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AN INVITATION TO READERS

Reasoned letters which comment, pro or con, on any of the articles printed in *Impact* or which present the writer's view on any subject discussed in *Impact* are welcomed. They should be addressed to the Editor, *Impact of Science on Society*, Unesco, 7 Place de Fontenoy, 75700 Paris (France).

The One True Light

Some Hindus brought an elephant, which they exhibited in a dark shed.

As seeing it with the eye was impossible, everyone felt it with the palm of his hand.

The hand of one fell on its trunk; he said, 'This animal is like a water pipe.'

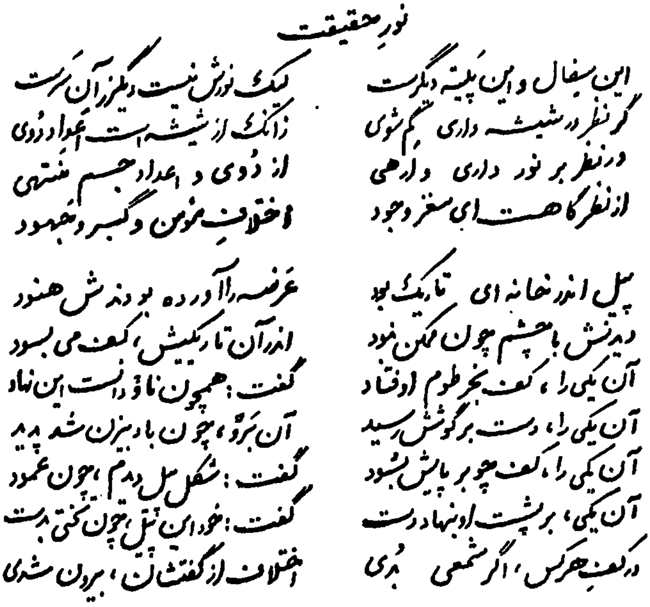
Another touched its ear; to him, the creature seemed like a fan.

Another handled its leg and described the elephant as having the shape of a pillar.

Another stroked its back. 'Truly,' he said, 'this elephant resembles a throne.'

Had each of them held a lighted candle, there would have been no contradiction in their words.

(From the works of the Persian poet and mystic Jalal'uddin Rūmī (1207–73), as translated by Reynold A. Nicholson. Calligraphy in Farsi executed by Khanak Echghi.)



Comment

To write all there is to say and speculate about the relationship between science and art, to arrive at *The One True Light,* in about one hundred printed pages, may seem to be presumptuous. Yet we believe that the authors in this issue have something special to say, that they expose their thoughts on the subject with both clarity and a calculated sense of provocation. We leave it to the reader, however, to decide if they reach as unanimous a conclusion as did the great writer of Persian verse when he concluded seven centuries ago that 'there would have been no contradiction' between what the eye can see and the hand can touch.

In using the term 'science' in the context of this issue's theme, we mean the word to include its applied phases—or technology—because that is where the art-science interface seems to be most manifest. We shall not banish from the scene, however, the theoretical and experimental phases of the natural sciences; see, for example, the amusing essay by Piet Hein (Copenhagen).

Our contributors have addressed themselves, by the approaches they deemed most appropriate, to a variety of important socio-cultural questions. The principal among these are:

What is the role of the artist as both innovator and human being in a world (whether 'developed' or 'developing') dominated by technical change?

What are the new art forms born of evolutionary science and technology?

Has artistic achievement become estranged from the world of research, or is there harmony between the two?

Is there a new relationship between the viewer and the objects viewed?
Is modern education geared to the integrating aspects of artistic and technical advancement?
What are the social constraints imposed on the progress of both science and art by man's current political organization?
There are other questions to be asked, whether satisfactory responses might be forthcoming or not. For example, have science and technology replaced the visual and performing arts? Or, what have the mass media done (good or bad) for art? Again, how does a visual artist compete with photography or a dramatic performer with television or a singer with electronically transcribed voices and music?

In the pages which follow, engineer-artist Frank Malina (Paris) discusses the opportunities and outlets available, or not, to those who possess artistic flair. David Dickson (London) examines the various cultural cloaks which sometimes disguise the true condition of scientific-artistic progress in today's socio-political setting, while Francesco d'Arcais (Rome) recalls the historical symbiosis between art and science. Rolf-Dieter Herrmann (Knoxville) analyses the role of perception by our senses of the imagery of art, and the place in our social universe of the product of the artist.

A professional educator of engineers, Robert Preusser (Boston), himself a specialist in design, recounts an unusual teaching experiment conceived to remove the barriers standing between the cultures of the technologist and the artist. Piet Hein reinforces the argument to hasten this removal. A trained dramatist and planner of exhibitions, Jasia Reichardt (also of London), recalls the changes which have taken place in the art-technics relationship during the past twenty years—less than the span of a single human generation. And, at the end of our textual portfolio, Zbigniew Czeczot-Gawrak (Warsaw) underscores our obligation to humanity's future generations to use all technical means at our disposal today to record the artistic aspect of contemporary culture, to mark it as a continuing and ineffacable part of mankind's total heritage.

Further, instead of merely discussing the art-science relationship, *Impact of Science on Society* presents (in the form of a glazed paper insert) illustrations of different kinds of art structures combining aesthetics with applied science. These reflect some of the enormous diversity in man's capacity to conceive, discover, invent and implement—imaginatively, effectively and tastefully.

IMPACT

On examining science and the other arts

by Piet Hein

We humans are prone to fall into thinking traps of our own invention. We separate thought and word, problem and solution, art and science, even objects from one another. We trace the very boundaries over which we proceed to stumble. One result has been the estrangement of artistic activity from the endeavours of research. Yet the core of creativity is the clear formulation of a problem, the novel restatement of a question. Intellectual innovation is essential to fill the gap separating the arts from the sciences.

Words are wonderfully well adapted to the function of saying what needs not be said because it has already been said so often. Indeed, what is better not said may be that because it rubs in further, randomly developed, limiting frames of thought. The reason for this is, of course, that words have been shaped by what has been said.

And, for the very same reason, words are wonderfully badly adapted to saying anything really new. Which is what we are expecting of words, nevertheless, and looking for in them all the time.

These are hard conditions in which to work, but not at all bad. To work in a willing medium is very alluring; it may lead you astray, away from reality, from real problems. An obstreperous medium forces you to fight with it, reinforce the thoughts you have against it; you end up by holding your own and managing to express some kind of reality which goes against the grain of the words. But this will happen only if, and in so far as, we realize that such is the state of affairs and come to grips with that obstinate field of force we call words.

Theoretical physicist, philosopher and inventor, Copenhagen-born Piet Hein also writes lyrical literature. Inventor as well of the beguiling short aphoristic poem known in Denmark as the gruk, *Hein is also a serious designer and architect. He can be reached at 'Heatherfield', Park Road, Stoke Poges, SL2 4PE (United Kingdom).*

Goethe on words and species

Johann Wolfgang Goethe said: 'Man usually believes, when he just hears words, that it must be possible to attach some meaning to them.' (Gewöhnlich glaubt der Mensch, wenn er nur Worte hört, es müsse sich doch dabei etwas denken lassen.)

The German writer gave an excellent example, unintentionally, of a case in which that belief is unjustified. In connexion with evolution, he said: 'All species are similar to each other, although no two are identical.' (Alle Arten ähnelen einander, doch keiner ist den andern gleich.) This leads one to wonder what two different species that are identical would be like. Or vice versa.

One could expand the first Goethe-word, above, by saying: the more rigid and well established words people hear, the more real and rounded-off units they believe must lie behind them. The very fact that we attempt, or even pretend, to represent reality by words (primarily nouns) tends, inadvertently, unconsciously to impose a character of quantization upon what is itself more often a continuum.

Plato's dialogues, and thus presumably the philosophy of Socrates (which they are supposed to represent), are fine examples of this fundamental error of identifying words with what they are supposed to describe. Even in Leonardo's theories on natural phenomena, one can easily follow how verbal units kept him away from the true nature of these phenomena. The same, deep-rooted effect is at work in our own time and in all of us, but it is more difficult to observe in ourselves.

The invention of words is an essential element in what makes us human. Words are concretizations and carriers of thought; they make possible the building of elaborate and enormous, otherwise unachievable, structures of thought. They are mixed in all sorts of proportions with those properties of words that have nothing to do with reality, but are simply wordy. Words make possible the communication to others of the structures of thought and passing them along to future generations.

We have made words guards of things and, if we don't take care, those custodians will keep us at a distance from reality. Words thus tend to think for us, to replace thinking by a very primitive and automatic process of permutating a set of units accepted once for all. They impose upon us, at the very roots of our thinking, an inert structure very different from the world around us. Discreetly and unnoticed, this inert structure opposes strongly any adaptation to experience which we might try.

In view of all the trouble words give us when we identify them (without justification) with reality, one can then make the following basic definition of the human species: Man is the animal that draws the lines over which he stumbles.

Art and its own image

One of those rigid, well established words is *art*. The word and the idea we automatically assume is behind it is a unit as hard, round and undifferentiated—and 'unfused' with the rest of the universe—as a steel ball. And art stands for no reality that resembles it in any way in these characteristics. But the very existence and acceptance of art, and its thoughtlessly repeated application, conjure up in the minds of people a pseudo-reality in its own image.

What is art? At its first mention, we think of paintings. Oil paintings, first and foremost. Then, on second thought, we include water-colours, and drawings and sculpture. A third thought evokes the art of acting. Are literature and music art? Yes, in spite of the fact that they are, well, literature and music. (Or, perhaps, that is exactly why they are art.) And is science art? No, of course not. And why not? Because it is science. And technology? No, it is simply technology.

Art in this sense is evidently a lumber-room conception, an empty enclosure where random odds and ends, not fitting elsewhere, are thrown in, and from which objects having names of their own are excluded. What comprises art is decided by criteria which are altogether outward, superficial. Going to the extreme to show the futility of this notion, one could use the ironical words of a certain Danish artist: Art is something rectangular hanging on the wall.

The definition is a simplification but, in principle, not a caricature of the way we implicitly define art in actual practice, within bounds staked out by the external, superficial criteria I have mentioned. Can art be defined more meaningfully in another way? Is there such a thing, an entity deserving of the name of art? If so, what are the criteria to be used in getting at what is essential in art?

