The Metamorphoses of Philosophy III

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An Account of Cognitive Emergence in Philosophy and Science

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Consider what it means to prove something to someone. This is done by showing that a certain truth is already contained in some other, which he acknowledges, according to the laws of thought which he is also prepared to grant; yet in agreeing on this, they have thereby failed to realise that all demonstration is ultimately based on something utterly indemonstable in itself.

FICHTE

PREFATORY NOTE

This volume contains Book IV of our four-part enquiry into cognitive emergence.

It could be said of the modern era that began in the latter part of the 18th century, that it is characterised by an escalation of perceptual and cognitive emergence that is as unprecedented as worrisome in the history of mankind. Indeed philosophy has been been pushed to the limits of its relevance and virtually abandoned its participation in this project. This unwholesome development in the 'House of Intellect' has agitated many fine minds, for as hinted in the Introduction to Vol. I, it seems that the perceptual order is already overstretched by experimental features of worlds beneath and beyond experience, for which a word much bandied about, 'counter-intuitive', must serve as an wholly inadequate signpost, whereas the conceptual order, confronted with masses of unworkable data (cf. the four-colour conjecture), delegates the effort of deriving solutions to inference devices whose results are virtually impossible to verify.

We have not shirked the attempt in this volume, of evaluating many of the concept structures and paradigmata to which this criticism applies, using the torchlight of philosophy which results, not surprisingly, in interrogation of their coherence. But whether this effort is relevant and meaningful, or a misguided striving to fashion a *philosophy* of science rather than a science of science, we must leave to the reader's discretion.

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Direct quotes from the philosophers have been set in italics and indented from the main text. Other quotations are in normal type, but indented from the main text.

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BOOK IV

The Terrain of Emergence

The world does not stop, nor do life and the spirit cease to exist, merely because there are things which offer resistance to our efforts to understand them. But if there was nothing for us to decipher, the world might indeed end without compunction; for a transparent universe would have scant reason for continuing—like a cheat who has been exposed or a prestidigitator, whose secret has been divulged.

VALÉRY

CHAPTER I

Epistemology Ascendant

❖

1. Science, Taxa, Methodology

1. *Geometry and the concept of space*. Throughout the ages, philosophers vacillated between regarding epistemology as an independent branch of philosophy proper or as a tributary of ontology. In myth and religion, the question scarcely arose, for the question of Being and Knowing are two sides of the same coin. To Greek thinking, notably Plato's, the same rules apply; it would not have made much sense to him to split the two apart. But with the advent of science the foundations of knowledge acquired a problematic side, when as a result of the rift between Galileo's and the Church's claims to be representing certain truths, it became manifest that a parting of the ways between ontology and epistemology, as well as metaphysics, was imminent. The means of acquiring and holding knowledge, the mode of ontological understanding, the large question mark looming over the assumptions of metaphysics: all these could no longer be perfectly attuned to each other. By the time of Kant's *Critiques*, the split had become a schism; Kant's philosophy reinforced it.

The effect of separation was not at first beneficial, and in the historical view it is clear that the new partnership of science with epistemology was to be fraught with crises and (owing to the shadow of ontology over both) uncertainties. The first significant tremors to shake the foundations of epistemology occurred in the second half of the 19th century; and since the debate concerned fundamental principles, many of which are not resolved even now, it is worthwhile to take some of these problems on board in a synoptic retrospective and preparatory to our chapter on contemporary scientific issues.

It began in the 1850s with the publication of various papers by Helmholtz which extended the criteria of the theory of knowledge (now explicitly so called) to embrace sensationist empiricism, specifically physiology and psychology.* This constituted among other things a new interpretation of Kant's *a priori* principles and caused great unhappiness in the philosophical fraternity, where the opinion held that one of the briefs of philosophy was the setting of the agenda for scientific research. But it was vain endeavour to point to Plato and Aristotle, the great scientific legislators of the days of yore, or even to Descartes and Leibniz: none of the professional philosophers contemporary with Helmholtz possessed the competence to judge scientific theories in commensurate depth, let alone prescribe a route for their investigation. For the beginning of research is *assertion*; and not infrequently such assertion aims into the blue void or arises from nothing more substantial than a hunch. It has the great merit, however, of fixing attention and setting a frame of reference. If the efforts in its behest draw a blank, no great harm is done; at most a few generations of scientists will have wasted their lives on a wild goose chase and this is not at all a reprehensible thing. For in the interests of truth, even failures must be acknowledged as achievements. Thus one of the effects of Helmholtz's work was the gradual emancipation of a *scientific epistemology* from the guidance of philosophy proper. Science would, in due course, develop its own philosophical criteria and leave it to the discretion of philosophers whether or not they would follow suit.

