

Masses and electric charges, atoms and molecules, are statically systematic; their performance is not a function of their age; there is not a different law of gravitation for each succeeding century. In contrast, organic, psychic, and intellectual development involves a succession of stages; and in that succession the previously impossible becomes possible and the previously awkward and difficult becomes a ready routine. Insight

INSIGHT AND THE STRATEGY OF BIOLOGY

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“What we have to do is not to regard ourselves as being outside the system of things we are studying, but to take as our material for study the system of ourselves studying things. We have to find conceptual models of our logical processes, and test the hypotheses that these lead to against the observable features of our mental activity.”¹

The moving force in contemporary biological investigation is essentially a cluster of questions centered on the genetic material. What is its nature? How does it act in determining the course of specific development? How do its nature, action and mutation account for the spatio-temporal distribution of organisms? Progress towards the solution of such problems depends on the refined techniques of protein chemistry, on the power of the electron microscope, on elaborate breeding experiments. But, rather obviously, it depends too on the intelligence which grasps what questions can be tackled immediately, how technological advances can be exploited, what experimental set-up will test a plausible hypothesis or be the source of a better one. It is intelligence which appreciates the possibilities for biological research of radio-isotopes. It is intelligence which correlates a particular diffraction pattern with a possible chromosome structure. It is intelligence which weighs the evidence for the correlation of the survival rates of varieties of the British Peppered Moth with

1. J. W. S. Pringle, *The Two Biologies* (Oxford, 1963), p. 25.

industrialization. However, that the obvious role of intelligence in such matters should become the center of attention in a discussion of biology may at first sight appear neither profitable nor even possible. While questions of profit and possibility may be decided on performance, some preliminary remarks on possibility will throw light on what follows.

Each of us has his own experience of the activities of intelligence, of looking for clues, of catching on, of weighing up the pros and cons. Some have had the experience within the field of biology, but all are capable of extending their experience into that field. Such experience of biology can be the starting point of a science, for science is man's response to wonder about his experience. Admittedly a science having as subject matter the experience of doing biology will have its peculiarities. Still, it will be found to follow the essential cycle of scientific inquiry. Just as the biologist seeks to understand growth by examining, not one, but many and varied instances of it, so the metabiologist — it we might so call him — seeks to understand the development of biology in himself by adverting to his experience of a range of biological insights. Just as the biologist must carry his investigation into the lower sciences to get beyond descriptive or even anthropomorphic notions, so the metabiologist must have recourse to instances of insight in mathematics and physics to deliver himself from vague and even mythic notions.² Just as the biologist is satisfied with his theory only when it stands the test of crucial experiment, so the metabiologist is satisfied only when his theory squares with the experience from which it took its origin. And so on. Briefly, metabiology, like biology, moves from data through insight and formulation to a third level of verification, but the data of metabiology includes all three levels of biological inquiry.³ In contrast with biology, the mode of understanding of metabiology is not direct, but indirect, or introspective. By introspection is meant, however, not some strange process of looking into oneself, but rather a shifting of attention.⁴ Both biologist and metabiologist engage in doing biology, but while the biologist's attention centers on the content, the metabiologist's attention centers on the activity — for his goal is not merely biological understanding, but an understanding of biological understanding.

It is clear that one cannot reach metabiology without biology, and so I will try here to engage the reader in elementary biological insights. Obviously, however, such elementary instances are no more adequate for metabiology than some random observations are for biology. Ideally, the reader should be led through a sequence of biological insights of growing complexity so that he would actively appreciate the need for, and nature of, the various complemen-

2. Cf. Bernard Lonergan, *Insight. A Study of Human Understanding* (London, 1957), pp. xx-xxi. Comparison of our initial example, the amoeba, with Father Lonergan's geometric example, the circle (pp. 7-13), will show how the mathematical example scores in precision. In *Insight* Father Lonergan wisely postpones a discussion of the particular method of biology until ch. XV. The apparent folly of the present treatment has, however, other advantages.

3. Cf. *Insight*, pp. 272-74; *De constitutione Christi ontologica et psychologica* (Rome, 1956), pp. 92-95. References, when no author is named, are to works of Lonergan.

4. *Insight*, pp. 320-21; *De constitutione Christi*, p. 87; *De Verbo Incarnato* (Rome, 1961), p. 276.

tary types of investigation which belong to biological method. In so short an essay, however, he can only be led to vaguely appreciate how the present view meets the facts in plausible fashion. Undoubtedly discussion might have been restricted to one particular problem. Still, a general survey seemed in place, not only because it best reveals the relevance of Father Lonergan's work, but also because it may lead some competent biologist to attempt the more extensive treatment clearly called for.