The technics-art frontier

I shall attempt to answer that question on the basis of a rather special range of experiences. According to this personal orientation, I was guided by my feeling of where I might concentrate my activity, to develop a professional field which is certainly a form of specialization but not one of the traditional specialist. Situated astride some of the well-established borderlines (one of these being the chasm separating the two half-worlds of science-and-technology and humanistics-and-art), I began in science by working with problems that might be called both technological and aesthetic and also engaged in literary work concerned with the co-ordination of both these half-worlds and one we can call that of *belles lettres.*

Moving between the various corners of that little field of mine entailed commuting to and from across the borderline between art and science, and working with people in fields on either side of that line. These contacts offered me a wealth of opportunity to watch, on both sides, creative people in action; these ranged from some of the most creative scientists of our time—not the least of whom were Albert Einstein, Niels Bohr and Norbert Wiener—through clever technicians to their opposite numbers in what we have traditionally called the arts, literature among these. These experiences were supplemented by my own creative activities, on a modest scale, which added the advantage of the possibility of introspection.

One all-pervading, fundamental feature was common to these experiences: the creative process in science and technology is of the same nature as in the forms of activity recognized as arts. It is mere myth and illusion to believe that scientists and technicians obtain their results by sheer, logical deduction and compilatory activity. It is a popular misconception, coloured by the logical and stringent character of these results, that the way leading to them should be of the same nature. Commonly admired by those far from their fields, engineers and scientists are esteemed for their wondrous ability to calculate their way to the one and only correct solution to a problem. When they are (sometimes) admirable, it is for the very opposite reason: they can obtain results even if logical deduction is not involved. Such specialists are more than mere accessories to a slide rule.

The activity, goals and outer appearances of a branch of science are different from those in a given artistic field—as different as physics, biology and astronomy are from painting, sculpture and literature. Yet the creative process is the same in all fields, as is the prerequisite of creative work. One needs first to do an immense amount of labour, treading his path across the professional field—clearing the way, as it were. Next, one lowers the fruits of this labour into the unconscious; from this unconscious emerges (if one has the right 'spiral channel' to infinity) fully finished, rounded-off units possessing a typical character of unity. These are results which could never have been arrived at piece-meal. In science and technology, these results must then be checked against empirical facts, a task comprising the outward rules of the game in the case of art forms.

The function of the unconscious in this process involves no mysticism; it is, rather, that explicit questions are the prerogative and within the pale of the conscious, whereas creativity presupposes non-explicit questions. Thus, taking the word art to signify the creative element, one can define art, in whatever field it appears, as: Art is the solving of problems that cannot be stated clearly before they have been solved. Once a problem has been formulated explicitly and in the right form to permit, and fit, its solution, solving the problem is routine deskwork. The truly creative part of the creative process is found in the fertile, hitherto unthought of way of posing the problem. Whoever invented the sphere surely did not think up, first, half the sphere and then put in as much creative effort to invent the second hemisphere. Problems and their solutions are so much an indivisible unity that the entire process of creativity can be described as the exploration of a vast maze. Often, what proves to be a solution comes first and one is happy to learn, afterwards, what are the problems fitting the solutions.

Is the artist wizard or idler?

In the human activities traditionally recognized as arts, in contrast to science and technology, this unity of problem and solution is generally accepted as being 'extradeductive'—to coin a word which, more aptly than deductive, points directly at the essential feature of this unity. Extradeductive, and even something to be marvelled at. People alien to the arts succumb to two seemingly insoluble problems concerning artists. They ask, either (a) how do those wizards accomplish their inexplicable works of creation? or (b) how do those idlers use their time and energy?

That the two problems can cancel one another, like an electron and a positron, doesn't seem to occur to them. The two do annihilate one another, time and energy not having been spent on deductive work in order to obtain results. So it is not a matter of solving explicitly formulated problems but what I prefer to call implicit problems, those implicit in the mutual oneness of problem and solution.

One could pose such a problem to Leonardo da Vinci, requiring him to paint a portrait of La Gioconda Lisa Gherardini and calling this an explicitly stated problem. In fact, one could pose the problem to anyone, but with very different results. But one could not pose the specific problem which Leonardo solved, a result of striking and convincing intensity, of a compactness and unity which have come down the ages under the appropriately condensed name of Mona Lisa—without having done, at the same time, creative work and proceeding all the way to its final unit, the solution to the problem. One would have had to stipulate: paint La Gioconda Lisa Gherardini wearing a specific garment, full face, but turned a bit to the right, dark against the background of such-and-such a landscape, in certain relative proportions, serious, serene, with a slight curvature of the mouth that can be interpreted as many different kinds of smile, and so on, a specified problem that only Leonardo could solve.

A miniature quotation from literature may throw some more light on the matter. Hans Christian Andersen, who was a master of understatement and a virtuoso in giving unexpected significance to quiet words, said something that could be said of many things: 'It is more than pretty, it is neat.' (Det er mere end nydeligt, det er pent.) 'Neat', in all its ordinary meanings, is somewhat less formidable than pretty. But by implicitly raising the word to mean something more, by its very place in context, 'neat' assumes a much higher value; 'neat' embeds, in fact, a philosophy of evaluation more by quiet, inner qualities than by outer appearance. This is perhaps a micro-example, but it is a clean case of the whole being the base and prerequisite for the significance of a detail. It is a fundamental fact that in art, in whatever form it appears, not only does the whole presuppose the details but the details presuppose the whole. In a certain sense the details must come before the whole, a triviality; the whole must also come before the details.

That is the gist of creativity, the ability to see things before they are there, to form new 'units'. What is the use of day-dreaming about things that don't exist ? The answer to that is that it is only the things we dream up which can become reality.

How our universe changed

In science and technology these conditions are further removed from general recognition than in the arts, the other arts. Yet these conditions are demonstrable as much in every little trace of creative contribution as in the greatest innovations. Let me mention three examples, taken from three great revolutions in our understanding of the universe.

First, what happened really when our picture of the earth changed in shape from plane surface to sphere? Before that transition, one could have said: we live on a surface which is a very special kind of sphere, a sphere of infinite radius—which is the same as a planar surface. But one did not say that: it would have been affected and there would have been no reason to explain things in that way. One could have wondered, however, whether the sphere's radius was truly infinite (or almost so), or only very big and of what actual size. The size would be measured with great ingenuity, calculating how far apart are two distant points on earth as well as the angular height of a single star in relation to these two points at the same time. The creative part of this challenge consisted of posing the problem the right (fertile) way, in conceiving that the shape of the planet could be one of infinitely many other spheres with radii of less than infinity.

The generally valid principle in this example of creative thought is the following. One begins with what hitherto has been accepted as a matter of course, as the only possible solution. One then generalizes this in an unexpected way, in an unthought of dimension. From these broader, manifold possibilities one picks a special case, here a sphere of finite radius, better fitting one's purpose (representation of the earth's actual shape). One has proceeded from the special case, theretofore the only thinkable one, to manifold possibilities and thence to a new, more special case. One has broadened one's view heretically, scanned the problems within new dimensions, and there found a newly created entity. It is the new generalization that is the new way of posing the problem. Once posed, the creative part of the work is done; solving the problem, answering the question, becomes relatively routine work.

A second example concerns the speed of light. The chase after this quantity began where a good detective's investigation would begin, with the chief of police. It was about the year 1673, three centuries ago, when Ole Rømer, master-general of police at Copenhagen, managed to measure with surprising accuracy the velocity of light. He used the big clockwork we have available in space, receding from us then approaching us again: the system of the planet Jupiter and its then four observable Galilean moons. What is the speed of light? seems to us to be an obvious question to ask, but it wasn't in Rømer's time. Light was taken for granted to be so different from matter that it was immediately omnipresent. This is beautifully expressed in the terms used to describe his discovery, 'the hesitation of light'.

Before that discovery, if one had explained the omnipresence of light by saying that the speed of light is infinite, the explanation would have been farfetched; it would have been inseparable from the suspicion that light might possibly have another, finite, velocity. To think of it in that way was the new, really creative part of the discovery, much more so than the planning of the setting that would make astronomical measurement possible and the subsequent execution of that measurement. In Einstein's theories of relativity, it is well known that the speed of light proved to be a central feature of the universe; it replaced 'infinite velocity' on many fundamental points, led to heretical abstractions similar to those I've already alluded to, and to new special cases within the new generalizations concerning the basic concepts of space, time, mass and energy.

My third example is that of the introduction into physics, by Max Planck, of the quantum of action. In this case it was not something 'infinitely big' but something 'infinitely small' (although not described as such) which was raised from the infinitely minute to a, certainly, small yet finite size. Under the compelling evidence of empirical, experimental fact, something theretofore taken *a priori* as having the nature of a continuum (the transmission of energy, in fact) had to be accepted as having a 'quantized' corpuscular or granular character. The description fitting the facts demanded a considerable stretch of the imagination, a feat of creativity comprising a generalization in an entirely unthought of dimension and the choice of one specific possibility from that new multitude of options.

From atomism to entirety

It has always been known that the universe hangs together. This is fundamental, common-sense knowledge, the framework of the picture we see every day of the world around us in which is rooted our mental model of the universe. This is so regardless of how refined sophisticated science has made this model with our expanding store of empirical knowledge and our increasingly penetrating perceptions and measurements. But from the outset theory has concentrated on the smallest elementary units, on the single points in the continuum, on the atomistic approach as it were. It is as if the meaning of the parts was not to be found in their connexions, leaving that all-important element to be judged by common sense, that human core that kept everything together.

It was with Newton that the connexions between things entered our conscious, analytical image of the universe in a grandiose, exact form—the law of gravity. Things act where they are not! Things are more than simply themselves. Einstein's theories of relativity took the concept further: things are not even themselves, independently of our spatial system of reference. A wider 'connexion' was forced on us. In the new world of the mechanics of quanta, sprung from Planck's quantum of action, from Bohr's atomic model which joined matter and radiation in a breathtakingly heretical and unifying fashion, as well as from Heisenberg's uncertain relation, the higher unity of things entered microcosmically our theoretical picture of the nature of things.

And in biology the higher levels of units (above the merely physical ones) seem to prove to be equally fundamental and necessary to our understanding of phenomena. The strict mathematical science behind cybernetics and electronic computers, so vital to our understanding of self-balancing in both electronic machines and living organisms, involves the introduction of feedback systems that can be described and comprehended only as a whole, a unit. And the development of psychology in our time, on an experimental, empirical basis, has led us away from point-to-point, atomistic representation. Instead, our descriptions include higher units as something fundamental. Where perception is concerned, we have come to realize that the descriptive situation is one in which we meet the outer world more than half-way with pictures that have the property of unity and are, in principle, our very own creative inventions.

