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THE ESTHETICS OF NON-CLASSICAL SCIENCE

I. The Esthetic Comprehension of the World

The theory of beauty has always rested on the representation of the infinite, understood in its finite expression and perceptible through the senses. The relationship of beauty to truth, of art to science, is inevitably modified with the new way of treating the infinite in the modern conception of the world. Non-classical science works with the notions of "infinitely large" and "infinitely small," modifying their meanings in terms of experimental observations. We put these words in quotation marks because the *Whole* may be considered as finite or infinite according to the angle from which it is viewed: the "infinitely small" only becomes so in determined circumstances, for example, when we consider the extended and discrete elements of space and time in a macroscopic approximation, as infinitely small elements of perpetual motion. Modern science studies these two poles of being—the *Whole* and its *parts*—in their interaction, admitting the dependence of macroscopic and even cosmic processes with

Translated by Jeanne Ferguson.

https://doi.org/10.1177/039219218102911505 Published online by Cambridge University Press

regard to the processes being created in infinitely small spheres (or, according to another interpretation, finite but extremely small). However, as characteristic of our time as these concepts are—most often hypothetical—they nonetheless express a very old historical tradition that contemporary retrospection, turned toward classical science and the past of science in general, allows us to discern very clearly. All the culture of the past was dominated by the principle of the authority of the *Whole* over its parts. In peripatetic cosmology and physics, individual processes depended on the cosmic harmony of the center and frontiers of the universe, on the spheres and places toward which bodies tend. This authority of the general law, of universal harmony, of the system hinging on individual processes, is confirmed in Aristotle's *Physics*, but not only there: we find it in almost all the thinkers of antiquity. On the plane of general logic, it received expression in the Hegelian concept of the *true infinite*, a concept constituting to a high degree the philosophical equivalent of classical science. In Hegel's time, this last was already drawing away somewhat from the idea of an absolute and strict subordination of elementary processes to integrating systems and general laws, laws being realized through the probability of microprocesses, thus statistical laws, and whose exact application ignored individual acts, for example, the mechanism of molecules in thermodynamics. The statistical theory of heat has rendered continual a discrete microcosm—for the movement of individual molecules it substituted the average speed of the molecules—and continual laws became supreme points determining macroscopic processes. These laws had a differential nature. In other words, they prescribed the defined relationships between the infinitely small increases in size. Also, the schema of the classic law consisted in defining infinitely small processes by an infinitely large integral legality because of the number of processes. The *infinitely true* of Hegel is the actual infinite being realized in each of its finite elements; it is the subjection of the finite element to the infinite.

To this dominant tendency was opposed another, contrary one. In antique and medieval cultures, and even more in Renaissance and modern culture, the idea was affirmed of the autonomy of the finite element with regard to the infinite multitude. This

tendency extended to the entire culture. Much more, it received its first impetus in the domain of the study of man. When Epicurus advanced his theory of *clinamen*—spontaneous splitting-off of atoms from the rectilinear trajectories that are prescribed to them by law—he tried to free men from the "authority of the physicists," more burdensome in his opinion than that of the gods. All the history of knowledge, from antiquity to the present, may be presented as the struggle between these two opposing tendencies. This struggle broke out of the framework of scientific knowledge; art participated in it and in certain periods became the principle arena. Art restored the autonomy and uniqueness of the Sensus and its object—the extended elements of the world; it defended them against the authoritarian claims of the Logos and its infinite constructions.

What did modern, non-classical science contribute to this struggle?

First of all, it sensualized the infinite, it made of the *Whole* not only an object of logical constructions but also an object of empirical knowledge, and it transformed empirical data into criteria allowing the term "infinite" to be accorded to the *Whole.* It modified logical constructions and norms that were themselves considered to be the autonomous conditions of knowledge, when they were in fact its results. The idea itself of variable logical norms, of what has been called metalogical transformation, is not a generalization of non-classical science. In fact, each scientific revolution is accompanied by similar transformations, but modern science has made this an *obvious* element of scientific knowledge. Here we clearly see the characteristic trait of the analysis of modern science and the epistemological effect of this science. This analysis is not based solely on the idea of a total universe but extends to the past and the future of science and obliges us to see in contemporary science the summation and generalization of the entire history of science and its future prospects.

Retrospection brings about the appearance of a rapport between scientific revolutions and the esthetic knowledge of the world. The link connecting the two is the notion of metalogical passages, passages that are one of the principle definitions of scientific revolutions. In the perspective of a given logic, the

choice of a new logic seems free. In reality, the metalogical passage is determined, but it is determined by the integral law, connecting the integral *before here-and-now* and the integral *after here-and-now,* which brings to mind the moment Mozart spoke of "in which the composer hears the symphony that he has not yet written." What occurs then is an inevitable break in the chain of unequivocal deductions of a judgement with regard to the one that preceded it. At the moment of these metalogical ruptures, there is an intuitive comprehension of the infinite. Now, it is precisely in this intuitive comprehension of the infinite —what is called "illumination"—that the essence of the beautiful resides. There is no better definition of a work of art than the remark we have just quoted concerning the moment in which the composer hears all at once the entire symphony he has not yet composed. When a thinker passes to a new logic, he lets himself be guided by the intuitive representation of the internal perfection of that logic. Therefore, the instantaneous nature of the intellectual process, that intuition not yet analyzed in differential equations and that for the moment only grasps the advantages of the new logic, creates the poetry of logic and allies it to music in which, according to Leibnitz, "the soul is already calculating without knowing it."