Paradoxically, however, the reader who is also a biologist may well be handicapped here, at least initially, by the temptation to assert that he knows quite well what biological understanding is. Perhaps he may best counter the temptation by recalling that non-biologists, even philosophers, at times call his own science in question by their claim that they know quite well what a dog or a daisy is.

Again, the reader may have his own views on the nature of biology. I would ask only that he check the present view, not against that theoretical account, but against his experience of doing biology.

Finally, there are questions concerning reality, objectivity, etc., to which answers might well be expected. These questions are, however, laid aside here. The present task is restricted to trying to understand correctly what is going on when one is knowing biology. Perhaps we might say that, unlike the prisoners in the *Republic*, our problem is, not to come forth from the cave, but to advert to what is in it.

Let us now turn from theory to practice. We join the scientist at his microscope. Within the field we distinguish a small blob. Careful observation reveals to us that it remains together, that it moves slowly about, that small particles in the surroundings are able to get into it and eventually pass through it. Our growing curiosity about the blob and its peculiarities may lead us soon to ask the question, Is it alive? where life means nothing more than an obscure correlation with the class of animals and plants. Perhaps indeed, if we are chemists, we will be slower to raise this question, for we are aware of the odd properties of drops of chloroform or of alcohol-injected clove oil. But eventually the question will be seriously entertained, and we move into the circle of empirical inquiry. For convenience we give the data a name: let us call it *Chaos*.⁵ The obscure correlation of life is an hypothesis to be tested. Relevant tests quickly suggest themselves and are carried out. We find, for example, that only one part can be properly said to survive dissection. Again, further observation reveals that *Chaos* divides into two of its kind. And so on, until we grasp that we have sufficient evidence to conclude that it is alive. But this is only a beginning, a process of generic classification which no more than determines the relevant investigator. It is for the biologist to raise the significant question, What is *Chaos*? Why is *Chaos* alive?⁶ in more methodical fashion.

5. More properly *Chaos Chaos*, the Linnean classification of, most probably, *Proteus Amoeba*.

6. For a discussion of the meaning of these questions in an Aristotelian context, cf. "The Concept of *Verbum* in the Writings of St. Thomas Aquinas," *Theological Studies* 7 (1946) 359-64; *Divinarum personarum conceptio analogica* (Rome, 1957), pp. 260-66.

At this stage no one will doubt but that our questions are raised regarding sensible data.⁷ To answer such questions one may well have to have recourse to images as well as data, but without the data or the images there is no understanding, and this no matter how far into abstract theory one has advanced.⁸ Like much else that we treat of here, this is a question for personal reflection, the answer to which might well echo Waddington's remark regarding his own model of the developing system: "Although the epigenetic landscape only provides a rough and ready picture of the developing embryo, and cannot be interpreted rigourously, it has certain merits for those who, like myself, find it comforting to have some mental picture, however vague, for what they are trying to think about."⁹

It is not, however, what he imagines, but what he sees, experiences, either directly or through instruments, that the biologist wishes to understand. He values only those insights that are verified, or at least have sensible consequences for which he can look. Thus, if he seeks to understand amoeboid motion he finds no place for the hypothesis of a *vis vitalis*, but he is willing to consider an hypothesis involving protein foldings, or diffusion forces. The search for these sensible consequences may well require the finest of microscopic and biochemical techniques, and perhaps wonder might fade into frustration were it not that besides pure science there is also applied science to foster research and to foot the bill.

At all events, the biologist is not allowed to fall short of the goal of his science, which is one of complete explanation. He cannot remain satisfied with description on any level. The goal of complete explanation requires that one take the clear step from description, which relates the data to us, to correlations verified in the data. Explanation, then, is not merely refined description: between it and description there is a clear discontinuity.¹⁰ One can see a spectrum, or register a diffraction pattern, but what is verified scientifically is a set of equations. Again, in our present example, the contractile vacuole may be described as a clear globule which grows within *Chaos* and gradually finds its way out. Then through a variety of experiments involving, say, changes in the medium, and by appealing to theories of osmosis, etc., we would gradually move towards an explanation, through a sequence of systematic correlations, of the varying geometry, physics and chemistry of the vacuole. But the vacuole process is also grasped as playing some obscure role in the life of the organism, and here too the transition from description to

7. The comments on this example are representative of the first five canons of empirical method, *Insight*, ch. III; the canon of statistical residues will be touched on later.

8. The image may be formal, virtual, or merely symbolic. Cf. "A Note on Geometric Possibility," *The Modern Schoolman* 27 (1949-50) 135; *Insight*, Index under 'Image'; "The Concept of *Verbum*," *Theol. Stud.* 7 (1946) 372-79; *De constitutione Christi*, p. 80.

9. C. H. Waddington, *The Strategy of the Genes* (London, 1957), p. 30. Waddington goes on to consider the heuristic value of the model. It is perhaps worth noting that the stress on the heuristic role of images in *Insight* is not in contradiction to M. Beckner's insistence on explanatory models (*The Biological Way of Thought*, New York, 1959, ch. 3); it is mainly a difference in terminology: we would prefer to consider explanatory models as abstract systems.

