PART ONE

PAPERS AND BOOK CHAPTERS (1948–1970)

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The Concept of Intelligibility in Modern Physics (1948)

[6](Written as an antithesis, after a discussion at the philosophical and physical scientific study-groups of the *Collegegemeinschaft* of Vienna, to Prof. Schrödinger's essay, "Die Besonderheit des Weltbildes der Naturwissenschaften".){1}

In modern physics, it is often said that it is utterly impossible to grasp what a philosopher understands by the concept of outside world. By contrast, it is maintained that some sort of regularity forces the physicist to hold fast to the phenomena, and remove from his mental picture all those elements that display no references to the phenomena. This purely descriptive attitude has become known as positivism, and has rapidly fallen into discredit among a large number of philosophers. Therefore, we have to try to provide a description of the foundations of this peculiar method, as well as of its epistemological assumptions.

We may proceed in two different ways. We may either let physics and philosophy have their say together, and listen to the discussion that emerges. Yet, I do not believe that much edifying may come from this, not the least because in the past century there has been a very important conceptual change in both disciplines.

The second approach, which will be followed here, is more indirect and leads through concepts that are generally common in everyday life (which, indeed, is the common point of departure of the exact sciences as well as of

{1} Erwin Schrödinger, "Die Besonderheit des Weltbildes der Naturwissenschaften", *Acta Physica Austriaca*, 1, 1948, pp. 201–245; translated into English as "On the Peculiarity of the Scientific World-View", in Erwin Schrödinger, *What is Life? And Other Scientific Essays*, Garden City: Doubleday, 1956, pp. 178–228.

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philosophy). We therefore replace the [2]pair of concepts, real external world/phenomenon, which represents our difficulty in philosophical terms, with the pair of concepts intelligible/abstract, and see what comes from it. First, the concept of intelligibility itself; in the natural sciences, we have always sought to resolve all phenomena available to the senses into simple visual models, and in so doing to make the mechanism intelligible. Such models explain macroscopic regularity, but do not themselves require any further explanation. They are immediately clear, evident, vivid, if we wish to put it this way. At this point, we can already see that the concept of intelligibility often almost coincides with that of vividness. In most cases, however, it is not just about whether this or that model can be pictured (we will indicate this with I), but rather, it is essentially about what laws it obeys (indicated with II). So, for example, a chair, which changes its size when we bring it to different places in a room, is vivid in the sense of no. I. It is, to be sure, not usual for chairs to behave in this way, but the processes at work can be observed, measured, and, in short, pictured. A vivid rendition in the second sense additionally means, however, that we expect the pictured object to behave like the familiar things we are accustomed to. In the case of Greek atomists, such a vivid rendition presupposes, quite primitively, that everything that happens can be traced back to collisions; whereas in the case of classical mechanics, to the motion of attracting masses. In the one case, it is a model that became plausible through the behavior of things in the immediate environment; in the other, it is a conception that comes from the regularity of planetary orbits, which was already understood. From the first point of view, the motion of the planets and the law that underlies it seems to be incomprehensible, absurd, and from the very beginning they tried to replace it with the strain properties of the intervening medium. The abundance of theories that appeared at the time, to which Newton was by no means the least contributor, is a psychologically interesting indication of how is it possible to grasp the concept of picturing. The dictum about the absurdity of action at a distance tells us nothing about the forces working in the universe. Today we know that very well. Rather, it tells us something about the way of thinking of those who cannot imagine something other than push, pull, or pressure, since these were the only kinds of forces in the immediate surroundings known at the time. Independently of that, Newton analyzes the relationships of the motion of the planets, and ascertains the law from which all the planetary orbits can be simply derived, by superposing a constant velocity factor. It was the first practical application of a way of thinking that today has become known as positivist.

It is very instructive, by contrast, to look at physics in the 18th and 19th centuries, which specifically analyzes and resolves, by way of models, the phenomena under consideration from the opposite side. It is the era of celestial mechanics, in which action at a distance became plausible to the extent that they even sought to trace immediately evident phenomena, such as the elastic reflection of a billiard ball from a wall, back to complex structured forces acting at a distance. Laplace's theory of capillary pressure is the best example of the extent to which the concept of intelligibility is subject to change, and how little the failure to picture a theory can be used as an argument against its content – an argument that certain physicists still [8]put forward against the modern development of the natural sciences.

To summarize:

Intelligible is any such regularity to which we have become accustomed through long use, whose structure is understood from itself. Thus, first, the regularities of the local environment; and next, those of distant environments which are directly accessible to us (celestial mechanics).

Toward the end of the previous century, they even tried to obtain models for the regularity of atoms on the basis of celestial mechanics. But from the beginning we can say that this approach cannot be in any way epistemologically justified, other than by the (heuristically important) principle of continuity, and that in the end success is but a matter of chance. For, in this case, we expect that atoms behave no more and no less than the objects of the world to which we have been so far accustomed; that the laws that our tables, chairs and bathtubs as a whole obey may also account for the emission of spectral lines or for the structural relations of atomic nuclei. If we look at this hypothesis in its full significance, we will not be surprised if, in the long run, there are certain divergences, which, with all good will, cannot be made sense of so primitively.