Now, let us reverse the problem and look, no longer for poetry in logic but for logic in poetry. Does this not resemble the performance—apparently not too pleasant—of which Pushkin accused Salieri: "I have confided harmony to algebra"? Is poetry going to preserve its Mozartian soul?

What must be understood is that Salieri's algebra was an already-established algebra, with definite invariants, and which, endowed with a geometric form could have been inscribed in the series of Kleinian, Erlangian geometries. Let us recall that in 1872 Felix Klein, in his course at the University of Erlangen, set up a hierarchy of continually more radical transformations and, hence, of continually more general geometries, each being defined by its invariant: for metric geometry, distance; for topology, the number of dimensions... However, those were transformations of reasoning. Now, if we recall the classic opposition between reason and understanding, we see that the transformations of understanding consist of passing from one algebra to

another, from one geometry to another, from one logic to another: such transformations are non-Erlangian transformations.

Classical science itself knew transformations of this type, but in non-classical physics the transformation of the law in its local application became particularly evident. The initial physical principles, mathematical axioms and logical laws are transformed.

What are the invariants of these radical, non-Erlangian transformations? They are the inevitable collisions, paradoxes, contradictions and processes that each period directs to the following one. These invariants cause the sentiment of the symphony that is not yet written to be born in the human soul, and it is this stirring in the soul, at the same time emotional and intellectual, that constitutes fundamental poetry and has received the name of inspiration. The moment in which the unwritten symphony is heard is the moment in which, somehow, the infinite coalesces, in which the entire eventual series of new events, sensations and ideas unrolls. It is the infinity of the *extra here-and-now* that becomes visible in the local *here-and-now*.

Properly speaking, poetry itself may be considered as a transformation. In the poet's work are blended innumerable statements, generalizations and emotions that take on the aspect of a definite system of words—a system that is phonetically, metrically and semantically arranged. This is what makes poetry the most general definition of the esthetic effect of the Logos, of knowledge and of scientific deduction. Poetry is just as emotional as music, but it uses words, that is, the universal means of generalization, systematization and logic. This ambivalence of poetry allows us to see a logic in it that is not a hindrance to the emotional effect but engenders it. The system of words—semantically, phonetically and metrically arranged—must arouse in the soul of the reader the same emotional effect that determined it in the soul of the poet. In this is found the invariant of poetic creation, of this transformation of ideas, sentiments and psychological states into a system of words and the ulterior transformation of the system of words into an ensemble of ideas, sentiments and states of mind. Only, these metamorphoses of states of mind into words and of words into states of mind are not aligned on any determined logic; they do not enter into Salieri's algebra. Therefore, looking for the logic of poetry, we

come back to the poetry of logic; poetry as transformation creates metalogical ruptures in logical deductions.

These metalogical ruptures reveal the nature of the cognitive function of art, its gnoseological value. We are referring to the poetry of knowledge but less to the esthetic effect of knowledge than to the gnoseological effect of poetry. We envisage poetry less as an artistic genre than as a general trait of art. Nevertheless, in poetry as a genre, the double nature of art—logical and conceptual, as well as emotional—is revealed in a particularly clear way.

II. Classical Science and Classical Poetry

In classical science, the foundation of knowledge is no longer the immobile harmony of being but its dynamic harmony: the emphasis passes from the integral system of the world to the differential elements of this world, to its *here-and-now* events. Classical science worked this change in perspective by relying on antique tradition, which was recalled in the 14th to 17th centuries, that is, throughout the entire period encompassing the historical origins of classical science and Renaissance culture, as well as in the prologue of the proto-Renaissance. In its representations of nature and the methods it applied to the study of nature, this period gained distinction through a return to the esthetic comprehension of the world, characteristic of antique culture, which explains why we may illustrate the epistemological role of poetry by referring, to begin with, to antique models. We abide by Lucretius and his presentation of the Epicurean philosophy in the poem, *De natura rerum*. The title of the work itself suffices to indicate that the poem is to be numbered among the essential links—marking a frontier between epochs—of a linear series of historical antecedents of modern science. It treats fundamental problems, to which are applied neither experimental methods nor mathematical analysis, which did not appear until several centuries later. Already, however, the idea was confirmed that the solution does not depend on references that are *a priori* to non-material principles. This is also indicated in the teaching of Epicurus, but the poetry of Lucretius is not limited to an