10. *Insight*, Index under 'Description'; *Divinarum personarum*, pp. 288-91.

explanation must occur. By means of the lower level correlations the biologist must move towards an understanding of the role of the process in the life-pattern of *Chaos*, and explanation on this level requires that one grasp the total process not only as correlated with other functions within the animal but as related to similar processes in a range of animals.

This description of biological investigation runs counter to a currently popular view which in fact stresses, not the sequence of insights involved, but the corresponding images.¹¹ This view gives the impression that if we had better equipment, small enough eyes, or big enough amoebae, we would be able to have a good look at the structure of chromosomes and the sequence of amino-acids; indeed, even to read off the genetic code in some mysterious way. Modern physics should help in driving out such illusions: no more than the atom is the gene a complex of small balls.¹² While the error may suffer exposure on the micro-level, it has its origin, so to speak, on the macro-level. Thus, when studying the heart, the anatomist "studies it chiefly as a visual object and owing to our preference for visual experience and our persistent naïve realism it is extremely easy to fall into the error of thinking of the visual heart as the very concrete heart itself."¹³ If indeed one can see the real heart, then one can see its parts, and the parts of its parts. Clearly, a better strategy would be to meet the error on a wider front. Since, however, that would demand another essay,¹⁴ we content ourselves here with calling attention to the alternative, a verified insight into data. Thus, at an earlier stage we raised the question, Is it alive? with regard to the blob called *Chaos*: implicitly we were asking, Is it a thing? Now to ask is, obviously, to admit that we do not know: but we had been led to conceive *Chaos* as a thing, and we eventually satisfy ourselves that it is, not by taking another look, but by experimental verification.

Finally, we may ask in general what type of explanation is reached. We have described it as an explanation to be had from the immediate data of sense, and to be expressed by a complex of verified correlations. Just as the first obscure correlation contained in the question, Is it alive? was a grasp of possibility based on the data, an hypothesis to be verified, so will any of the correlations be. If verified, they form part of the slow scientific transition from the obscure notion 'the nature of *Chaos*' to the still unknown goal of a definition of *Chaos*. If we here associate the Aristotelian form with that goal, we must insist that it denotes precisely a goal, what is to be known by scientific insight. It does not denote some deeper reality in the amoeba which philosophers alone can intuit.¹⁵

Our next example takes us, so to speak, into the fields. We raise the question, What is a buttercup? A first step towards an answer is to replace everyday description by scientific description.¹⁶ Spontaneously we expect a difference of

11. *Insight*, pp. 439–40; 480–81.

12. Biology indeed has already taken the road of modern physics. For a recent discussion of the nature of the gene, cf. Richard B. Goldschmidt, *Theoretical Genetics* (University of California, 1955), Part I.

13. J. H. Woodger, *Biological Principles* (London, 1948), p. 328.

14. Cf. *Insight* on the "already-out-there-now-real" and related notions.

15. *Ibid.*, pp. 269, 415, 432, 498.

16. *Ibid.*, pp. 37, 63–64.

insight when data are significantly different, and so sensible differences give rise to preliminary classification. Thus, variation in sepals, flower stalk, etc., leads us to group buttercups into three types. These in turn are related to a larger group of similar plants to form the genus *Ranunculus*. The genus in its turns finds its place within a general classification of plants. Now while this classification is based on more than sensible similarity, nevertheless the clear transition from descriptive to explanatory classification requires the implementation of such a basis of classification as is provided by an evolutionary theory.¹⁷ We postpone for the present a discussion of the nature of such an evolutionary hypothesis, but its role in biology as a principle of explanation is worth emphasizing at this stage. One might compare the significance for biology of Darwin's insight with that of Mendeleef's formulation of the periodic law for chemistry. Just as the periodic table correlates the chemical elements and, less proximately, chemical compounds, so an evolutionary hypothesis makes possible the correlation of cell-types, organs and organisms. It is not then a kind of after-thought to biological investigation, as if one might first achieve complete understanding of various organisms and later correlate them evolutionarily. It is, on the contrary, what properly constitutes biology as an explanatory science. It is within the context of this methodological hypothesis that the explanation of a given organism must fall, and the hypothesis, far from being the source of obscure generalizations, increases rather the demand for that transition from description to explanation already repeatedly emphasized.