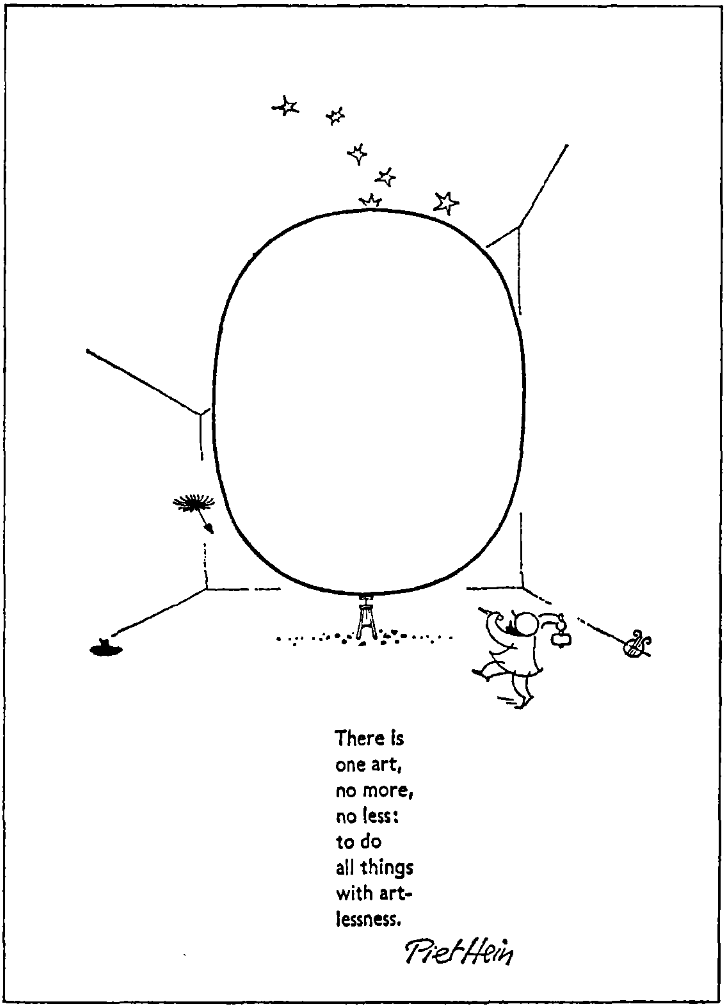
Squaring the circle

In recent years I have had an experience which I cite because it is representative, in various ways, of our habit of imposing cleavages and partitions in the world around us, and then regarding these separations as objective, inevitable and insurmountable realities.

A substantial portion of the central areas of Stockholm has been torn down during this period and rebuilt in order to make this oldest part of the city fit to be the centre of a modern community. The cobbled pattern of small, old houses in narrow, winding streets has been cut through by two avenues perpendicular one to the other. Where these intersect, a vast new rectangular plaza has been cleared, the centre of which was planned as a large pond with hundreds of fountains and, at a higher level, another, smaller pond containing a combination of a rather obelisk-like sculpture and more fountains. Below street level (reserved for wheeled traffic) is a level for pedestrians; this will comprise a concourse marked by an oval row of columns round a large, glass-walled restaurant, both lying under the large pond of fountains and of its same shape and receiving daylight through the pond's glass bottom. This huge and elaborate construction had to be suitably rounded off to match, psychologically, its function as the central point in the heart of the city and to allow a smooth flow of traffic. At the same time, the design would have to fit harmoniously into the city's orthogonal pattern and fill the rectangular plaza in a reasonable manner.

The problem was not to be solved by the classical ellipse, which is simply a drawn out circle having surprisingly pointed ends. The ellipse is in no way related to the rectangle, and leaves meaningless triangular spaces in the corners of the rectangular area. A shape patched together of eight circular arches of different curvature was then tried; this proved to be a very disharmonious compromise; it fell to pieces, so to speak, where the arches were fitted together. The curvature jumped abruptly and was not repeatable in different sizes, as the plan demanded, with any effect of parallelism or harmony.

At this stage the chief architect responsible for the rebuilding of the new city centre, knowing of my interest in borderline problems straddling technology and mathematics on the one hand and psychology and aesthetics on the other, posed the problem to me. With an old affection for curves and their mathematical equations but no knowledge of what mathematical analysis might have already been used in this application, I guessed that the obvious solution would have to be a curve represented by the same equation as that of the circle or ellipse but



with an exponent higher than 2. Equations with exponents varying between 2 and infinity would represent a family of curves filling the gaps between circle and square, between ellipse and rectangle, curves that would be truly related to both seemingly mutually unrelated extremes.

I called these curves superellipses; I chose the Latin prefix 'super' since the identical Greek prefix 'hyper' was already used in the name of curves related to the ellipse, hyperbolas. The superellipse proved to be the solution to the problem and was accepted by the city of Stockholm. Within the next few years, as the great superellipse in the city's centre materialized into a new curve with a surprising character of unity in design, architecture and town planning, I was approached by specialists in these fields from many countries. They explained that this family of curves proved to be the solution to their own problems. Their reactions were no surprise to me, merely testimony of the niche of the superellipse in our pattern of civilization. We had already imposed on our world two conflicting design patterns, the rectangular and the circular. This was because of the elementary nature of these shapes, the psychological advantage of simple forms (you know the whole when seeing only a part of it), and lack of imagination and mathematical knowledge. Superellipses have the same unity and simplicity as shapes lying somewhere between the circle and the rectangle; they mediate between these contrasting and hitherto unreconciled configurations. Superellipses should set the pattern for some of the world we shape about us, connecting and reconciling seemingly conflicting principles.

The point is that, before the superellipse, we had a tangible example of an unnecessary schism and controversy imposed on ourselves, silently regarded as inherent in the nature of things. I had come across, in the literal sense, what I had meant abstractly in that old formulation of mine: man is the animal that draws the lines over which he stumbles.

Words and the 'two cultures'

What is it that creates and maintains those illusory dividing lines which confuse our image of reality and hinder the relationship with it—including our conceptions of science, technology and what we conventionally call the arts, the close kinship between these, and the unity of human creativity?

It is, first, the consequence of the fact that words think for us. The automatic mechanics of established verbal labels replace the more demanding process of perceiving, without prejudice but with sensitivity, the nature and relation of things. Words tend to be identified with things rather than with the relations between them or their nuances. Is a football round or brown? Is a tomato a berry or a vegetable? Is a certain creative activity science or art?

Second, this oversimplification facilitates enormously the work in various fields. As long as such divisions or limitations, or amputations, are accepted as natural and inherent, the oversimplification will continue unconsciously, saving intellectual energy, and regardless of the loss of a deeper and broader meaning and unity.

So instead of one human universe we have two half-worlds characterized by two different approaches, two split worlds which I have long since called 'technocy' and 'cultism', terms coined before C. P. Snow published his *Two Cultures* and not identical with these, probing beyond the problem of higher education, penetrating the total atmosphere of the societies of modern civilization. The cleavage between technocy and cultism has gone so far that it is taken for granted that the two cannot be recombined, that ignorance of science is almost a matter of pride in the half-world of the humanities and a criterion of experience within the realm of culture, including art. Logically speaking, it should be an indication of expertise in both fields to prove to be an ignoramus in either one.

Pushing the argument to extremes, one can say that cultists are concerned with the purpose of a thing entire but, not having kept up with the development of science and technology, do not know the means. The technocists know the means but have lost sight of the purpose, the human aspects.

Art, science and expression

It could prove to be something even more fundamental to say that art, in the traditional sense (including literature), is the function of expressing oneself; that science and technology, having created the basis of our world today, are human activities possessing the important results needing to be expressed. In other words, with the world divided in two parts, the one capable of expression has nothing to express; the other has something to say, but cannot formulate its expression. And if one tries to connect the two, he commits the deadly sin of mixing things that should never, never be blended.

When the dividing lines are drawn so sharply, in so few words, they become a monstrous oversimplification. The important element is that the cleavage, be it ever so diffuse, is there—without justification and much to our disadvantage. Without close connexion or unity between the two fields of human activity, neither really makes sense. Science will be dehumanized and humanity will fail to absorb the fruits of science (epistemologically, philosophically, technologically). The two half-worlds will drift further, much further, apart than now; they could become even meaningless and automatic functions.

Isolationism on the part of what are only facets of meaningful human activity is only another kind of provincialism, like the one we all experience when traces of national self-righteousness and self-sufficiency linger on our closely connected planet: tribal ways in a global world. What I tried to say, in another connexion, about mankind's problem of co-ordination and collaboration applies as well to the unity of human orientation and activity in art and science. Four words: coexistence or no coexistence. It takes, in short, creative imagination to see that things could be fundamentally different from what they are now and to visualize things non-existent.

But the very unity of the reality behind our words and frames of thought has begun to force us to bridge the gap between the half-worlds of art and science. It is most encouraging to perceive the appreciation with which every little effort in that respect is received. The forces and institutions at work in our time to keep mankind together should concentrate on the vitally important task of unifying the human universe in this fundamental dimension.

TO DELVE MORE DEEPLY

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Reflections of an artist-engineer on the art-science interface

by Frank J. Malina

In a world increasingly concerned about the social results of scientific discovery and technical change, we tend to lose sight of the artist as innovator and human being. Whatever his specialty, the artist needs his daily bread. Yet the practising artist is unevenly trained, erratically effective, and often applies his skills hidden from public view. The absence of art is sensed especially keenly in industrialized societies. Creative talent needs opportunity lest it continue to be almost as rare as the genius of the great scientist.

It will be necessary to limit the scope of my subject in order to arrive at comments that, hopefully, will have some significance. Much has been written on the relationships between visual or plastic fine art, science and technology, especially during the last two decades. But many aspects of the subject remain controversial because of the uncertainty as to what is fine art and what is its role in society.

By art, I shall have in mind visual fine art made manifest as artefacts in the form of objects. Traditionally these have been limited to still or static paintings and to modelled sculpture, but I shall include any two- or three-dimensional object, whether static or incorporating real motion and changes of colour with time.

Such objects have an invariant property in that wherever they are placed, whether in an art gallery or a junk yard, they are recognizable as art objects, for they have no other utilitarian purpose than to affect human emotions. For example, neither a piece of scientific appa-

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ratus nor a kitchen stove nor an African Masai shield becomes an art object when placed in an art gallery because, when any one is in the place for which it was made, it is not so recognized. The fact that an object has the invariant property of being art within a culture in no way means that it will be of importance to the evolution of art or to the evolution of the general public interested in art at any point in time.

The chief purposes of fine art are to stimulate and satisfy human emotions, to help the mind emotionally to grasp knowledge and conceptions of the universe and of the world of human beings and to widen and deepen affective perception of portions of the environment selected by an artist. One can say, simply, that works of visual fine art are made to be looked at, to be contemplated repeatedly at leisure. They provide a meditative experience that cannot be experienced by a spectator of theatre, cinema or television.

What art and science mean

It is important to realize that art of any kind is part of a world of fiction, not one in which the truth of facts must be respected. Therefore, works of art should not be confused with reality or be used as a basis for making practical decisions in real life. An artistic style, furthermore, like scientific knowledge, is ethically neutral and may be applied for either constructive or destructive purposes. Art has been a means for encouraging superstitions and ideas that violate, in effect, the Universal Declaration of Human Rights.