exposition of the teaching of Epicurus. "Measure and rhythm," wrote Lessing, "do not transform into poetry the system that is exposed in it."[1] The poem of Lucretius was a poetic presentation and poetry was, to all evidence, the essential element of scientific progress. Lucretius did not take up logical arguments, the Epicurean "canon." The poem contains visual images and artistic forms. These sensual and concrete images express the intuitive sentiment of the knowledgeability of the world, and here knowledgeability means the possibility to cause the structure of the world to appear through ideas graspable by the senses. If it had been only a matter of metrically expressing the philosophy of Epicurus, Lucretius' poetry would have been only simple versification. However, it is a matter of a description of the world through colors and sensations, with an underlying emotional content and everything that disengages essentially non-representable ideas from the system. The poetics of Lucretius, his images, his choice of epithets, the resonance itself of the rhythmic discourse, creates the sentiment of the sensual knowledgeability of the world and gives the intuitive certainty of the possibility of comprehension through the senses. According to one of the commentators on Lucretius, the distinction between the evidence of the image and the logical demonstration disappears in *De Natura Rerum*.[2]

For the Renaissance, the artistic comprehension of the world did not follow a logical apprehension, as it did in antiquity; it preceded it. The art of the proto-Renaissance, especially the *Divine Comedy*, was among the historical sources of 16th-century physio-philosophic thought. What is exciting in Dante's poem is the understanding of the structure of the world through the human spirit, although the picture remains traditional. To a certain degree, the concept itself of the work, in which the protagonist learns about the organization of inferno, purgatory and paradise through direct observation, is to be put on the same plane as the apologias, so frequent in the poem, of

[1] Lessing, *Werke*, (t.v.), Leipzig, 1911, p. 459.
[2] Ia. M. Borovskij, "Poetika dokazatel'stva ou Loukretsia," in *Loukretsij, O Prirode Vechchej*, Vol. II, Moscow, 1947, p. 205.

thought as a means to penetrate into the order of things. Dante's work, the ideas of Galileo and the notions of modern physics are situated on the same axis, that of the progressive sensualization of knowledge, of the passage to concepts having sensual equivalents. At each of these stages, this sensualization was in opposition to the leveling of the individual "being," to its absorption into the *Whole*; it made the *Whole* empirically understandable, and in this sense it long since prepared the new science.

The rapport that exists between the ideas of Galileo, upon which classic science was built, plus the poetry of knowledge and the esthetic understanding of the world, may be illustrated by Galileo's notes in the margins of *Orlando Furioso*. In these remarks, Galileo borrows Ariosto's smile, the smile that accompanies the fantastic episodes of the poem.

In fact, it is the smile that the Renaissance and modernity directed to the Middle Ages, which ceased to be the direct and active enemy and became—in spite of a counter-attack—the past. What interested Galileo was not really the content of *Orlando Furioso* but Ariosto's smile; so similar to that of Cervantes in *Don Quixote*, it was poetry destroying the rigid and immobile principles of medieval thought and associated with the intuitive prescience of the new reflection on the world and on man himself. We must point out the rather discreet, not at all evident but indubitable rapport between Ariosto's poetry and the passage to the logic of the new science—infinitely-bivalent—leading to the differential representation of movement from one point to another, from one moment to another, in other words, to a contingent universal vision of the world. This differential representation, connected to the infinitely-bivalent logic, became obvious and clear in the 18th century, but already in the 17th century, with Galileo, it had become the ideal of scientific knowledge. In the 17th century it was not yet an unequivocal and indisputable statement but a hope, a value, an emotional impulse. Galileo could not deduce his infinitely-bivalent logic from the traditional, peripatetic, bivalent logic. A metalogical rupture, a metodological passage, was needed for that and, as we have said, this kind of passage does not require logical deduction but an emotional impulse, the moment in which intuitively we grasp

the unwritten symphony—in this case, the symphony of mathematical science applied to nature, resting on the analysis of the infinitely small.

It is to such a metalogical passage that the poetics of the *Dialogue* correspond; in it esthetic criteria guarantee not only the epistemological effect of the passage but also its emotional effect.

What could Ariosto bring to Galileo? Why did Galileo pay so much attention to *Orlando Furioso*? Why do the remarks he wrote in the margins of this work seem to be an integral part of his scientific, philosophic and cultural accomplishment?

The poetics of Galileo—a poetics of logic—was motivated by Ariosto's logic—the logic of poetry. In rereading Ariosto, we perceive the sentiments that animated the poet: a luminous anticipation of the new structure of thought and a joyous irony with regard to the past. The harmonious, rational, contingently ordered world spoken of in the 17th century by Malebranche and Spinoza was still in the 15th and 16th centuries only the uncomposed symphony. It was not the result of a logic, but its condition, the premise of the metalogical passage. The logic of poetry is metalogical.