Let us return to the buttercup. Here observation soon gives place to dissection and controlled experiment. In this way a description of parts and of the role they play in the plant is reached, and the way is prepared for more detailed and particular investigations.¹⁸ With this stage is associated one of the great classics of empirical inquiry — the long series of experiments and the sequence of insights involved in determining the role of leaves in the plant. Such a determination is, however, only a beginning. One must push on into physical and chemical experiment and theory in search of an explanatory account of the complex of energy exchanges and chemical cycles involved, and of the interplay of photosynthesis with various other cyclic processes in the plant. Explanation is sought at all levels even though it require large groups of experimenters, a large range of experiments, and incursions into the rarified regions of cybernetics, quantum physics, and the thermodynamics of open systems.

In the course of such investigations one finds that probability theory is regularly called upon to complement what we may call the classical method of empirical science, and its use gives rise to an acknowledged statistical method of investigation. Here let us restrict ourselves to a simple example involving the three species of buttercup.

Briefly, it is found that the distribution of the three species on ridge and furrow grassland is such that one species betrays a clear preference for the

17. *Ibid.*, p. 78.

18. *Ibid.*, pp. 463–67. The very fact that our discussion of the amoeba and the plant involves essential simplifications can be a help towards understanding not merely biological method but even the structure of the book, *Insight*.

ridges, the second is concentrated in the furrows, and the third occupies the intermediate zone. Now while such separation into distinct microhabitats is suggestive in many different ways, one clear suspicion that it gives rise to is that there is a correlation between species-habitat and water table. A series of experiments with potted flowers and controlled water tables serves to justify the suspicion.

Even in this simple example several general characteristics of statistical investigation can be detected.¹⁹ In the first place, knowledge of the distribution does not immediately add to knowledge of the particular types of the plant. Rather, use is made in the definition of the distribution of the classification which was already to hand, and the knowledge which it gives is knowledge of the occurrence of these types. Again, if there had been no previous clue regarding habitat preference, the statistical enquirer would have expected a uniform distribution for all three species, but he would not have shown surprise at some departure from uniformity, for he knows that uniform distribution is an ideal from which, in the concrete, random departures are to be expected. Still, the departure in the present case is in fact significant — the statistician has his own way of judging what is random and what is significant — and such significant departure gives rise to further classical investigation concerning the species and their environment.

Presently we will touch on more complex aspects of the interplay of classical and statistical inquiry. Before doing so, however, we must turn our attention to a rather obvious question concerning the plant: How does it grow? More properly, we are asking about the understanding of the development of the plant, and, in an essay such as this, one cannot but raise the fundamental question, What is development? As Paul Weiss remarks at the beginning of his book ²⁰, this question seems trivial. “Does not everybody have some notion of what development implies? Undoubtedly most of us have. But when it comes to formulating these notions they usually turn out to be very vague.” Weiss himself seeks to get beyond this vagueness, beyond, too, the type of explanation which “cannot survive the first rigid test on a concrete phenomenon of development,” ²¹ by staying as close as possible in his considerations to specific phenomena. Thus, while he sees progressive differentiation as the keynote of development, detailed illustrated discussion of differentiation leaves no room for an accusation of a mere shift of obscurity. Again, the hierarchy of organizations of the organism has to be explained, first by decomposing the complex phenomenon into simple processes of biological order, then further by attempting “to trace the roots of biological process into the known realms of physical and chemical phenomena,” ²² the ultimate aim being “to describe and understand any state of the living system as conditioned by the immediately preceding states.” ²³

Weiss' book represents rather the earlier stage, that of discussing processes

19. *Insight*, pp. 63–66; 106–112.

20. *Principles of Development* (New York, 1939).

21. *Ibid.*, p. 75.

22. *Ibid.*, p. 108.

23. *Ibid.*, 120.

of a biological order. Associated with the second stage, where the stress is on physics and chemistry, are the much popularized recent advances in molecular biology. We will refer to the third stage later.

The study of development on the level described by Weiss depends to a great extent on the contrast of normal and abnormal, and this calls for experimental techniques of isolation, tissue culture, mutilation, transplantation, etc. Results vary from organism to organism; so, for example, while defect experiments in some mollusks would seem to favor a mosaic theory of development with an early specification of part function,²⁴ similar experiments on sea-urchin eggs betray quite startling developmental flexibility.²⁵ Hence the need for, and advantage of, experiments over a wide range of organisms and over the sequence of states of any given organism. Rates of development of different organs and different organisms are thus compared, the multiplicity and heterogeneity of determinative factors revealed, and the relationships of the gradients, energies and patterns of the particular fields of these factors investigated.²⁶ And so on. In such a way one gradually reaches verified specifications of the general principle of progressive determination.

I have referred in this fashion to Weiss' work not merely to pave the way for Lonergan's treatment of development but also because the elementary device of page references serves to draw attention to the range of phenomena and the length of investigation involved in generating some insight into development. This in turn reminds us of the nature of the task we are outlining here. It is by reproducing in ourselves the insights of the biologist that we hope to reach an understanding of his method, and we try to reproduce these insights with the stress, not on content, but on our activity. It is only in this way that we can hope to come to an understanding of how we go about understanding development, or in other words, that we can hope to reach a heuristic definition of development. One may indeed read and remember the conclusions of an author concerning development, but unless one also reproduces in oneself his insights, then one has merely replaced the common and vague notion of development by the memory of someone else's definition.

