; while *evil*, the immediately or ultimately painful, is a feature of reality which conscious effort tends to remove or overcome. The former has thus within itself a property or character which favors its continuance and increase; the latter is inherently unstable.

Scientific analysis shows that stability in all highly diversified or composite systems requires harmonious relations—relations of mutual support or equilibrium—between the different components and activities. But every natural system, if it is highly individualized, acts automatically to preserve its own status and condition; hence conflicts of interest inevitably arise between different individuals when they come into contact. Each individual, if it acts solely in its character as isolated and self-centered, tries to secure stability and advancement at the expense of the others. Nevertheless, what we call "beauty" —harmony of parts, harmonious interplay of processes, as seen in living organisms or in arts like music— is widespread in nature, although it fails to be realized, or is destroyed, when the individual interests (or what seem to be such) come into irreconcilable conflict. This is by now sufficiently evident; but what should be better known and more widely acted upon is that integration *between* different individuals, as seen in the mutually helpful relations of the various units in many human and animal communities—or even between different species of animals and plants— is as much a factor in biological survival and evolution as is conflict.[10] The avoidance of useless conflict, and the subordination of individual interests to the interest of the whole reality which includes the individuals, would thus seem to be rational aims for all conscious beings; and these aims have the further sanction of religion when the whole is conceived in its character as ultimate value or deity

[10] This was fully recognized by Darwin and has recently been emphasized by W. C. Allee in his vice-presidential address before the American Society of Zoölogists: "Where Angels Fear To Tread" (*Science*, XCVII [1943], 517). See also Whitehead's discussion in *Science and the Modern World*, pp. 288–90. He remarks elsewhere in the same book: "Romantic ruthlessness is no nearer to real politics than is romantic self-abnegation."

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