The connection between poetry and the logic of science may be further illustrated by the rapport of Schiller's poetry and esthetic ideas with Hegel's logic and esthetics. The logic of permanent and rigid norms that does not know metalogical transformations is very clearly distinguishable from the logic of Hegel, from generalization tied to the object and content of judgements, living—of developing knowledge. The path leading to this visibly non-*a priori* logic, with its clearly metalogical passages, passed not only through the official philosophy but also through the poetics of the century of German enlightenment, through the work of Lessing, Goethe and Schiller; and not only through their poetic practice, their poetry. After what we have said about the metalogical as result and condition of the poetic comprehension of the world, the present historico-philosophical and historico-cultural statement is easily explained. The esthetic comprehension of the world allows the passage from one logic to another, the transgression of a given logic: thus it is that it shows its capacity to evolve and its independence with regard to the *a priori*.

We see this role of the comprehension of the beautiful perfectly in the poetic work and esthetic concepts of Schiller. We purposely say "see" and not "illustrate." When it is a matter of the modification of logical constructions that operate at the moment of the esthetic perception of the world, we can no longer speak of schematic illustrations, since they fix the schema in an immutable form. Poetry plays an active, reconstructive role here and appears in its concreteness, which could not be related to immutable schemas. The poetics of Schiller was the inner motor of the evolution of his esthetic ideas. Initially, Schiller considered beauty as subordinated to the good, to the moral ideal. By moral ideal we intend the moral greatness of man, his submission to duty. It is a subjective ideal, and it is precisely this subjective greatness, made up of the pain of refusing nature in the name of duty, it is this tragic triumph of duty, its victory over nature, that art, tragic by nature, depicts.

However, it sometimes happens that the ideas become reconciled with being, with nature and with history. Schiller, as a consequence, places beauty on the same level as the good. Whatever had been the philosophical causes of this evolution, it undoubtedly had something to do with poetry. In *The Gods of Greece* Schiller admires the pagan beauty of the Bacchic festivals, but what we have in the work is an elegy and not a hymn: the poet was saddened by what caused the disappearance of beauty. However, the evolution of Schiller did not stop there. A year after *The Gods of Greece* appeared *The Artists*. There it was no longer a matter of the disappearance of antique beauty but an apologia for history, the creator of a new beauty. Then came the decisive step: from Kant to Goethe and later to Hegel, with his *Letters on the Aesthetic Education of Man*. Beauty was no longer subordinated to the good, it was in essence above the moral. Schiller now clearly saw the good as a vector, good was defined as *direction* in which man's activity and action are exercised. The beautiful, on the contrary, is what characterizes the power of the intellect, its capacity to act, independently of the orientation of action. This power corresponds to the ratio of the vector, to the realization of human liberty, to the possibility of choosing a direction and to the power to move in the chosen direction.

III. The Esthetics of the Infinite

Let us return to contemporary science. As we have said, this science is above all characterized by its infinite gradations—that in other systems of reference are finite—and by a representation of the infinite involving the combination of *exterior justification* and *internal perfection*. The common and constant representation of the infinite, such as is found in all periods, has a direct relationship with the dualism of Einsteinian criteria. The internal perfection of a scientific theory means that a given observation will become the logical deduction of a principle that will tend to bring with it the explanation of an infinite number of cases. In the beginning, the object of the observation is a finite domain of space-time, a *here-and-now* that, when the explanation intervenes, enters into relationship with the infinite multitude of analogous situations included in the general case, with the infinite *extra here-and-now*. Thus is produced an *infinitization of the finite*. On the other hand, the *exterior justification* means that the principle of the general case in its application requires the confrontation, in experiment, with the finite processes of the *here-and-now*, limited in space and time. In that way a *finitization of the infinite* occurs. If we now remember that after Aristotle the beautiful was presented as the reflection of the infinite in the finite, the connection of esthetic ideas with the concept of infinity becomes indisputable.

This notion evolved within the framework of the opposition between the two versions of the infinite—that of actual infinity, that is, the already existing and unlimited multitude, and that of potential infinity, that is, the multitude that grows without limits while remaining constantly finite. However, there is also another idea of the infinite that departs from the framework of actual and potential versions. Riemann differentiated the notions of infinity and limitlessness. Infinity became a local definition, dependent on the curve of space. Riemann expressed this idea on the geometric plane, Einstein gave it a physical character by identifying the gravitational field with the curve of space, and during the last half of our century the attention of astronomers and physicists who have begun to study the fate of distant galaxies and metagalaxies has been given to the problems that

are closely connected to the *relative infinity* of the structure of the universe, significant for a given point in space, determinable through the observation of the *here-and-now*. The Einsteinian universe is finite in space but infinite as space-time diversity. On the whole, the answer to the question, "Is the world finite or infinite?" has ceased to be an alternative answer, and the double answer to the question has here a character of principle. This fundamental duality is equally characteristic for the question of the infinity of time. What was admitted during the decade from 1960 to 1970 or, more exactly, what was presented as plausible with regard to the "beginning" of time and the initial phase of the existence of the metagalaxy, relativizes the infinity of time.

Does the relativization of the infinite modify the rapport of this latter with its axiological expressions, with good, truth and beauty? What are the relationships of these components of the "triple incarnation of infinity" with the new non-classical concept of infinity that is so characteristic of modern science?