In discussing the manner in which micromeres transplanted into the isolated animal half of the sea-urchin egg give rise to a practically normal individual, Weiss remarks on the possible misconception of the micromere action as deliberative, purposive.²⁷ As he says, even competent biologists in the past have considered regulation in this anthropomorphic way. Now while the question of purpose is no longer of serious debate, there still remains a more general question which seems by no means settled — the question of the relevance of final causes to biological investigation. Since clarity in this matter is essential to the proper understanding of development we will digress here to deal with it. This digression leads to another and more important digression concerning a general basis of explanation not unrelated to evolution theory. Only then will we have a sufficient background for a methodological analysis of development.

24. *Ibid.*, pp. 237–46.

25. *Ibid.*, pp. 269–88.

26. *Ibid.*, pp. 289–435.

27. *Ibid.*, p. 274.

We concluded earlier that the type of explanation sought by the biologist was an intelligibility immanent in the data, and we related that intelligibility to the Aristotelian formal cause. In the case of the life history of the organism the data is extremely complex, but the general features of its understanding should by now be sufficiently apparent. The biologist's quest here takes the form of an investigation of development, and his basic verification is of the organism as a particular type of dynamic system, one in which movement is normally in the direction of greater specification. Now this empirically verified directed dynamism is in fact a clear instance of finality, where finality is taken in the well-defined sense of *Insight*.²⁸ But finality in this sense is clearly distinguishable from final causality. What specifies final causality is the good as cause: for final causality to be present, not only must a process be orientated to a term, but it must be so orientated because the term is good.²⁹ On the other hand, finality can be affirmed without reference to the term as good, even without reference to the term as determined — for the affirmation of finality is an affirmation of an indeterminately directed dynamism. Final causes belong to a range of further questions with which the empirical investigator is not concerned;³⁰ finality, on the contrary, denotes an intelligibility immanent in data, which is precisely the empirical investigator's concern, and the causality to which it pertains is formal.

Clearly enough, however, the verified directed dynamism of biological inquiry lends itself to distortion. Because of the nature of his subject, the biologist's understanding can take a proleptic form in which his grasp of the structure of a particular stage of development is associated with a grasp of the future stages or of the possible term of such development.³¹ But such understanding can be unscientifically projected, and then, for example, the foetal eye becomes a structure with an aim and an ambition. Still, even if one adheres to verification as opposed to extroversion, one uncovers here genuine difficulties of a related type regarding biological processes. Thus we have the puzzle of what Bertalanffy³² calls static teleology, where an arrangement seems to be useful for a certain purpose. Again, there is the dynamic teleology of directedness of process such as appears in the complex balanced feedback mechanisms of the organism. Speaking of the explanation of these Bertalanffy remarks: "Fitness in organic structures can probably be explained by the causal play of random mutations and natural selection. This explanation is, however, much less plausible for the origin of the very complicated organic mechanisms

28. *Insight*, pp. 444–51.

29. Cf. "Finality, Love, Marriage," *Theol. Stud.* 4 (1943) 478–83; also a book review, *ibid.* 7 (1946) 607–608; and "The Concept of *Verbum*," *ibid.*, 10 (1949) 378, n. 89.

30. *Insight*, pp. 33, 76, 128.

31. While Aristotle does not provide an analysis of development, the above point is made by him. Cf. *Physics*, Bk. II, and St. Thomas' commentary. Relevant to the avoidance of the projection mentioned immediately in the text above is the distinction: "finis est principium, non quidem actionis sed ratiocinationis, quia a fine incipimus ratiocinari de iis quae sunt ad finem" (*In II Phys.*, lect. 15. n. 5).

32. *British Journal for the Philosophy of Science*, 1950: "An Outline of General System Theory," p. 159.

and feed-back systems.”³³ In considering these difficulties now we hope to show the general structure of the explanation at which Bertalanffy hints.

First, we may recall Aristotle’s position on such matters. Unlike modern biologists, he saw no hope of an explanation through chance: for him it was either purpose or necessity, and he opted for purpose. His statement of the position he rejects has a modern ring about it and may lead the reader to reflect on the nature of the lacuna to be filled: “If a man’s crop is spoiled on the threshing-floor, the rain did not fall for the sake of this — in order that the crop might be spoiled — but that result just followed. Why then should it not be the same with the parts in nature, e.g., that our teeth should come up of *necessity* — the front teeth sharp, fitted for tearing, the molars broad and useful for grinding down the food — since they did not arise for this end, but it was merely a coincidental result; and so with all other parts in which we suppose that there is purpose? Wherever then all the parts came about just what they would have been if they had come to be for an end, such things survived, being organized spontaneously in a fitting way; whereas those which grew otherwise perished and continued to perish, as Empedocles says his ‘man-faced ox-progeny’ did.”³⁴

Now it would seem that we must indeed agree with Aristotle that chance explains nothing. But he appears here to reject a position to which we moderns find ourselves attracted. The relevant question is, What insight did Aristotle miss?

