COMMITTEE IV
The Relationship Between Science
and The Arts and Its Relevance to
Cultural Transformation

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SCIENCE AND ART:
A STUDY IN CULTURAL PLATE TECTONICS

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SCIENCE AND ART

A Study in Cultural Plate Tectonics

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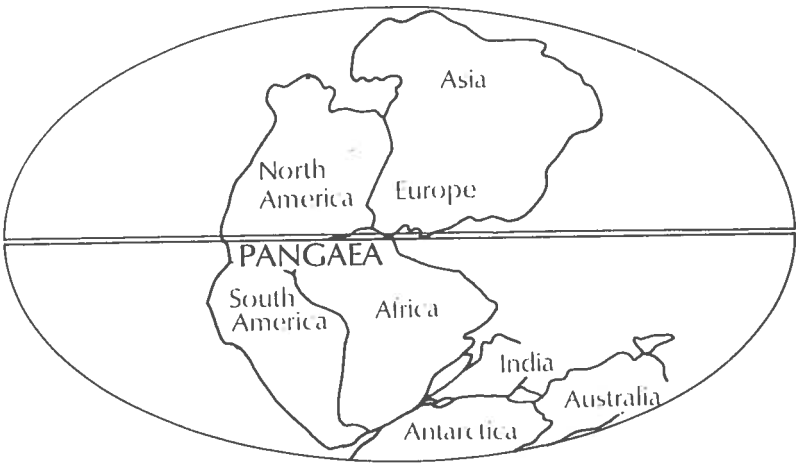


Whenever detailed information is sacrificed for patterns that show up only on a large-scale map, the trick is to recognize what details to leave out. In other words, the essence of this kind of geological analysis is always to separate the "signal" from the "noise".

Raymond Siever

1.PREAMBLE

The following is an attempt to account for the intricate relation between science and art and its dynamic development over more than two thousand years. Can the Cultural Earthquake, introduced by Maurice Goldsmith, be useful in this context? Perhaps, in particular if one were to extend the metaphore into a full-fledged Cultural Plate Tectonics paradigm.

As an explanatory device plate tectonics seems to have unique features. The idea of convection currents in the earth's mantle, driven by heat from radioactive decay, provides a beautiful explanation for the observed phenomenon of continental drift. While this is indeed remarkable it is also obvious that the actual course of events on the surface of the continents relates to the currents deep down under in a very remote and partial way only. In the language of physics circumstantial "boundary conditions" play an overwhelmingly decisive role. At any given time the actual appearance of the continental surface has little to do with what takes place in the interior of the earth. Yet, the surface would look very different indeed it if were not for the currents underneath. And this applies in particular to the relation between the continents on the global surface. Since it is a relation, which is the main

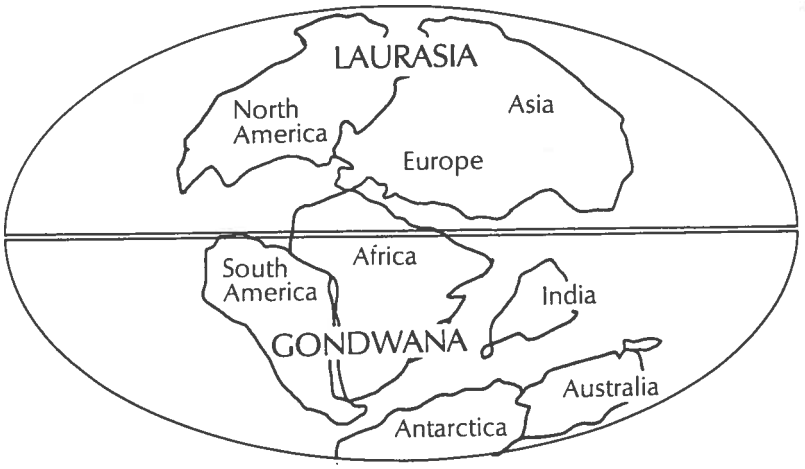
subject of this paper, the Cultural Plate Tectonics paradigm seems highly appropriate.

This explanatory device will therefore be used in an attempt to prove that the underlying metaphysics accounts for the major trends in the development of the science/art relation. In spite of major cultural earthquakes a primordial unity remained up till, and in fact through, the Renaissance. But then a rift appeared. Science and art were carried apart by mighty underground forces. A widening gulf opened in the midst of what was once a unified culture.

In the 19th century, however, began a series of cultural earthquakes possibly signalling a new turn of the subcultural currents. It is not impossible that these forces are now working, slowly but steadily, towards a cultural unity to be completed in some distant future. We may be heading for a cultural New Gondwana.

For reasons which will become obvious this paper deals almost exclusively with physics and mathematics. Only a few references are made, in passing, to the other natural sciences. As far as the arts are concerned the discussion is also limited. It deals primarily with painting, which by nature of the medium renders itself naturally to twodimensional "illustrations". This is not to belittle the importance of music, which in its relations to science has a lot in common with the visual arts.

But when presented on paper music necessarily has to be translated into symbols to be seen rather than listened to.



The only way to avoid becoming a metaphysician is to say nothing.

E.A.Burtt.

2. GONDWANA

2.1 The metaphysical foundation

It is often said that science is distinct from art. Science strives for the true and art for the beautiful. But the alleged difference disappears if beautiful is understood in Newton's [3] sense:"this most beautiful system of the sun, planets and comets" i.e. if beauty stands for something which has an autonomous value "a perfection that excites admiration and delight for itself rather than for its uses" (Webster)[3], then there is no distinction between the aims of (pure) science and those of (true) art. Truth is beautiful.

This was the ancient Greek conception. In their cultural Gondwana the very word cosmos signified order and beauty.

Edwin A. Burtt had modern science in mind, but his words apply, of course, to science in general and also to art. In fact, underneath all cultural phenomena there is a foundation of metaphysics, which has to be accepted, consciously or subconsciously, in order to make any cultural activity possible, including the activities in science and art.

Cultural unity can be expected, if and only if, the members of the cultural elite naturally express themselves within a common metaphysical framework. If not they will find themselves unable to communicate. The cultural Pangaea splits into individual continents setting out on divergent trajectories.

In metaphysics there are, of course, a number of problems to be addressed. But in this context we may restrict ourselves to only two: the ontological question - what can we have knowledge about - and the epistemological question - how can we know anything at all.

How can we know anything? Truth can conceivably be revealed to us in two different ways: through contemplation (rationalism) and/or through observation (empirism). What can we know? We are realists if we think of the objects of knowledge as existing in themselves and by their own nature regardless of whether we have knowledge of them or not. The nature of the objects is of secondary importance. It does not matter whether they are "material" or "immaterial". Realism comes in different ways: perceptual (materialism) and conceptual (idealism). What matters is the autonomy of their existence, however defined.

But how can objects of our knowledge exist independent of and prior to our knowledge of them? Phenomenalists find this notion unacceptable and argue that human knowledge is forever confined to the world of appearances. What lies beyond perception - if anything - is excluded from the realm of knowledge - but not necessarily beyond belief.

The concepts thus introduced may be combined to form a fourfield "metaphysical matrix":

How? \ What?	Realism	Phenomenalism
Rationalism		
Empirism		

In spite of its admittedly gross simplification it is nevertheless hoped that the metaphysical matrix makes it easier to follow some of the arguments advanced in the following.

2.2 Philosophers and artisans

In ancient Greece poetry, dance and music were originally conceived of as a unified whole centered around dancing, as a performance, a cult and a cathartic act. This, seemingly innocent, social activity was pregnant with cultural offspring.

Dancing (*choréia*) may be regarded the origin of science and of art as well. Stemming from *choros* (chorus) and *rhein* (to flow), *choréia* establishes an etymological relation between the arithmetic of mathematics and the rhythm of music which both have the common root *rhein*.

The cathartic effect was attributed to the underlying order and lawfulness. The secret powers of the ritual dance were to be found, therefore, in the theoretical background rather than in its overt manifestations. Thus music with its inherent order and structure established itself as the superior art. Its prestige became even more pronounced when the phytagoreans combined arithmetic with the theory of music and developed mathematical music into a full-fledged natural philosophy based on numerology.

It must be remembered, however, that *musiké téchne* stood for much more than the mathematics of integers and musical theory with its consonances, harmonies and rythms. *Musiké téchne* included also the theory and practice of composition as well as the actual musical performance. In fact even what we would call non-musical arts, such as poetry and painting, were accepted.

To the ancient Greeks there was a difference in degree only between the artist and the artisan. The artisan was supposed to deliver what he was told to produce. However, because of his superior philosophical insights the artist was considered able to

discern the presence of beauty in nature. Like the composer who tells the performing musicians what to play and how to play it, the artist instructs the artisan on what to make an image of and how to shape it and paint it. It is these instructions rather than the manual production that turns the artifact into a piece of art. And, of course, in the visual world too, numerology was the key to true beauty.

Thus it was in his capacity as a philosopher with intellectual insights into the secrets of nature the artist distinguished himself from the artisan. Otherwise there was not much of a difference between them and it is subject to debate whether the artist enjoyed much more of social recognition that the fairly modest amount bestowed upon the artisan.

The essential point is that art was never considered a creative activity. Simonides' famous definition of painting as mute poetry and of poetry as talking painting [4] should not be considered merely an expression of artistic egalitarianism. Simonides hinted at something much more significant, a common denominator: the ability to imitate.

The Greeks referred to the visual arts - to painting and sculpture - as mimethike techné, the imitative arts, the general word, techné, indicated that men, by imitating the way nature operates, are able to produce new things*. Architecture

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* The word technology stems, of course, from techné

is the prime example. It was accepted by Plato, all austere judge of art, precisely because it was not an imitative art** To Plato architecture was passable because it was concerned with the construction of real useful things rather than the useless and illusory artifacts of the mimetic arts.

