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MUTATIONS IN SYSTEMS IN THE
NATURAL SCIENCES AND MUSIC IN
THE FIRST HALF OF THE TWENTIETH
CENTURY

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area in which there is the greatest possible pluriformity), but of necessity limits itself to a formal homogeneity as a result of the ontological-epistemological status of systematics. Music has always been a privileged metaphor for the articulation of a world-view. This continues to be true of music in the setting of twentieth-century culture. The contemporary paradigm is just as beautiful as, for example, that of Pythagoras or Kepler, and just as transitory.

It is important to state at the outset that it is *not* the purpose of this monograph to investigate the potential application of some or all of the concepts which have been the by-product of advances in modern theoretical physics (or have been reformulated in the light of progress in this area) to the field of (contemporary) music. An unnuanced transplantation of specific concepts between systems which each have their own characteristic dynamism, range, significance and finality is, in most cases, generally contrived and somewhat forced. And yet, although no advocate of a one-to-one comparison of concepts and contents between theoretical physics



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and atonal (dodecaphonic) music, it does seem to us possible to conduct a plausible inquiry into whether there is some connection between the fact that historically classical physics and classical tonality were called in question at roughly the same time. What interests us thus is a historical-cultural link between these two system mutations as such and the new world-view they produced. At various stages in the past links were posited between for example the theory of relativity and Schoenberg's dodecaphony. This may have been on the basis of Schoenberg's concept of the »relativity of the dissonance« (a phenomenon which is actually due to habituation and thus intimately bound up with a musical system¹ and the historical changes effected within it), or has it perhaps more to do with his opinion regarding the »unity of the musical space« (in which the equalization of horizontalism and verticalism is strictly speaking actually theoretically mistaken, and in which the series may well be at the origin of the »musical system«, but is by no means identical with it)? This correlation between dodecaphony and relativity theory has virtually always been posited on the basis of a superficial knowledge of both elements in the equation.

In the meantime numerous books have appeared which provide sound surveys of recent developments in theoretical physics and yet are accessible, albeit with a certain intellectual effort, to the interested layman. This present study has drawn principally on the studies of Albert Einstein,² Max Wildiers,³ John Gribbin,⁴ Heinz Pagels,⁵ Gary Zukav,⁶ Ilya Prigogine and Isabelle Stengers.⁷ There is no attempt here to reproduce *in extenso* the history of the different phases of development in modern physics: we will focus rather on certain consequences of advances in this domain which made a dramatic impact on modern views of the world and science (e.g. probability taking over from determinism, the pivotal role of the observer, theoretical pluralism, etc.) (A) so as to then compare them with the cardinal principles of the modern musical systems (B). Section A will examine the fundamental premisses of special and general relativity theory (1), quantum physics (2) and the epistemological status of physics (3).

¹ Throughout this essay the term »musical system« is used as an equivalent of the German word »Tonsystem«, i.e. a collection of tones and their mutual relationships.

² A. EINSTEIN, *Über die spezielle und allgemeine Relativitätstheorie*, Braunschweig 1916.

³ M. WILDIERS, *De muziek der sferen. Vier opstellen over wereldbeeld en cultuur*, Antwerp-Amsterdam 1983; ID., *Wereldbeeld en theologie. Van de middeleeuwen tot vandaag*, 2nd. ed., Antwerp-Amsterdam 1977.

⁴ J. GRIBBIN, *In search of Schrödinger's cat. Quantumphysics and reality*, reprint 1985, London 1987.

⁵ H. R. PAGELS, *The Cosmic Code. Quantum Physics as the Language of Nature*, London 1982.

⁶ G. ZUKAV, *De dansende Woe-Li meesters. Een overzicht van de nieuwe fysica*, transl. by R. JONKERS, reprint 1981, Amsterdam 1986.

⁷ I. PRIGOGINE and I. STENGERS, *La nouvelle alliance*, Paris 1979.

A. Mutations in the systems of the natural sciences

1. Special and general relativity theory

It was as a result of Albert Einstein's special (1905) and general (1915—16) theory of relativity that account was taken for the first time of the observer's localization in time and space, for uniform motion and all forms of motion (with their corresponding modes of geometric description) respectively. Even if serious doubt was cast on the notion of reality as an imperturbable mechanism totally separate from the observer, Einstein was nonetheless able to rescue deterministic physics by formulating laws of transformation (which made possible a smooth transition from a world without to a world with an observer situated in a time-space continuum).

Reduced to its simplest terms, the theory of special relativity states that the time interval between two occurrences, and the spatial interval (distance) between two points of a fixed body are dependent on the motion of the reference body: determinations of time and space are thus relative. Einstein's famous example of the train and the railway track illustrates this fact. When a train rides along a track at a constant velocity (the special relativity theory is exclusively concerned with *uniform* motion), one can describe the motion from two points of view: either from the viewpoint of someone standing outside the train (on the platform for example) or from the viewpoint of a person sitting in the moving train. In the first case the track (or the platform) functions as a fixed reference body in regard to which the railway carriage is in motion, while in the second case (in the eyes of the passenger) the track is moving vis à vis the fixed reference body »train«. There is a difference between the time specification for these two reference bodies (coordinates). Two flashes of lightning A and B, for example, can be perceived simultaneously by an observer on the platform because he happens to be standing at a point M which is the middle point between the beams of light emitted by A and B. On the other hand the points A and B on the platform correspond to positions A and B in the train in regard to which a middle point M' can also be established. When the train is standing still and the observer in the train is at point M', then, of course, he will see the flashes of lightning at the same time. If, on the other hand, the train is moving at a constant velocity the observer at point M' (in the moving train) will speed towards the beam of light from B and run ahead of the beam from A: in other words he will first see B, then A.

Not only time, but distance too is dependent on the motion of the reference body. The length of the window in the moving train is shorter for the person on the platform than for the passenger in the train. The faster the train is travelling, the shorter will be the measurement for the observer standing on the platform until at a hypothetical velocity of ± 300.000 kilometers per second (the speed of light) the distance would be zero (and time would stand still). Both the clock which is losing time

and the shrinking measuring-scale are ultimately explained by the speed of light (which conveys information) and this speed Einstein termed an absolute constant, i.e. a constant velocity (300.000 km. per sec.) which is totally independent of our own speed. The time-space determination of the observer however is relative to the motion of the reference body. Time can no longer be measured independently of measurements of space and vice versa. The world is a four-dimensional continuum (three spatial coordinates: length, breadth, height and one time coordinate). Minkowski conferred a geometrical shape on this four-dimensional world, while the co-called Lorentz-transformations provided the mathematical bridge between the three-dimensional (Newtonian) and the four-dimensional (Einsteinian) world. An important consequence of the postulate of a constant speed of light is the abolition of the distinction between mass and energy. According to Newtonian physics velocity could accelerate *ad infinitum* so long as a force was continually applied to a mass considered as constant. Einstein, on the other hand, demonstrated that it is not the mass which remains constant but the velocity (with an upper limit of 300.000 km. per sec.) and that thus the mass had to increase in proportion to the velocity with which it moved (in the case of the speed of light, a mass of infinite dimensions). Accelerating velocity is equivalent to increasing mass (which actually slows down velocity), and as a result the limit of the speed of light can never be exceeded.