Extend this to asking, *who* sets the parameters? The great physicist Max Planck was one who realised well that research parameters do not fall out of the sky:

> There is no single definite principle available a priori which enables a classification suitable for every purpose. . . . It is important to grasp this clearly, for it is a fact of fundamental significance and demonstrates how essential it is—if there is to be any kind of scientific knowledge—that we work in accordance with established principles and pursue our studies along those lines. The determination of principles, however,

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* Helmholtz, Hermann von: *Vorträge und Reden*. Braunschweig, Vieweg & Sohn 1896; *Science and Culture: Popular and Philosophical Essays*, Chicago University Press 1995.—Helmholtz, not a philosopher, but a tremendously influential *Gelehrter*, dominated the intellectual climate in the exact sciences in Germany.

> cannot be made merely to suit practical considerations: questions of value play their part.*

Helmholtz's papers were not the direct cause of the break. That came with the discovery of non-Euclidean geometry. It is hardly realised today that acceptance of its basic criteria was not a question restricted to technical issues inside mathematics, but—especially in the form which they acquired under the hands of Bernhard Riemann—entailed *a completely new concept of space.*† In the historical perspective we can see something in this which their contemporaries missed. The concept contained nothing that was unfamiliar to the *sensible* creature, but much that was highly unorthodox to the *thinker* whose mind and habits were conditioned by percepts inculcated in him by the undiminished authority of Euclid, which is to say that straight lines were seen and thought of as idealised straight lines—in contradiction to physical reality. Predictably, then, there was considerable resistance to the idea: the compass and straight-edge mentality was difficult to overturn and the philosophical inheritance from Plato to Kant reinforced it. Hence it was not unusual to find mathematicians and philosophers of the time casting aspersion on the sanity of those who taught that non-Euclidean space could effectively represent the 'real' space of reality.

Felix Klein eventually cut this Gordian knot with his 'Erlanger Programme' of 1872, which introduced the theory of groups and set about the reorientation of geometry away from its now suspect affiliation with ontology. Henceforth geometry was to proceed on the basis of internal self-consistency, relying chiefly on logical transformations, with those questions of 'truth' which impinged on its operations sidelined as intrusions of a dubious empiricism. This might have made the programme a welcome solution technically, and it was without doubt a *tour de force* of logical thinking, but satisfaction did not extend so far as to

*Planck, Max: *The Philosophy of Physics*. London, Allen & Unwin 1936, Ch. 1.

† *Über die Hypothesen, die der Geometrie zugrunde liegen* (On the Fundamental Hypotheses of Geometry), 1854. That Einstein found in Riemann's geometic concepts a model of space which was available to him 'off the shelf' is one of those fortunate accidents which occasionally happen in history (cf. Apollonios and Kepler!). But for the purpose of the text, it is important for the reader to appreciate the *ontological* implications.

solve the inherent dilemma that geometry was popularly and philosophically aligned to the subjective interpretation of spatial 'facts of life'. The superiority of the Euclidean type of intuition was occasionally admitted—quite unabashedly, for instance, by Henri Poincaré, who conceded that ingrained habits like this enjoy the enviable authority of their simplicity. But as a scientist he was obliged to remark that this was a concession; for him it was a matter of conviction that geometry could neither be proved nor disproved empirically. Euclidean figures are idealised, and one cannot experiment with or observe ideas.*

Something to be kept in hand in these systems and beliefs is the fact that geometry originated as a system of mensuration, as its name indicates. Emancipation from measurement was thus bought at a price, as further developments were to prove. The 'bottom line', here as elsewhere in efforts to axiomise mathematics, is the inescapable truism that somewhere all trains of arguments and operations come to stop beside the symbol '=': and here, if not sooner, a relation to reality is re-established. This is one of the points on the agenda that suffers no bending or twisting: it is a predicament of intelligibility that runs through all philosophical arguments on geometry and mathematics today as much as then.

2. *Arithmetic to the fore*. There was no lack of recognition of this special problem—of the need to reconcile the empiricist and nominalist positions on foundations. It would clearly not do on the one hand to reduce mathematics to a subjective scheme of ideas for the purpose of "counting cookies and pebbles" (Frege on J.S. Mill), nor on the other to pretend that the obvious intuitive and empirical notions brought into it from outside could be dismissed as inoperative. That question had to be addressed from the ground up—not from the vantage point of geometry but from that of *arithmetic*, on which all other mathematical forms and branches are reared.

But Frege could scarcely expect that his contribution to the epistemological debate was to become the trigger which set off a seismic upheaval in both mathematics and philosophy. For the time being, everything looked rosy: an airtight system of arith-

*Poincaré, Henri: *Foundations of Science*. New York, Science Press 1913, p. 55.

metical statements was clearly a desideratum of the first order, and Frege delivered it by furnishing a 'science of numbers' whose truth value relished strict objectivity and impartiality.* His effort proceeded over two decades and carried the attack on two broad fronts: (a) in the area of logic, providing an axiomatic foundation which included distinctions between propositions and truth assertion as well as the concept of material implication; and (b) building up arithmetic from these newly raised foundations of logic, so that his definitions and law of number could be derived from logical premises; in fact they were constructed on set theoretical principles and commanded considerably more respect in the late 20th century than in their own day.