The term 'science' is commonly used to cover a wide range of activities stretching from the accumulation of knowledge about the myriad phenomena and relationships of the universe and of the world of human beings to the application of this knowledge for human purposes. Research into the unknown is called basic, pure or undirected science, while the application of this knowledge in novel ways is called applied science and includes, for example, engineering and medical research. There is an interplay between the basic and applied sciences, they do not function in isolation. This is also true of the fine and applied arts, such as illustration, theatre decor and industrial design.

It needs to be stressed that science is devoted to the truth of facts and to their rational interpretation in order to permit the accurate prediction of the behaviour of well-defined phenomena, processes and events. Thus, I am limiting myself to the natural sciences and shall not take note of those important aspects of technology and of the applied arts that involve duplication or replication of ideas or objects. That is, I shall not be concerned with artist-craftsmen who paint, for example, portraits in the manner of creative artists of earlier epochs or with practical engineers who design bridges or aircraft of conventional types.

Finally, my observations will be restricted to advanced technology and the industrialized countries, since the topic of this essay makes little or no sense in societies where there is widespread malnutrition and illiteracy and modern transportation and communication systems are only embryonic. As regards the economic and social status of artists and scientists, I shall consider only non-communist countries, with which I am most familiar.

Professionals and their training

It has been pointed out often that there are more scientists alive today than have lived since modern science began about three hundred years ago. This is also probably true in the case of artists, since at about the same time the one who made fine-art objects was becoming recognized as something more than an artisan. Those who practise the basic and applied sciences are accepted as professionals after having completed a minimum educational curriculum established and controlled by professionals in these fields. The minimal requirements do not guarantee, of course, that those who meet them will become more than cogs in the machinery of routine practical work or uninspiring teachers themselves.

Whether studio artists (artists who actually produce works) are or are not professionals has been an issue for a long time because so many of them have had little or no formal training. This uncertainty poses perplexing questions of professional status especially to educators and to tax collectors. The tendency in higher art education is now to require studio artists wishing to teach to have some kind of art degree from an art college or university, as is the case with teachers of science. At this point, one needs to understand what scientists mean by the term 'professional educators'. Scientists mean those who specialize in the world of education without themselves contributing to the advancement of knowledge in any particular field of science.

Up to the present time, professional educators have had difficulty in dominating professional scientists as regards scientific education in institutions of higher learning. That studio artists do not control art education is indicated by the recent invention of the category 'artist in residence', as though they were akin to an exotic species of beast installed for observation in zoos.

There is the not uncommon layman's idea that artists need to suffer physical want in order to be creative. Others believe that artists, as useful members of society, should be appropriately rewarded financially. The latter attitude raises troublesome problems for governments from the point of view of public support and taxation. In the Netherlands, those who can prove that they are bona fide artists receive government grants, while in Ireland, artists are not subject to income tax.

The present income-tax laws in the United States of America require an artist to prove that he is engaged in an activity for profit in order to deduct expenses connected with his work. An activity is generally considered to be for profit if it shows a profit for two of five consecutive years. The American regulations list nine objective standards that can be applied to help determine whether an activity is intended as a business or as a hobby not for profit. It is very unlikely that Van Gogh or Cezanne could have satisfied the requirements, since they made no profit from their work during their lifetimes and the opinion of the art world of their time was that what they made was not art.

Tools for art and science

The idea that physical want is essential for artistic creativity is becoming more and more untenable. It is evident that poor artists cannot use relatively expensive products of modern technology as media, even if they wish to respond to the artistic possibilities of their time. Scientists who carry out basic research with expensive equipment of no apparent useful value to society have been more fortunate, for they have been able to do their work in universities where they are given reasonable teaching loads with adequate free time for their research. Those artists who are accepted as teachers frequently are given so much teaching to do that they have little time or energy left for creative work.

The character of the outputs of scientists and contemporary artists shows a striking difference. In science when the results of a study are published, republication of the same results (even with minor variations) is frowned upon as contributing to the pollution of the printed word. In art, it is taken for granted that a quantity of examples will be made of a work of originality that are but minor variations of it. This situation is the result primarily of economic pressures on the artist to produce expensive 'originals', even though technology has provided excellent methods of reproduction that could permit objects to be sold to the admiring public at low prices. Furthermore, computers and other sophisticated machines have already demonstrated the possibility of making a wide variety of variations of an original art work. Thus one might expect that, in the future, adventurous artists will be able to escape the frustration of replication.

Scientists in universities and artists able to survive in their studios are among the few in industrial society who escape the worst aspects of employment in business and governmental organizations. They work when and how they wish, more or less, and (since they do what interests them) one can say that they do not 'work' as do most of their neighbours. They can hope, moreover, to have the rare experience of ecstasy that accompanies discovery. But they must have a very strong internal drive—studio artists in particular—to persist in the face of the highly likely lack of appreciation of their efforts by their peers and by society, and of the possibility that important contributions will sometimes not be recognized until after they are dead. Artists are almost certain to have their blissful studio life shattered when they try to show and sell their works.

The universality of the results of the natural sciences is unchallenged. Because something approaching an international way of life is developing round the world, one can expect that distinctions between the arts of isolated societies will gradually disappear, since artists manipulate the information, materials and processes that surround them. When technological developments depended basically on empirical methods, that is, before modern science came into being, those who made art objects also could make technological innovations. Today, an artist without a scientific background is very unlikely to make such innovations. Additionally, the objective of art itself has proved, relative to science, ineffective in uncovering new knowledge of the external world and of the inside world of the brain. This means that artists are ever closer to applied scientists who make use of knowledge and experience for specific purposes: the former for the emotional aspects of life, the latter for the material ones.

Art and its popular patronage

Both artists and scientists suffer from the fact that the vast majority of people do not regard either art or science of vital importance to mental life and as sources of deep pleasure. This state of affairs is brought out, for example, in the Unesco report on *Cultural Policy in Great Britain,* which was prepared by Michael Green and Michael Wilding, in consultation with Richard Hoggart. They point out that in 1968 some 85 per cent of the people there never entered a bookshop. The director of the Midlands Arts Centre for Young People is quoted as believing that the number of people visiting his gallery was less than it was in the nineteenth century, although the population had multiplied four or five times. The secretary of the Federation of British Artists estimated in 1968 that there were over 100,000 trained artists, about 46,000 art students and thousands of would-be professionals, but that only fifty artists were fully employed in painting and sculpting. I wonder how many of my readers devote a few hours each week to contemplating art objects or to reading about the fine arts, and attempting to grasp the new knowledge provided by science.

It seems to me evident that every citizen needs to understand at least the outlines of developments in science and technology, since they impinge directly on the physical and mental well-being of everyone. Whether everyone should be interested in visual fine art is not evident, since emotional satisfaction can be sought from other arts, such as music, the dance, theatre and literature; to keep up with any domain of art is very demanding, and life is short.

Enthusiasts tend to overemphasize the possible role of their particular art in the good life and in the professions. For example, some have claimed that a visual fine-art course can make an important contribution to the education of superior scientists and engineers. This is difficult to prove. I find it hard to believe that Newton and Einstein would have been more creative scientists if they had learned to wield a brush or a chisel. It is true that Einstein loved music and was an amateur violinist, but he admired Mozart, rather than innovative composers of his own day. Theodore von Kármán, a leading research engineer in aeronautics and astronautics during the first half of the twentieth century, obtained much satisfaction from poetry and literature but visual fine art intrigued him very little. Nevertheless, he was noted for his capability of visualizing the intricacies of complex physical phenomena and he made excellent technical sketches on paper or blackboard.

In spite of the lack of understanding of science by the general public, the basic and applied sciences have received considerable financial support from governments, especially since the Second World War. That support is being questioned at the start of this decade, however, while expenditures for military purposes continue to increase. The amount of money spent in the world of fine art on education, publications, purchase of works by institutions and individuals and on the operation of museums and galleries is negligible when compared to either military expenditures or those made for science and its applications for peaceful purposes. It is thus difficult to escape the conclusion that art is considered of minor importance by industrial societies.

Even though science and art play but a small role in the conscious mental life of most persons, people's attitude to the two activities is very different. Science is accepted as so intellectually demanding that most of us find it unthinkable to question or judge its results and methods. At best, we may show hostility to results that overturn our beliefs or opinions. Those in the basic sciences may be held responsible, unjustly, for the misuse of knowledge by society.

Every man an art expert

Works of art, however, are not regarded as beyond the province of anyone's judgement. The guiding principle of judgement is usually 'I know what I like' (what is really meant is 'I like what I know'), unless a purchase for a large amount is involved, in which case an art 'expert' is consulted. Public officials favour art with messages supporting their outlook on life and their short-term political programmes, presented in a manner understandable to as many people as possible, which makes it difficult for them to give support to truly creative artists. Whereas governments depend on the advice of scientists to determine which research-and-development projects should be supported and encouraged, the advice of artists is seldom sought; instead, promoters and administrators of art are consulted when decisions regarding the support and dissemination of art are to be made.

While discussing generalities, one should bear in mind the existence of the 'two cultures' syndrome, which was forcefully analysed in connexion with the situation in the United Kingdom by Lord Snow in 1959. Numerous voices in the arts and humanities have denied the existence of the almost hermetically separated worlds of science-technology and the arts, but my experience after working in both worlds leads me to conclude sadly that their denials are based on wishful thinking. Attempts to bring the two worlds into fruitful collaboration, even at university level, are still tentative and rare.

Efforts to improve collaboration are at the moment being hampered by a strong wave of anti-intellectualism and of adulation of the irrational in the art world. Even the basic attitudes of scepticism, rigorous thinking and demand for proof in science have been undermined to some extent by scientists giving way to the temptations of delusion. I find most alarming the arrival on the scene of scientists who, for dissemination by the mass media, make prophecies instead of sober, well-founded predictions. There is a demand in society for instant answers in all branches of science and technology to problems of great complexity and, if the answers are not forthcoming, the proven methods of science are said to have reached their limit of usefulness and methods 'beyond' science must be found. The possibility that answers to these problems will be found by future generations using current scientific methods requires of us human beings, with our extremely short lifespan, more intestinal fortitude than most of us can bear.

The creative approach

When art and science are discussed, the term 'creativity' is sure to appear. Many meetings have tried, without success, to arrive at an agreement as to what the term means. An artist is frequently said to create rather than make, produce, construct or develop something. Besides, the idea has been put forward (in the spirit of egalitarianism) that everyone is creative, even a child learning its mother tongue or playing imaginatively with building blocks. It seems to me that if the term is to be of value in analysis, it should refer to human accomplishments that are unique and of broad significance in the domains in which the creative act was performed. In order to make a particular creative contribution, a person must be born at the right time, with appropriate genetic characteristics, in a stimulating cultural environment and be blessed by good luck. The low probability of the coincidence of these factors probably accounts for the rarity of genius.