All of this brings us right into the domain of the general theory of relativity which attempted to extend the laws of the special theory of relativity to non-uniform motion (i.e. motion with variable direction and velocity). Einstein discovered that non-uniform motion was indistinguishable from gravity. This fact becomes clearer if we think of a spacecraft which finds itself outside all fields of gravity. When the spacecraft accelerates, the astronaut becomes glued to the floor. Stones of varying mass which are simultaneously released all reach the floor of the accelerating craft with equal speed (thus at the same time), just the same way as stones of varying mass which are thrown from a housetop (or from the leaning tower of Pisa) crash to the ground with the same speed (thanks to the pull of gravity). In order to generalize measurements of space and time for observers who *vis à vis* one another are not in uniform motion, Einstein appealed to Bernard Riemann's geometry of curved space. Therein parallel emitted beams of light will not maintain equal distance from one another as in flat Euclidian space, but after a certain lapse of time they will begin to converge (in spherical form) or diverge (in hyperbolic form). In both these latter cases space is conceived of as three- or even four-dimensional, and then the Riemann geometry becomes operative.

From Einstein's $E = mc^2$ law (mass and energy are identical) the link between the equivalence of gravity with non-uniform motion on the one hand and the curving of space on the other hand becomes clearer: since a transmitted beam of light possesses energy, it also has mass. Given that mass is subject to the power of gravity, the beam will »curve« once it

experiences gravitational pull. One could also look at matters from the opposite point of view, and that is precisely what Einstein has done: gravity is nothing more than mass (e.g. a planet) that curves the space, or if you will, gravity is the curving of space and time. It is not our purpose here to explore any further the fact that, resulting from Einstein's insight, the universe need no longer be conceived of as static but rather as constantly changing (expanding or contracting). One could observe, in conclusion, that the theory of relativity knocked the supposedly unsailable concept of scientific objectivity for six. In the traditional view of objectivity the observer was completely separate from the object observed, while ever since Einstein's epoch-making insight he is situated in a given reference system which is itself relative to other reference systems. Absolute temporal coincidence of events separated by space for example could be demonstrated and measured by the classical Newtonian physics (because everything was taken into account except the physical reality of the »subjective« observer), yet was quite impossible for relativity physics within which different »world views« are the adequate expression of localized observations.

2. Quantum physics

Quantum physics studies a micro world which is not directly observable but some aspects of which can be measured without ever yielding an »overview« of the totality of this micro world. Born of the search for the components of matter (the »elemental particles«) quantum physics has revealed that the atomic and subatomic components of matter demonstrate different behaviour patterns to things from the macroscopic world. Given moreover that this behaviour proved unpredictable, serious questions were raised regarding the universal validity of deterministic Newtonian physics.

In the first phase of the evolution of quantum theory (first quarter of the twentieth century) researchers of the Max Planck-Albert Einstein generation attempted to come up with a *pons asinorum* between the reality level of the classical mechanical physics and the physics of the »quantum capriciousness«. As of 1925 theoretical physicists such as Niels Bohr, Max Born, Werner Heisenberg, Erwin Schrödinger, Wolfgang Pauli, Paul Dirac and many others began to realize more and more that quantum reality could not be described with the current concepts derived from observations of day to day reality, and even less with the classical laws of physics. This realization came as a rude shock for the Western physics community. It was in fact firm in its conviction that the whole of reality could be described on the basis of a few laws: it was, for example, the same law of gravity which determined the fall of the apple from the tree as the course of the planets. In that way the world could be described (exhaustively, it was claimed) as an enormous machine, in which every occurrence was causally determined (and thus could be calculated and predicted). Quantum physics made an end to all that: even when the

qualitative difference between micro- and macro-worlds is not lost sight of (in the case of the latter the laws of Newtonian physics continue to apply and concepts such as objectivity and causality can be maintained), nonetheless the realization that »the laws of physics« did not govern the whole of reality but only a part of it (and that these laws have been experimentally refuted for other levels of reality), turned the conventional world-view topsyturvy and was comparable in its impact only to the consequences of Copernicus' introduction of the heliocentric planetary system.

Modern physics is well aware of the fact that it only comes up with answers to the specific questions it poses. These questions can only be fitted into a model which explains a part of reality and not its totality: the realism which characterized classical physics (the universal applicability of the laws of nature) has been replaced by the search for a consistent subsystem. Gradually it became apparent that the choice of questions to be asked and observations necessary to answer these questions involved an intervention in reality itself (Heisenberg's principle of uncertainty), i.e. that a phenomenon cannot be observed without effecting a change in it (not just a change in the observer, but genuine ontological change!). To some extent thus it is the observer who selects a certain reality (one of a number of possibilities) and by this very fact creates this reality: this is particularly well illustrated by the notion of complementary concepts, a key notion in quantum physics. The fact that mutually exclusive principles (based on different forms of observation), such as for example the particle or wave characteristics of light, are required to explain the phenomenon of light would seem to suggest that reality is so multi-faceted and rich that it cannot be fully captured by a single language or system of logic. Another area in which the new physics differed from the classical physics was that of prediction: in quantum theory one no longer forecasts developments (as a consequence of determinism) but rather probabilities (indeterminism). In other words one can only calculate statistically whether a certain event will occur. Over the next few paragraphs a number of specific examples will be discussed (matrix- and/or wave-mechanics, complementary concepts, Schrödinger's cat, the Copenhagen interpretation, Boolean logic and quantum logic, etc.) to back up general assertions made concerning quantum theory.

When Max Planck discovered that heat radiation could not entirely be explained by wave activity in classical mechanics, he came to the conclusion that the energy exchange between matter and radiation was not a continuous occurrence but came about only by means of discreet steps. These latter are clearly distinguishable energy packages (energy quanta) and the dimensions of each step between these quanta is expressed by the universal constant » h « ($6,625 \times 10^{-34}$ Js), otherwise known as the Planck constant. Einstein went on to demonstrate by means of the photo-electronic effect, that electromagnetic radiation too (i.e. light) can be described with Planck's quanta, and that here too the wave theory, found

in experiments to be correct, only offered a partial description along with that of the light particles (in this case photons). Even though this was an extremely risky step, Einstein drew the only possible valid conclusion from the fact that the experimental results of both descriptive methods appeared correct: he pioneered the principle that light is a wave as well as a particle. By means of Planck's constant a link was established between these two mutually conflicting theories of light, so that in practice this dualism no longer posed a serious problem (in research in the area of applied physics). Even if it became possible to »translate« all of this into a new mathematical language whose application led to perfectly logical and experimentally satisfying results, the question as to how something could be at the same time wave and particle remained unanswered. This is due to the fact that the quantum particles here at issue are not particles in the sense of »objects« which contain energy and momentum calculable by classical mechanics (the way in which we usually imagine particles), but are only an expression of one or other measured quantity (e.g. position or momentum, never together in reality because they cannot be measured simultaneously; this impossibility is in turn the consequence of the fact that Planck's constant establishes the link between wave length and momentum so that these are no longer variables which can be measured independently of one another as in classical physics: the act of measuring the position alters the velocity and vice versa).