When we consider the moral canons from a historical point of view, what comes to the fore is the potential infinity of progress toward the moral ideal. As far as truth is concerned, after the Renaissance, the Reformation and the collapse of the medieval dogmatic representations of the world (a collapse prepared by the slow development of opposing motives throughout the Middle Ages) absolute truth gave way to a sum of relative truths, to the notion of the potential infinity of knowledge. The infinite knowledge of the true was regarded even in the 18th and 19th centuries as an ideal toward which an endless road led. Relative truths do not change certain eternal laws that remain the ideal of the knowledge of truth. However, in the 19th century the idea appeared that these immutable laws themselves could be budged, that science in its entirety incarnates potential infinity; the notion of absolute truth as infinite knowledge became dynamic. In its historical development, the theory of knowledge has preserved the aforementioned struggle of actual infinity and potential infinity. This position corresponds to the ideas of the end of the 19th century according to which there was nothing more to be done except to perfect (perhaps for eternity) the details of the picture already drawn in its essentials.

It went somewhat differently for esthetics, more closely tied

to the world of finite realities. Let us once more recall the definition of the beautiful as the infinite expressed in the finite. This expression has a very obvious gnoseological function: it defends the finite, the sensually comprehended and the individual against absorption by the infinite abstract multitude. This defense corresponds to the old meaning of the word esthetic—still found in Kant—and to the notion of sensual perception. Introduced by Baumgarten in 1750, this word, whose meaning is connected to the notion of beauty, has a new nuance. As we have said, the beautiful is not a vector, it is not defined by a cognitive or normative end. It reveals the good and the true through the module of the vector and through the power possessed by the moral or cognitive act. This affirmation is one of the master ideas in Schiller's *Letters on the Aesthetic Education of Man.* It allows us to understand the role of esthetic comprehension of the world in modern science.

IV. The Beauty of Knowledge

Let us pause now to consider the meaning and sources of the upsurge in esthetic thought that occurred at the end of the 18th and beginning of the 19th centuries, under the influence of the ideas of German classic philosophy. Let us try to find in the esthetic concepts of the past what has become particularly important for the esthetics of modern science and for the esthetics of knowledge relativizing the infinite. It is the content of the esthetic ideas of the 18th and 19th centuries that is the closest to both contemporary thought and that of the most distant past. The collisions of the finite and the infinite, of the rational and the sensual, the problems of the relationship of beauty to good and truth that modern science resolves in a completely new way, are extremely important collisions and esthetic problems that have been presented ever since antiquity. What connection is there between the esthetic ideas of Plato and those of Aristotle; what is the most general definition of ancient Greek esthetics? It is the *canonicity* of the esthetic norms, the theoretic and philosophical justification of the canons of Greek art. With Plato, beauty is inseparable from good and truth, and aspiration to

beauty, just as aspiration to truth and good, is the souvenir the soul keeps of the world of pure ideas, of pure archtypes of being. This world is connected to the observable terrestrial world by geometry, symmetry and the eternal metric relationships between things. With Aristotle the Platonic chimera of the world of pure ideas disappears: the Greek thinker sensualizes the world and transfers its being into the system of finite relationships perceived through the senses; he takes for a criterion of beauty the tie between unity and variety. Beauty disappears if the object loses its unity and if one of the elements of variety is neglected. The infinite does not abandon esthetics, but beauty becomes the finite reflection of the infinite. The collision of the finite and the infinite is settled by the finitization of the infinite, this latter is put outside the limits of the esthetic norms of the "*peuple-artiste.*" For Greek thought and for the intuitive sentiment of the sensual knowledgeability of being, art, like science, was the comprehension of the infinite in the finite. Aristotle did not immobilize being, as the Eleatics did; he sought to escape from the *aporia* of Zeno, but the solution had to confirm the reality of Achilles running and the arrows flying, the reality of the world perceptible through the senses.

With that began a long, irreversible process of sensualization of knowledge and sensualization of esthetics. This process arrived at its relative accomplishment in 1750, when Baumgarten, in *Aesthetica*, gave to the theory of the beautiful the name of esthetics, a word whose Greek etymology goes back to the idea of "sensual." Contemporary science, that studied the infinite without turning away from sensual and experimental observation, could not keep from introducing new principles into the sensualization of the esthetic that followed.

This process was and is linked to another, that of *gnoseological* esthetics, the treatment of esthetic impressions as elements of *knowledge*. The long controversy over the subjective and the objective nature of esthetic judgements became complicated and at the same time found a solution in the notion of beauty of *knowledge*, in which the source of artistic perception was neither the subject nor the object but the knowledge of the object by the subject. We will return to this old process, whose form and meaning have been so radically modified in modern science. Just

like the sensualization of knowledge, the gnoseologization of the esthetic remains one of the principal definitions of the proto-Renaissance and the Renaissance. The art of the 14th to 16th centuries is inevitably a part of the history of science: the *Divine Comedy* was a scientific encyclopedia of its time, as much as it was a political and moral one. However, the bond between art and science that we point out was not broken in modernity, when science became differentiated and when it acquired precise forms of experimentation and mathematical analysis, nor when it received criteria of truth that were independent of the good and the beautiful.