But few were as critical as Plato. On the contrary artistic activity was generally highly appreciated by the Greeks who insisted on its "philosophical" bearings. The producing artist/artisan was inferior to the reflecting artist/philosopher. Centuries later Roman scholars challenged the Greek authorities on this point. Horace [5] proclaimed that the artist should be true to nature as it appears to him. Implicite in this perceptual realism is an appreciation of the artistic activity as such. Horace's famous "ut pictura poesis" (with the poetry is it as with the picture) emphasizes the common didactic goal of all forms of artistic expression. But it did not last long until the didactic "artes pueriles" (poetry and performed music) were considered equal to the mathematical sciences and the theoretical music of the artes liberales. Finally Cicero [6] announced that from having been thought of as a simple artisan in the service of techné or at best a productive force comparable to

** In fact architecture was not included among the "belle arts" until the middle of the 18th century.

those of nature, the artist should be considered equal to the philosopher.

He was soon to be seen as superior. According to Philo Judaeus [7] the poet is like a creator "a second God". Whereas Plato despiced the poet as a lunatic possessed by *mania*, Philo praised mania as a source of divine inspiration for the creation of *new* (!) truths. Finally with Pseudo-Longinus' [8] *On the Sublime* the stage was set for the romantic genius of art. At this moment the cultural Gondwana was on the verge of cracking up setting the continents of the sciences and of the arts, respectively, adrift on different courses. But for strange and unexpected reasons this did not happen. What was about to take place was postponed for well over a thousand years.

> Glaucon: How, then, do you mean to reform the study of astronomy?
> Socrates: In this way. Those intricate traceries in the sky are, no doubt, the loveliest and most perfect of the *material* things, but they are still part of the visible world, and therefore fall short of the true realities - the true movements, in the *ideal* world of numbers and geometrical figures which are responsible for these rotations. Those, you will agree, have to be worked out by reason and thought and cannot be observed.
>
> Plato, *Republic*

2.3 Maidens of Kroton

If the mimethiké téchne are nothing but imitative arts, why then paint and sculpture? Should not the beauty of the original objects, present in nature, be sufficient? Perhaps not.

According to an ancient legend Zeuxis - the sculptor - was asked to make a statue of Hera Lakinia to be placed at her temple at Kroton. To make her appear as admirable as possible Zeuxis selected the five most beautiful maidens of Kroton and combined imitations of their loveliest parts into the statue of Hera.

What Zeuxis achieved was the perfect female body. But from where came its superior beauty? Was the ideal present in Zeuxis' mind prior to his selection such that he could measure the actual proportions of the maidens in Kroton against his inner vision? Or had the sculptor arrived at his concept of female beauty by eager and curious observations prior to his assignment in Kroton? A rationalist would say that, upon comtemplation, the pure idea presented itself afresh in Zeuxis' mind. But an empirist would rather explain the sculptor's expert knowledge of female beauty by his previous poking.

The rationalist slant in Greek thinking favored the former alternative, but Heraclitus' dynamic philosophy is an interesting exception. According to him reason guides perception.It is only because of this guidance that human beings can acquire objective knowledge of the world as it appears to them.

The sophist carried this line of reasoning an adventurous step forward. Just as reason guides us to truth it also shows us the way to beauty. In fact reason makes it possible for us to produce beautiful new things by conscious, goaldirected activities. Beautiful,that is, as they appear to us. Beauty, the sophist argued, is "what flatters the eye or the ear". But this was too much to stomach. Their sensualistic conception of art brought a forceful rebuke from Plato.

In the famous cave allegory Plato makes a distinction between what really is - eidos (idea) - and what merely appears to be - eidolon (phenomenon). To experience an object as beautiful is to comprehend its pure idea in the transcendental world of existence.

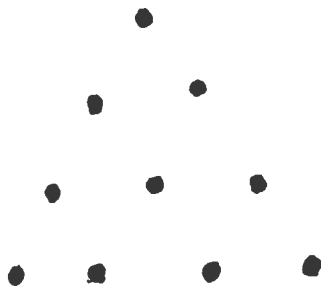
Plato could accept Egyptian art because of its respect for the objectively given measures of the things as they really are. But he was critical about the mimetic arts since all they seem to offer is an illusory resemblance with the seducive phenomena in the world of senses, and he spoke harshly of what we would now call "impressionism". For Plato the use of the perspective, and of shadows, to obtain an illusion of depth in a flat surface was just as disgusting as the tricky dialectics the sophists applied to make lies appear as if they were true.

In denouncing phenomenalism and perceptual realism alike Plato was much in tune with traditional Greek thinking. To

behold beauty is to mentally perceive the mathematical truths of natural philosophy. For the artist the key to success is the grasping of these mathematical ideas such that he may employ them consciously in the practice of art.

In Polykleitos' famous Kanon i symmetria[10] it is suggested that the mathematical proportions of the (ideal) human body mirror the cosmic order as comprehended by the human mind. "Man is the measure of all things" as Protagoras put it. This enthralling idea became a resounding theme during centuries to come.

Among other things the pythagoreans managed to prove that the sum of all integers can always be expressed as equilateral triangles of which the tetraktys: 1+2+3+4=10 expressed as:



was particularly sacred.

While this agreement between mathematical order and geometrical shape was reassuring, their numerology suffered an irreparable set back with the discovery of irrational numbers, certainly one of the most magnificent achievements of ancient Greek mathematics. When it was found that there must be a distinct class of numbers which, by virtue of their own nature, cannot be expressed as quotients of two integers, such as π or $\sqrt{2}$ arithmetic appeared to be inherently inferior to geometry.

This fateful mathematical discovery had an enormous impact on the development of art. The prestige of the "geometrical" arts - painting and sculpture - was elevated at the expense of that of music - the "arithmetic" art. Of particular importance in connection with art (and for peculiar reasons to which we will return) is the irrational number $\sqrt{5}$ appearing in the expression:

$$1 : \frac{5 - 1}{2} = 0.618034.....$$

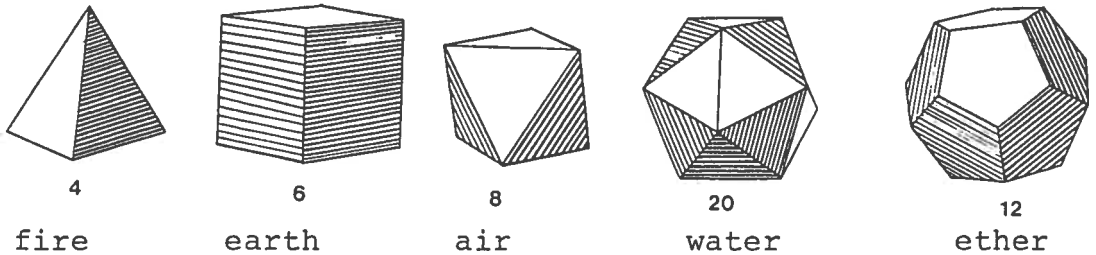
i.e. "the golden section".

The development of Greek arithmetics was much hampered by its awkward lack of technical perfection. They were limited to integral positive numbers. They did not have the zero nor the

negative numbers. They even lacked the position system and with the discovery of the irrational numbers they were faced with what appeared to be a major defect in the very foundations of their mathematics. What could not be done arithmetically - such as π, $\sqrt{2}$ or the golden section - could easily be demonstrated geometrically.

Geometry, the science of surface and space and as such the source of beauty in painting and sculpture, was obviously superior to the science of onedimensional time containing the beauty of music. In the paragone (ranking list) debate this was of considerable importance for the mimetic arts and for their artists.

Furthering this trend was the remarkable discovery that there are five, and only five, regular convex polyhedrons, namely



by Plato, in Timaeus[11], associated with the four elements of nature - fire, air, water and earth - plus the fifth element, quinta essentia, the quintessance, or "ether", supposed to be the stuff of which the heavenly bodies are made.

Plato attributes the mathematical proof of the existence of the five "platonic bodies" to the pythagorean Theaetetos. It is well known that the regular convex polyhedrons play an important role in Plato's cosmology as developed in Timaeus. Their impact on the history of science, and of art, can hardly be exaggerated. In the metaphysical matrix Plato placed himself firmly in the upper left corner together with the eleatics and the pythagoreans. In this aestethetics as well as in his natural philosophy Plato was an outspoken rationalist and conceptual realist. As such he was diametrically opposed to the sophists on both ontological and epistemological grounds.

What? / How?	Realism	Phenomenalism
Rationalism	Plato The eleatics The pythagoreans	Heraclitus
Empirism	Aristotle	The sophists

Like Plato, Aristotle is a realist, but being more matter-of-factly Aristotle replaced Plato's ideas (eidos) with his own concept universals (katholon). From the logical and semantical points of view there is not much difference between these two terms, but Aristotle wanted to rid his philosophy of the transcendental aspects of platonian idealism. In his epistemology, however, Aristotle is very different from Plato. Aristotle represents an interesting, and portent, combination of realism and empirism with deep implications for the natural sciences as well as for the mimetic arts.

But these were for the future. The immediate impact of Aristotle's thinking was of a different nature. His teleological philosophy centered on the actualization of potential goals. As such it prepared the ground for applied science. Scientists and artists are like craftsmen working for the implementation of the potential goals of a higher social order. Although Aristotle emphasized the didactic aspects, his aestetics contains something entirely new. The activities of the mimetic artists are not merely means to an end. They are meaningful acts in themselves.

With Aristotle the four quadrants of the metaphysical matrix had all found their authorative spokesmen. It was left to hellenistic eclectics to pick and choose, Impressed by the

dynamic heraclitean vision of the world, as one of an eternal flux of perceptions, the stoics focussed on sense impressions and their empirism was carried further by the epicureans.

Both stoics and epicureans considered the artifacts of the mimetic arts inferior to the natural objects they were made to resemble. The sceptic Sextus Empiricus [12] went as far as to question the alleged didactic and cathartic virtues of artistic endeavor. The ontological claims of music, for instance, Sextus Empiricus denounced as "mere innovations".

But in that very same century - the third AD - a weird and heady brand of platonism appeared in Rome. Neoplatonism found its most pretentious expression in the mysticism of Plotinos [13] where the gap between eidos and eidolon is bridged by a supernatural light emanating from the sacred Unity. The pagan Rome was ready to receive the Gospel.