The wave-particle duality of light was transferred by Louis de Broglie to matter invisible to the naked eye. While an electron was generally described as a particle, de Broglie was able to demonstrate that electrons could behave like waves too and that furthermore one could establish and calculate the characteristics of these waves experimentally (e.g. refraction or interference). The calculation was done by way of the Schrödinger comparison which became the basis for wave mechanics. The atomic quantum world could now not only be described by way of a mechanics of particles but also through a mechanics of waves, and in a manner which was just as consistent and verifiable by experiment. The question now arose as to how the behaviour of an electron as particle was to be reconciled with the behaviour of the same electron as a wave (both behaviours having been »demonstrated«). Max Born's intuition that the electron-waves were not concrete waves, but rather probability waves (which statistically calculate the probable presence of a particle in a given place: the square of Schrödinger's wave amplitude yields for every point in space the probability of encountering an electron), despite the radical break with the determinism of classical physics (which calculates the presence of a particle rather than its statistically probable presence), does seem to be the right one. On the other hand, thanks to Werner Heisenberg, the almost equally implausible particle mechanics attained mathematical respectability in the matrix-theory, in which Planck's constant again offered the bridge between simple numbers (with which, for example, place and momentum of a body were described in classical physics)

and the matrices (with which moving particles could be measured in quantum mechanics). The difference between the results of a multiplication of the factors in an alternative sequence (matrices are what are termed »non-commutative«) is in proportion to Planck's constant. Finally, Heisenberg's matrix mechanics and Schrödinger's wave mechanics were combined in Paul Dirac's transformation theory which ended up identical with quantum mechanics as such. Two contradictory descriptive techniques appeared to be each for itself valid because, given that on the level of micro investigation it is quite impossible to say how things really are, one can only contrive different ways of imagining how they *might* be. In 1906 J. J. Thomson won the Nobel Prize on account of having proved by experiment that electrons were particles. In 1937 his son — George Thomson — won the Nobel Prize after he had proved by experiment that electrons were waves. This fact is remarkable only because *both* were right.

The combination of Born's statistical wave function, Heisenberg's principle of uncertainty and Born's complementarity led to what is known as the »Copenhagen interpretation«. The latter enables us to investigate further the principles of uncertainty and complementarity which solve one and the same problem (i.e. the wave-particle duality) along parallel lines. Heisenberg introduced the principle of uncertainty as a direct result of his application of matrix mathematics to the description of moving particles. Given that matrices are not commutative, their combination does create certain difficulties. Let us imagine p as (the measurement result of) the momentum of an electron and Δp as the statistical average of the deviations in the different momentum measurements; let us then imagine q as (the measurement result of) the localization of an electron and Δq as the statistical average of the deviations in the different localization measurements. Because p and q are non-commutative matrices, $pq \neq qp$ applies and it proves impossible ever to establish what p and q are. In Heisenberg's principle of uncertainty this conclusion is expressed in the formula that $\Delta p \times \Delta q$ must always be greater than or equal to h , Planck's constant. It is true admittedly that h is an extremely low value, yet not equal to zero, so that when for example Δp were equal to zero (the statistical average of the deviations in the momentum measurements is zero; there are no deviations, thus the measurement is completely precise), Δq will necessarily be infinite (the uncertainty regarding the measurement of localization must be of infinite dimensions) and vice versa. We can therefore measure extremely precisely the momentum of an electron (at the expense of the localization) or the localization of an electron (at the expense of the momentum measurement), yet we can never award a given value to p and q simultaneously. The more one knows about the electron as a particle (for which the fixing of localization helps greatly), the less one knows about this electron as a wave (expressed among other things by the fixing of the momentum), and experiments can only be set up to investigate one of the two properties.

Niels Bohr's theory of complementarity is based on the recognition that quantum reality cannot be described in terms of classical physics. By means of conventional physics it is possible to calculate precisely the position of bodies in space and time, and it is furthermore possible to predict their behaviour (determinism on the basis of the principle of causality): in this approach it is always assumed that this furnishes a description of »reality« which is also independent of the fact of whether or not we observe it (objectivity). Things are very different in quantum physics: both wave and particle properties of, for example, an electron are part of quantum reality (both are valid, equivalent and complementary) yet, as has been pointed out, the observation of the one irredeemably destroys the other with the result that these properties can never be observed simultaneously. The type of question we ask, the way in which we set up these experiments, is in other words crucial for the reality we are describing. The behaviour of an electron as a particle or as a wave only exists if we wish to measure the position or the momentum of this particular electron respectively (it being impossible to measure both properties together). The observer participates in what he is observing to such a high degree, that he actually *creates* the reality through the act of observing it (in contrast with the classical physicist who »observed objectively«). One can know absolutely nothing about the electron when one does not look at it. An electron does not even exist if it is not being looked at, and when we do manage to observe its properties we are only dealing with probabilities (the observation forces the system to select only one of the possible options). To sum up, one can state that in the Copenhagen interpretation of the quantum theory both the determinism and the objectivity principle of classical physics are knocked for six. On the one hand measurements have become untrustworthy (one can no longer base any theory of causality on them) and are replaced by statistical divisions of measurement results. The quantum reality which is described by these measurements, is thus equally no more certain (determined) but statistically probable. On the other hand, that reality is also essentially co-constituted by the way we look at it. Instead of being cool detached observers we become involved participants who create properties by choosing them as object of our observation.

Up to the present nothing has been better able to illustrate the implications of the Copenhagen interpretation than Erwin Schrödinger's so-called »cat-paradox«. Nonetheless Schrödinger had elaborated this intellectual experiment so as to demonstrate what were in his view the unpalatable consequences of the Copenhagen interpretation. It is a fact that in the cat-paradox the major points of difference between quantum reality on the one hand and our everyday experience of reality and the classical physics based on it on the other come to light. Even though this paradox still raises many significant questions, it has not yet been able to topple the Copenhagen interpretation and has actually given rise to other theories of reality of an even more radical kind (e.g. Hugh Everett's »many

worlds hypothesis«). We have got to picture Schrödinger's cat in a sealed box, where in addition to this animal we have an atom, a detector and a flash of poisonous gas. As a result of radioactive decay the atom emits an electron which is observed by the detector, upon which the flash is automatically broken and the cat dies. Now the radioactive decay is unpredictable: one can only forecast its statistical probability (by means of Born's wave function). The experiment can of course be set up in such a way that the chance of an electron being released is one in two. »Common sense« (used also by classical physics) tells us that the cat is either alive or dead, and that this is a fact we can ascertain by opening the box. In the view of the Copenhagen interpretation, on the other hand, as long as we have not looked in the box there is both radioactive decay and no radioactive decay, both a broken flash and an intact flash, a dead cat and a living cat. Both possibilities, with their equivalent degree of probability, exist side by side, right up until the moment when we look into the box: at that moment Born's probability wave collapses and, through the focus of our specific observation we create a dead or a live cat (instead of superposition of both by non-observation), and automatically the other corresponding possibility (in this case a live cat or a dead cat respectively) disappears.