But now as to the approach itself:

First, we know the atomic weight through measurements of the density of the elements. The velocity, and maybe also the rough structure (spherical, elliptical, dumbbell-shaped) of molecules, follow from thermodynamics and the molecular theory of gases. Thomson's experiments established the fact that every atom contains the same amount of positive and negative electricity. We knows the necessity of repulsive forces from the law of the attraction of electricity. In analogy to the regularity of the planetary orbits, Bohr constructed a model in which the centrifugal force of the revolving electron takes over the role of the repulsive force required. So far, everything is quite clear and satisfactory. Yet, the matter gets disputable as soon as we further consider the conditions of motion in atoms according to the classical laws: first, each nonuniformly moving charge is a source of electromagnetic radiation; secondly, according to the law of the conservation of energy, the radiation process produces a loss of the motion, so that the atom would eventually collapse under continuous emission.

Against this we have:

1. The stability of atoms.
2. The sharpness of spectral lines.

As a consequence, the model appears to be useless. But now (principle of continuity) begin the attempts to rescue it (auxiliary hypotheses):

(a) The electron, to be sure, goes around the core; but it is at the same time unable to emit radiation.
(b) It circles only on certain orbits (consequence of the quantization principle); hence, it does not have the capability of planets to describe arbitrary orbits.
(c) The emission and absorption process produces a sudden change in the direction of the electrons, which – though not bound to any specific orbit – leads the electron discontinuously to the next energy level.

[9]Each of the points (a), (b), and (c) eliminates a classical law. The model, to be sure, is still clear, but by now only in the sense of no. I. It resembles more a haunted house than a physical edifice.

We see what is going on here: the approach of the classical model will necessarily be transformed until nothing remains of it. (Last remnant: Sommerfeld's smeared electron [*Wimmelelektron*].){2}

This raises the question whether this anticipation of classical laws is in any way an appropriate route to a satisfactory conception of the structure of atoms, whether we do not here stand in front of what is in principle a new field, which cannot be grasped with pictures from the world of tables and chairs, and whether it is not methodologically more effective first to simply register those regularities without immediately referring them to a structured carrier, "*atom*". This is the position of modern physics. We might find it unsatisfactory, just as the Cartesians found the idea of direct action at a distance unsatisfactory, although shortly thereafter they thought they understood these regularities. Now, just as then, we are dealing with a transitional phase, at the end of which we will think that

{2} *Wimmelelektron* seems to be a coinage of Feyerabend's. Johannes Stark used the term *Wimmelbewegung* in his article "Die Kausalität im Verhalten des Elektrons", *Annalen der Physik*, 6, 1930, pp. 681–699: pp. 681, 684–686 (and elsewhere), to refer to Brownian motion; "smeared" gives the idea of swarming, and fits well with Feyerabend's use of the term.

a different way of thinking is clear and intelligible. But, in that case as in the present one, all elements of the earlier way of thinking must be resolutely removed, in order to allow for the new regularities to emerge. *This* is the position of today's positivism. It makes it possible to formulate the connections that will appear intelligible tomorrow.

Its line of action is radical: "atom" is not this or that thing, but the sum of phenomena known in a certain domain. This is to be understood in this way: the phenomenal differentiation of elements leads to a preliminary, primitive classification (periodic system of the first kind). Finer investigations, which admittedly presuppose the identity of the substrate, allow us to find the nuclear shell as the chief feature of comparison, according to which the sequence of elementary building blocks can be ordered. Classified in this way, these elements are examined with respect to their spectrum, of their behavior in a magnetic field, etc. In this way, a series of regularities comes to light, which are assigned to the elements of the corresponding atomic number. The sum of all these regularities is then "the atom X".

Now, from the laws themselves follow certain quantities, which turn out be largely independent of changing external conditions (mathematically speaking: of arbitrary transformations), and which themselves still retain such invariance, even if the building blocks of earlier physics have already been through several changes. A well-known example of such a quantity is the interval in the general theory of relativity. It may look as if the transformation of space and time coordinates (which so far had a meaning independently of velocity) opens the door to all sorts of unpredictability. Nevertheless, even here there is a quantity, admittedly not directly observable, which turns out to be completely independent of velocity and gravitational deformation. This shows that the objects of our perception cannot be the ultimate invariants, and therefore are also unsuited for an invariant representation of all laws of nature.

Once we have clarified these relations, which are mostly only mathematically formulable, for ourselves, we recognize [10]a simplicity of a completely different kind than was the case in the classical picture. We fare like a wanderer who, after many travels, sees right in front of him a region that was hitherto completely unknown and amazing to him. We understand the new area from its immanent regularity, and have thereby made more progress than we would have, had we built a model from sticks and hooks, which, after a few operations would have been doomed to stagnation. Admittedly, it is always and everywhere possible to transfer already known relations to newly discovered areas, and in practice – for the sake of continuity (= convenience) – one will initially proceed like that. But there is no principle that could permanently guarantee the success of this method. For the so-called "unity of natural forces" only persists in a given worldview, and may be reduced ad absurdum by any new discovery.