You shall not make a carved image for yourself nor the likeness of anything in the heavens above, or on the earth below, or in the waters under the earth.

Exodus 20:4

What has Jerusalem to do with Athens, the Church with the Academy, the Christian with the heretic? Our own doctrine comes from the House of Salomon, and the Salomon himself has taught us: one must seek for the Lord in the simplicity of one's heart. Let us have nothing to do with a stoic Christianity or a Platonist or a dialectial Christianity. All curiosity is at an end after Jesus, all research after the Gospel. Let us have Faith, and wish for nothing more.

Tertullian

2.4 Credo ut intelligam

Suddenly philosphers as well as artists found themselves confronted with a common enemy: the young Christian Church. Clearly directed towards idolatry the prohibition against images in Exodus 20:4 was taken verbatim and applied against all forms of imaging arts. The stern Tertullian thought of the painters and sculptors as comparable to the pimps of prostitutes and he hardly held the natural philosophers in any higher esteem. Once in power the first Christian emperor Justinian closed the academy in Athens and the teachers left for Persia.

But the young Church found itself openly exposed to paganism which was creeping into its ritual practice in all forms of disguise. Soon there was an established iconographic tradition if very questionable origin. To Tertullian's great dissatisfaction neoplatonism was covertly entertained by Christians in the always spiritually minded Alexandria.

The Alexandrian attempt to square the problematic relation between the Old and the New Testament by means of an umbra (shadow) and veritas (truths) analogue was firmly rejected by Tertullian, who insisted that every single word in the Bible was to be understood as literally true. To manage the formidable difficulties thus encountered Tertullian came up with an ingenious idea. The Old Testament, he suggested, relates to the New like a mold (forma) to its cast (figura). The real meaning of the historical events recorded in the Old Testament become manifest in the New.

This explains why in medieval paintings one often finds parallell scenes from the Old and the New Testament. The irony that the mold as well as the cast are both pictured should not be missed .

It was a bright idea, but the forma-figura analogue only brought new problems. It prepared the Christian minds for the didactic claims of the imitating arts. What lies hidden in the Old Testament's matrix is revealed in the form of an image in the New Testament. In East Rome, more favorably inclined to the world of phenomena, Basilios the Great compared God to a sculptor and referred to nature as a piece of art reflecting the intellect of its Creator [15]. From there on it is but a small step to the belief that God himself is present in the image just like he is in the figura of Christ. And, Sancta Sanctorum, a figure of Christ "not made by human hands" was soon put on display! The stage was set for more than a century of iconoclastic feud.

When if finally ended it was with a set of highly codified rules for the painting of ikons. Only abstract geometrical forms and stereotyped symbols were accepted. Every precaution was taken to make sure that the image was not to be mistaken for the real thing.

This was never a major problem in the western part of the Christian world where phenomenalism was consistently rejected. More or less wholeheartedly endorsing Plato's rationalism Saint Augustine [16] praised music for its order and harmony.

According to the Father of the Church imageing arts ranked lower than music and in his musical theories the unfortunate Boethius [17] closely followed Saint Augustine's teachings.

On the other hand the liberal arts, addressing themselves to reason, are much superior to the "mechanical" arts, charged with the practical aspects of artistic activity, performance and production. The latter, by appealing to the senses, can only give a confused and blurred appreciation of the divine cosmic order.

There are no creative artists. At best art can only reveal the inherent sacred order of the universe. Thus, duly converted and sprinkled with the holy water, platonic realism endured through the centuries. It resounds in Mignot's [18] famous sentence ars sine scientia nihil est - art without science is nothing - but it did not pass unchallenged as witnessed, for instance, by the fierce but abortive attacs from nominalists in the 11th century.

> It starts with only the bare outlines of the seven liberal arts and ends in possession of the Roman and Canon law, the new Aristotle, the new Euclid and Ptolemai, and the Greek and the Arabic physicians, thus making possible a new philosophy and a new science.
>
> H Haskins

2.5 Summa Theologica

Inspired by the advanced Arabic culture and much influenced by the great Byzantine empire 12th century Europe made impressive progress, especially in France. Through Arabic mediation the reintroduction of aristotelian philosophy was surprisingly swiftly accomplished, thanks mainly to Thomas Aquinas' cunning intervention. No doubt thomism with its emphasize on aristotelian empirism, represents a great leap forward for European science as well as art.

According to the aristotelian teleological philosophy the actualization of potential forms is the overriding principle of organization. Since it applies not only to the course of events in nature but also to human affairs the principle has a direct bearing on artistic activities. In Summa Theologica [20] God is the ultimate goal - the last cause - and man the intelligent

agent able to discern, all by himself, the presence of the divine principle in nature. Hence studies of natural philosophy, in particular in the biological and medical disciplines, contribute to our knowledge of God.

According to Aquinas the artistic activity resembles the way nature itself proceeds. The artist makes his intentions manifest in matter just as nature in its actualization of potential goals fills form (eidos) with matter (hyle). By being essentially mental the activities (sapientia) of the artist is more akin to those of science (scientia) than to the work of artisans (téchne). Craftsmen produce useful things, such as tools, but the work of an artist is a goal in itself contributing to the fulfillment of human life.

How? \ What?	Realism	Phenomenalism
Rationalism	St Augustine	
Empirism	Thomas Aquinas	Occam

In the metaphysical matrix Aquinas - an empirical realist - belongs in the lower left quadrant. The artist cannot create beauty, but he can reproduce, or imitate, the beautiful things he finds in nature. If our knowledge of reality comes from sense perceptions only, as the empirists claim, by means of what mental faulty is the artist able to tell what is and what is not beautiful? In other words on what grounds is he able to select natural beauty for artistic imitation?

At his crucial point Aquinas can only refer to the "aimless pleasure" the beholder of fine art experiences. But, alas, in his attempts to explain the origin of this "aimless pleasure" the great Aquinas resorts to platonic idealism and even to the ancient idea of the human body as a microcosm of an intrinsic mathematical structure, i.e. to the homo quadratus, which had been lurching around ever since the golden days of Polykleitos and the pythagoreans. This was not very satisfactory.

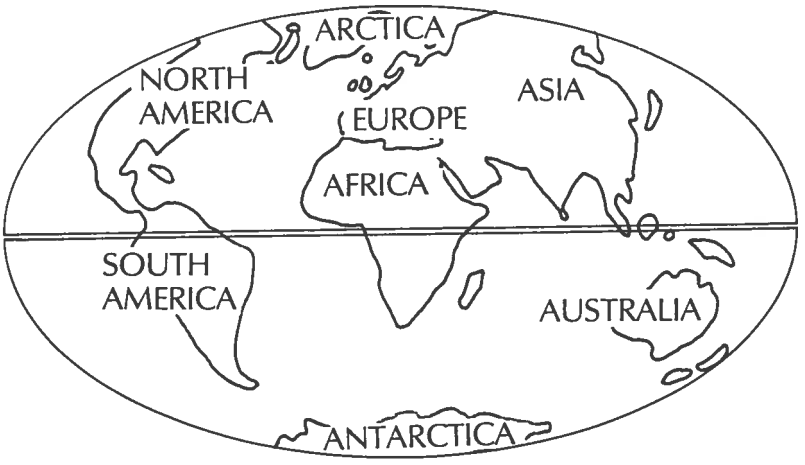
It was therefore soon suggested that the artist was endowed with a particular faculty - ingenium. This very special gift allows the artist to identify the beautiful objects in nature that most suitably render themselves to imitation. But this was merely begging the question and Bonaventura [21] felt it necessary to probe deeper. He therefore made a distinction

between the beauty of the object as such and the beauty of the image of the object. A picture is beautiful if it has a formal beauty - ut pictura - obtained by resembling the real object. But this is not enough. The picture must also resemble the mental image the artist has made for himself of the object - ut imago- the imitative beauty. And finally, Bonaventura suggested, true beauty is present if, and only if, the formal and mental images are "in harmony".

In the final analysis, therefore, beauty depends on a harmonious relation between the objects of the transcendental reality and the perceived phenomena in the world of senses. Bonaventura's estetics boils down to sheer neoplatonism.

The Oxford philosophers defended the infallibility of true artists by comparing their activities to those of nature. Occam [22], excluding everything but the empirical content of knowledge, refused to accept beauty as something which existed independent of observation. Beauty can be present only in the individual object. According to Occam the splendor of Hera's statue must be entirely due to Zeuxi's interest in attractive women and to the artists knowledge of the female body, gained through experience.

But the ingenium was a virulent concept. It was soon referred to as a creative faculty in terms which bring Genesis in mind. Time was ripe for a reappraisal of the artist/artisan. According to Lorenzo Valla [23], one of the humanists, the artists with their knowledge through ingenium are by no means inferior to the students of the liberal arts "who excel in their sciences thanks to the learning they have acquired through diligent studies".



Philosophy is written in that great book which ever lies before our eyes - I mean the universe - but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. This book is written in the mathematical language, and the symbols are triangles, circles, and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders in vain through a dark labyrinth.

Galileo

He who is not a mathematician according to my principles must not read me. Oh students, study mathematics, and do not build without foundation.

Leonardo

3. COMING APART

3.1 Tremors and cracks

What might have happened in third century Rome took place in the Italian renaissance. Accompanied by a mighty display of cultural earthquakery the breakup lasted for well over a century. But when the process was completed the cultural continent of Gondwana had split in two parts. The sciences and the arts had both acquired new distinct and separate identities. From then on few think of the arts as coming from the artes liberales and even less of the liberal arts as the origin of the mathematical sciences.

Permeated by aristotelian philosophy the Church softened its stand against artistic realism. Realistic painting had always been a tempting proposition and it was less dangerous to entertain now that idolatry did not seem to pose a problem. Moreover empirism was endorsed by the thomistic philosophy, which had become the official doctrine of the Church. Thus Dante [26] hailed painters such as Gimabue and Giotto, who according to

Villani [27], had reintroduced truth to nature in their paintings, a virtue which had been lost in the preceeding centuries due to the "ingnorance and naivety" of medieval painters.