This summary overview of certain important aspects of quantum physics can appropriately be rounded off with a short discussion of the extension of quantum theory into the area of logic. From the foregoing paragraphs it will already be obvious that in various respects quantum logic functions »differently« from traditional logic (also known as Boolean logic) which, for example, lies hidden in everyday language-grammar. Could it be any other way with premisses which express probabilities instead of certainties? Since Boolean logic is a formalization of human thought, it could happen that a logic which deviates from it might be irrational, arbitrary and meaningless. Yet nothing could be further from the truth: in quantum logic, for example, Born's probability functions which are in turn based on Schrödinger's wave comparisons are mathematical formulae which express, it is true, unimaginable reasoning patterns, yet are *completely consistent*. The fact that quantum theory has such wide application in contemporary technology would seem to suggest that its formal deductions are correct, and that the results of these logical deductions have furthermore a prolongation in reality. Quantum logic allows one thus to think validly as well as practically. Once we are able to renounce the set thought processes, once we can experience reality in a different way, we discover totally different systems of knowledge which are actually just as true, valid or efficient. The way in which we work with symbols and logical operators in Boolean logic can illustrate this fact. In classical logic the factors which are linked with an »either . . . or« phrase mutually cancel one another out (either the one or the other but not both at the same time): $p \neq \neg p$. Such a divorce does not prevail in the world of quantum logic: elementary matter for example can at the

same time (and depending on the way we look at it) be a particle (p) and a wave (-p). Here in other words we have a superposition of possibilities which cannot be grasped by the conventional reasoning process with its strict separations (either this, or that). As an effort to bridge the gap between the mutually exclusive categories of Boolean logic, quantum logic is in doing so both internally consistent and compatible with experience.

3. The epistemological status of physics

Such a superficial overview as ours can certainly create the impression that modern physics developed of its own accord and that researchers had only to draw the right conclusions from what they saw in order to arrive at new insights. In practice things were actually quite different. There is highly convincing documentary evidence to show that even the »young Turks« of quantum physics were very close to despair in the mid 1920's because, on the one hand, the old theory was found wanting in certain respects and on the other hand, the new theory was not sufficiently developed to offer an exhaustive and consistent description (let alone explanation) of physical reality. The »lamentable hodgepodge of hypotheses, principles, theorems and computational recipes«⁸ signified chaos for every right-minded researcher. John Gribbin describes this phase ($\pm$ 1925) as follows:

»Every problem in quantum physics had to be first 'solved' using classical physics, and then be reworked by the judicious insertion of quantum numbers more by inspired guesswork than cool reasoning. The quantum theory was neither autonomous nor logically consistent, but existed as a parasite on classical physics, an exotic bloom without roots.«⁹

The critical situation in which physics found itself round 1925 was probably due to the fact that the thought patterns of the old physics — which after all had worked well for centuries and had led to brilliant results in theory and in practice — were only abandoned with the greatest reluctance. We tend to cherish scientific theories just as long as they are »useful« in explaining the world about us, and only when phenomena arise which can no longer be understood on the basis of the old theories does our world-vision change. Werner Heisenberg has described the radical character of such a change as follows:

»... as soon as new clusters of phenomena force changes in the pattern of thought [...] even the most eminent physicists are confronted with major problems. The changes now required in the thought

⁸ Expression of Max Jammer in *The Conceptual Development of Quantum Mechanics*, New York 1966; quoted in J. GRIBBIN, *op. cit.*, p. 100.

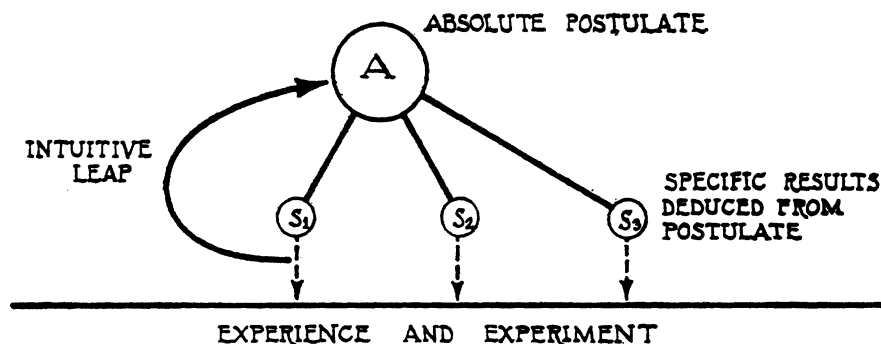
⁹ J. GRIBBIN, *op. cit.*, p. 100.

pattern can create the feeling that the carpet is being pulled from under one's feet [...] In my view the problems these gentlemen encounter cannot be overestimated. When one has once witnessed the despair with which intelligent, calm research scientists react to the need to alter the pattern of thought, one can only be surprised that such revolutions in science were possible at all.¹⁰

John Gribbin concludes his book on quantum physics with the following quotation from Richard Feynman's *The Character of Physical Law*:

»... what we need is imagination, but imagination in a terrible strait-jacket. We have to find a new view of the world that has to agree with everything that is known, but disagrees in its predictions somewhere, otherwise it is not interesting. And in that disagreement it must agree with nature. If you can find any other view of the world which agrees over the entire range where things have already been observed, but disagrees somewhere else, you have made a great discovery. It is very nearly impossible, but not quite...¹¹

The way in which such new theories take shape in practice is very well illustrated by a diagram from one of Einstein's letters (quoted by H. Pagels¹²):



The physicist moves in the world of experience: thanks to his experiments he is in possession of some measurements. When these measurements do not answer to the laws of conventional physics, it is quite possible that he makes a completely intuitive leap from experience (concrete) to an absolute postulate (abstract). This absolute postulate can then be tested (verified or falsified) for its validity (veracity) by a number of experi-

¹⁰ W. HEISENBERG, *Across the Frontiers*, New York 1974; quoted in G. ZUKAV, *op. cit.*, p. 229.

¹¹ R. FEYNMAN, *The Character of Physical Law*, Cambridge (Mass.) 1967; quoted in J. GRIBBIN, *op. cit.*, p. 275.

¹² H. PAGELS, *op. cit.*, p. 57.

ments which can yield a definitive answer regarding the correctness of the theoretical deductions from the absolute postulate. It is obvious that the positivist method is not in itself sufficient to explain scientific creativity: the intuitive leap goes beyond experience. This is very clearly the case with Einstein's principle of equivalence: the coordination of gravity = geometry (absolute postulate) cannot itself be observed, yet the deviation in Mercurius' orbit (theoretical deduction, verified by experiment) does offer a confirmation of the equivalence.

Pagel's description of physicists as »conservative revolutionaries« is particularly apt, for they only abandon the tried and tested theories when absolutely forced to do so by the weight of experimental proofs. Werner Heisenberg had the following to say:

»Modern theory did not arise from revolutionary ideas which have been, so to speak, introduced into the exact sciences from without. On the contrary, they have forced their way into research which was attempting consistently to carry out the program of classical physics — they arise out of its very nature.«¹³

Only when it became apparent that quantum theory was totally incompatible with existing physics (during the chaos of the mid-twenties) was the need felt for a new »absolute postulate« which was very shortly created (the Copenhagen interpretation). Up until then all possible means were resorted to force the new data into the strait jacket of Newtonian physics, an approach that was doomed from the start.