The important point of departure in the epistemological sense was the point where abstractions and experience seemed set to follow divergent paths. All knowledge clearly has to be *knowledge of* something: but although this does not imply that numbers must enumerate something to make sense, they must refer to a substratum of experience. This critical shaft was aimed by philosopher-historian Cassirer against epistemologists of the Frege and Poincaré type:

> The correspondence between concept and thing, the 'adequatio intellectus et rei', is [the] supreme postulate that must be complied with in every case—no matter whether we deal with mathematical or empirical conceptions. These differ according to their origin and content but not in respect to their mode of dependence upon their corresponding objects. Even mathematical thought can never be a mere cogitation, for no bounds could be set to such a process . . . hence even in pure mathematics we cannot speak of 'free creations' of thought without endangering its content of truth. There must always be a 'fundamentum in re': it must be related to some given objective factual content with which its ideas correspond and which it will bring to expression.†

But, Cassirer goes on, this is not the only way; there is another way of relating object and thought, which is called "the

* Frege, Gottlob: *Begriffsschrift (*Calculus of Concepts*)*, 1879; *Grundlagen der Arithmetic*; *Grundgesetze der Arithmetic* (Foundations/Laws of Arithmetic), 1884 and 1893-1903.

† Cassirer, Ernst: *The Problem of Knowledge*. Yale University Press 1950, pp. 61-2.

functional view of knowledge", in which the object is not the referent of knowledge, but its starting point, and here "the first question is not what [objects] are, but by what medium they are conveyed to us; through what instrumentality of knowledge the knowing of them is made possible." Entailed in this interpretation of 'number' is the notion of non-mathematical procedures capable of *generating* a concept of number and impregnating the idea from the outset with an operational significance. Numbers do not exist *a priori,* but come into being as resultants of a *cut* in a universal ordered structure.

This 'functionalism' (or 'nominalism') was first propounded by Dedekind, but actually builds on an idea of Leibniz, who (as we saw in the section on him) conceived the idea of a number symbolism capable of manipulation as number *symbols* rather than numbers *per se*. These symbols derive their ultimate content from the relations of objects to one another and thus form a substructure within the theory of forms. The theory of numbers is here seen as *evolving* from concepts of succession. At first approach it seems puzzling where the difference lies; but these two disparate number concepts are actually diametrically opposed. 'Conceptual realism' begins somewhere in a primordial setting with the concept 1,2,3,... applied to countable objects, whereas the 'nominalism' of Leibniz and his successors sees arithmetic as born from the womb of an already ordered structure whose continuity is partitioned by the arbitrary cuts of Dedekind, yielding a number sequence and its interpretation from an 'included reality'.*

Let me clarify: if we partition the number spectrum into classes such as 'all numbers greater than 2' and 'all numbers less than 2', then the number 2 identifies the 'cut' that distributes these numbers into their respective classes. But there are number symbols capable of performing this office although they do not of themselves represent numerical existence, for example the cut identified by the relation 'all numbers greater/less than $\sqrt{2}$. A noteworthy epistemological dilemma arises from this logical statement, namely that it acknowledges the irrevocability of *size* and thereby implies an object or quantity, irrespective

* Dedekind, Richard: *Was sind und was sollen die Zahlen?* (On the Nature and Purpose of Numbers), Braunschweig 1893.

of whether it be deemed real or fictive. Consequently even an incommensurable number is required to stand in some relation to a nearby number, size or quantity, which is *real* in the sense of tangible actuality; and this in turn implies that 'greater' and 'lesser' indicate a real comparative relation.

Accordingly such a number, however elusive and impossible to pin down to an exact value, still occupies a location in the number continuum and must therefore represent reality to the same degree as any object or event which for some reason disdains to present us with a sharp outline. Intuitively we are tempted to deny the logicality of these propositions, for such a 'number' as the square root of two simply does not exist. But this is begging the question in another sense. Poincaré points out that the number continuum which includes such apparently nonsensical terms is in fact an indispensable requirement. For example, subjects asked to discriminate weights of 10 and 11 grams have been unsuccessfully tested for their discernibility in succession; similarly with 9 and 10 grams on one side and 11 and 12 grams on the other, which would therefore be represented mathematically by the relation A=B, B=C, C=D, therefore A=D. However, 9 and 12 grams are distinguishable and the formerly satisfactory logical relation suddenly acquires nonsensicality. When, by contrast, highly sensitive instruments are used, the indistinguishableness of A and B is not only removed, but intercalating new terms would not pose a problem until the sensitivity of the instrument is in its own turn exhausted. Finally "the geometer makes a further effort; without entirely renouncing the aid of the senses, he tries to reach the concept of the line without breadth and the point without extension:

> Conceive of a straight line divided into two rays . . . without an interval between them. The common part will appear to us as a point which will always remain when we try to imagine the bands narrower and narrower, so that we admit as an intuitive truth that if a straight line is cut into two rays, their common frontier is a point; we recognise here the conception of Dedekind, in which an incommensurable number was regarded as the common frontier of two classes of rational numbers."*

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* Poincaré, op. cit., pp. 18-22.