Alberti's Della Pittura[28] is a veritable textbook in the art of painting. It was published in 1426. It is interesting to note - as an omen - that he comes out very clearly against the use of gold in pictures. Traditionally the glittering of pure gold signified the presence of the divine and therefore endowed upon the picture, apart from the material value, a special significance of metaphysical nature. But to Alberti the brilliance of metallic gold was sheer cheating. It is "the painter who imitates the glittering of gold by colors only, who deserves admiration and praise".

From a direct comparison between the writings of Alberti and the somewhat younger Piero della Francesca it becomes clear that something strange is going on.

In his Della Pittura Alberti quotes Protagoras' "men is the measure of all things", meaning that the artist should strive for the most precise imitation of nature as perceived by the human eye. To this effect Alberti recommends the use of the

perspective - a "legitimate construction" to use his own phrase - and the author shows how to handle the perspective in a technically proper way.*

Piero della Francesca's booklet [29] De Quinque Corporibus Regolaribus was probably completed around 1490 but did not appear in print until 1509 when it was published by Luca Pacioli under his own name "mean and fraudulent as he was" (Vasari). Here again there is a reference to Protagoras, but now the meaning is quite different. For Piero "the measure of all things" is the ancient philosophers' homo quadratus not the faithful observer. Like Alberti, Piero favors the perspective and in his paintings he proves himself a master of the legitimate construction. But for Piero the motivation is different. Any resemblance with human perceptions is purely fortuitous and absolutely irrelevant. Piero used the perspective because to him it was a representation of the divine mathematical structure of physical space. As such it is an autonomous entity existing in

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* This, by the way, is the beginning of projective geometry, a non-euclidean branch of geometry which, after a few abortive attempts, had to wait until the end of the 18th century for the mathematicians to realize its possibilities.

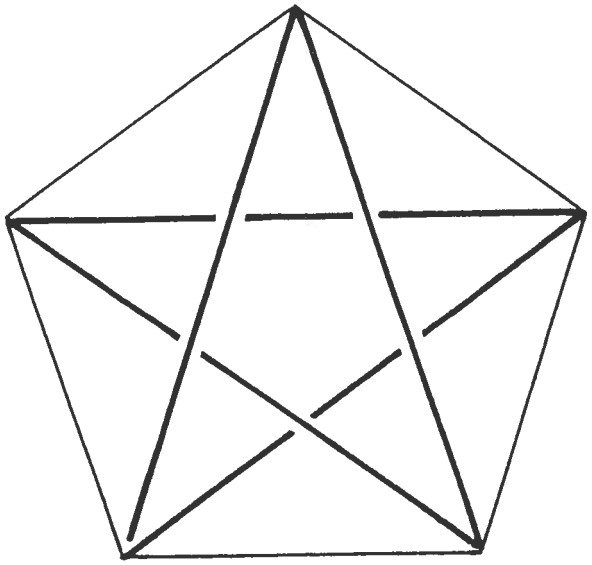
itself and by its own nature. It has nothing to do with human vision.

This, of course, is not new but Piero's treatise contains something else which is extremely interesting. He sets out to account for creation in platonic terms and meets with astounding success!

According to Plato the sphere is the most perfect of all three dimensional forms. It must therefore be the symbol of God when he makes himself manifest in this world. This granted, Piero take great pains to show, the euclidean way, that the five regular convex polyhedrons all can be inscribed in a sphere. This shows, according to Piero, that God in his supreme perfection transcends everything else.

Again, this is hardly new, but lo and behold, Piero provides indisputable geometrical proof that the most sacred of the polyhedrons, the dodecahedron, contains the other four which according to Plato combine to make up the world of perception. The dodecahedron cannot be taken apart and put together into something but a dodecahedron. It is therefore indestructable and represents not only God's presence in everything created but also his omnipotence and immutability.

What makes the dodecahedron so special? It is made up of twelve pentagons and twelve is, of course, a sacred number. But there is more to it than that. As shown in figure the pentagon defines the pentagram.



The five pronged pentagram star was the sacred symbol of the pythagoreans. The crux of the matter, and the real reason for its sacredness, is the fact that the pentagram (and consequently also the pentagon, the dodecahedron and the other four polyhedrons) is based on the "analogon".

$$\frac{a}{b} = \frac{b}{c}$$

where $c = a + b$ such that

$$\frac{a}{b} = \frac{b}{a + b}$$

which is the "golden section"! The solution is

$$\frac{a}{b} = \frac{\sqrt{5} - 1}{2} = 0.618034$$

It may be shown that a/b equals the ratio of the distances between the adjacent and opposed prongs of the pentagram.

According to Piero the triad a , b and c stands for Trinity. Through the mathematical analogon the Father, the Son

and the Holy Spirit are related in the one and only possible way. And to our deep satisfaction this relation cannot be rationally expressed since $\sqrt{5}$ is, indeed, an irrational number. The ratio is therefore "hidden and secret" to use Piero's own words.

To the mathematical mind, at least, this is very beautiful. And what is even more remarkable it is entirely new! It may seem strange that Piero not claims credit for these mathematical discoveries. On the contrary he attributes everything he has done to Plato. But in his modesty he was not alone. The mathematician Scipio del Ferro, for instance, succeded in finding a general solution to equations of the third order, a task the ancient Greeks failed to accomplish. But Scipio never published his results. The method was rediscovered by Tartaglia - "the stutterer" - who confidentially showed his solution to the great mathematician Cardano. To Tartaglia's dismay Cardano broke his promise and published the sensational discovery, which he honestly attributed to Tartaglia. Nevertheless it is known as "Cardano's solution".

It must have been an enticing thought: the authorities could be successfully challenged! It was possible to gain insights which has been denied to the ancient masters!

This was soon a commonly accepted notion. Creative mathematical thinking produced astonishing results. Negative (- 2), irrational (2) and imaginary (-2) numbers were rapidly introduced almost without hesitation. Piero's beautiful model of the universe as a divine creation of spheres and regular polyhedrons soon looked hopelessly outdated and even naive. Time was ripe for something entirely new.

After all our disputes are about the sensible world and not one of paper.... Let us proceed to demonstrations, observations and experiments.

3.2 The experimental method

To Leonardo art and science were one. Painting was not merely an imitation of nature, it was a way to explore, analyze and visualize the structure of matter and the course of natural events. If poetry was regarded part of moral philosophy, then art could surely be considered a philosophy of nature. In the paragone question Leonardo considered painting comparable to music since the mathematical harmonies audibly offered the ear are likewise visually presented to the eye by the imaging arts*.

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* Leonardo refers to the fact that in the perspective the relative size of equally large objects decrease inversely proportional to their distance such that the series 1:2:3:4 is reproduced as $1:\frac{1}{2}:\frac{1}{3}:\frac{1}{4}$

The argument is not very convincing.

Leonardo's numerous caricatures and monstrous drawings show that to him nature was not necessarily beautiful. But it was nevertheless worth studying as carefully as possible, because "once the rational principle has been grasped one can depart from empirical observations and proceed to general conclusions" [31]. In this enlightened position the artist becomes "a second God"[32], a creator of wonders even more remarkable than those found in nature.

In this daring transgression over the borders of empirism Leonardo was soon to be followed by many. Rafael [33] admitted that since women of impeccable beauty are scarce he - contrary to Zeuxis - preferred to paint from "a certain idea" of female loveliness that he had formed in his own imagination.

Polizianio [34] ridiculed "the possive reproduction of parrots" in an argument against Cortese who consistently defended the imitating art.

In Germany Dürer made meticulous empirical studies of human bodies. But he failed to find any meaningful mathematical relations in his data and became increasingly convinced that measurements and mathematical studies are of no avail in the artist's

search for beauty. Like Rafael, Dürer would rather rely on the mental images the artist/creator carried inside himself.

In this transition, from the renaissance to the baroque, the case of Michelangelo is perhaps the most interesting. He started off as a convinced platonist but as an artist he allowed himself increasingly greater latitudes. Faced with the problem of justifying these dubious liberties he encountered all sorts of metaphysical difficulties and ended a remarkable artistic career by renouncing his own creative works![35)].

Over on the other side of the widening gulf there was also a great deal of cultural earthquakery centering around Galileo and the experimental method. Strongly influenced by Plato, Galileo shared the Greek master's respect for mathematics. But this he developed into nothing less than an entirely new philosphy of science, which among other things included a critical attitude to Plato's rationalism. Galileo refused to accept the suggestion that the primary task of philosophers is to indulge in dialects. Reality cannot be understood through literary studies and contemplation. There is only one way to find out how the world is made - by observations and experiments.

Galileo is well aware that as sources of human knowledge the senses are obscure and ambigous. Yet he concludes:[36].

> Now, whenever I conceive of any material or corporeal substance, I am necessarily constrained to conceive of that substance as bounded and as possessing this or that shape, as large or small in relationship to some other body, as in this or that place during this or that time, as in motion or at rest, as in contact or not in contact with some other body, as being one, many, or few - and by no stretch of imagination can I conceive of any corporeal body apart from these conditions. But I do not at all feel myself compelled to conceive of bodies as necessarily conjoined with such further conditions as being red or white, bitter or sweet, having sound or being mute, or possessing a pleasant or unpleasant fragrance. On the contrary, were they not escorted by our physical senses, perhaps neither reason nor understanding would ever, by themselves, arrive at such notions. I think, therefore, that these tastes, odors, colors, etc., so far as their objective existence is concerned, are nothing but mere names for something which resides exclusively in our sensitive body (corpo sensitivo), so that if the perceiving creatures were removed, all of these qualities would be annihilated and abolished from existence. But just because we have given special names to these qualities, different from the names we have given to the primary and real properties, we are tempted into believing that the former really and truly exist as the latter.

This was written when Frederigo Baroccio, together with Rafael and Corregio, turned manierism into full-fledged baroque by appealing to precisely those qualities which according to Galilei do not exist in reality and "are nothing but mere names for something which resides exclusively in our sensitive body".