As a result of the developments (in twentieth century physics) described above, physics quite clearly acquired a new status. Newtonian physics, with its vision of the world as a clockwork in which the wheels function independently of human beings (who can at most try to fathom the mechanism) by a causal-mechanical device, did claim to describe reality as it really was. By means of a few universal physical laws classical physics was able to describe this wheel-work and thus — from its on point of view — the whole of reality. Forecasts which turned out to be correct (with enormous application potential) on the basis of these laws of physics confirmed to a large extent this deterministic word-view. One thinks about physics totally different *after* the quantum revolution, however. Physical laws are no longer descriptions of how reality in fact is, but rather are theoretical models created by the human mind which attempt as accurately as possible to channel our experience of reality. The only requirements are that they must be logically consistent (we must stick to the rules of the game we ourselves have determined), and that they must correspond to our experience of the world (not with »the world«). A physical system is thus one of the possible ways of explaining the data of experience intrinsically consistently (in this regard it is striking how rationality receives a totally different content, yet — fortunately — re-

¹³ Quoted in H. PAGELS, *op. cit.*, p. 67.

mains the stuff and goal of scientific inquiry). Gary Zukav put it as follows (in connection with the ontological status of virtual photons, but also applicable to the whole field of physics):

»Virtual photons, even if they are only loaded particles, due to their extremely short life-span, cannot be rendered visible in a cloud chamber. Their existence is deduced mathematically. For that reason this extraordinary theory that particles exert pressure by exchanging other particles, is quite clearly a »free creation« of the human spirit. There is no intrinsic necessity which would dictate that nature should be so, it is only a cautious mental construct which manages to correctly forecast the way in which nature will probably behave. There are other mental constructs theoretically possible, indeed they may be able to do the job just as well or even better (even though the physicists have not yet come up with them). The only thing that can be stated about these or other theories is not whether or not they are »true« but only whether or not they actually work; i.e. they fulfill what is required of them.«¹⁴

B. Correspondences between mutations in the fields of physics and musical systems

It is worth recalling that it is not the purpose of the present monograph to make an in-depth comparison between the insights produced by theoretical physics and music theory during the first half of the twentieth century. The only thing we wish to investigate is whether or not the same angle on reality (»world-view«) might lie at the origin of two otherwise totally autonomous, independent developments in theoretical physics and the theory and practice of musical composition: the fact that the »foundational principles« (those which determine the structure of our observation and reflexion) in these two areas seem very similar during the same period does lead us to suspect a historico-cultural connection. In is our conviction that there are three facts of cardinal importance to be noted in this regard. Indeterminism, the reevaluation of human creativity and epistemological relativism are to be found in both modern physics and the modern musical systems (atonality and dodecaphony): they determine the character and outlook of these systems in a crucial way. Where music is concerned this is apparent in the disappearance of determinism in the musical system (1), musical systems as »free creations« of the human spirit (2) and a pluralism integral to these same systems (3). This classification corresponds only partially (only thus where the 3-subsections are concerned) to the three-part structure of the foregoing section. In our discussion of the repeal of determinism in the theory of musical systems, reference will be made principally to our discussion of quantum

¹⁴ G. ZUKAV, *op. cit.*, p. 263.

physics, and where the relationship between composer (theoretician) — musical system is concerned, reference will be made to our over-views of relativity theory (special and general) as well as of quantum physics. In that way they can function as points of comparison.

1. The disappearance of determinism from musical systems

In many respects the determinism inherent in tonality theory reflects the determinism in classical physics. In order to corroborate this assertion it is essential to investigate first to what extent tonality can be considered a deterministic theory. This can best be done by examining more closely the theory's central thesis: tonality is an in-built type of order which, on the basis of the nature of the material being used (i.e. tones) is unavoidable. Due to the fact that in music tones are employed which possess a certain overtone structure (cause), then in every individual composition account will necessarily have to be taken of that overtone structure (consequence). The very fact that the tonality is integral to the tonal material makes it an ontological necessity. The principal elements of the determinist approach can be summed up in a nutshell: the principle of causality, necessity and an unchangeable system. Furthermore there is an evident parallelism with Newtonian physics, given that in both cases universal laws are derived from (experimentally established and measured) natural phenomena. In music too »naturalness« was the guarantee for the epistemological validity of the theory from the empirical-inductive point of view (the physical properties [of one tone] demonstrated by experiment determine the totality of the music) and the logical-deductive point of view (every musical operation is valid in so far as it is a formal analogous derivative of the tonal principle): tonality derived its »truth value« from its substantial and formal correspondence with Newtonian physics.

Without pretending to an exhaustive treatment of the matter, it is important to demonstrate in somewhat more specific terms the deterministic character of tonal theory by exploring one or two basic concepts at greater length. Tonal music is characterised by the presence of a central tone, to which all other tones are subordinated in a fixed hierarchy. The fact that this tonic is also known as the »ground-note« demonstrates that the principle of gravity plays a certain role. In the hermeneutics of tonality, every other tone (than the tonic) is considered to be an overtone of the tonic. Given that this tonic remains the lowest tone (ground-note), all the other tones gravitate »in a natural way« towards this fundamental tone, depending on their localization in the overtone spectrum (decisive for the strength of the gravity pull). The »weightiest« interval is the fifth (the first non-identical overtone) and the tonal theoreticians have based the mechanism of functionality upon it. According to this school of thought music possesses only three functions: in addition to the tonic (the hierarchical middle point) the dominant and the subdominant (a fifth higher and a fifth lower than the tonic respectively) govern all music. Every chord can be reduced to one of these three principal functions (or to one

of their subordinate substitutes) by establishing the chord's root, to which all notes in the chord gravitate »in a natural way«. The tonal clockwork functions perfectly so long as the laws of cause and effect are taken into account for the succession of chords.

The foregoing paragraph contained a very rough sketch of the theory of tonality (according to its own hermeneutics). In any case this study treats of a period in which this theory can scarcely be considered the predominant paradigm. Only one aspect of tonal hermeneutics is of immediate interest here because of its quite remarkable parallelism with Newtonian physics, i.e. the unchangeable character of tonality. Given that the raw material used in making music (tones) is grounded in nature according to these musical theorists, tonality — even when we imagine, hear or write as much as one single tone — is a law of natural necessity. As a »law of physics« it falls completely outside the human will or creativity: tonality would exist as a physical law totally independently of man. Such a theory is permeated by the mechanical world-view of Newtonian physics in which man can do nothing more than take note of the physical world's unchanging character. Deterministic physical laws (tonality-laws) would thus explain how the world (music) functions. The enormous developments in tonal harmony during the nineteenth or twentieth centuries ought not, according to these theorists, call into question the unchanging, a priori existence of tonality: just like Einstein's theory of relativity in the realm of physics, the extension of tonality could be interpreted as the ultimate confirmation of physical determinism (albeit not without difficulty in either case).