These developments brought about a resurgence of interest in the ontology of number. Nonetheless Dedekind insisted that ordinal numbers do not owe their 'being' to anything outside their positions in an ordered series, and this insistence made possible the inclusion of irrational and imaginary numbers, which (as noted) have no real ontological meaning.

We end, inevitably, on a two-fold view on the relation of mathematics to epistemology. On one side is the purely formal, logical nature of its terms and operations, on the other the 'cracked mirror' of mathematics as a child of reality, which through no fault of its own was to be shifted into the courts of 'applied' mathematics, to become an (albeit highly sophisticated) handmaiden to physics and technology. With philosophers no longer competent in the higher reaches of mathematics and mathematicians insufficiently adept at philosophy, the problem of the epistemological significance of mathematics was still awaiting a solution.*

3. *Two worlds of physics*. Leaving mathematical epistemology momentarily unresolved, we turn to physics, which as the science of the fundamentals of matter attracted the lion's share of attention from philosophically-minded scientists. In this science, great progress had been made with the concept of force, which, as the century progressed, moved into the centre of investigations:

> The appointed task of physics [is] to refer natural phenomena to unchangeable attractive and repulsive forces whose intensity depends upon distance. The solution of this problem is at the same time the prerequisite for a thorough understanding of Nature . . . The work of science will have been completed only when phenomena have been traced back to the simple forces, and when it can be shown also that the given account is the only possible one admitted by the phenomena. Then this would have been proven to be the necessary way of interpreting Nature, and it would be the one to which objective truth should be ascribed.†

Thus spake the great Helmholtz. As we know, the mechanis-

*Russell and Whitehead could be regarded living contradictions to this statement. Alas: Both men, in writing the *Principia Mathematica*, were engaged on this task as *mathematicians* and *logicians*. As philosophers they *ignored* this offspring of their joint researches—as indeed did nearly everyone else!
† Helmholtz, *Sci. Cult.*, p. 96ff.

tic explanation long held the stage, based on strict causal principles and the postulate of a luminiferous aether. It was the failure to experimentally derive the actual existence of this medium (the famous Michelson-Morley experiments) which produced the first cracks in this picture. Thus two lines of enquiry were to travel side by side, but on different rails, their most prominent spokesmen being Heinrich Hertz and Ernst Mach, both eloquent, learned and highly influential.

The epistemological question is cast from two dies, not only "What can we know?" but also "What are the limits to knowledge?" Phenomenalist theories are concerned with both, since they rely on perceptive reality; and endorsing the latter in all its ramifications leads at once to an admission that there are things we *cannot* know. This is Mach's view.

It is futile, according to him, to derive laws of causality from mechanistic axioms, because too many phenomena exist that are not reducible to mechanistic explanations. Mach shifted the emphasis from purely scientific to evolutionary principles. "Let us not lose track of the guiding hand of history: it made everything and can change everything," he wrote. All theory has grown from very primitive, instinctive experiences collected for millennia during the hunter-gatherer phase of mankind's evolution; whatever reflections and intellectual constructions we now impose on these basic perceptions are consequences of *our* development and not to be sought primarily in Nature. For instance:

> *Numbers are often called 'free creations of the human spirit'. The admiration for the human spirit that is expressed in this phrase is natural enough, given the imposing structure of arithmetic. However, our understanding of this creation is better served by tracing its instinctive beginnings. Perhaps this will lead us to the insight that the first formulations in this field were unconsciously forced on humans by biological and material conditions and their value was recognised only after they had proved useful.**

Hence, although Nature is their source, reflection and abstractions are *products*, comprising the understandings attained through accumulated observations; and consequently we cannot

* Mach, Ernst: *Knowledge and Error*. Dordrecht, Reidel Publishing 1976, p. 243.

pretend that theories raised in an idealised vacuum contain descriptions of reality.

In short, physics works best by explaining phenomena in their mutual relationships and without recourse to metaphysical suppositions; and this applies equally to our intuitions of space and time:

> *As we recognise what we call time and space only through certain phenomena, spatial and temporal determinations are achieved only by way of other phenomena. When, for example, we express the positions of the heavenly bodies as functions of time, that is, of the Earth's angle of rotation, we have merely found out that these positions depend upon one another . . . The same is true of space. We know the situation with respect to space through an effect on the retina, on our optical or other means of comparison, and actually the x, y and z in the equations of physics are no more than convenient terms for these effects . . . The present effort of physics is directed towards representing every phenomenon as a function of other phenomena and certain positions in time and space.**

To Mach, such a view on principles constituted an act of liberation from metaphysical bondage, parent of innumerable imaginary problems. However, there are palpable limitations to this philosophy, attributable in the main to the fact that every force demanded a specific material agent. Light, magnetism, electricity became unwitting victims, but could not in the long run remain fettered to such conceptions. Objections were raised, drawing their support not from metaphysics, but from the mathematics pertaining to these forces. The two sides of the argument could be held in balance, for the freedom granted to physics by Mach's principles was indisputable. As to the underlying mechanics, these would be answered from the other side of the epistemological main stream.