Kant's philosophy endeavored to make the philosophical balance-sheet of the classical science of the 17th and 18th centuries. That attempt produced the system of transcendental esthetics, the idea of space and time as *a priori* forms of knowledge. However, this balance-sheet was in reality only that of what limited classical science, of what was historically transitory. In this, as in other cases, idealism was grafted on the living tree of knowledge following an illegitimate absolutization of a transitory segment of the curve of knowledge. For the transcendental esthetics of Kant, this segment of the curve of knowledge was the relative invariability of geometric forms, a certain way of treating space as a "rented barracks," the invariability of temporal measurement. Kant's transcendental esthetics and the *a priori* doctrine of space and time were an illegitimate philosophical generalization of classical science—without the theory of the field, without preparation for the modifications of concepts of space and time, without Gauss and Lobatchevski, without everything that urged classical science toward the radical revision of its bases and toward the new scientific revolution.

From transcendental esthetics came Kantian esthetics, in the usual sense after Baumgarten of the study of the beautiful or, to remain closer to Kant's terminology, the study of esthetic judgements, judgements of taste. Kant desired to create the same immutable genre for esthetic judgement as for his categorical imperative for moral judgements. On the whole, Kant's esthetics could not become the foundation of the esthetics of knowledge; it rested on *a priori* and did not include the *process* of knowledge, the development and thorough research of the

principal representations of the world, of its space-time objective reality.

This divorce between esthetic understanding and the space-time analysis of the reality of the world, a scientific analysis inasmuch as it was a synthesis of the empirical and logical, led to the Kantian idea of *works of genius*. Kant refused to speak of scientific works of genius. Genius does not obey the norms, it violates them and creates them: this is the prerogative of the artist. Artistic work may have genius. Schelling said that the savant *may* be a genius, but the artist *must* be a genius. He identified genius with a particular obsession, a particular destiny transforming works of art into expressions of superior force.

There is a particle of truth in that: the intuitive anticipation of new norms, what we have called metalogical illumination, approaches the scientific thought of the esthetic comprehension of the world. In spite of this approach, however, the thought continues to be scientific, the work of genius integrates the esthetics of science and knowledge without leaving the framework of science. What we have just said applies to all of science, to all its historical development, but it is 20th-century science that most clearly illustrates the position of the esthetics of knowledge within science. The most fundamental research in contemporary science is devoted to the study of the fundamental space-time structure of the world as an objective reality being progressively revealed to knowlege, which consequently changes with both the object and the result of its own rules and norms. Modern science allows us to speak of genius not only to describe such or such a work of a thinker but also to globally describe a school, tendency or discipline.

Let us now turn to another aspect of esthetics that has played an essential role in its development and has a very great importance for the understanding of the esthetics of contemporary science. It concerns the rapport of art with reality. One of the principal affirmations of classical esthetics is the presentation of beauty as disinterested. In the *Critique of Judgement* Kant maintains that taste as a basis for esthetic judgement involves a complete indifference to the usefulness of the object being judged. Moreover, esthetic judgements, according to Kant, are deprived of cognitive meaning, and thus beauty has no rapport with the

true and the good. The esthetic comprehension of the world is independent of the criterion of value, the criteria of the true and the good. However, after the middle of the 19th century a new esthetic concept appeared linking beauty to reality and, in this sense, giving it back its unity with truth and good. This concept was that of Tchernichevsky, the continuator of the esthetic ideas of Feuerbach and the initiator of a new esthetic truth in his work, *Rapport Between Art and Reality*. In Tchernichevsky's realist treatment of art, the beauty of art becomes the image of reality, of this content that is larger than art, that the limited concept of beauty does not hide and that broadens it. We come once again, therefore, to the traditional representation of the esthetic understanding of the world, with its practically infinite variety, expressed in sensually-perceived finite images and to the no less traditional representation of the good, the true and the beautiful as a triple incarnation of the infinite. A reflection of reality, art enters into reality itself and transforms it by integrating an always more precise picture of the world, by getting closer to science and introducing into it criteria of truth. The transformation of reality brings in criteria of utility, rationality and the good. This conclusion anticipated what was going to become particularly clear in our day and required a substantial modification of the criterion of *disinterestedness* that so often appeared in classical esthetics to characterize esthetic impressions. Without going into the evolution of this notion in art theory, let us pause to consider another component of esthetics—the esthetics of knowledge, of which we have already spoken. In this domain the modification of the criterion of disinterestedness as a characteristic trait of esthetic impressions is linked to the question of disinterestedness in the theory and history of science. In this regard, our epoch presents absolutely general characteristics of the esthetics of science. In the course of its development, science has always speculated about itself; it has always sought to define its sources, methods, effect and its place in the civilization of the world. Never has it been a passive reflection of being: it has transformed the world and has not been content with passive contemplation. However, precisely in the esthetic understanding of the world as a component of science, the active transforming role has been masked by an entire series of historic