The origin of what later has been denounced "reductionism" is to be found right here in the distinction between what John

Locke [37] later called primary and secondary qualities. Only the former belong to reality. And since they are both necessary and sufficient, reality can in fact be considered the totality of the primary qualities. All other qualitites, color, smell, sound, taste etc exist only subjectively in our perception.

Ever since Galilei this distinction has played a prominent role in science, although the borderline between "primary" and "secondary" has often been subject to dramatic revisions.

The distinction is of instrumental importance for the experimental method. In the following words "our disputes are about the sensible world, and not one of paper ... Let us proceed to demonstrations, observations and experiments." Galileo presents, his scientific philosophy in a nutshell. The world is "sensible" provided we concentrate our attention to the primary qualities only. The mathematical principles behind all natural phenomena thus observed are accessible to human reason if we proceed to "observations, demonstrations and experiments". Each one of these words has a special meaning.

On the basis of observations the scientist formulates an hypothesis. From this he proceeds to "demonstrations", i.e conclusions drawn by logical and mathematical means. He predicts what is bound to happen under given circumstances provided the

hypothesis holds true. Finally the scientist subjects these predictions to experimental tests. If the outcome of the experiments agree with the theoretical predictions, the hypothesis is "experimentally verified" and may be regarded as a true statement about reality.

The experimental method has proven to be of priceless value to science not because of the alleged certitude thus obtained, but simply because it sets a very efficient program for scientific work, albeit at a high price. When Reality was defined as the totality of primary qualities only, art was in effect driven out of the realm of science. It did not last long until the mathematical physicists, "who reduce the elephant to a point with mass m", were openly despised in artistic circles. With Jonathan Swift [38] people laughed at "scientific progress":

> So naturalists observe, a flea
> Has smaller fleas that on him prey;
> And these have smaller still to bite 'em
> And so proceed ad infinitum.

> Before their eyes in sudden view appear
> The secrets of the hoary Deep - a dark
> Illimitable Ocean, without bound
> without dimension; where length, breath and highth,
> and time, and place, are lost.
>
> Milton, Paradise lost

3.3 Far apart

Scientific realism is a very peculiar combination of empirism and realism. But science owes its astonishing success more to the experimental method as such than to its metaphysical underpinnings.

Yet the amazing achievements culminating in newtonian mechanics and maxwellian electrodynamics made people mistake the scientific model of the world for the world itself. And this was a world they did not like. "The eternal silence of these boundless depths frightens me", Pascal confessed.[40)]

With the acceptance of the copernican system everything seemed quite different. It happened suddenly. Shakespeare's world is still medieval. But with the somewhat younger Milton an entirely new conception of reality is already present. Shakespeare, it has been said, lived in a world of time, Milton in a universe of space.[41)] In Cecil Arnold's An Index to Shake-

speare's Thought[42] there are only 32 references to space but several pages to time.

Empirism was challenged by philosophers such as Descartes, Spinoza and Leibnitz and realism by Hume and Berkely, who dealt next to mortal blows to the scientists' innocent and naive ontological beliefs. But hardly bothered by philosophical subtleties experimental science triumphed.

An attac of a somewhat different nature was launched by the perspicacious Giambattista Vico [43] who in his Principii di una scienza nuova correctly pointed out that human beings are entitled to a complete insight into the world of mathematics because mathematics has been invented by men. But the universe has not been created by humans. Only God can fully comprehend his own creation.

But unshaken stood the house of science and almost all scientists accepted for a fact that scientific realism was nothing but an enlighted form of common sense. The whole problem was finally dismissed by Bertrand Russell [44] with the ironic remark: " the 'thing' was invented by the prehistoric metaphysicians to whom common sense is due".

By his bold attempt to mend "the scandal of philosophy" by putting scientific realism on a sound philosophical basis, Kant [45] achieved something very different. The gates were swung wide open to "transcendental philosophy", and romanticism was suddenly socially acceptable - at least in Germany.

How? \ What?	Realism	Phenomenalism
Rationalism	Descartes Leibnitz Spinoza	romanticism
Empirism	scientific realism	Vico Hume Berkeley

The artists were delighted. This was something else than Hume's harsh statement [46]: "beauty is no quality in things. It exists merely in the mind which contemplates them, and each mind perceives a different beauty". In other words: beauty does not

exist in reality - "out there" - it is made up of secondary qualities only.

Since romanticism is the very antithesis of scientific realism the cultural continents of the arts and the sciences were now located at their mutual apogees. Painters like Delacroix, Theodore Rousseau, Corot and, of course, Turner were inspired to do experiments with light and colors and managed to achieve new and suggestive effects.

In England Ruskin [47] objected to Hume's pragmatic statement that pieces of art are beautiful "in proportion to their fitness for the use of man". But, according to Ruskins "beautiful things are useful to men because they are beautiful and for the sake of their beauty only", which probably is supposed to mean that beauty has an autonomous value, which cannot be further analyzed.

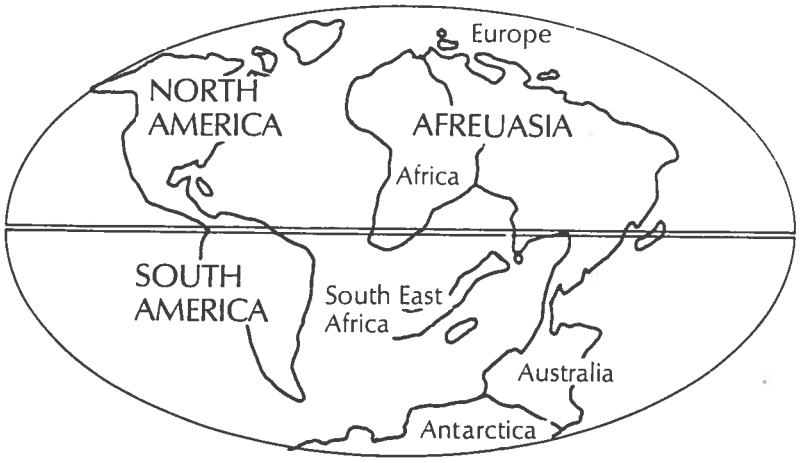
But in spite of the philosophers' attentive courting surprisingly little of lasting value was achieved. Perhaps because the philosophers' love affair turned out to be a brief episode only. It started in 1749 with Rousseau's scathing rejection of the sciences [48] - " there is nothing in romanticism that is not in Rousseau, there is nothing in Rousseau

that is not romantic". The climax came only a few decades later with the verbose deliberations of Schelling [49] and the two Schlegels [50]. With Hegel [51] the fire was already gone. It is true that to Hegel art is a manifestation of the Soul in the world of phenomena and as such it is an important means to the Soul's self-realization. But since this feat had already been accomplished in Hegel's Prussia, there was no need for any further artistic activities!

Following Hegel, and probably as the first European philosopher notably influenced by buddhism Schopenhauer [52] ended up in a sheer pessimism, in denial of the world of senses and in a longing for Nirvana as the ultimate and only true blessing. Under the spell of darwinism his more cynical student Nietzsche [53] recommended the exhilarative fight for power as an antidote to boredom.

In other words, the community of artists had to look elsewhere for philosophical guidance and encouragement. Over on the other side science made enormous progress. Could the scientist's "realism" be worth trying? In France Courbet declared that, as a painter, his major objective was to be true to reality [54] and in 1857 Daumier's political caricatures were

praised in a booklet published by Champfleury [55]. This treatise, incidently, carried a boding title: Le Realism.



What vanity is not the art of painting, making us admire the similarity with things we would not admire in reality!

Pascal

If this refusal to seek underlying causes of observed regularities is applied consistently it trivializes the entire scientific enterprise. Science is reduced to a set of recipes for predicting future observations from a knowledge of past ones. Any notion of science as "the study of nature" is impossible; nature is a phantom.

Bernard d'Espagnat

4. THE CRISIS OF REALISM

4.1 Geometry and space

The first in the series of cultural earthquakes, signalling the coming of a new era, ocurred in such a remote and inaccesible region of the intellectual world, that it passed almost unnoticed. But a few perceptive minds realized immediately that something incredible had indeed taken place.

When Gauss, Bolyai and Lobachevsky almost simultaneously and quite independently of each other, discovered the existence of non-euclidean geometries, the bottom fell out of platonism. Up till that moment it had never been talk of euclidean geometry, but of geometry, pure and simple, as if there were and only could be one single geometry - the true, euclidean. And now one was suddenly faced with alternatives, in fact, as it turned out, of three different kinds. All three of them were just as logically irruptible and mathematically consistent as the euclidean geometry, although some of the results obtained challenged common sense. Depending on the "curvature" the sum of the angles in a triangle can be larger (or smaller) than 180^{o}, the ratio of the circumference and the diameter in a circle must not necessarily be equal to ; it can be larger or smaller and so on.

Vico was right, after all, at least on this point. Mathematics is nothing but a produce of the human brain. And geometry soon turned out to be a much richer and more multifarious subject than anybody ever could have imagined. The elliptic and hyperbolic alternatives to the "flat" euclidean geometry, were supplemented with four, five and n-dimensional forms of euclidean or non-euclidean metrics.

The very existence of non-euclidean geometries made mockery of the kantian philosophy, since according to Kant, these were literally "unthinkable". But to the scientists the mathematical discoveries presented a challenge: which of the mathematical geometries applied to physical space? In other words which one of the alternate geometries was true?

Only experiments could tell. And such experiments have been performed, but so far not the slightest trace of a departure from the euclidean predictions has been found*.

It was against those experiments and the conclusions the empirical results eventually might lead to, that Poincaré directed his famous remark [57]:

> If Lobachevsky's geometry applies, a very distant star must exhibit a finite parallax, if Riemann's holds true it must be negative. These are observations that seem to lie within experimental reach and people have expressed hopes that it will become possible for us to decide between the three geometries. However, in astronomy a "straight line" simply means "the path of a light ray". Thus, if we find negative parallaxes or, if it turns out that all parallaxes exceed a certain limit we have two alternatives to chose among. We may renounce the Euclidean geometry or

* In fact such experiments are still being done. But the "curvature", i.e. the non-euclidean nature of physical space is obviously very minute. Indeed space is so surprisingly "flat" and that it is, in fact, a major problem in modern cosmology, a problem to which the "inflationary" universe seems to offer a possible solution.

we may modify the the laws of optics and suppose that light does not propagate exactly along a straight line. Needless to say that the latter alternative will be deemed preferable. Thus Euclidean geometry has nothing to fear from new experiments.