We have already considered the relevance of statistical method to biological inquiry. In Aristotle’s time there was no theory of probability to lead him to appreciate that relevance and so he developed his own way of handling nature and chance and of accounting for the order of the universe. Nowadays the explanatory power of statistical laws is a commonplace and, taken against the general background of scientific development, it puts us in a position to go clearly beyond the Aristotelian world view. Obviously a short article is not the place in which to undertake a presentation of the resulting position; instead we shall touch on some points relevant to its understanding and, as we shall see, to an understanding of the autonomy of biology.³⁵

Consider the general Newtonian equation for the path of a particle moving under a central force proportional to the inverse square of the separation distance. The equation is abstract: it represents a general conic in a Euclidean plane.³⁶ Furthermore, the equation is indeterminate.³⁷ If it is to apply to a particular orbit we must introduce initial conditions; if it is to apply to a real situation, then these initial conditions must be determined through insight into that situation.³⁸ Suppose that such insight yields two sets of initial conditions for two particles whose orbits are hyperbolae. Whether or not one is

33. *Ibid.*, p. 160.

34. *Physics*, II, 8, 198b, 21–34; Ross’s translation.

35. Cf. footnote 57 *infra* and the text following it.

36. *Insight*, pp. 86–90.

37. *Ibid.*, pp. 100–102; 491–94.

38. *Ibid.*, p. 46.

considering interaction, one does not expect the two sets to be related. More precisely, they are coincidental in the sense that, in the general case, while one can deduce either set once one knows the details of the particles' entries into their orbits, one does not expect to deduce them together, from a unified set of equations, systematically.³⁹ Indeed, in the concrete, far from coming together to make possible such a systematization, the prior conditions for these initial conditions diverge.⁴⁰ Somewhat similarly, in such a simple physical system as an ideal gas there is no question of the individual paths being beyond investigation. Nevertheless, the whole process is non-systematic, the events in it are a coincidental aggregate, and the physicist does not undertake a classical account of the motion. Yet he does provide a statistical account. And here one may reach the odd insight that lies behind statistical theory: one does not expect the elements of a coincidental aggregate to show systematic relations; one is suspicious if it is always heads and never tails.⁴¹

Next, let us consider the scheme of recurrence.⁴² Think of the orbits discussed above, where now they are ellipses. The first significant thing about the scheme of recurrence is its power to tame the coincidental aggregate by closing the diverging series of conditions. Again, the scheme is a means of combining various laws — one may think of the laws of physics and chemistry which fall within the dietary schemes of animals. Further, the scheme of recurrence is realised in the concrete according to probabilities — a significant decrease in velocity in a hyperbolic orbit can be excluded only by such a proviso as “other things being equal.” Moreover, the probability of a scheme can depend on the existence of a prior scheme, and its actual functioning can be linked with that of another scheme. One may think of such examples as the dietary scheme of herbiferous animals or the complex of schemes associated with photosynthesis. Next must be noted that things occur within schemes and so the probability of emergence of things is related to the probability of emergence of their including schemes.⁴³ Already we have noted that coincidental aggregates are not expected to behave systematically. Still, probability theory allows for the mere appearance of system where in fact there is none: so, for example, a coincidental aggregate of chemicals could go through the process called cell-division without violating the laws of chemistry. Now, loosely speaking, a thing is defined by its explained properties. These properties may be considered as systematizations of coincidental aggregates of the properties of lower things. Since the non-systematic occurrence of such aggregates of processes is within the bounds of probability, one might plausibly postulate the guarantee of regular recurrence by the emergence of the properties of higher things.

In such a manner one may come towards the notion of a conditioned series of schemes and things which underlies the definitions of emergent probability⁴⁴ and the sequential postulate.⁴⁵ At any rate our remarks are probably sufficient

39. *Ibid.*, pp. 48–50.

40. *Ibid.*, pp. 93–96.

41. *Ibid.*, pp. 54, 61–62.

42. *Ibid.*, pp. 117 ff.

43. *Ibid.*, pp. 259 ff.

44. *Ibid.*, pp. 121–28.