In contrast with his tonal colleague, the atonal composer works with a collection of pitches in which relationships and meanings are not fixed prior to the activity of composition. In both the so-called free atonality as in dodecaphony the composer arranges the tones completely autonomously (in the first case formally and contents-wise, in the latter case contents-wise: the system-thrust is, through the conception of the series, created by the composer himself: in both cases, each composition strictly speaking represents a unique musical system). The approach he adopts is determined by the aesthetic effect he wishes the composition in question to have. Laws of composition are purely internal to a particular work: they flow forth from the options taken by the composer in the arrangement of his material. In quantum physics too external determinism and causality were toppled. The description of reality in terms of probability represented the triumph of ontological indeterminism over the mechanical determinism of classical physics. And yet we must resist the temptation to transplant the idea of probability from modern physics to modern music. While it is true that the phenomenon of aleatory music is not unimportant, to begin with it falls outside the terms of reference of this study (aleatoric music strictly speaking only came into existence in the second half of the twentieth century), and moreover it would be a dangerous basis for comparison given the concrete nature of the factors to be com-

pared. (Not that we believe abstraction *per se* to be a quality, yet for this type of research — as has already been said — the greatest prudence is advisable: Born's probability waves disown the determinism of classical physics, while aleatoric music in no way represents a reaction to the determinism of classical tonality.) It would be all too easy to claim that there was no connection whatever between musical atonality and physical probability because in the former no direct traces of the latter are found. The notion of »probability« has had the wavering of determinism as first and foremost consequence in quantum physics. It is in this regard that we see an affinity, a similarity between the two. Regardless of whether we are concerned with a physical system or a musical system, the potential existence of non-determinist systems has been established. To sum up, we can conclude that quantum physics and atonality share an indeterministic rationale. This indeterminism was positively affirmed in modern physics in the principle of probability, while in atonal music it was confined to the disappearance of external determinism (tonality).

2. Musical systems as »free creations« of the human spirit

The realization that the observing subject does not stand outside the system observed created a veritable revolution in the »positive« sciences. The positivist principle of objectivity was undermined in two stages: firstly, Einstein demonstrated in his special and general theories of relativity that the position of the observer did in fact effect measurement results (even though, by a masterly stroke, Einstein was able to »smooth out« the location of the observer in a particular reference system in the hypothetical supra-reference system which was known as »reality« in classical physics); secondly, the Copenhagen interpretation sounded the death knell for the supposed neutrality in the relationship between the observing subject and the observed object. Heisenberg's uncertainty principle and Bohr's principle of complementarity (two important components of the Copenhagen interpretation) demonstrate not only that a form of interaction exists between the observer and the system of observation, they imply furthermore that the observer to a certain extent creates reality. Prior to discussing what is in our view a clear parallelism with modern opinions regarding the musical system (and its exemplary embodiment in atonality), it is essential to analyse again very clearly the terms in which the comparison will be made. The Copenhagen interpretation is primarily a hypothesis whose field of application is the micro level of quantum reality. From the logical and empirical standpoint this hypothesis functioned extremely efficiently in the description of micro processes. Newtonian physics too was characterised by a large degree of internal consistency, empirical verifiability and practical applicability. The fact that both physical systems are valid implies that reality is not to be completely captured under one hold-all net, and suggests that in principle at least man has the capacity to develop systems which are capable of furnishing a

pragmatic description of reality which is also theoretically correct. It follows from this insight that Newtonian physics is no longer the codification of how reality really is, but only a particular human approach (one of many possible ones) to reality. One could go on to point out the fundamental difference between macro and micro reality and thus indirectly make a case for a theoretical and ontological division of the inventory. It has, however, become apparent that, where the quantum processes turned out in experimental conditions to be in contradiction to the supposed universal laws of classical physics, these latter could be integrated into quantum physics as a special case, so that quantum physics can be taken as a more comprehensive paradigm thanks to its greater range of application.

In the first half of the twentieth century the idea gained currency that in music too a system was not so much a physical reality and an eternal universally valid law, but rather one of the possible devices used by man to impose order on external reality. This idea works in music much the same way as it does in physics: on the level of the classical theories (an altered perspective on the status of Newtonian physics and tonality respectively), as well as on the level of the new systematic approaches (quantum physics and atonality respectively). Where tonality is concerned this means that its objective reality outside the mind of the observer was called in question. Such fundamental components of tonality as the concepts of ground-note, centrality, functional mechanism, intonational system, consonance-dissonance, scale etc. are not qualities present in nature (of tone) which the composer merely takes for granted. Composers and music theorists are anything but neutral observers who »objectively« and slavishly follow laws of nature. They are rather creative spirits who decide for themselves what tonal material they will use (Pythagorean, »just«, equal tempered 12-, or other intonations), who themselves define the tonal relationships (orientation towards a fundamental tone, functionality), who themselves distinguish between consonant and dissonant chords etc. The options they take spring from exclusively pragmatic considerations: the arrangement which allows for the greatest possible aesthetic efficiency is automatically the best. Alternative compositional intentions can require alternative forms of arrangement or systems (»manners of approach to musical reality«), and this is precisely what occurred in the first half of the twentieth century. If we were to sum up the parallelism between the conceptions which modern physics and modern music have of the Newtonian laws of physics and laws of tonality respectively we could observe that in both cases we are dealing with a system evaluation which stresses the human (rather than the natural) origin on the one hand, and relativity (rather than the absolute truth) on the other. The points of contact which the old physical and musical systems had with physical reality now represent but one vantage point from which to systematize reality, and this latter systematization can never claim to function as the key to all reality.

In the field of music the counterparts of quantum physics were atonality and dodecaphony: not only did these three theories endure and act as catalysts for a reinterpretation of the classical systems (see above), they also embodied an alternative for them. In our view atonality and dodecaphony are from both the theoretical and practical standpoints ideal applications of the maxim found in the Copenhagen interpretation of quantum physics, namely that the human subject chooses a certain reality and by this very fact creates this reality: the composer chooses the tone-relationships which are meaningful, and on that basis alone produces meaningful compositions. Pure or free atonality offers him no methodological foothold whatever to assist him. The atonal composer only has at his disposal a limited number of tones (in the Western European musical tradition usually twelve; sometimes more, sometimes too deliberately less; where the number of tones actually does have an influence on the final sound produced, the quantity is quite irrelevant where this theoretical model for musical systematics is concerned) which are not remotely connected. It is up to him to organize this material step by step *ex nihilo*. There is quite simply no atonal theory which determines the manner in which he must proceed nor the logical order he ought to follow. For example the atonal composer can first construct chords and then define their connection: this preliminary study signifies neither more nor less than the creation of a harmonic system; he can string tones melodically into motifs or themes with a constructive and expressive value (the intervals used can be the same as those which occur in the chord construction, yet they can just as easily be different); he can also conceive the relation of melodic intervals in such a way that the musical significance comes into being largely on the basis of the interaction between super-imposed melodies etc. It is a fact, however, that once he has made a particular choice, this has a direct impact on the further shaping of the piece: internal consistency is required as much in aesthetics as it is in science. When the foregoing is compared with the genesis and functioning of the Copenhagen interpretation (summed up in a nutshell in subsection A2) a whole series of very specific and detailed common features can be noted. So as not to lose sight of the principal thrust of this whole study, it is best to ascetically desist from further consideration of these common features and confine ourselves to observing that the same general ideas function as a paradigm in quantum physics and atonality, the most significant being that of the conferment of meaning by the human subject.