Some claim that there is an underlying unity of art and science—which may be true as regards creativity—but since so little is known about the process, I do not find that the claim is of much help to those who are trying to bring about a better understanding between artists and scientists. It is certain that a clarification of what is involved in the creative process would have tremendous implications for society.

Even if the creative process of scientists and artists should be shown to be similar or identical, the different objectives of art, science and technology would not permit these activities to be interchangeable. If aeronautical engineers should adopt an artistic approach to the design of aircraft, then I would not step aboard one again! The domains of sociology and psychology are especially susceptible to being invaded by literary intellectuals who analyse works of fiction in order to arrive at non-fictional conclusions. These are then widely disseminated to confuse the unwary.

Making a work of art

Artists, in making art objects, are confronted with decisions to be made in three major realms: (a) the selection of the subject matter, content or message of their work; (b) the visual conception or code or style to be used in the presentation of the subject matter; and (c) the choice of a medium and a technique felt to be appropriate to the execution of the work. Rarely, indeed, in any epoch can one find an artist who made decisions that led to creative contributions in all three of these realms.

For the last hundred years or so, modern science and technology have had a strong impact on these decisions. As regards subject matter, new knowledge of man and of nature, ranging from the evolutionary theory of living organisms to psychology, to biology, to the physics of energy and matter, to new technologies of communication, transportation and the production of consumer goods—all this has been responded to by intellectually adventurous artists. Visual experiences provided by new ways of social life, by instrumental extensions of the eye and by new perspectives of the earth and of the cosmos have found their way into pictorial images and three-dimensional forms. Quantitatively speaking, familiarly traditional figurative art subjects still dominate the art scene by far rather than non-figurative or (what is unfortunately called 'abstract' art subjects. (I say unfortunately because art objects, by their very nature, contain abstractions of subject matter.)

A contemporary artist is thus confronted with a vast range of substantive material from which to select what he feels is meaningful to his philosophical outlook on life. In spite of the number of possible subjects, the decision as to which ones to depict is easier than the next two decisions.

Once a subject is chosen, the question is posed as to the manner of its artistic presentation. Creative artists today will not be content merely to present a subject in the form of illustration or of a straightforward image of the kind that can be produced by an optical device of photography or of holography. These artists can make use of visual illusions, multiple meanings of an image, and other artistic resources to enrich the aesthetic experience of viewers. The laws of nature and of society impose but few restrictions on the manner of aesthetic expression where novel combinations of forms and colours in a composition are concerned.

There are reasons to believe or to hope that the new field of experimental aesthetics (also called the science of art) might find that certain qualities of artistic presentation produce in the normal adult human nervous system—in this case through the sense of vision—a feeling of pleasure or of visual 'rightness'. Since, as I have pointed out, visual fine art is of interest to so few people at present, one could conclude that either most human nervous systems are incapable of responding to visual aesthetic qualities ('aesthetic blindness') or artists after thousands of years of using empirical methods in their work have not found the way effectively to trigger the aesthetic response mechanism.

Deciding on medium, technique

The decision as to which medium and by which technique the medium should be exploited in making an art object is much more complicated today than it has ever been. Science and technology have provided new tools and materials of much greater variety and complexity than the traditional ones. Perhaps the introduction into fine art objects of changes readily perceptible with time, in addition to form and colour, is so far the most interesting development of this century. Artists apply in such kinetic objects either three-dimensional mechanical motion (as, for example, in air-driven mobiles) or two-dimensional motion of electric-light images. Changes with time of forms and of colours, without perceptible motion is also accomplished through the use of polarized or of flashing light.

Science and technology are forcing us to come to terms with changes of unprecendented rapidity in our way of life. In the past, people thought of time either in terms of how to survive the next day or how to prepare themselves for eternity. Now the evolution of technology has reached a stage that not only permits but demands of individuals that they plan in terms of a lifetime and of societies in terms of decades. Kinetic rather than static art objects may be of value in helping people to prepare their minds for coping with these scales of time.

The flood of new visible phenomena, media and materials provided by science and technology can, as one might expect, either benefit or threaten art. Since art is basically of a fictional character, an artist can on the one hand do more and on the other do less than a scientist or an engineer. If an artist, overwhelmed by the conceptions of science and products of technology, merely attempts to duplicate them, the emotional aspects of life will be the poorer for his effort. I am convinced that artists are ill-prepared to compete with psychologists of the science of perception who study, for example, visual illusions and colour interactions or with skilled craftsmen who construct objects for the popularization of science.

Artists wishing to use new types of materials, electric or electronic systems and novel devices, such as computers, must realize that considerable mental effort to understand them is necessary before their artistic intuition can function. Attempts to bring art and science into closer harmony are handicapped because so many artists believe that they possess an emotional mystique not requiring rational support.

Isolation of the artist

Aestheticians, historians of art, writers and critics, museum directors, educators, dealers and collectors, architects, interior decorators, cinema and television producers depend, more or less, on the work of studio artists. The amazing fact is that artists are regarded by many of these professionals as beggars or freaks, and some artists succumb to perpetuating the stereotype. It is disturbing for an artist to hear a group of collectors discussing only artists' private lives and the current prices of their works, without a word as to the meaning or effectiveness of these creations.

Furthermore, there is little if any feeling of fraternity between artists of the kind one finds among scientists and engineers, both on the local and the international scale. I do not mean to imply that the *prima donna* is absent in the highly competitive world of science; there are many of them, but those who are trained to be basic or applied scientists are at least encouraged to recognize and credit the contributions made by their colleagues to the advancement of science and technology.

When I seriously took up art, I was amazed to find that artists had no journal or magazine of their own in which they could calmly describe and discuss their work, exchange ideas and provide information that might be helpful to teachers and lovers of art. Contradictory reasons given for the lack of a journal included views such as: art is non-accumulative as regards ideas and techniques, artists have brains that lack a verbalizing capacity, it is immodest for an artist to discuss his own work, art involves creativity and intuition whose mysteries are beyond understanding, and artists need to guard the secrets of their work.

The views of a specialist

None of these reasons seemed convincing to me, so in 1965 I took steps to launch an international journal of the contemporary artist with an approach, style and ethic comparable to those of professional journals in science and technology. One of the objectives of the journal is to provide a forum for discussion of the possible relationships between art, science and technology. The journal (called *Leonardo*) came into existence in 1968 when Robert Maxwell, founder of Pergamon Press at Oxford, gave the venture his support. My experience as editor of the journal has had a bearing, as you can imagine, on some of the observations I have made here. To conclude, here are a few more remarks emanating from that experience.

Artists who are concerned with non-traditional subjects and new visual conceptions, or who use non-traditional materials and processes, write of their work as well or as badly as scientists and engineers. Some at first imitate the literary style of many art critics, even though they tend to regard such writing with derision. To write on one's art in a rational, descriptive and analytical manner and to acknowledge one's debts to other artists and to scholars of art is not easy, especially since few teachers of art encourage their students to think in these ways.

The vast majority of artists ignore studies by aestheticians and historians of art because they believe them to be of little relevance to their work, perhaps with some reason. There are now encouraging signs that aestheticians, in particular, are initiating dialogues with contemporary artists and that artists are being accepted into the ranks of aestheticians.

The growing impact of science, in a broad sense, and of advanced technology upon visual fine art may contribute to a transformation of visual fine art's present negligible role in the lives of most members of industrial societies. In turn, one can hope that this art, in addition to providing individuals with deep emotional satisfaction, will help societies to make better use of science and technology for the welfare of humanity everywhere.

TO DELVE MORE DEEPLY

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Evolution of the influences between science and art

by Francesco d'Arcais

The linking of art to the progress of science and technology reveals irregularities in the relationship. One has affected the other variously over the ages, art having had a significant role in the emergence of our industrial era. Expanding scientific research and its technical applications caused, in turn, some art forms to pass from figurative to abstract. Technology has helped popularize art but made businessmen of some artists. Today's creative artist risks being seen by society as a mere craftsman. Can our technical age ennoble him once more?

Any discussion of this subject should be based on the premise that there is a fundamental unity underlying all the means which man has had at his disposal, in any particular historical period, for expressing and communicating his thought, his feelings and his vision and interpretation of the world. I shall discuss this unity, although to prove that it exists is not feasible within the compass of the article. At the same time, it cannot be assumed that all readers will be prepared blindly to accept my premises on this extremely controversial subject. My aim will be, therefore, to present certain arguments which can be logically inferred from a critical analysis of the different historical periods which have marked the development, especially of Western civilization, until the present day. These arguments obviously apply, *mutatis mutandis*, to all other geographical areas of the world.

The first step, in dealing with any specific historical period, must be to explain the meaning of the words 'cultural unity'. Unity is not the same as uniformity, nor does it signify a set of common connotations. It implies neither sameness

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nor resemblance, only the recognition that the characteristic or typical features of each particular form of cultural expression derive from a common matrix, common sources of inspiration and common demands. This implies admitting that the unity of any given historical period will be marked by exceptions, more apparent than real, since dialectical contrast is a force making for the unity of culture. We have only to think of the 'exceptions' in Baroque, which in fact (being explicitly dissimilar or controversial) form an essential element of this phase of Western culture. It should be added that, in the case of the most distinctive styles—notably Baroque, but also Renaissance, Rococo, Decadence and Futurism—it is impossible to state precisely either when they start or when they end. Note that there is always a temptation to attribute the initiation of an epoch to some outstanding event. In fact, every epoch is preceded by a slow, often imperceptible, preparatory phase and succeeded, usually, by a period of gradual decline, during which the first stirrings of a new period become apparent. There are two reasons why this should be so.

The first, already mentioned, is that no epoch is ever initiated and characterized by a single event. The second is that the different cultural expressions of any epoch do not arise simultaneously but gradually, in the course of the preparatory phase, and most often in one particular mode of expression (science, art or technology) paving the way for the rest. That this is so merely confirms that the time has come to accept, safeguard and combine in a single, significant whole all man's new forms of expression and self-expression. Adopting this view—suggested by chance indications rather than any positive proof—we are inclined to concentrate on experiments which have lasted a long time, and so have left their mark on different eras; yet we cannot ignore those which have either failed or lasted too short a time to leave their imprint. Innovations are important only when they become part of history, and that is something that can be judged only by subsequent generations.

Thus all men live in a period of transition. They will be conscious of this if the signs of crisis or approaching change are comparatively clear to them, but not necessarily if the epoch into which they are born gives the illusion of lasting stability. The point is to determine whether cultural unity is indeed possible, whether there are common elements in modes of expression so disparate as literature, art, music, science and technology. Again, to demonstrate this conclusively would involve a critical analysis of the history of the different ages and their cultural features which, as I stated earlier, is out of the question here. To put the matter in much simpler, though no less significant terms, it can be said that every man—in this instance every man of culture, although I have no intention of defining what is meant by this—communicates with his fellow by the means of his choice which, however technically diverse, are influenced by given historical situations.