Hertz, who entered the fray on the 'energetists' side, was the man who provided experimental verification for Maxwell's electromagnetic theories. He drew certain conclusions from the results of these experiments:

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* Mach, Ernst: *Principles of Mechanics*. Quoted in Weaver, J. H.: *The World of Physics*. New York, Simon & Schuster 1987, Vol. II, pp. 7-10.

> It is the first and, in a way, the most important task of natural science to enable us to predict future experience so that we may direct our present activities accordingly. But our procedure . . . is always this: we set up subjective pictures or symbols of the external objects, and of such a type that their intellectually necessary consequences are invariably symbols again . . . [these] are our ideas of things; with these objects they have one essential conformity, which lies in the fulfilment of the practical demand we have mentioned above, but it is not necessary to their purpose that they have any further sort of resemblance to things. In fact we do not even know and have no way of discovering whether our ideas correspond with objects in any other way than just this one fundamental relationship.*

The tenor of this quote strikes a clear note of opposition to Mach. The 'data' on which we work are neither truly empirical nor raw facts: they are intellectual processes imbued with complexities which transcend their reduction to simple mechanistic principles. Physical concepts such as electromagnetism were first of all *patterns of possible experiences*, and it was up to the verification process to make the transition from latency to actuality. This was an idea apt to be received in some quarters as turning things on their head, for these definitions now involved only three concepts: time, space and mass. The methodological advantages accruing from this simplified picture were reflected in the greater economy of procedure and the removal of many of the superfluous elements which had hitherto impeded the rational progress of physics.

One of Hertz's fellow-travellers in this realm of thought, Henri Poincaré, went even further with his proposal that physical facts must now undergo translation into mathematical facts; the idea of the universality of principles takes it out of the scientists' hands to minister to "brute facts" and "replicas of experiences". The final stage in this epistemology prior to the advent of relativity was reached in the work of Pierre Duhem, who wrote that no factual conclusions we reach can help including an implicit as-

* Hertz, Heinrich: *Principles of Mechanics*, 1894: Preface. Quoted in Heisenberg, *The Physicist's Conception of Nature*, London, Hutchinson 1958, pp. 154-7.

sertion of principle. Hence science is not a two-pronged activity, hedged in by naive realism on one side and theoretical structures on the other: for *measurement is impossible without prejudgement of mensurability*. But of the essence to the physicist is the concept of quantity; quality is unmeasurable and intrinsically undetectable and must be excluded from its reach. Research results, in order to be communicable, rely on mathematics: no scientist could report his findings reliably using terms loaded with ocular or tactile associations. Instead he must translate these into abstract, idealised, *symbolic* forms, which can then interact with other symbolic forms.*

The word symbol, introduced here with full deliberation, marks the end stage of this line of epistemological thinking. The juncture reached requires us to know how a symbol can vouchsafe truth if it cannot mediate experience. Duhem refused this concession. Over the head of Kelvin's protest, physicists gradually became accustomed to the impossibility of modelling reality on the basis of symbolic structures and thus paved the way for the theory of relativity, which demanded even greater sacrifices from common sense and naive realism. Physics seemed to have entered a realm ruled by the imperative "thou shalt not make a graven image of my world". The consolation was that this proved indeed the way into the future, to an almost limitless process of discovery and an almost infinite multiplication of headaches for the theory of knowledge.

Yet contrary to overt appearances, it would be wrong to think that Mach's position died with him. Much of Einstein's opposition to quantum theory is tinctured by the positivism that was his legacy from the "revered teacher"; and yet on the other side, the pennant bearer Niels Bohr was himself a persistent believer in the ultimate 'classical' comprehensibility of quantum riddles: "The aim of our argumentation is to emphasise that all experience, whether in science, philosophy or art, which may be helpful to mankind, must be capable of being communicated by human means of expression, and it is on this basis that we shall approach the question of the *unity of knowledge*."† That sentence could have fallen from the lips of Ernst Mach just as it stands.

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* Duhem, Pierre: 'Quantity and Quality'. In Weaver, op. cit., pp. 33-45.
† Bohr, Niels: *Essays* 1958-62. London, Wiley, 1963, p. 14 [*italics added*].

4. *More 'fundamental' than fundamental principles*. It may be natural to look for epistemological guidance among the sciences concerned with 'fundamental' principles, i.e mathematics and physics, yet this is not an entirely satisfactory restriction. For no matter how fundamental the insights into the 'stuff of life' might be, *consciousness* takes precedence. Without consciousness there would be no-one to investigate the universe. Consequently a complete theory of knowledge cannot dispense with contributions from the biological sciences.