The prediction, as such, turned out to be wrong. A non-euclidean alternative has indeed been "deemed" preferrable, but for technical reasons only. In essence Poincaré was right: we cannot experimentally (or otherwise) find out which geometry is true. Our understanding of the physical world is - at least partly - based on conventions.

This is extremely interesting. For the first time a leading scientist frankly admits that we cannot objectively find out how it is in reality, that scientific realism is an untenable position. But even more important: Poincaré points out that there is a social element - as evidenced by the presence of postulates and conventions - inherent in the scientific quest for knowledge.

Over on the other side the artists arrived, by different means, at a similar conclusion.

Thou knowst we work by wit and not by witchcraft and wit depends on dilatory time.

Shakespeare

4.2 Le coefficient d'art

Classical physics* worked perfectly in spite of the fact that the luminiferous ether of maxwellian electrodynamics is incompatible with the atoms-and-void concept of newtonian mechanics. Yet no major problems were encountered as long as phenomena of essentially electromagnetic or mechanical nature were studied separately. But when the two great theories were confronted, their mutual inconsistently became manifest. Significantly, Einstein's first publication on the special theory of relativity carried the title: "On the electromagnetic properties of moving bodies". Likewise Bohr initiated the development in quantum physics with a model of the hydrogen atom,

* "Classical physics" is the general name for 19th century physics composed of newtonian mechanics and maxwellian electrodynamics. Philosophically classical physics represents a materialistic brand of perceptual realism, where all of the phenomena in nature are supposed, at least in principle, to be reducable to primary qualities of either mechanical or electromagnetic nature or both.

which could account - at least partly - for hydrogen's electromagnetic spectrum.

The turbulent era that followed has shaken a lot more than the world of physics. It has taken almost a century to complete the transition from classical to modern physics and even now the philosophical situation is far from clear as witnessed, for instance, by the current intense debate on the philosophical foundations of quantum mechanics.

It is generally acknowledged that Marcel Duchamp's famous painting Nu descendant un escalier is an attempt to capture, in the plane of the picture, a sense of fourdimensional spacetime. It is indeed remarkable that this piece of art was shown in New York in 1913 i.e. only eight years after the publication of Einstein's first paper on special relativity in Annalen der Physik.

Some of the outrageous consequences of special relativity seemed to challenge common sense: length contraction, time dilation, the relativity of simultaneousness and the fateful $E=mc^2$ relation, to mention but a few. Yet the spacetime concept of special relativity has a lot in common with the ordinary three-dimensional space of classical physics, notably the property of being a passive container of matter.

What is entirely new, however, and of particular relevance in this context, is the emphasis on the observer in the two basic postulates* of the special theory of relativity. This caught the artist's attention. Faced with his motif the painter is placed in a somewhat similar situation. The alert Marcel Duchamp expressed it very precisely in one of his earlier notes in the famous boite verte [58] (parentheses added):

> On one hand: the chief of the naked (the senses) should stand before the other four naked. (the empty fourdimensional spacetime) turned towards this route Jura-Paris (from the past to the present). On the other hand: the lanternchild (the observer), who should be the victorious instrument for this very same route Jura-Paris. This lanternchild could, graphically, be a comet with its tail in front of itself (i.e. what the physicist would call "the lightcone").

The imagery could scarcely be more precise. It is hard to believe that this note was written already in 1913!

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* These postulates are:

1. The principle of relativity: it is impossible for an observer to determine by means of any physical experiments whether he is at rest or in a state of uniform rectilinear (i.e. unaccelerated) motion.
2. The constancy of the velocity of light: the velocity of light is a universal constant, the same for all observers whether they are at rest or in motion relative to the light source.

But Duchamp's interest in relativity was not merely one of a superficial visionary. He went to the heart of the matter and he even performed experiments himself, let alone of an unconventional and artistic nature. A one meter long wire was made to fall freely a distance of one meter onto a flat surface made of canvas which had been painted black. During the fall the wire deformed itself "as it pleased". The actual shape of the wire,when at rest on the surface, was recorded by fixing the string to the canvas. The experiment was repeated three times and the "experimental results" were glued onto long narrow plates of glass. For each one of the wires the artist also made a correspondingly shaped ruler and finally everything was neatly packed into a croquet* box!

To a physicist the meaning of all this (or at least a meaning) seems clear enough. The wire represents the einstein interval, an invariant quantity which may be written as

$$s^2 = x^2 + y^2 + z^2 - c^2t^2$$

When projected into the observer's world of perception the einstein interval ecomes a distance ($\sqrt{x^2 + y^2 + z^2}$) and a lapse of time t. Both of these may be experienced differently

* As Ulf Linde has pointed out croquet sounds like croqué and croqui.

by different observers. Yet when comparing the different results the human mind performs an act of "restoration approaching the unity of the lenght", as Duchamp put it.

In his studies of what he later called le coefficient d'art, the artist seems to be exploring the possibilities of the new conceptual realism Einstein held in prospect.

But realism was in more troubled waters than the incredible "marchand du sel" ever could imagine. In science there has always been a tacit concordance between realism and determinism. The reason is very simple. A scientific account of what takes place in reality ultimately rests on the assumption that inductive inference applies, in other words that there real causes for observed effects*. Scientific realism therefore has to be deterministic.

When the newtonian concept of absolute time** was abolished

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* This is not to say that because events are caused to happen they have to happen. The cause is completely hypothetical until the effect appears.

** "Absolute, true, and mathematical time, of itself, and from its own nature, flows equable without regard to anything external" Newton, Principia

the notion of an instantaneous, universal and omnipresent now no longer could be held. And since this is a sine qua non for all forms of perceptual realism the very idea of realism was seriously threatened. It found, however, a humble retreat.

According to the theory of relativity cause and effect cannot couple faster than with the speed of light. Therefore anything causally connected with an occurrence at a given location must be present within a sphere centered at the point of the observed effect and with a radius which is equal to the velocity of light multiplied with the time lapsed between the cause and the effect.

An example may help to explain. Let C be an object "out there" in reality with a characteristic property p, such as the quality of being explosive. The cause x represents the ignition of the fuse and y is the subsequent explosion. The causal connection may then be expressed as follows*:

$$Cp + x - y$$

* The phenomenalist would object that Cp is purely hypothetical. All of what we really know from observation is contained in x and y.

Let us now suppose that the lapse of time from the cause x to the effect y is t then anything that possibly could be causally connected to y must be present within a sphere with the center at y and with the radius

$$r = ct$$

where c is the velocity of light. In this way special relativity is reconciled with the layman's perceptual realism but at great expense: realism becomes local.

Even though it is not strictly relevant, it may be useful to give the reason for the increased interest of the contemporary physicists in the problems of epistemology and ontology. The reason is, in a nutshell, that physicists have found it impossible to give a satisfactory description of atomic phenomena without reference to the consciousness. This had little to do with the oft rehashed problem of wave and particle duality, rather, to the process called "reductions of the wave packet". This takes place whenever the result of an observation enters the

consciousness of the observer - or, to be even more painfully precise, my own consciousness, since I am the only observer, all other people being only subjects of my observations. Alternatively, one could say that quantum mechanics provides only probability connections between the results of my observation as I perceive them. Whichever formulations one adopts, the consciousness evidently plays an indispensable role.

Eugene P. Wigner

4.3 Spooky physics?

The second of the two major cultural earthquakes in modern physics - relativity theory being the first - began with the Bohr model, a highly original, but primitive concept, which rapidly developed into the most complete, precise and revolutionary theory ever known: quantum electrodynamics.

Because of it's incredible advance quantum mechanics almost immediately ran into open conflict with relativity theory and this for a very simple, but profound reason: the "tacit concordance" between realism and determinism. With the advent of quantum mechanics determinism seems to be at stake.

With the same symbols as in the previous section:

$$Cp + x \rightarrow y$$

the ignition (x) causes the charge (Cp) to explode (y).
This is determinism. "Der liebe Gott würfelt nicht". God is not casting dices, as Einstein put it. Not necessarily because He is

against gambling as such, but for a more compelling reason: He can not gamble! Since the Almighty has complete insights to His own creation the future is as intelligible to Him as the past. To God nothing comes as a surprise. To God, and to God only, gambling is denied!

But let us now suppose that Cp represents an atom in an excited state. The transition to the ground state takes place through the emission of one (or several) photons. This is the observable effect (y), and the question naturally arises: what x causes this "microscopic explosion"? According to quantum mechanics nothing! There is no cause. There is no difference between the atom which is just about to make the transition and one which will remain in its excited state for the time being. There is only a certain probability that the transition will take place right now rather than later. These statements of quantum mechanics can obviously not be reconciled with determinism. But are they compatible with a realistic view of the world?

It all boils down to Heisenberg's indeterminacy principle, which states that in measuring one of a pair of conjugates physical quantities characterizing a microsystem, e.g. the position-momentum or time-energy, the experimental measuring act necessarily destroys the possibility of measuring the other to arbitrary accuracy.

The indeterminancy principle is the core of the wave-particle duality implying that energy ultimately comes in packages, which under certain well defined experimental conditions behave as if they were particles and under other, equally well defined, circumstances show wavelike properties. But the two qualities are never simultaneously expressed.

This "complementarity principle" has been imaginatively illustrated by Mauritz C. Escher. In one of his works one may see the flight of white birds heading leftwards or the flight of identical, but black, birds going to the right. One can easily adjust from one view to the other. But by no act of imagination seems it possible to perceive the two complementary views at the same time. And yet in reality, simultaneously and complementary, the two are right there in front of us.

The philosophical meaning of this complementarity principle seems far from clear, however. The real question is not, as Wigner pointed out, "the oft rehashed problem of wave and particle duality" but the indeterminacy principle itself.