Where its basic principles are concerned dodecaphony has a great deal in common with quantum theory generally and the Copenhagen interpretation in particular. With its potential value as a system it has to be considered, just like free atonality, as a »free creation« of the human spirit. The dodecaphonic composer defines the musical system with which he will work by conceiving an arrangement of intervals between the twelve chromatic tones. This initial arrangement in the form of a series is of paramount importance: a selection is thereby made not only of the

melodic and contrapuntal relationships of the composition, but also of the harmonic relationships (anyone who has ever laid eyes on Alban Berg's sketches for *Lulu* knows that research into the harmonic implications and qualities of a 12-tone series in its preliminary stages can grow into a coherent and highly differentiated »harmonic theory« in the strict sense of the word). The difference between pure atonality and dodecaphony therefore is that in the case of the latter one is in possession of a technique which can regulate the organic connection of the pitches at all levels at the same time. When due account is taken of the totality of intervals in the basic series, the same series can be used in a wide variety of different guises, while the internal connection nevertheless remains intact. In free atonality the pre-structuring is less far-reaching, with the result that the technique and pattern of composition is less neatly circumscribed (one proceeds more in step by step fashion). The strait jacket imposed by the system is less in dodecaphony than for example in the case of tonality (with its set chord progressions and tonal connections). Furthermore, there is an essential qualitative difference between the restriction imposed by the system in the case of tonality and that of dodecaphony: the former is uniform in contents and, if one is to believe the claims of the orthodox tonal theorists, imposed from outside: the latter is created anew in a different form by the composer for each new musical composition. Just like the quantum physicist, the dodecaphonic composer makes choices which involve the very being of reality and elaborates his options in a consistent and pragmatic fashion.

According to the prevailing twentieth century view musical systems, like scientific systems, depend on the »position of the observer« (the factor of which increasing account was taken in the recent history of physics, from Einstein's theory of relativity up to the Copenhagen interpretation), because they are not something existing outside the composer (their mechanism does not need to be »objectively« observed and imitated), but rather are created by him. In atonality and dodecaphony it is entirely up to the composer how he is to create connection, relationships, meaning and aesthetic significance (or whatever one cares to call it) between the tones. On him falls the weighty responsibility of doing this from scratch in each new composition he produces. It has often been pointed out how modern physics' discovery of indeterminism in the quantum world made human freedom possible once again. This same human freedom is also markedly present in a music, in which the composer is continually obliged to take decisions on the systematic level.

3. Pluralism in musical systems

The observations made in the preceding section (A) concerning the epistemological status of physics can, thanks to their formal disposition, be applied almost literally to an assessment of musical systems. A first point of agreement is the admission of the interregnum between two paradigms. In the world of music too the genesis of a new system is a

precarious undertaking indeed because the new forms are on the one hand determined by but also at variance with the old system, while on the other they give but faint hints of the embryonic new system. The transition from tonality to atonality in particular caused great chaos (at least for a time). The extended tonality and a good deal of the early atonality were on the one hand founded on tonal principles, yet a whole series of compositional problems did not admit of solutions along the lines of traditional tonality. In much the same way as John Gribbin described the transition from Newtonian to quantum physics (see quote p. 13), one can also view extended tonality and early atonality as »inspired guessing« at the basic principles of a provisionally inconsistent and partially dependent new theory (still sponging on the old system).

Tonality's long lease of life — much like the persistence of classical physics — is doubtless explained by the successful artistic (and in the case of physics, scientific) effects which have been achieved by its application. It is not easy to let go of a musical system in which masterpieces of indescribable beauty have been produced for centuries, nor is it easy to abandon a theory which was believed to be as absolutely true as a law of nature, just as it was no easy task to jettison a system of physics which from time immemorial had offered an explanation of all reality and, through its practical application, had rendered incalculable services to humanity. When a system's time is up, when it has had its innings, when new phenomena raise their heads and cannot be either understood or treated by the old theory (quantum processes in physics, atonality in music), it is high time for a handful of creative people to branch out from the well-trodden paths and search for a new system, for a new perspective on reality which appears capable of incorporating the new modes of experience and experiential data. The quotation in which Heisenberg articulated the despair of the physicists when confronted with such a task (see above p. 13—14) is nicely matched by the following texts (on the mutation of musical systems):

»... da waren Hemmungen der fürchterlichsten Art zu überwinden, eine Angst: 'ist denn das möglich'.«

(Anton Webern concerning the period between Schoenberg's opus 11 and the creation of dodecaphony)¹⁵

»Nur Meister dürfen niemals alles schreiben, sondern müssen das Notwendige tun: ihre Aufgabe erfüllen. Auf die sich vorzubereiten, mit allem Fleiss, unter tausend Zweifeln, ob man ausreicht, mit tausend Skrupeln, ob man recht verstanden, was eine höhere Macht aufträgt: das ist denen vorbehalten, die den Mut und Inbrust haben, die Konsequenzen zu tragen, wie die Last, die ihnen gegen ihren

¹⁵ A. WEBERN, *Der Weg zur neuen Musik*, ed. by W. REICH, Vienna 1960, p. 48.

Willen aufgebürdet wurde. Das ist weit entfernt von dem Mutwillen einer Richtung. Und kühner.«

(Arnold Schoenberg)¹⁶

»Once in the army, I was asked if I was really the composer A. S. 'Somebody had to be', I said, 'and nobody else wanted to, so I took it on myself'. Perhaps I too had to say things — unpopular things, it seems — that had to be said.«

(Arnold Schoenberg)¹⁷

The unpopularity alluded to by Schoenberg in the last citation was also the lot of innovative systems in the domain of physics, yet to a much lesser degree. It is apparently easier for the public at large to appreciate laser technology (and the quantum theory on which it is based) than the aesthetic value of a work such as *Moses und Aron* (and the dodecaphony on which it is based). It is in any case the efficiency of the new systems which will ultimately decide whether they are accepted or rejected.

Hein Pagel's labelling of physicists as »conservative revolutionaries« (see above p. 15, and also the Heisenberg quotation on the same page) sounds familiar to those who study the mutations of musical systems during the first half of the twentieth century. Schoenberg for example emphatically rejected the label »revolutionary« for his contribution to music as a theoretist and composer, and stressed again and again how one step flowed so naturally from the preceding one (thus evolution instead of revolution). A famous monograph devoted to the composer was even entitled *Schönberg oder der konservative Revolutionär*¹⁸. He was conservative to the extent that any innovation he pioneered was based on the old system: the whole development of tonal harmony in the nineteenth and early twentieth centuries bears witness to the fact that this system was destroying itself. Every extension, every deviation is motivated by the tonal principle itself. The intrinsic, inbuilt lack of restraint in this tonal dynamic led finally to outright jetisoning of the tonal system. Atonality is accordingly not at all a new musical system that came into being alongside tonality, but rather one which emerged as a result of »consequent implementation« of tonality. We need only refer back to the quotation from Werner Heisenberg (p. 15 to see that the relationship between modern physics and classical physics is identical to that in the domain of music.