The problems associated with admitting the results of the life sciences into epistemology are palpable. Where does one draw the line between fact and psychology? Yet evading it by pretending that the rubber band of subjective definitions is best dealt with by ignoring them is already a tacit confession of infestation with an unacknowledged metaphysical virus.

Questions of such ultimate fundamentality as "What is life (and hence: death)?"; "what is the meaning, purpose, direction of life?"; "what is an organism?" (a question transcending the capability of physics); problems relating to cognition, perception, imagination, psyche; to the forms which life has taken on this planet, including their reproductive and propagative mechanisms, heredity and species evolution; and finally questions pertaining to factors of chemical valence which encourage those combinations whose results are complex self-propagating macromolecules: all these questions, formerly the exclusive preserve of metaphysics, ought to have the same criteria of objectivity applied to them that we accord to theories of physics. And last but not least, what can we know of the role the universe has assigned to consciousness (if any); and is consciousness a condition prevailing just in this little corner of the cosmos where human beings habitate, or is the universe suffused with (or destined to become suffused with) consciousness? Again these are matters beyond the possibilities of physics. Indeed its adherents tend to be rather cavalier with the obvious fact that *consciousness is not directly detectable.*

5. *Biology from Kant.* In the 19th century, the endeavours of biology to claim a stake as a philosophically valid system had to be built up from the *Critique of Judgement,* for the insufficiency of all preceding philosophies of Nature had become manifest. For Aristotle as much as Descartes, biology was a branch of physics;

it did not go far beyond rudimentary classifications and answered most of the vital questions wrongly. Kant's philosophy was the first to address the lack of an autonomous methodology of pertinence to biological science. The starting point was necessarily the introduction of a 'critical object' cognate with the findings of the *Critique of Pure Reason*, but such objects can obviously not be classed under the rubric of the *Ding an sich*: they must reflect "analogies of experience". Biological objects must further be discriminated from objects of physics by acknowledging that immediacy of understanding is possible in principle, and further that the concept of organicity implies *purpose*.

The concept of purpose, in fact, is part and parcel of biological systems, whether animal or plant. It is inexpugnably evident that an organism develops towards something other than what it is at any momentary stage of its life cycle; and in cognisance of this fact the laws of causality require a different interpretation (namely purpose-directed) than when they deal with inorganic systems. This causality, as Kant understood it, is *regulative* rather than constitutive; and from this flows a discernment of the nature of biological processes which may be defined as *cognisance*—a principle evidently not subsumable under the standard quantitative laws of Nature.

Causality and purpose therefore conspire (in a manner of speaking) to compel the philosopher to "spell out the phenomena so that we may read them as experiences", while owing to the enforced discrimination between the two types of objects—natural and transcendental forms—the only permissible overlap is that both are equally amenable to study under the same system of knowledge.

6. *From taxonomy to typology*. Even before Kant came to excogitate these philosophical schemata, a taxonomy of superb scientific coherence and exhaustiveness had burst upon the world in the *Philosophia botanica* (1751) of Linnaeus. Inasmuch as it preceded the philosophy, it is likely that its panorama of species and genera, classifications and groupings had their effect on Kant, who would have recognised that the categories of Linnaeus are part logic, part empiricism, and altogether reinforce the notion that Nature obeys her own laws even in the generation of *diversity*, which is the hallmark of her creativity. The major point of difference between a physical and biological law, however, is that while the former is predictive, the latter cannot be. Yet there is discoverable an affinity among the forms which communicates itself to us by what Kant calls the "adaptation" of Nature to our modes of understanding—as if Nature favoured developments which concede from the outset the classifiability of her forms by a human mind.

The limits of Linnaeus' system were understood by its creator perhaps better than anyone else: it is true that the advance on Aristotle was immense on every front; yet from an epistemological point of view very little was gained beyond the convenience of *aides-memoire*. This was an issue to which Cuvier devoted his life. Going beyond Linnaeus towards a morphology of living system, he evolved a *theory of types* based on comparative anatomy. He was never for a moment in doubt that all life is organised and no part of any living system the result of mere caprice. Anatomy would yield a universal methodology of structure, origin and purpose (in the Kantian sense); and once it had revealed the types of development to which each particular organism is aligned, it would become possible to *deduce* laws from them. This would permit the identification of certain structures on the basis of analogy and enable (for example) the reconstruction of a complete animal from a skeleton, since all parts of a living body are interrelated and condition each other's structure and functionality.

In terms of the theory of knowledge, this was more than just a great advance—it was historically the first valid *system of biological inferences.* That it was also somewhat mechanical and stiff is explained by its providing the base for others to raise new and more flexible theories: foundations have to be solid, because they must carry the weight of ideas yet to come. Even so the immediate fruitfulness of Cuvier's ideas was revealed in their transfer by Candolle into the field of botany, enabling a new and comprehensive system of classification according to the criterion of "designed symmetry", which was Candolle's equivalent of the theory of types.