It is certainly one of the most important discoveries ever made in physics, if not the most important. It should come as no surprise, therefore, that it almost immediately caught the interest of a keen intellect such as Duchamp's. In one of the notes in the intriguing boite verte the artist makes a telling

distinction between "the ministry of gravity" and "the regim of chance".

More to the point, however, is some of the works behind Duchamp's masterpiece La mariée mis a nu par ses célibataires, meme. (The bride stripped naked by her batchelors, in person). Here Duchamp has made what appears to be a demonstration of the indeterminacy principle. A toy gun was loaded with a match and fired towards the glass, which in this case replaces the painter's canvas. The head of the match had been dipped in color such that the point of impact was marked.

The experiment was repeated nine times with the gun always aimed at the same point. The random spread of the shots were recorded and afterwards the artist drilled small holes at the nine different points of intersection. These holes are all in the upper right quadrant of the glass.

The significance of the mysterious holes becomes evident when it is realized that the nine batchelors in the lower left part of the picture are situated precisely on the relative positions of the holes when projected perspectively into the plane of the glass from the point towards which the gun was originally aimed.

What is the meaning (or a meaning) of all this? It seems reasonable to assume that the flying matches represents the momentum which is completely lost at the position of impact.

If there had been a hole -"an inscription"- nothing would have hindered the flight. The goal had been reached and this particular batchelor would have lost his chastity.. "The inscription activates the tired" as Duchamp put it.

In the famous discussion with Bohr on the epistemological foundations of quantum mechanics Einstein failed to overthrough the indeterminancy principle. But he came up with an ingenious rebuff - the famous Einstein-Podolsky-Rosen "Gedanken-experiment"[60] (the EPR thought experiment).

The argument is very simple. Two elementary particles collide. Prior to the collision it is in principle possible to measure with any given accuracy either the total momentum of the two particles or the exact positions of their center of gravity.

After the collision the particles fly apart. The collision process itself is, according to quantum mechanics, subject to the same conservation laws as in classical physics.

When the particles are well separated one of them, A say, is subject to observation. Its unobserved partner B is so far away that a signal travelling at the speed of light cannot reach B before the measurement on A is completed. The measurement can therefore not influence the behavior of B.

It is possible to determine with arbitrary degree of precision either the momentum or the position of particle A. A straight forward application of the conservation laws tells us

that the unobserved particle B must have a well-defined momentum and an exact position, since it has no way of "knowing" which of the two observables we have decided to determine for its partner A.

The fact that it is impossible to measure both the momentum and the position simultaneously, with arbitrary degrees of accuracy, does not exclude the possibility that these two quantities nevertheless are precisely determined in reality.

Bohr[61] responded by insisting that it makes no sense to speak about observables, prior to observation. But this did not convince the physicists. They were enthralled by the magics of quantum mechanics and applied its formulas without hesitation. They even developed its theoretical machinery into breathtaking mathematical complexity. But deep in their heart they remained faithful to scientific realism. They accepted the quantum mechanical theory with enthusiasm but refused to buy its associated "Copenhagen interpretation".

For half a century the physicists remained in the fortunate position of being able to combine a pragmatic use of quantum electrodynamics with a realistic ontology*.

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* In the "methaphysical matrix" Einstein has been placed in the lower left quadrant. But he sometimes expressed a rationalistic inclination. The gist of General Relativity is no doubt more akin to platonism than to scientific realism. Bohr, on the other hand, never made his position on ontology clear. But, as discussed in the text, quantum-electrodynamics is hardly compatible with realism.

How? \ What?	Realism	Phenomenalism
Rationalism		
Empirism	Einstein	Bohr

But the situation became alarming when it was shown that the predictions obtained for the EPR experiment from local realism are different from those given by quantum mechanics. Such experiments were finally performed. The results obtained from very careful experimental studies are incompatible with the predictions derived from local realism. The agreement with quantum mechanics, however, is perfect!

Unless one is willing to accept some mysterious "spooky" action at a distance, there seems to be no way out. The Spook must be expected not only to act instantaneously, and in some unknown fashion, but it must also be thought of as endowed with precognition!

The present situation is neatly summed up by John S. Rigden[62] in his May 1986 editorial in the American Journal of Physics:

It seems that either our ideas of realism or our ideas of locality must be abandoned. In either case, new meanings, profound in their implications, will be required.

Or consider experiments that examine the behavior of single photons. I do not mean a gedanken experiment, quite the contrary. With ingenious techniques, physicists can design interferometer experiments with one photon... just one photon in the interferometer at any one time. In these experiments, solitary photons pass through a beam splitter and, from that point, each photon either travels one path or the other through the device or each photon travels both paths simultaneously and interferes with itself upon recombination. It would seem that the photon "knows", while it it still in the beam splitter, what type of measurement lies ahead and "decides" accordingly whether to proceed via one path or two. Further, in delayed-choice experiments, physicists try to deceive the photon by changing the experiment after the photon has already decided whether to travel by only one path or to go by both. Nothing changes: The photon seems to anticipate the deception. What can be the meaning?

> No phenomenon is a phenomenon until it is observed... The universe does not "exist out there" independently of all acts of observation. It is in some strange sense a participatory Universe.

John Wheeler is giving up more than a circle; he is abandoning more than the ether. In Wheeler's world there is nothing more basic than our observations themselves. Apart from them there is no meaning. Is the meaning, no meaning?

Whether Mr. Mutt with his own hands made the fountain or not has no importance. He CHOSE it. He took an ordinary article of life, placed it so that its useful significance disappeared under the new title and point of view - created a new thought for that object.

The Blind Man. Editorial

4.4 Ready maids

When Courbet said he only wanted to be true to reality it seemed simple enough. But the realistic artists soon found themselves faced with all sorts of problems. Some of these were anticipated. It came as no surprise that the public furiously complained about the ugliness of the motifs. Were not, people argued, artists supposed to select beautiful objects for their paintings? Was not the quest for beauty the very essence of art?

These objections were easily countered. Why should art be beautiful when reality is not? What is beauty if it is not true? Moreover, after Guernica an honest and sensible observer can hardly deny that Picasso's painting is gifted with the most serene beauty in spite of - or perhaps just because of - its horrendous motif.

The impressionists eagerly adopted "scientific" methods obtained from theoretical studies of colors, such as Chevreul's book on simultaneous contrasts[63], from experiments with Maxwell's color wheels and, last but not least, from listening to the excentric scientist Charles Henry, who lectured in Sorbonne on an "esthétique scientifique" of his own invention.

But they soon discovered that methods, such as the laborious pointillist technique, were not enough. For Zola, who in his novels shows a profound interest in the problems of art and therefore had a considerable influence on the artistic community, it was necessary for the reproduction of reality to proceed beyond the sensual surface to the essence of things. To be true to the reality the scientist explored, the artist must leave the world of "secondary qualities".

Seurat's masterpiece La Grande Jatte was a great breakthrough. It was first shown in the Brussels exhibition of 1887 and immediately arouse an enormous interest. During the opening day there were fifteen hundred visitors. Sven Lofgren [64], a Swedish expert on Seurat's art, has summarized his analysis of La Grand Jatte as follows:

> With this composition Seurat created tension of great artistic effect, between the phenomenal and the noumenal between the observed and the imagined. All technical methods were applied to reach this end. The picture is dematerialized by the abolition of every tendency, towards tactile values. As far as the colours are concerned, the painting is monotonously uniform. The aim of the artist is no longer, in the style of the impressionists, to record the perceptive sphere. Instead he attempts to capture the emotional experiences according to definite aesthetic formulas. His endeavours to delve deeply into the disparate elements of existence in order to create with intuitive clarity a new synthesis were to him - as to many of his contemporaries - an agonizing pilgrimage towards the illusive autonomous work of art, towards a unique world of symbols in which the artist, by virtue of his knowledge and poetic power, is the supreme ruler.

Similar steps were soon taken by Gaugin and van Gogh. More drastic measures were required, however, in order to get to the truth, i.e. to the "primary qualities". To this effect Picasso and Braque invented cubism. Realism, after all, rests on the proposition that objects have an autonomous existence. The things "out there" are not blotted out of existence the moment the illuminating light is extinguished. And even in the dark they must retain their own true colors. In the name of truth, therefore, the cubists rejected, just as Plato once did, the use of perspective and of shadows as means to achieve an illusory ressemblance with the phenomena of perception. They even went as far as to paint motifs in natural size only. Mondrian spoke lyrically about his true love for the objects of the "free and universal reality".

But this was not the end of their difficulties. When the treacherous perspective and the deceiving shadows were exorcised then, alas, depth also disappeared! To restore threedimensionality they experimented with multiple light sources, but in the final analysis the objects seemed to owe their very existence to the fact that they were, somehow, illuminated!

In this way they finally arrived at the ultimate solution: the collage. At last the objects in the picture were <u>real</u>. But what the use! They had reached the end of the road and were forced to retreat*. "Everybody knows", Picasso snorted, "that art

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* It took Marcel Duchamp's iron logic to pursue this line of reasoning to its ultimate conclusion: the <u>ready made.</u>

is never true" and he summarized his experience of realism in words which naturally bring to mind Karl Popper's falsificationist philosophy of science. "Through art", Picasso declared, "we express our understanding of what nature is not".

Kandinsky said he lost his "belief in an objective reality"** when he was told that the scientists had managed to split the atom. Instead he joined the other branch of modernism - a conceptual realism with deep roots in German and French romanticism as well as in writings of Baudelaire and of Edgar Allan Poe and in Wagner's music.

To Kandinsky art was not science. Art is, or at least it should be, immediately experienced by the spectator. The emphasis is on the spontaneity. There should be nothing between the painting and the spectator in terms of analysis and explanation. It should be nothing but "pure" art.

When the purists aimed at this spontaneous appreciations of the artistic content they naturally arrived at a non-figurative art. This new form of art, they suggested, should be based on objective scientific laws of perception. As Hans Arp put it: "We

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** i.e. what here has been called perceptual realism or materialism.

do not want to imitate nature. We want to create, not recreate... And we want to create directly without interpretation."