45. *Ibid.*, p. 260.

to make clear the distinction between Father Lonergan's view and that of Darwin or of his successors.⁴⁶ Darwin's objective, indeed, would seem to have been the same: he sought an intelligibility immanent in data, an explanation of the distribution of species, of their emergence and survival. Such an explanation inevitably leans on probability and so, while more than one biologist has criticized the expression "natural selection of chance variations," one has only to explicitate that dependence on probability to reveal the significance of the insight. Natural selection becomes an instance of probability of survival; chance variation an instance of probability of emergence.⁴⁷

The present view, however, differs from Darwinism on two main points. First, it shifts the emphasis from species to schemes of recurrence in which plant or animal may be a component.⁴⁸ Secondly it regards a species, not as an accumulated aggregate of variations, nor as defined by some microscopic complex, but as an intelligible solution to the problem of living in a given environment.⁴⁹ At first sight, no doubt, criteria involving macro- or micro-variations or components may seem much more scientific. But it must be remembered that the solution in question requires insight into a hierarchy of aggregates and a range of previous solutions. Furthermore, not only does the heuristic notion of species of *Insight* provide an integration of microinvestigation and interbreeding criteria, but it also extends beyond biology, falling as it does within a full account of genera and species which has no rival.⁵⁰

The foregoing discussion of development as treated by Weiss, of finality, of emergent probability and the associated world-view, has perhaps already led the reader to anticipate the lines of a more basic treatment of development.⁵¹ That basic treatment rests on an understanding of how probability theory allows for the emergence of the systematic from the non-systematic. Development considered from this point of view is seen to be a sequence of transitions in which posterior states are systematizations of previous states. In earlier examples, like that of *Chaos*, we treated the organism and its properties as an integration of physico-chemical cycles and events. Such a treatment should now be viewed as a simplification convenient for that stage of our investigation. At this stage it can be more meaningfully pointed out that *Chaos*, or the buttercup, is not one but a sequence of systematizations. This sequence of integrations, as previous illustrations show, is orderly but flexible. Each integration is related to preceding ones as higher to lower, for each integration manifests an increase in specification, in capacity for environment control. This continuous transition is achieved because each integration is not only an integration but also an operator, where operator connotes such a systematization as makes way in positive fashion for its own replacement by a further integration.⁵² The

46. *Ibid.*, pp. 132-34.

47. Cf. "Finality, Love, Marriage," *Theol. Stud.* 4 (1943) 481. In footnote 16 Father Lonergan notes the affinity between modern statistical law and the *contingens ut in maiori parte*, between modern chance variation and the *contingens ut in minore parte*.

48. *Insight*, p. 134.

49. *Ibid.*, pp. 264-65.

50. *Ibid.*, pp. 254-67; 437-42.

51. *Ibid.*, pp. 451-58.

52. *Ibid.*, pp. 465-67.

sequence of integrations is dynamic, where the meaning of the term dynamic is that associated, not with mathematical physics, but with finality.

Through such considerations one may arrive at some appreciation of a methodological account of development. The importance of such an account lies in its heuristic nature: for the general notion of development thus attained implies a method for studying any particular development, a method which may conveniently be called genetic method. Just as classical method involves the specification of an indeterminate function, so genetic method calls for a specification of the heuristic notion of development. But it is to be noted that, unlike the determination of the unknown function or of the differential equation, the specification of the notion of development is not just a matter of precise measurement: precise measurement is necessary indeed, but its efficacy diminishes as one moves from science to higher science.⁵³

In general, genetic method leads one to seek an understanding of a linked sequence of integrations through specifying each integration as operator, as a source of transition to further integrations. This notion of specifying the operator may well puzzle the reader and lead him to ask, What, in the particular case of an organism, is this operator? But, like the much abused question, What is life? the question, What is the operator? can be answered in only two ways that are of scientific significance. Either the answer is an actual specification of the operator through a verified understanding of the data involved, or it is a heuristic consideration of the operator. The latter answer is to be expected from metabiology. The former answer can be reached only through the collaboration of a large number of specialists in very diverse fields of biological inquiry.⁵⁴

One may further appreciate the nature of genetic method by considering it as a source of sufficient distinction of biology from physics and chemistry.⁵⁵ Investigation of the periodic law, of gas laws, of laws for changes of state, etc., involve classical and statistical methods in various combinations. But the understanding of development calls forth this third scientific method. The correlations verified in adult organisms are clearly different from those verified at earlier stages. But they are related: the process leading from one set to the other is flexible yet regular. That regularity cannot be explained by classical method, for classical method does not deal with changes in classical laws. Nor, precisely because these changes are regular, can it be handled by statistical method. So the study of the organism involves us in a type of understanding that differs from those types with which, as physicists and chemists, we are familiar, and it gradually distinguishes itself as a scientific method.

It is worth noting, too, that the emergence of genetic method is itself an instance of development, the development of human intelligence, and so its study calls for a further application of genetic method. Advertence to this, indeed, is relevant to a fuller understanding of the first sentence of this essay: for the operator in the case of intellectual development is the relevant question.