Two problems remain to be addressed:

(1) The question of the causal determination of atomic processes; and
(2) The question of the possibility of metaphysical constructions.

As to (1), it can also be rephrased in this way: does causality hold at the atomic level? Given the previous discussion, the answer is clear: if by causality we understand the relation that allows the motion of ponderable particles to depend on one another or on certain forces, then something of this kind cannot be found among atoms, not because there are no laws in that case, but merely because we can no longer get by with the picture of ponderable particles and the representations we know from the macroscopic domain. Or, more explicitly: there is no position where a mass point must be located with absolute precision, because mass points and positions no longer are the essential descriptive notions. The strict connection, which on the large scale we call causality, exists between certain mathematical quantities, and no longer between objects of our perception (particle A and particle B). If we regard those particles as essential, then admittedly all those problems quantum theory offers to a primitive and vivid explanation arise.

As to (2): after what has been said so far, there is no difficulty, from now on, to transferring the newly discovered invariances to real things, and to set up a metaphysics on this basis. For, from (1), the argument of the unknowability of the so-called external world ceases to apply. If we focus on ponderable particles, then, admittedly, it is problematic to see how the external world is to be constructed. If, however, we use the new concepts, there is no reason why we should not speak of the external world in this context as well. To determine this is, indeed, already a task for philosophy itself.

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Physics and Ontology (1954)

1.

[464]One goal that philosophers and scientists of all times set themselves was to get to know the world, so that it would become possible, on the basis of a *picture* of the world, to explain in a satisfactory way at least its most important phenomena. The history of the efforts to obtain such a picture of the world shows three clearly separated stages: the mythological stage, the metaphysical stage, and the stage of natural science. We have to move the beginning of the metaphysical stage to the time of the Ionic natural philosophers, when we began for the first time to seek tradition-independent reasons for the construction of a particular system to explain the world. Later, above all with Plato's *Timaeus* and Aristotle, a return to a more abstract form of mythical [465]stage occurred. We will talk about this in what follows. However, the beginning of the scientific stage took place only recently, and was initiated by the so-called revolution in physics. The meaning of this revolution for philosophy – not only for the content of its teachings, but also for the methods it employed – cannot be emphasized enough. In this essay, therefore, I will focus above all on this third stage.

2.

For what follows it is important to see that, ever since Plato and Aristotle, a prejudice has been spread in philosophy, which from now on will be referred to as the ontological prejudice. According to the ontological prejudice, knowledge is necessarily linked to certainty. On the other hand, it is assumed that only claims that are certain say something about the world: as a consequence, we must be able to formulate a picture of the world by way of propositions whose truth stands once and for all, and whence doubt is forever removed. Statements about being are absolutely true. Statements whose truth we may doubt do not concern being, even when they are capable of providing good service as tools for the prediction of interesting phenomena.

The ontological prejudice leads to a division of the originally unitary attempt to create a unitary and satisfying picture of the world. The Presocratics still discuss the validity and usefulness of a cosmological description by appealing to the same arguments about the validity of a statement about the fundamental parts of the world. Empirical arguments and speculation go hand in hand. As soon as absolute truth is demanded only for statements providing a picture of the world, we have a sharp distinction between "mere" descriptions – which, being uncertain, do not convey knowledge, and, as a consequence, do not touch being, either – or "opinion", on the one side, and knowledge on the other. We may attain opinion with experiment in conjunction with speculation. But in order to achieve knowledge, we need a different method.

These methods were developed by Plato and Aristotle and were further cultivated by their followers. One organ of knowledge is intellectual intuition – a direct capacity, a direct insight into the principles that lay the basis of the course of the world. Knowledge, which originates in intellectual intuition, is absolutely certain. Intellectual intuition is especially suited for philosophers, and the return to it distinguishes philosophy more than other disciplines (with the single exception of mathematics, perhaps). Philosophers look at the world as it really is. Thereby, the separation between philosophy and science is sharp, and drawn once and for all: the birth of philosophy as an autonomous discipline, which is not only independent from scientific considerations, but insists that it is the only one capable of providing a picture of the world, goes together with the ontological prejudice, with the idea of absolutely certain claims, and with the assumption that only such claims are "ontologically relevant", that is, only they show us a picture of the world, as it "really" is. The conflict between knowledge directed at reality and opinion, which is appropriate to prediction, clearly emerges in St. Thomas. In *Summa* I, 32 he calls attention to two differing ways of giving an account of something.

> The first is that one proves a certain principle in an adequate way. So in cosmology one offers an adequate reason for believing that the motion of the heavens is uniform. According to the second type, one introduces no reason that grounds the