circumstances. As we have said, the esthetic understanding of the world acts with particular energy at the moment of metalogical transformations, when there is a modification of the fundamental norms of scientific analysis and essential positive representations—when there is a change in paradigm. Modifications of this kind occurred in the past, but they did not take place in one generation; the radical transformations of the image of the world did not infringe on the rights of a conviction that the "best of all possible worlds" could be consciously represented by the adequate schema of the absolute best. What we may call the historical antecedent of the esthetics of modern science was not the poetry of transformation. When Malebranche and the other philosophers of the 17th century spoke of a beautiful world, discovered through modern science, the esthetic effect did not have as a principle the modification but the confirmation of representations claiming an absolute character. In today's science, the beautiful is revealed not only through the knowledge of the world but also through the self-knowledge of this science itself, through the sentimenti it has of its own kinetic power, its aptitude for change. When we speak of the beauty of the theory of relativity, we do not imply any definitive character of relativist physics.

From this comes a transformation of the criterion of the "disinterestedness" of esthetic perception. If esthetics (in any case, the esthetics of knowledge) is a question not of passive contemplation but of transformation of the object, then a certain "interestedness" appears. But this "interestedness" is not at all direct. The cognitive task is not yet directly tied to an effect; this is not known. Nevertheless, it is included in the series of deductions (*internal perfection*) and experiments (*exterior justification*) that, without being yet made clear nevertheless become the elements of esthetic impression. Thus, we return to the notion of esthetic judgement as the intuitive sentiment of the power of reason, of the module of the vector directed toward such or such a goal.

V. Criteria of Beauty and Elegance in Science

If we admit that the "beautiful" is in the act of knowledge, we may then say, borrowing the language of modern science, that the esthetic effect of this act is measured by the transformation it brings about in the picture of the world. In this regard, modern science contrasts singularly with the past. In our day, astrophysics and the theory of elementary particles make wide use of the models (that are far from being unequivocal) of the initial influence of local processes on macroscopic and cosmic processes, on the infinite, in the relative meaning it has received in relativist cosmology. The beauty of modern science is not merely the infinite expressed in the finite, it is the infinite depending on the finite, the local, the sensually perceptible. This function, esthetic *par excellence*, this relativization of the infinite, characteristic of our epoch, and this new relationship between the esthetic comprehension of the infinite world and its conceptual knowledge, considerably enlarge the role of esthetic criteria in modern science. In this *raprochement* of the criteria of truth and beauty, Einsteinian criteria find their realization. *Exterior justification* brings with it not only the empirical verification of the theory but also the intuitive sentiment of the general character and reach of the results of the verification. *Internal perfection* brings not only deduction beginning with the most general definitions of the Whole but also the esthetic impression of the infinite, empirical and sensually comprehensible verification of the new theory.

The esthetics of relative infinity cannot in any way be reduced to the criterion of *elegance*, well known and so well described by Henri Poincaré. Here, the essential esthetic criterion is the criterion of *beauty*. What is the difference between the two?

The criterion of elegance is close to the criterion of *internal perfection*. It has as specific traits the generality and natural character of conclusions and the absence of *a priori* propositions. Poincaré compared elegant mathematical deduction to the support that freely and naturally upheld the antique order. *Exterior justification* does not play an important role here. To go from elegance to beauty is to go from the sentiment of the natural and general character of logical or mathematical deduction to the

sentiment of generality and experimental demonstrability of the sensual comprehensibility of the world. If the criterion of elegance corresponds to *internal perfection*, the criterion of beauty then corresponds to the combination of *exterior justification* and *internal perfection*. The transformation of mathematics into ontological theory and the physicalization of logic correspond to the transformation of elegance into beauty.

Scientific concepts that introduce irreversible transformations into the picture of the world satisfy the criterion of beauty, and there again the distinction appears between criterion of beauty and criterion of elegance. The deduction that leads to a conclusion that science does not conserve may have elegance, but the discovery that will remain in science and be modified, whose meaning will change following new discoveries but that nevertheless cannot be discarded or forgotten, possesses beauty.

The criteria of elegance and beauty have one characteristic that is common to all esthetic criteria. We refer to eternity, to the agelessness of artistic values. The *Iliad*, the *Monna Lisa* and the *Kreutzer Sonata* do not grow old. The search for truth, if we refer to the content of scientific concepts, does not result in this type of imperishable values. Performed today, the Kreutzer Sonata, with its permanent resonance, seems not at all out of date, while using the theory of Descartes today to explain gravity would astonish everyone. Scientific conquests acquire immortality not as links in an irreversible evolution but through themselves, in their transitory form such as it is conserved throughout the centuries; they acquire it as artistic value, and it is as movements in human thought, as witnesses to its power, ingenuity and daring, that they do not age. Thus, we return to the classical definitions of beauty. Works of art have an epistemological function; they reveal the world in its sensually-comprehended elements and, because of this, they bring elements susceptible to modification, representations of the world subjected to historical change. For their part, conquests of science have an artistic value that immortalizes works such as Galileo's *Dialogue* or Newton's *Mathematical Principles of Natural Philosophy*, in their concrete form.