53. *Ibid.*, p. 463.

54. For a survey of the complex data for which the answer must account, cf. R. B. Goldschmidt, *Theoretical Genetics*, Part III.

55. *Insight*, pp. 481–82; 458–63.

Unlike the development of the organism, however, the development of human understanding can display an odd perversity which can be handled scientifically only by the employment of a further, dialectic method.⁵⁶ And awareness of this accounts, to some extent, for the structural oddities of the present article.

Genetic method sufficiently distinguishes biology from physics and chemistry. Let us now move further to a consideration of the necessary condition for the autonomy of biology.⁵⁷ Briefly, this requires the existence of a set of laws, implicitly defining biological terms and relations, to which there is no logical transition from the laws of physics and chemistry. Perhaps we might best throw light on this by taking our start from the role of schemes of recurrence in the genesis of science. One may recall such a classic instance as the investigation of the orbit of Mars. Now, just as the data on the motion of Mars led Kepler to the mathematics of its orbit and, further, led Newton to the correlation which defined mass⁵⁸ and accounted for the scheme, so data on the schemes of recurrence which include, say, reproduction in protozoa, lead the biologist first to the physics and chemistry of each scheme and further to the correlations which define a particular capacity for dealing with environment, and account for the schemes. On the one hand there is a correlation of masses, on the other a correlation of protozoa. Just as it was not logic but insight that led Newton beyond Kepler's three spatio-temporal laws to a scientific definition of mass, so it is not logic but insight that leads the biologist beyond cellular chemistry to an evolutionary theory of reproduction.

Consider now the total range of schemes in which the correlates defining reproduction occur. Obviously these correlates vary appreciably as we move through the range from protozoa to primate. In amoebae, for instance, the same chemical aggregate is cell, organ and animal. On the other hand, the monkey, as we now consider it, is an aggregate of aggregates (organs) of aggregates (cells) of physico-chemical events. Each type of aggregate is, so to speak, the locus of verification of particular correlates relating it to the corresponding aggregates in other primates. These correlations lead to definitions of, for example, the aggregate named sperm cell, the aggregate of cells which make up the reproductive organ, the aggregate of organs of the specific plant or animal.⁵⁹ Aggregates of the latter type are the loci of verification of a unified set of physical, chemical, biological and descriptive correlates and, whatever the biologist's view on objectivity, he finds the synthetic construct, the biological thing, indispensable.⁶⁰

This way of considering biological investigation may seem somewhat strange. We, as it were, line up the plants and animals, cast a chemist's eye on them, and see in them only a coincidental sequence of four-dimensional aggregates. Yet there is in fact a verified systematization of these chemical aggregates which

56. *Ibid.*, pp. 253-54; 484-85.

57. *Ibid.*, pp. 205-206; 255-57; 439-40; 608.

58. *Ibid.*, pp. 80; 334-35; 437.

59. *Ibid.*, pp. 262-64. It is as well to note here what we have ignored throughout the article: that the study of animals calls into play the autonomous science of animal psychology. Cf. *Insight*, p. 265.

60. *Ibid.*, pp. 247-48; 435-36.

may be given the general title of evolution theory. The strangeness of this viewpoint resides most, perhaps, in its contrast with the historical development of biology which begins from a common sense acknowledgment of living things and their regularities and moves through preliminary classification to physical and chemical investigation, towards increasingly comprehensive biological systematization. The stranger viewpoint, however, succeeds in clearly opposing coincidental aggregates to their systematization through evolutionary correlations. This opposition serves to emphasize the connection between coincidental aggregates and the possibility of autonomous sciences. Too obviously, we have not attempted here to explain pedagogically or in detail the notion of coincidental aggregates or the manner in which their systematization occurs in a higher science.

Indeed, as the reader familiar with Father Lonergan's work will notice, the whole of the foregoing account has some of the characteristics and failings of a popular sketch. So, for example, while we touched on the notions of emergent probability and development, we came nowhere near precise definition, much less elaborate discussion. Again, we struggled along as best we could without introducing such notions as empirical residue, conjugate form, etc. We have already given reasons for attempting this type of survey. The survey, clearly, is no more the heuristic science than popular Relativity is Relativity theory. Furthermore, it is a survey of a science which is still in its infancy. The details of the reorientation of biological knowledge⁶¹ which it makes possible lie in the future. To the future also belongs its beneficial influence on text-book and technical journal. But obviously if its development and influence are to be assured, its significance and nature as science must be seriously acknowledged, and the task of understanding which it sets accordingly undertaken. If this article has succeeded in drawing attention to the science, to the general features of the task it involves, to the foundation given it by Father Lonergan, and to the central role of insight throughout, then it has fulfilled its purpose.

61. *Ibid.*, pp. 398–99.