Expression limited to medium

For very many centuries, before writing existed, or before it was common, painting took its place. We know nothing of music until after the time when the means of transcribing it were invented. Painters, expressing themselves through signs and colours, are very seldom good writers. Musicians express themselves through sounds and melodies, but find it difficult to communicate by other means. Poets, too, have their own means of expression which are not those of the scientist, and vice versa. And it has been said that even scientific writing can on occasion attain to the heights of poetry.

It is perhaps this very difference in modes of expression that demonstrates the existence of a basic unity, since it is hard to see why men should wish to communicate, albeit by the use of different methods, unless there were some common basis such that the message could be received by those not versed in the specific technique used for transmitting it. But, in the past, the word 'technique' was used mainly to indicate the rules governing the internal development of each particular expression of human activity. Nowadays, it is used generally to signify an independent means of showing the intellectual initiative which can change study, theories and principles into applications, instruments and other objects.

From this standpoint, techniques are as ancient as man himself. It could be stated unhesitatingly that man can be defined as man from the time of the emergence of *homo faber*. I admit, however, that there are those who, identifying techniques with machines, maintain that techniques are the invention solely of the modern or even the most contemporary epoch.

It is impossible to resolve so vast a problem within the space of a few pages. But if we wish to make any progress on the subject, it is essential to define or determine the meaning of that word 'technique', if only theoretically and from a personal standpoint. Preference seems to be given to the view that man was *homo faber* from the outset, partly perhaps out of religious considerations, interpreting the injunction to rest on the seventh day as an indication that God gave man the task of continuing, freely and independently, the work of creation. Many anthropologists take perhaps the same view, although for different or even diametrically opposed reasons. Despite this, however, we need to remember that it was not until recently that man succeeded in producing instruments capable not merely of helping him in his work but actually (to a point) replacing him. These instruments may be regarded, in some sense, as an extension of man, thus raising the question of a possible symbiosis between man and the machine. It must be borne in mind, therefore, when writing the history of techniques, that their natural, irresistible development is due to man's intelligence and his capacity to proceed from a few rudimentary achievements to more and more complex and 'sophisticated' ones. I use this term, which originally had mainly aesthetic connotations, in the strictly technical sense it has now acquired in several languages.

Thus if there is a connexion (for this is the hypothesis advanced) between all human manifestations, a connexion evident within certain well-defined historical periods, special attention must be paid to the relations between the various manifestations of human intelligence in periods when particular emphasis has been placed on one such manifestation, i.e. technology, to which we have just referred. So if we admit that technology is the keynote of the contemporary age, it must be used as the yardstick for measuring the relations with other traditional human activities, including, in the first place, art.

The art-technology relation

How did the connexion between art and technology originally come about, in our times? Did this connexion give rise to a distinctive epoch, with a special label? And does this era still exist, or has the connexion between the two elements entirely changed its character? There are fairly full answers to all these questions, but they at once give rise to another question: which of the two, art or technology, should we take first? Any choice, in such conditions, is necessarily subjective. So let us begin with technology, taking the main turning points in its development and seeing how they affected the arts. Of course we reserve the right, when necessary, to reverse the process and investigate whether certain 'phases' of art might not have accelerated the development of technology and of science—which technology includes and subtends.

It is hardly necessary to recall that the technological age in which we are living began with the introduction of mechanical power to replace the work of man. This was the invention of the steam engine and the discovery of electricity, two centuries ago. A long time elapsed before means were found, first, to put these inventions to rational use (the second stage of the technological era) and, second, of surpassing these new sources of power—not, however, eliminating them, but radically transforming them. It is this third stage of the technological revolution with which we are particularly concerned.

The rational exploitation of power was not a technological but an economic phenomenon; that social strife was born at the same time is no mere chance. Not until this period had become stabilized did the sources of power become, as it were, part of the cultural context. The concept of speed was known from ancient times, but it was not until the contemporary age that it became a fact, a 'phenomenon', in the etymological sense of that Greek word. The existential and not merely conceptual experience of speed was a turning-point in the various forms of intellectual expression. It engendered the need to 'comprehend' (in the sense of knowing the nature of) speed, and therefore to analyse it and investigate all its possible consequences in every sphere. These embraced the limits of speed, and its successive stages, including that of separate, fleeting instantaneity.

Science has never gone backward. Between relativity, probability and the quantum theory lies a whole period of basic research on the implications of speed. Technology proper has aimed, for example, at overcoming the force of gravity, long regarded as a natural feature of the human condition, and now the subject of research studies.

The principal merit of the artistic and literary movement known as Futurism was that it realized that the existential experience of speed could not be confined to theoretical or applied research, but must also extend to every sector of intellectual activity. It succeeded in incorporating or, more often, anticipating this trend, and advancing hand in hand with science and technology. Futurism was the art of the speed age. As Marinetti wrote in *Le Figaro* (Paris) of 20 February 1909: 'We maintain that the glory of the world has been enriched by a new form of beauty, the beauty of speed.'

Figurative cedes to abstract

The art of the Futurist period—which both in Europe and elsewhere was called by different names, though its origins and aims were substantially the same—was thus an attempt to represent speed: first by breaking it down into a succession of moments, and then by trying to depict the moment, which is inevitably a distortion of reality since what we observe is a continuum. Seen in this way, it was realized, figures cease to have a definite shape; they leave only a fleeting trace, to be glimpsed and sensed rather than seen and observed. Thus figurative art gave place gradually to abstract art in which colour was used as the means of expression and communication, dispensing with the use of images (which passed into the realm of photography). Thus, whenever a new, more convenient, and in this case also more mechanical, method suceeds in producing results confined theretofore to another form of communication, the latter is forced to change in order to survive.

At the same time science, in its study of speed, adopted probability as an instrument of knowledge. That is to say, science adopted a form of reality so minutely decomposed as to bear no apparent relation to objective fact; it discovered relativity and indetermination, which were other ways of softening the outlines of physical reality, considered as such because this reality could always be represented objectively in terms of traditional physics. Even biology carried the dissection of man a stage further,[1] and psychology delved into realms hitherto deemed impenetrable. The image of man and the images which man gave of himself through means of expression radically different from the traditional ones really constituted innovations which could be precisely defined. Since these innovations had duration—which varied for the different forms of intellectual expression because the temporal extensions of this expression and its intrinsic methodological consequences varied—it was legitimate to deduce the existence of a new epoch, not wholly futurist, although this term could be used to describe the new period.

It is impossible these days to state correctly the problem of the relationship between science and art, in the broad sense of the two, without reference to the birth and development of Futurism in my own country and of similar movements in other parts of the world during the early years of the present century.

Not everything in Futurism, or for that matter in any other similar movement, is equally acceptable either as a cultural basis (being often paradoxically and unnecessarily controversial) or as an instrument for making lasting contacts

1. The author refers to Röntgen's discovery of X-rays.—Ed.

with other forms of expression. But there can be no gainsaying that Futurism 'created' an entirely new relationship between man and the machine. What followed it has the origins and causes I have mentioned. This still continues to exist, even though, as a cultural phenomenon, Futurism now belongs to the past. It was called Futurism at that time precisely because it was an anticipation of what was to come and, above all and obviously, an instinctive response to a wide variety of demands.

Then for several decades Futurism appeared to be dormant, if not actually dead: a fleeting fashion, like so many others. In fact Futurism was like a seed, which needs time to germinate before producing its real fruit. In those decades, meantime, much else had come to pass. The boundaries between science and technology, in many fields, became increasingly tenuous. Art was seeking new forms of expression in an attempt to reflect not only speed but also movement, instants in time and the essence of colours and space, without reverting to the figurative. This again corresponded, in some measure, to the growth and development of science.

How design influences art

Mass production has become the keynote of the last part of the machine age. It was as it still is an economic necessity, since it was essential that the products of increasingly complex and costly machines should not cost more than traditional hand-made objects. At the same time artists, influenced by the experience of the designers, or else perhaps by the attractions of mass production, began to reflect on their position in the modern age. Artists knew something of mass production, though only on a small scale. The technique of engraving or its variant (etching) had been known for centuries; the artists soon took it up again and improved it. Starting with the traditional black-and-white etching, they developed the techniques of engraving with several colours, to which, as a result of technical refinements, half-tints and background colours were later added.

At the same time, the use of lithography spread. (This is a method of reproduction using a special type of stone, difficult to handle on account of its size and above all its weight). Engraving and lithography have always required the personal participation of the printer, in the preparatory stage as well as during the execution of the work, so that the relationship between the artist and the printer was entirely different from that existing in the mass production related to the work of an industrial designer. Each copy emerging from the hand-press, after meticulous individual preparation, was very slightly different from the others, so that to refer to mass production was not, strictly speaking, correct. Indeed, there were slight differences of tone or depth of incision in every engraving and every lithograph, which gave to each its unique value. The fact that the number of prints was limited is what made engravings or lithographs valuable.

Mass production in industry proved, however, to be deplorably contagious. The artist yielded to the temptation of allowing larger printing runs, and the printer to that of adopting mechanical

Does form follow function?

The development of technology, in the original sense of the word, immediately raised the problem of its relation with art. The objects produced by technology, in addition to serving a purpose, must also assume some form. The situation was a new one in that the choice of form was based on the criterion of functionality. Industrial design represents the point of contact between art and technology. For the first time in history, utility became conscious of the demands of beauty. It is true that this situation had, sporadically, arisen in the past. In nature, from time immemorial, utility and beauty had, on occasion, formed a partnership which had enabled nature to survive. It was now realized that objects, in addition to serving their purpose, could also be aesthetically pleasing. And since the course of historical development is not necessarily regular or strictly rational, beauty now heeded the requirements of utility.

Art today demands increasingly to serve as a means of communication and to express itself by way of the most modern and highly perfected instruments man is able to fashion. Design, brought into being and developed with the machine, is concerned with planning the large-scale production of objects (mass production) of cultural and aesthetic as well as technical and economic value. Creation and production combine and overlap, just as it comes to be realized that beauty and functionality are not necessarily mutually exclusive. But the term 'object' covers an almost unlimited number of things, which man may desire, possess, invent, imagine and hope for. Useful and superfluous things alike are objects which fulfil a function and which, therefore, can and should assume a form calculated to ennoble their function, almost concealing it behind contemplation.

As soon as beauty and utility combined, 'design' became an independent form of expression and communication. Artistic considerations finally prevailed over functional utility, giving the initial impulse to mass production. We shall see further on what effect the predominance of aesthetic over utilitarian considerations has had. The important point at this juncture is to emphasize that artistic or cultural considerations contrive to produce a structure which performs a function and corresponds to a practical demand. Design, aesthetic in origin, becomes functional.