7. *Metamorphosis*. The poet Goethe, a contemporary of Cuvier, retained a lifelong interest in Nature studies and made a number of salient contributions to several of them, but none more important than his principle of the *metamorphosis of* *plants*.* Form and type, as in Cuvier's system, are at the heart of Goethe's thought, but modified in one crucial respect. Form is not merely a geometrical, but also a temporal concept: *form must realise itself in time*.

From this flows the principle of metamorphosis, which is illuminated by the illustration of the single plant which, while retaining throughout its life a recognisable affinity to type, varies in form in a continuous pattern of development. The immanent law was not of a kind that could easily be accommodated to quasi-mathematical taxonomies, but it made all the difference to *understanding*, and thereby to epistemology. Goethe was led from considerations of the dynamism inherent in evolutionary patterns to the idea of an 'ancestral plant', which contains all the variants permissible to the type in embryo—and "the same law is applicable to all other living things," he wrote. It was the birth in a poetic mind of the *connectedness of idea and appearance* and of the scientific branch of comparative morphology.†

8. *Vitalism supplanted*. But the main thrust of biology's effort had necessarily to be directed against the principle then known as 'vitalism', whose appeals to the lacunae in scientific knowledge construed evidence of 'eternally irresolvable' secrets, for example the forces by which life differentiates itself from matter, which supposedly are not susceptible to quantitative investigation.

The battle was carried by men whose names figure prominently in the history of life sciences, from Johannes Müller to Justus von Liebig and their equally famous pupils. In their hands, biology grew to an early maturity and accumulated strengths from which practically all succeeding generations derived nourishment. Their emphases can be read from the discoveries to which they laid claim, such as demonstrations of the physicality of animal heat (Helmholtz; Bernard); of electrical stimulation as the agent of nervous activity (DuBois); of cell structures

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* Goethe, Johann Wolfgang von: 'Metamorphose der Pflanzen', in *Sämtliche Werke*, Zurich, Artemis-Verlag 1949, Vol. 17, pp. 22-61.

† At a meeting of a learned society in Jena, Goethe took the opportunity of presenting his theory, but confessed to a feeling of perplexity when his future comrade in arms Schiller exclaimed that what he had heard was nothing referrable to experience, but an *idea*. Yet Schiller had hit the nail on the head. It *was* an idea, and epistemologically with profound consequences.

as the minimal elements of biological products (Schleiden). A whole chapter of vitalism collapsed when it was finally shown that body heat could be set in one-to-one correspondence with its energy output.

But it was not a one-sided slaughter. In their naivety, these pioneers simply replaced one force by another, equally mysterious. What is 'energy'? The movement of atoms, according to scientists such as DuBois-Reymond or Roux; but the invisibility, and hence inexplicability, of that physical movement was a blight not easily allayed and culminated in the notorious apostasy of one of the great embryologists, Hans Driesch.*

We have to remember, in assessing the work of these scientists, whether vitalists or physicalists, that they laboured under handicaps which sometimes seem almost antediluvian to us. And yet, in spite of these limitations, they succeeded to a notable degree with laying the foundation for the scientific rigour which such research demands.

The momentous contribution of cytology deserves separate mention; it may exemplify the strain towards knowledge in a science which was still largely ruled by the law of higgledy-piggledy and not seriously admitted to the court of science, which even then was heavily weighted in favour of physics.

The momentous instigation towards a revaluation of 'life forces' came in the wake of Robert Brown's discovery of the cell nucleus in 1831, which culminated quickly in an epistemological assault on the biological massif by Schleiden and Schwann (1838-9) who independently demonstrated the cellular nature of biological tissue in all botanical and creature life. To quote Mayr: "Few publications have ever caused such a sensation as Schwann's magnificent monograph. It demonstrated that animals and plants consist of the same building blocks—cells—and that a unity therefore exists throughout the entire organic world."†

A critical year was 1858, when Rudolf Virchow published his treatise on cellular pathology. In this work, he announced his seminal doctrine of cell theory, whose outlines remain in force to this day. It brings us to a watershed in the evolution of the cognitive appreciation of organic structure. Virchow recognised

* Mayr, Ernst: *This is Biology*. Harvard University Press 1997, pp. 5-6.
† Op. cit., p. 85.

that cells 'make themselves', not from free matter or structureless fluids as Schwann had supposed, but from pre-existing cells by the process of cell division. Thus his motto *Omnis cellula e cellula* marks both a scientific and epistemological divide. For with this recognition came the understanding that the concept of matter could, and must be, partitioned into two mutually incompatible compartments, each reflecting a previously unsuspected dimension pertaining to *organisation*. Virchow's theory established the realm of *living matter* as an autonomous division, and that of *nonliving matter* as another; and the frontier between them was clearly defined as well as unbreachable. The keyword to find application in this segregation was 'metabolism'.*