The esthetization of science is part of a more general tendency, one toward the *rapprochement* of contemporary science and the

general current of culture. The interrogative component is characteristic of non-classical science, which could not have developed without equivocal prognostics, without quasi-physical concepts, without new questions being asked after each answer. The development of classical science occurred principally through unequivocal decisions. There were controversies and contradictory interpretations of facts, but each stage nevertheless depended directly and largely on the one before. This vertical dependence still exists today, but alongside it has rapidly developed a *horizontal* dependence of science with regard to art, production, an influence of the parallel currents of culture on science. These parallels meet: Euclid's postulate is quite often transgressed. Why, for example, are the hypothetical particles—of which may be composed certain particles that are known to us—called *quarks*, a word describing the cry of birds, borrowed from a novel by James Joyce? The name is arbitrary, but the borrowing from artistic literature, "fiction," is legitimate and significant. It is not rare in contemporary science to see the appearance of new notions, without precedent, without a more general denomination that can be slightly modified to apply to a new situation. The borrowing is on a parallel current and thus is created the horizontal connection. Art is like a reservoir of analogical notions; this is a question of metalogical passage, free from any former norm, and so characteristic of the theory of relativity, of quantum mechanics and even more of quanto-relativist generalizations.

The esthetization of science has another aspect that we could call the scientization of art. The contemporary writer, painter, composer, critic or art historian cannot do without the notions and images that are intimated to them by physics, more precisely, non-classical physics. An artistic "Monroe Doctrine" would be just as archaic as a "Monroe Doctrine" in physics. For example, we find in one of the works of H.G. Wells the following stage direction, preceding the prologue in which a conversation takes place between God and the Devil (a rather traditional interview in dramaturgy!): "The scene should resemble a modern picture painted by an artist who is slightly familiar with contemporary physics." It is not a question here of mode. Simply, contemporary

art has the same thirst for internal perfection that physics has, if not more. As in physics, furthermore, there has been a realization that the old canons were not at all absolute. As in physics, there is a large field of exterior justification: the experiment verifies and justifies a host of concepts, a large number of which are artificial and are only introduced to justify the experiment but have no logical relationship to the general principle. This sometimes leads to works that are manifestly arbitrary, recalling more or less the immortal performance in the Théâtre de Colombe, in *The Twelve Chairs* of Ilf and Petrov. It may happen that artistic works have a truly very intuitive and unconscious rapport with general principles, and in this case the authors are like poor Jourdain, speaking prose without knowing it. (This character may in addition serve on occasion for physicists). The problem is that what Monsieur Jourdain did no longer corresponds to the level of self-knowledge of modern culture in its different domains. Today, there is a bond between the conscious parallels of inter-disciplines; a conscious unity of culture on the one hand and the development of components of culture on the other. By insinuating themselves into other cultural disciplines, the notions of physics are modified; they take on a more general form that sometimes increases their auristic value. Inversely, the notions or images emigrating from the artistic domain into science undergo an analogous modification at the time of their generalization.

The esthetization of science and the scientization of art are evidence of a very deep and broad transformation of culture on the whole. In ancient culture, there was a profoundly harmonious unity of moral, epistemological and esthetic criteria. Then differentiation began. Medieval culture knew the dictatorship of the good—detached from sensually-apprehended forms and bound by sacrosanct rules. The ideals of the good then ceased to be ideals and became canons. The criteria of beauty were subjected to those canons. To be convinced of that, it suffices to recall the *Triumph of St. Thomas Aquinas*, by Andrea da Firenze, a painting whose composition so rigorously obeys the dogmatic schema of angels, saints and sinners; we could cite many other cultural

treasures that are still medieval in spirit.[3] Like the criteria of beauty, the criteria of truth were also subjected to the dogmatized hierarchy of moral values, deprived of sensual verification. The Renaissance liberated esthetic criteria from this subjection, and the criteria of truth were liberated—although incompletely—by the scientific revolution of the 16th and 17th centuries, as well as by the onset of classical science. As for what characterizes non-classical science, it is the *dynamic* tie between these different criteria; they do not canonize each other. The adjunction of the criterion of beauty to the criterion of elegance, or more exactly, the union of these two criteria, is a penetration of the ideals of truth into the esthetic. Works of art express not only the truth of the understanding of the objective world but also the truth of the logical procedures of knowledge that find their expression in the *internal perfection* of scientific theory, a perfection that corresponds in the highest degree to the criterion of elegance. In non-classical science the Logos and the Sensus are inseparable, the logical bases of the data from the experimentation and self-knowledge of science itself are inseparable from the knowledge of the world. Modern science is the very expression of this indissociability. This means, in other words, that there is a connection between the study of man—thinking and transforming his world—and the study of nature, that there is a humanization of science.

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[3] A. Kh. Gorfounkel, "Ot Torjestva Fomy k Afinskoj Chkole," in *Istoria filosofii i vaprosy koultoury*, Moscow, 1971, pp. 131-166.