Futurism was thus followed by—perhaps unwittingly gave birth to—a new style which cannot yet be said to represent an epoch (since it may be not a fashion but rather a passing necessity). This is the 'design' style, which extends to furniture and architecture, utensils and ornaments, both objects to be used and luxury articles. It is a style which sees the form of objects in relation to the space available, the setting for which they are intended and their ease and simplicity of use, together with a purity of line and proportion which makes the object or its plan both functional and aesthetically pleasing.

This encounter between art and technology has not ennobled either one. For a long time, at least, 'designers' did not rank as artists in the traditional sense of the term. Their form of expression was closely conditioned by the use and purpose for which the objects they produced were intended, whereas an artist should be completely free. But when it was realized that form is capable, in some degree, of conditioning or affecting the use of an object, 'designers' demanded to rank as artists, albeit working in a new medium. It was they who determined (a) the direction of mass production through the application of artistic principles and (b) the behaviour of people, increasingly immersed in the new environment and associated with the use of the new objects.

The effect on man's behaviour of the new marriage between art and technology may be such that design will last longer than certain other ephemeral experiments of contemporary art, so that there may be some justification for speaking, albeit tentatively, of an industrial design civilization.

methods of reproduction. This raised the problem of the attitude to art in an era when it can be reproduced so easily by technical means. I refer, of course, to reproduction in the sense already indicated, not to copies made by hand-press of unique, individual works of art. The result has been to reduce graphic art at the level of the products of the printing industry. Even the traditional materials and techniques have been supplanted by far more rapid and profitable systems to the detriment, in most cases, of the artist's work. Though graphic art has indeed deteriorated in those cases where authenticity has been preserved, small series of engravings and lithographs have given the artist access to a market which otherwise he could not have had. Original paintings or works of sculpture could only be acquired by collectors or galleries, so that art became, not intrinsically but for economic reasons, the prerogative of the privileged few. On the other hand, the spread of reproductions brought art once more within the reach of the general public.

The same sort of thing occurred with works of sculpture. Small-scale reproductions were produced, though at a price that few but collectors could afford. Reproductions executed with the utmost skill have been the great innovation of the past few years, both for artists and for the public. But the former realized to their great dismay that they had debased their own work, and the latter that reproductions now cost almost as much as originals.

In short, the existence of reproductions gave rise to a crisis in contemporary art, but only in so far as an attempt was made to reproduce works of art on more than the traditional scale. Why, indeed, should it be thought permissible to reproduce a drawing by means of engravings or lithographs, but not make small series of a sculpture or a jewel? Tradition in this instance was governed wholly by environmental and technical conditions. Cultural and economic factors favoured the mass production of engravings (but not of sculpture and certainly not of jewels), yet coins and commemorative medals could be struck in large numbers. There is absolutely no reason why procedures which were not customary in the past should not be accepted now that conditions and techniques have changed.

The art-business dilemma

The problem thus assumes a different form and may be stated thus: can art, in an epoch and a society where mechanical reproduction has become both inexpensive and feasible, remain aloof? There are two possible answers. If art is regarded not as a marketable article but as free creative activity, the main purpose of which is to give enjoyment, then economic and commercial considerations carry no weight. Art and science are intellectual activities on which no price can be put. But if, on the other hand, works of art are subject to the laws of economics, then they must be regarded as marketable products, to be bought and sold rather than merely looked at. There is no reason why reproduction should not become widespread, though perhaps not universal. The artist who thus makes his creative work available to a larger number of people is likely to feel that he has been reduced to the status—a noble one, it is true—of the craftsman. But what he does not realize is that, otherwise, he is at the level of the businessman. Can this dilemma be resolved? Times of crisis are, by definition, times when no answer has yet been found to the question asked.

After what may appear to have been a long digression, we can now revert to our original premise and reaffirm that (a) all cultural activities in a given period form part of a single system and (b) there are, unfortunately, inherent in this system certain utilitarian, commercial and economic factors (the three adjectives are not synonymous) which have distorted and impaired the relationship between art and technology. In this account of the situation I have assumed that science forms the background of a cultural era characterized by the triumph and domination of the machine. Whether man becomes the slave or the master of the machine depends in large measure on the relationship established between technology and the freest and most imaginative of the activities of the spirit.

The problem, therefore, still needs urgently to be resolved. And it will not be solved until we have emerged from this period of crisis, which may be many decades hence. The machine is changing, slowly but inexorably. From being an extension of the arm of man, it is becoming a projection of his brain. When this occurs, the whole situation will change yet again. Not only will cultural activities occupy a different position in man's life but the origins, development and aims of the cultural 'products' themselves eventually will be transformed. To think this is to imagine an ineluctable symbiosis of man and machine, the first signs of which are as yet barely perceptible.

The other possibility is that man, discarding the non-cultural components by which he is largely conditioned today, will devote his spiritual faculties to independent, original creation, in which imagination—and therefore freedom—are supreme. But in an epoch when the position of the intellectual in the world is discussed with some anguish, this does not appear likely to occur in the near future. All the great historical periods in which the culture of a country or the civilization of a people of one century or several centuries is revealed to be homogeneous (though form may differ widely), have been characterized by a conception of man and the world that is predominant. Yet the world of today seems unable either to find its own way of making history and contributing to the progress of history or to shape and ennoble man. The very existence of different ideologies which, today, makes any unambiguous assessment of the present-day world out of the question will probably, in time, make sense of a world in search of change. But this speculation takes us too far beyond the limits of our subject, so it is time to bring my discourse to a close.

In any case, the main point is not always to solve a problem, but to propound it as correctly as possible. Perhaps the rest will then follow.

TO DELVE MORE DEEPLY

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Twenty years of symbiosis between art and science

by Jasia Reichardt

Although the relationship between art and the world of science-technology dates from at least the Stone Age, it is in the past two decades that fast evolving technics have brought a radically new dimension to most art forms. New biology, nuclear physics, computer and material sciences, and advanced audio-visual engineering have stimulated the artist and his innovations to breath-taking levels of achievement. But the more science and art interact, the more we can ask: Is it art? and, How much do we understand science?

There are certain parallels between art and science which occur without obvious reason. For instance, at the time when Langevin discussed his idea of partial relativity in Bologna in 1911, the Futurists had just published their technical manifesto. Langevin related a parable dealing with a space ship which leaves the earth with clocks on board. At two revolutions a day, the hour hands of the clocks will have made 730 revolutions in a year's time. When the ship, which will have travelled at an average speed of about 150 metres per second less than the speed of light,[1] comes back to earth, the astronauts after the year they experienced will have found that their contemporaries have vanished. The earth would have added in this period another 1,000 years to its history. The Futurist manifesto was also about speed and time and their effect: 'Everything moves, everything runs,

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1. According to the Lawrence contraction, or time dilatation, factor.—Ed.

everything changes rapidly. A profile is never stable in front of our eyes, but constantly appears and disappears. On account of the persistency of an image upon the retina, moving objects constantly multiply themselves, they are deformed and succeed each other like vibrations in the space they move through. Thus a galloping horse has not four legs, but twenty, whose movements are triangular.'

It is not important even to know whether Marinetti, Balla, and their colleagues were familiar with Langevin's theory. What is interesting is that they found the same problems relevant to their work at about the same time.

While the laws of chance have been harnessed in science in the form of probability theory and statistics, in twentieth-century art they have been used to generate an element of surprise. Statisticians have been using books of random numbers to make predictions, as the Dada artists and poets have pulled words out of a hat to make poetry. Hans Arp scattered papers on the floor to arrive at compositions which were then to be made permanent, the Surrealist artists sought hitherto unfamiliar associations by allowing the unconscious to direct the hand holding a pencil, and fifty years later the best contemporary composers (Cage, Stockhausen, Xenakis) developed complex procedures in order to allow chance to participate in the creation and performance of their works.

From biochemistry and op art

When in the 1950s, with the work of Pauling, Crick and Watson, the world became aware of the importance of structure in science, the significance of form in molecular biology, and the vital importance of the way in which things fit together, the artists were already there. At about the same time one became aware of references, in connexion with abstract art, to form as content. Indeed within a few years an entire movement emerged of which this was conclusively true—op art. In the work of op artists, form and content became indivisible as the paintings were not about anything other than the effects which the forms themselves generated. A good example of form as content in art is the paintings of Ellsworth Kelly which are purely sensory experiences with two bold, colourful forms, alternating as figure and background. These examples of parallel concerns prove nothing, but there are enough of them to show that both artists and scientists use the same ideas and the same cultural forces to get on with their work.

There is something else: during the past thirty years, many artists have been producing images of the same general sort as are to be found in science. Anyone familiar with modern art is likely to derive pleasure from looking at thermograms, micrographs of diatoms, electronic microcircuits, vibration patterns, as well as the 'hardware' in any highly sophisticated technological laboratory. Abstract paintings, as has been demonstrated in any number of books and exhibitions which set out to associate art and science, often correspond to nature. But what I want to stress is that this is true of more than nature, and that countless items of technological hardware look like contemporary sculptures, and vice versa. In some cases, as with Eduardo Paolozzi, the association is obvious since he is inspired by forms in industry and indeed uses industrial techniques; in others, even in some sculptures by Picasso, similarities are to be found without such an obvious connexion.

On my wall hangs a micrograph of a receptor in the barbel of a catfish, one of a series done by T. A. Quilliam of University College, London. Artists, and others who see it often ask which member of the CoBrA[1] group was responsible for the painting of which this micrograph is thought to be a reproduction.

The similarity between images in art and science is sometimes conscious, sometimes quite gratuitous. There is another category, however, which is more deliberate. Some artists have recognized forms derived in pursuit of science as of fundamental interest and have proceeded to paint them. *Scientific American* has published portfolios of collected reproductions of paintings by artists whose work had been reproduced in the magazine. The pictures range in subject matter from fractured metal to experiments with animals and examples of projective geometry. These works demonstrate that although the artist (as a recorder of events) is no longer necessary to science, through a personal interpretation of what he sees he can throw different light on a subject. Photography could never be a substitute for this process.

Nuclear energy, abstract art

The Los Alamos Scientific Laboratory, which has become a centre for research in plasma physics, recently organized an art exhibition. All the paintings (which were abstract) were selected by scientists on the basis of their capacity to portray symbolically the essence of the research under way at Los Alamos. Those familiar with art and, indeed the artists themselves, may have found it surprising that the range of abstract paintings symbolized nuclear energy. Yet the illustrations had been selected by scientists in the field as conveying something essential about the work in which they are engaged.

Other artists have made connexions with science by adopting the language of science. Many conceptual artists and the British group which calls itself Art Language borrow from the languages of symbolic logic, linguistics, philosophy, and physics in a way which renders their work incomprehensible to the layman and infuriating to the scientist. Despite the fact that their works (consisting mostly of texts) are unsatisfactory as objects which are supposed in some way to appeal to the senses, nevertheless they show the aspiration of certain artists to affiliate themselves with science although they appear to misunderstand it either genuinely or on purpose. The language of science has become for them a material for making collages.