The impact of this discovery on cognitive apprehension and the concomitant perception of matter differentiating itself by organisation was momentous. Organisms exhibit spontaneous and continuous self-regeneration, and the process was easily demonstrated to be a closed cycle—no organism could be structured from inorganic materials. It gave tremendous impulses to the investigation of fundamental problems entailed in the concept of self-organisation—problems still at the focus of efforts near the end of the 20th century

It is not superfluous to emphasise again that as theorists these men were steeped in Kantian philosophy and entertained a hearty contempt for the wishy-washy science philosophies of the Schelling-Hegel type which enjoyed much greater vogue in educated lay circles where Kant's spartan doctrine had still not taken root. The validity of this statement is not diminished by admitting at once that the epigenetic slant which both Schleiden and Schwann put on their discoveries suffered a pretty terminal refutation at the hands of subsequent researchers (e.g. Virchow, 1855)—such minor details of 'philosophical' interpretation frequently superimpose themselves and are the more readily discarded as empirical research hardens the underlying realities. We can see this coming to the fore even more starkly on reaching the next plateau, which was concerned with fertilisation, another mystery according to many a traditional viewpoint, where the hand of God had accommodated itself to the beast in man.

* Toulmin, Stephen and Goodfield, June: *The Architecture of Matter*. Hutchinson, London 1962, pp. 352-3.

It did not take long for both egg and sperm to be recognised as cell types (Kölliker); but in the ensuing debates we can follow very clearly that intriguing process of discovery which though seemingly proceeding apace, is yet a piecemeal progress, with several scientists actually staring the solution in the face and yet not seeing it on account of their allegiance to pre-formed conceptions of what they were looking for—for example, the entry of the spermatozoon into the egg, which Oskar Hertwig reported in 1876, might have been announced 20 years earlier. Another interesting instance occurred to Jacques Loeb, who inadvertently befogged a very clear issue arising out of his success with chemically induced fertilisation by ignoring the role of spermatozoon in delivering genetic material to the egg and ingenuously announcing the result of his experiments as confirmation of artificial parthenogenesis.*

As far the 19th century is concerned, the epistemological drive chronicled here reached its peak with the discovery of the function of chromosomes by August Weismann, which in the strictest sense was a *theoretical* discovery, guided by *intuition,* for the simple reason that its promulgator was blind. To set the scene, le me quote the relevant passage from Mayr's book:

> The starting point of the ensuing speculations was the observation that well-formed chromatin bodies, later called chromosomes, are observed during cell division (mitosis) but were seemingly replaced by a granular mass or a network of thin threads in the resting stage of the nucleus. *The problem was to find a meaning for what happens* when this irregular chromatic material is converted into the well-defined chromosomes, particularly after it had been shown that each species had a fixed number of mitotic chromosomes. It was rather difficult at first to develop a theory as long as one had no idea whatsoever as to what the biological role of the chromatin was. [*italics added*]†

* "The empiricists, who did the superb microscopic work, often missed the correct interpretation of their findings simply because they did not have an appropriate theoretical framework. Often they did not ask the question why something was happening." (Mayr, op. cit., p. 88). They did not ask because they knew *beforehand* what they were looking for. In this, as later chapter of this book set out to demonstrate, we are dealing with common human foibles.

† Ibid., pp. 89-90.

Until 1870, Weismann, a zoologist, had been a superb worker at the microscope; failing eyesight drove him to reading and theorising, where his philosophical bent and training aided him in the formulation of one of the great breakthroughs, which came in 1887, when during the Manchester Congress he announced his conception of the chromosomes' functions in sexual reproduction, namely that in the process of forming a germ cell, nuclei halve their complement of chromosomes in order to recombine the haploid sets from its two sources into one complete set in the descendant:

> The germ cells of one and the same organism must consequently contain very different combinations of . . . primary constituents from those which were present in its parents. [Accordingly] the dissimilarity between the children of the same parents [results from] the process of 'reducing division', which takes place in a different manner each time [and] gives rise to a surprising number of combinations.*

Adds Darlington, from whose book on genetics this extract is taken, "This prediction has since been confirmed for all plants and animals", going on to draw the following summary which in the context of our studies is of the highest pertinence:

> That Weismann's synthesis was possible at all on such a slender basis of evidence as was then to be found was remarkable enough. But that it should have survived the passage of over 60 years undiminished in its cogency is a token of the great uniformity of behaviour of the chromosomes and in turn of their basic position in the government of life. *Here was in fact, for the first time, a generalisation in biology on a footing with the generalisations of physics and chemistry*, and also connected with those sciences through the material of the chromosomes. [*italics added*]†

9. *Evolution and heredity.* With these tremendous achievements behind them, the life sciences were ready for their great transformation.

There is no need to engage in another account of Darwin and Darwinism, except to note that it was not only a momentous

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* Weismann, August: *Das Keimplasma* (1892), quoted by Darlington, Cyril: *Genetics and Man*. Penguin, Harmondsworth 1966, pp. 75-6.
†Darlington, loc. cit.