But the spectator is not an empty receptor to be filled with artistic impressions. The spectator compares his experiences with memories of previous impressions, he interprets what he sees and he transforms his experience into something highly personal. Art is always about something. Pure art, void of all meaning, can be nothing but decoration.

Ulf Linde has pointed out that:

> When the doctrine of pure form is carried to its extreme one arrives at an critical point: one is either forced to accept that a piece of art is nothing but sheer triviality or to admit that a form in a picture can never be "independent", in some sense it is always a sign. The latter alternative is the only viable - lest it will become impossible to speak about art at all.

Marcel Duchamp, finally, took an entirely different route. After having experimented with various forms of "fourdimensional" realism he too met with a crisis: "I began to feel that my art was more and more introspective, the external world became less interesting to me." Finally it occurred to him that an artist could use anything "even the most conventional or unconventional symbol to express what he wanted to say."[65)]

To prove this point Duchamp invented the ready made*: he

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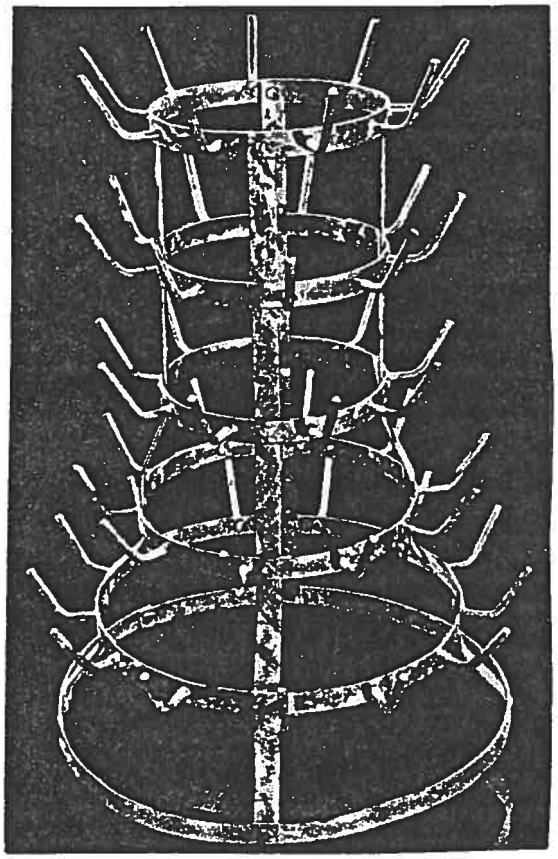
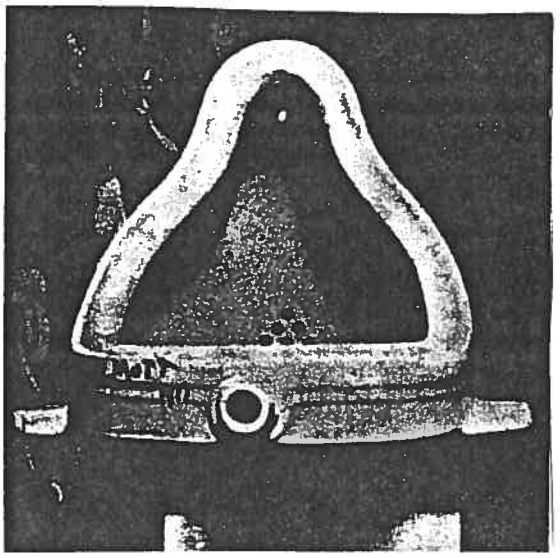
* That "ready made" sounds exactly like "ready maid" is certainly no accident. Duchamp's ready mades are very different from the real objects used in the cubistic collage. To Duchamp the object was merely an invitation to an artistic effect, which for its fulfilment requires the spectator's active participation and commitment.

took a manufactured artifact and turned it into a piece of art "through the simple choice of the artist". [65]. This first attempt was the notorious bottle drier put on display in 1914.



The public took it for a blasphemous provocation and got furious. But Duchamp had proven his point: the one and only thing that turns an object into a piece of art is the simple fact that somebody calls it art. The fact that people got mad showed that to them, the spectators, the "bottledrier" was no longer a harmless commodity from a nearby grocery store. They acknowledged the invitations and got involved.

The success led Duchamp to further experiments with ready mades, the most scandalous of which was the "fountain". Under the pseudonym Richard Mutt he submitted, in 1917, a pissotière for display at the Independents salon in New York. It was not accepted. The refusal received the following editorial comment in The Blind Man magazine*:



* This magazine was published by Marcel Duchamp.

The Richard Mutt Case

They say any artist paying six dollars may exhibit. Mr. Richard Mutt sent in a fountain. Without discussion this article disappeared and never was exhibited.

What were the grounds for refusing Mr. Mutt's fountain -

1. Some contended it was immoral, vulgar.
2. Others, it was plagiarism, a plain piece of plumbing.

Now Mr. Mutt's fountain is not immoral, that is absurd, no more than a bath tub is immoral. It is a fixture that you see every day in plumbers' show windows.

Whether Mr. Mutt with his own hands made the fountain or not has no importance. He CHOSE it. He took an ordinary article of life, placed it so that its useful significance disappeared under the new title and point of view - created a new thought for that object.

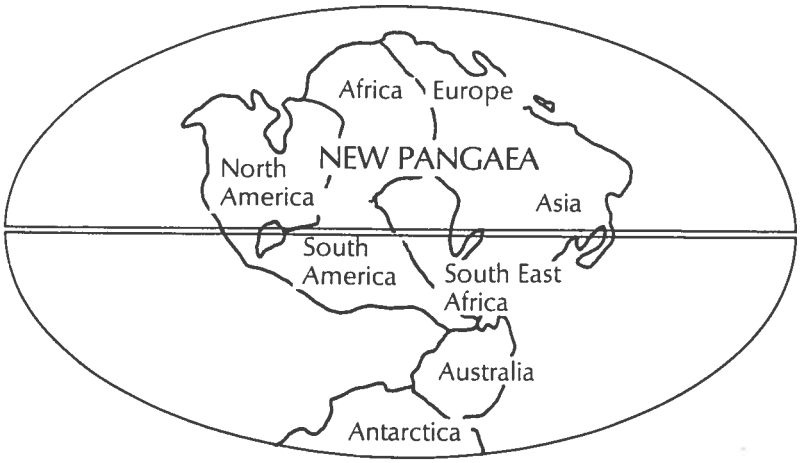
As for plumbing, that is absurd. The only works of art America has given are her plumbing and her bridges.

The ready mades were intended to demonstrate the crucial role played by the spectator. Duchamp even went as far as to claim that it is "the spectators that make the picture". This may seem absurd, but note the plural: the artist himself is, of course, included as the first of the spectators.

With his ready mades Duchamp turned against contemporary realists. Art is not concerned with what enters the perceptive sphere or with the autonomous objects "out there". Art is never "pure". The essence of art is - and has always been - an act of communication. As such art is a cultural phenomenon based on

social conventions, just as science, and art depends, just as science does, ultimately on people for its very existence.

Unfortunately, after having made this point, this exceptionally gifted artist found nothing else worth saying and terminated his artistic career. It is a matter of opinion, of course, but it may be argued that since then very little of value has been said about science and art.



5. EPILOGUE

In the foregoing an analysis of the relations between science and art based on a cultural plate tectonics paradigm has been presented. It is left for the reader to judge whether the elaborations presented above make any sense at all. If they seem to do, however, a question naturally arises: what next? How will the relation between science and art develop in the future?

A theory, which is good for the past may not apply to the future. The darwinian theory of evolution, for instance, has no

predictive power at all. It is not to be expected that something as subtle as the science/art relation renders itself to forecasting. Yet, a few general remarks may nevertheless be ventured.

If the underlying metaphysics serves as an explanation, in the way suggested above, it seems safe to say that the harmonious unity of the upper left quadrant is forever lost. For compelling socioeconomic reasons empirism will certainly be with us for the future, since this is the only way to guarantee the viability of the technology on which the industrialized society ultimately rests. To turn away from empirism is to invite disaster.

The transition from realism to phenomenalism seems completed as far as the arts are concerned. But when it comes to the sciences this passage seems far from assured. The majority of the scientists will probably resist any deviation from realism. Yet, to the author at least, this course seems inevitable. When (or rather if) the transition is completed science and art will find

What? / How?	Realism	Phenomenalism
Rationalism	Truth and Beaty	Beaty rather than Truth
Empirism	Truth rather than Beaty	Neither truth nor beaty

themselves together again, but now located in the lower right quadrant. And, alas, this is not the most productive state of cultural affaires. But this may be precisely where the explanatory power of the metaphysical matrix empties.

The current emphasis on the social element* in the sciences as well as in the arts represents an entirely new dimension. It is not impossible that it is in this direction we must look for the future of science and art. The emancipation of mathematics in the 19th century has lead to an enormous outburst of creativity. When it finally let the last traces of realism go, mathematical thinking took off in all directions. The results have been truely astonishing. But - and this is important - modern mathematics owes its success both to its new won freedom and to its unyielding adherence of utmost mathematical rigor and logical discipline.

Mathematics may set the example for both art and science. If this happens we may indeed be heading towards a new unity - towards a New Gondwana.

June 1986

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* In this paper this new trend has been illustrated for the sciences by Poincaré's conventionalism and by the presence of postulates in scientific theories and for the arts by Duchamp's ready mades. Other, and perhaps more telling, examples could undoubtedly be found.

Acknowledgements:

I am much indebted to Ulf Linde who first called my attention to the relation between science and art. Linde's enlightened analysis of what has been called the crisis of realism and in particular of Marcel Duchamp's artistic development has been followed here almost verbatim. And the same applies to his studies of Piero della Francesca. I am also influenced by Sven Lofgren's The Genesis of Modernism and in particular of his studies of Seurat's art. Finally I would like to acknowledge my dependence of Götz Pochat's Estetik och Konst-teori, which for me has been rich source of information.

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