Before drawing general conclusions from all the foregoing, it is essential to consider briefly a subject which has very important implications for the epistemological status of a musical system (in the modern sense

¹⁶ A. SCHÖNBERG, *Harmonielehre*, reprint 1923, Vienna 1966, p. 487.

¹⁷ A. SCHOENBERG, *Letters*, ed. by E. STEIN, transl. by E. WILKINS and F. KAISER, London 1974, p. 290.

¹⁸ W. REICH, *Schönberg oder der konservative Revolutionär*, Vienna 1969.

of that term). It has already been seen how the old conception of a musical system was characterized by a high degree of determinism: tonality was unavoidably present even when one single tone was sounded. The human subject (the composer) is completely outside this mechanism. The only thing he can do is draw up a theorem in which the physical and acoustic laws are described as accurately as possible. The composer was guaranteed a meaningful musical arrangement so long as he followed the laws of tonality, because they were regarded as the description (codification) of how sonorous reality as a whole really is, always has been and always will be. Just as in Newtonian physics, the following of these laws of nature in tonal music led to quite incredible practical applications (in the area of music they took the form of imperishable masterpieces). In the meantime beautiful works have been composed in atonality and dodecaphony too, and this fact combined with the idiosyncratic working method described in the preceding paragraphs has led to a completely new view of the epistemological status of a musical system. A musical system is no more a description of how reality really is than is a system in physics, but rather a theoretical model conceived by the composer (theorist) the only aim of which is to make it possible to compose music that achieves some sort of aesthetic effect. The model will help to enable (and even stimulate) the composer to inject an element of consistency into his work, although it must not become too much of a strait jacket for the composer's creative genius. Viewed in this way — and knowing that relationships between tones only exist thanks to the composer's grasp of arrangement — it comes as no surprise that a wide plurality of musical systems is the order of the day: the composer creates the model (musical system) best suited to achieving the musical (aesthetic) objective of a particular work, and perhaps creates another model for a subsequent composition. This variability is, in an absolute sense, a feature of atonality (an atonal work can be structured in an infinity of different ways, none of which can be exhaustively described by the term »atonal«), and is also a feature of dodecaphony: in the case of the latter structural pluriformity was in a certain way built in into the musical system itself (where their basic technique is concerned dodecaphonic compositions are cast in a uniform mould i.e. there is a formal similarity, yet this basic technique allows for an innumerable quantity of different structurings, i.e. in concert cases, a diversity *qua* contents). The ultimate theoretical truth of all these models (musical systems) is, in this regard, of no great importance. It might even be claimed that *not one single* theory of musical systems is completely correct: regardless of whether we take tonality, extended tonality, the various guises taken by atonality or dodecaphony, none of these theories offers the key to all musical phenomena (not even those within the compass of their »own« musical system), and all of these theories internally have serious shortcomings. This theoretical imperfection is, however, totally irrelevant: as long as it was possible (or is possible) to produce aesthetically valuable compositions on the basis of these musi-

cal systems, then their existence is more than justified. Also where the epistemological status of the systems is concerned, there seems to be a congruence between modern physics and modern musical theory.

Conclusion

An intrinsic pluriformity of the systems in both music and physics is at once cause and effect of the epistemological status of these systems. What are the consequences for our contemporary world-view? On the one hand this research has revealed very essential similarities between two such diverse fields of human endeavour as physics and music (which seems to suggest a common »perspective on reality«), yet on the other hand one can legitimately ask whether in a case of such pluriformity (which seems to be necessitated by the predispositions of each system) one can still speak of a »world-view«? Up to now a world-view has always been characterized by a uniformity of its points of departure *and* a homogeneity in the cultural products derived from them. In the Pythagorean world-view, for example, the doctrine of proportionality of numbers (for which the »organon« of music had such epistemological importance) penetrated various different domains of knowledge such as astronomy, musical theory, psychology, medicine etc., and also became the basis for all forms of artistic creativity. A world-view actually does more than impregnate these cultural expressions: it provides the foundation for all forms of human activity and endeavour. For that very reason any breach made in the homogeneity of a world-view enduces a hue and cry about the lack of unity and sense in a particular culture. The finger is pointed at our twentieth century culture in particular: the existence of cultures sharply divided from one another side by side, of nihilism, of materialism and particularly of subjectivism are all seen as symptoms of the disintegration (i.e. the absence of a coherent world-view) of western civilization in the present stage of its development. It is our view, however, that beyond the superficial disharmony there does exist a world-view in our culture and that furthermore it is characterized by a high degree of homogeneity. When it comes to recognizing this world-view it is important that we confine ourselves to the foundational principles of our culture without wishing to see all the concrete cultural expressions rooted in one single vision of reality. In other words we must accept that we only possess a homogeneous world-view at a »formal« level, while it is contentswise enormously diverse and can find expression in a wide variety of ways. An attempt has been made in the present study to demonstrate this on the basis of a comparison between the conceptualization of systems in modern physics and modern music. Basic assumptions which buttressed and oriented these systems in their entirety appeared to be amazingly similar for both areas (indeterminism, the system produced by the human creation of meaning, the epistemological status). These principles necessarily imply a pluriformity of con-

tents. We now realize that there are a variety of geometries (Euclidian, non-Euclidian), of logics (Boolean logic, quantum logic), of mechanics (Newtonian, relativistic, quantum) all of which are valid, and that there are a variety of musical systems (tonalities, atonalities with their characteristic openness, dodecaphonies with their institutionalized plurality at the musical system-level) which can all be used as vehicles of composition: all these systems are created by man and tolerated by reality. It may well be for this reason that the metaphor of a work of art is employed so often to describe the world-view of contemporary culture: never before has a world-view as homogeneous and all-embracing as ours been linked in such a »harmonic« way with human creativity and freedom.

(translated by Dr. P. H. Daly)

Sažetak**MUTACIJE U SISTEMIMA U PRIRODNIM ZNANOSTIMA I GLAZBI U PRVOJ POLOVINI 20. STOLJEĆA**

Ovom se studijom pokazuje da su formiranje i vrijednosna procjena sistema u fizici i glazbi 20. stoljeća potaknuti istim operativnim načelima i uvidima. Ova kulturno-povijesna veza između dvaju tako različitih područja kao što su fizika i glazba, osobito s obzirom na visok stupanj sličnosti, dopušta nam govoriti o novom svjetonazoru. Ovaj novi svjetonazor 20. stoljeća, što nije slučaj s njegovim prethodnicima, ne proširuje se na sadržaje plodova čovjekovih kulturnih nastojanja (područja u kojem vlada najveća moguća višefornost), nego se nužno ograničuje na formalnu homogenost kao rezultat ontološko-epistemološkog statusa sistematičnosti. Glazba je uvijek bila povlaštenom metaforom za artikuliranje svjetonazora, a to se pokazuje istinitim i za glazbu u okviru kulture 20. stoljeća. Suvremena paradigma jednako je tako lijepa kao primjerice i ona Pitagorina ili Keplerova, a jednako je tako i prolazna.