There is another area in which artists show their concern with science, and that is the area of ecology. There are groups like the British Society for Social Responsibility in Science which have artists as

1. A group of artists from Copenhagen, Brussels and Amsterdam who launched a movement of protest and rebellion in 1949; is was not accidental that the name of the group is also that of a poisonous snake.—Ed.

well as scientists among their members. An artist in the north of England, John Wood, whose main interest is with cybernetic systems, has been working on a domestic life-support garden as a work of art. Wood considers it to be the most interesting type of cybernetic model which he is likely to be involved with in the foreseeable future. This would be a pilot eco-garden on the scale of an average urban garden. Wood envisages a self-perpetuating enclosed unit which could satisfy the nutritional needs of a small family. Twenty years ago no artist would have envisaged agriculture as a realm connected with art.

So much for the influence and cross currents between the two areas of art and science. The closest links between the two are forged by artists who actually make use of science and technology. Thus in the 1960s there was a close connexion between art and technology, in the 1970s we approached an even more ambitious area—the rapport between art and the biological sciences.

Art and some technologies

The art which has made use of technology in the 1960s could be divided into the following areas: kinetic, electronic, video, computer and cybernetic art.

Artists working in kinetic art and the video idiom use technology principally as the means of achieving certain results. Very often their work does not show that they are consciously aware of the implications of their media. In fields such as cybernetics, the degree of technological sophistication is much greater and therefore the artist's awareness of the bridging of the gap between art and science is very much more obvious.

Kinetic art involves movement as one of its attributes. The movement can be generated by a motor, the wind or a hefty push. Kinetic art evolves with and in time; and at no single moment is it possible to see the entire work since its repertoire of possibilities unfolds before the spectator. Some works in this idiom involve spectator participation, and in the heroic statements surrounding these works, this fact is an important one. On the other hand, the use of movement in art does not bring its exponents together since among them one finds expressionists, abstractionists, and figurative artists, as well as humorists. Although the history of kinetic art goes back to the turn of the century and the colour-music organs, there were more artists working in this field in the 1960s than at any other time.

One of the great exponents of the motorized variety of kinetic art is Swiss-born Jean Tinguely—who creates sculptures which look, feel and behave like machines and produce nothing other than visual and sound effects. His famous machine which shattered itself outside the Museum of Modern Art in New York in 1960 was one of the most powerful statements about what art can do in an age of technology and how it can see its role: 'It's maddening,' wrote Tinguely, 'the work I'm doing. The possibilities are immense. After all, we're living in an age when the wildest fantasies become daily truths. Anything is possible. Dematerialization, for example, that will enable people to travel by becoming sound waves or something. Why not?

'These things are serious for me. Absurdity can be carried a long way, and when it's carried far enough, its effect is to make conventional values ridiculous, cut them down to size, cast some badly needed doubt on this "wonderful age" we're living in.'

Man dehumanized by machine

The sentiments expressed with Tinguely's autodestructive sculpture were parallelled in England by Bruce Lacey. His robots and humanoids demonstrated Lacey's fears about the future. His *Superman*, for instance, is constructed with the aid of three linked motors, each with an independent and automatic interruption system set at different intervals. Thus the movement of the various parts, which go through a great variety of motions, does not follow the same repetitive pattern. Lacey described *Superman* to me as follows: 'Man's obsession with the machine as being the God that can give him more leisure time is symbolized in this construction. This is a man who has been dehumanized by the machine and has become in fact a machine himself. Now, he just performs a few simple operations designed to make him feel he is still human.'

While Tinguely and Lacey used the motor to comment on the fallibility of the machine, others in a more serious vein produced often beautiful effects with colour, light, and sound. Hundreds of artists throughout Western Europe, America, and Japan have produced mysterious boxes, cylinders, and spheres in transparent plastic, in which an abstract spectacle —with elements of stainless steel, lights and polarized screens—revealed itself through a sequence of events when the object was set in motion.

Not all kinetic artists have been using light, sound and movement as a continually changing panorama. Greek-born Takis, for instance, has employed magnets to make things move 'from a distance, freely, without all the friction and labour of the machine'. For Takis to use bits of machinery was to get away from the conventions of art and to approach more closely the invisible forces of nature. One of his works, for instance, uses part of an old radar set. 'Radar is an instrument for listening to the music in infinity, so I include the whole thing,' he has said with some emotion. Takis' objects were created with the intention 'of penetrating into the unknown and I believe that the work must contain the Impossible—the crossing of space, the transference of electrons from one body to another, the elevation and flight of my spirit and yours: it should be as simple as breathing'.

Other artists, like Michael McKinnon, have used liquids. McKinnon filled transparent plastic discs, revolving on a wall, with coloured non-immiscible liquids. Thus he achieved a continuously flowing and always changing pattern. Mixtures of chemicals were also used for some of the most mind-bending light shows displayed on the occasions of pop-group concerts in the 1960s. Artists involved in this particular area of effort have concentrated on the mysterious, colourful and unexpected effects of whatever technology they employed. The practical aspects and, indeed, the reasons for which the particular technology was originally invented, were of no importance.

Technical terminology for art

The language of technology, however, has been used by these artists quite extensively. The descriptive language used to introduce a kinetic-art exhibition can often sound like a list from a manual of technology. The *Lights in Orbit* exhibition held in New York in 1967 was prefaced as follows: 'High intensity quartz-iodide lights; electronic circuitry; laser beams; magnetic distortion of electron beams; polarized light; plastics irradiated by gamma rays; polyester films coated with a mono-molecular layer of aluminium; new phosphors having varying controlled rates of decay; these are among the tools made available by the New Technology that 36 artist-scientists have used to achieve the works included in the *Lights in Orbit* exhibition opening at the Howard Wise Gallery on Saturday, February 4, 1967.' The exhibits consisted of kaleidoscopic film projections, moiré patterns, changing colour images produced by polarized light over plastic discs, and countless swaying, flashing, and vibrating light effects.

Several years later, an even more ambitious light exhibition was organized in London by the architect, Michael Leonard. Under the title *Electric Theatre*, the entire ambience became an orchestration of visual and sound effects, with the spectator finding that whatever sound or movement he made, albeit inadvertently, had some consequential effect on the appearance of his surroundings. A typical exhibit was another work by Bruce Lacey called *Super Shadow*. This consisted of two tall panels placed side by side. One of the panels was covered by cadmium sulphide cells on to which a beam of light was directed. When a spectator stood between the light and the panel, his shadow was cast on to the cells. Each cell was wired to a small bulb in the corresponding position on the adjacent panel, and as the spectator's shadow fell on to the cells on one side, the corresponding bulbs lit up on the other side, recreating a positive 'shadow'.

That kinetic art had penetrated public consciousness in the 1960s there is no doubt. *The New Yorker* published a cartoon showing a large block of flats, all darkened in the middle of the night. A man in his pyjamas is leaning out of one of only two windows which were lit, screaming in despair toward the other one: 'Turn down that damn sculpture!' That art moves and makes a noise is clearly accepted by the public at large.

Another technological movement of the 1960s followed the advent of video and other techniques of visual broadcasting. Already in 1965, Nam June Paik, a Korean artist living in New York, said that the television tube will displace the canvas as an artist's medium, and then proceeded to do something about it. Paik has been working with television for many years, mostly transforming the transmitted image in various ways using an array of old television sets. His most recent work in colour, using the Paik-Abe video synthesizer is a magical toy for adults. The effects are so many and so vibrant that the spectator can play for hours, mixing visual material from a number of different cameras and superimposing a wide range of colours, all by turning a few knobs. Most other artists who work with video, however, fail to astound us with such extraordinary effects.

The automatic sketchbook

Videotape, which like ordinary film can be screened on the cathode ray tube singly or severally, has the added advantage that it can be used to record an event and then be played back immediately since no intermediate processing is necessary. For most artists working in this field, video tape is like a sketchbook in which to record work in progress or make the equivalent of home movies—but showing rather incongruous events or happenings without an audience. But so far, video as a medium has failed to attract many artists who can use it in an exciting way.

The most complex and sophisticated area of technological art of the last decade involved computer and cybernetic systems. Because the ratio of technical know-how to artistic talent was disproportionate in favour of technology, a great many fantastic systems were sometimes used to produce somewhat thin and naive images. Among artists and scientists working in this field, however, there were some who spanned both technology and art equally well and whose works represent some of the most beautiful and amazing images to date. Thus of the two major trends of computer art and cybernetic devices, the former is more prolific if somewhat less interesting.

Exponents of computer art include not only artists, but engineers, composers, physicians, mathematicians, and others who, through access to computer hardware, have been in a position to generate visual images in series and permutations with the computer plotter pen, the teletype, or the cathode ray-tube display. Of the immense number of types of computer pictures, only of interest are those which employ the computer to draw figures that would be extremely arduous to achieve in any other way: I refer, for instance, to images which undergo a translation process from one to another, or a deformation according to specific principles.

One of the best examples of the first category was a picture made by the members of the Computer Technique Group in Tokyo, called *Running Cola is Africa*, in which a running man changes through a series of transformations into a Coca Cola bottle and eventually into the outline of a map of Africa. To work out this sequence with drawing instruments would have been a formidable task. The same is true of the transformations of an image according to a mathematical or a geometrical series or, indeed, according to any other principle one might care to work out.

Technology replaces dexterity

Some of those involved in computer-generated pictures proceeded to confuse randomness with intuitive spontaneity, but for others the main attraction was something else. The electronic data system, made it possible for those who have visual ideas—but no talent or ability to draw—to realize their ideas. It is a significant and an unprecedented event that technology enables us to circumvent the lack of manual dexterity in a creative process. Anyone capable of originating an idea and then finding a system appropriate for its expression can, with the aid of computers, produce the most complex and extraordinary images.

The most sophisticated electronic systems and cybernetic machines were made by artists who had training in engineering, or vice versa. The bridges between art and science are finally only built by those who embody something of the two disciplines. China-born Wen-ying Tsai's cybernetic sculptures are among the best examples of such skills in combination. Tsai has had training in both engineering and art and his works are inventive both in terms of technique and visual impetus. Most of his works consist of steel rods on a base, the rods vibrating at a constant rate. Sometimes the rods are capped by discs, rectangular plates, or diffraction gratings. In conjunction with a stroboscopic light the rods appear to undulate or become quite still. The cybernetic element is provided by the use of sound. The strobe is connected to a microphone; by clapping, whistling, or making any other sort of noise, the spectator can alter the rate of flash of the strobe and, thereby, the apparent behaviour of the sculpture.

There is one sculpture of Tsai's in particular which has the shape of an umbrella with a range of behaviour which changes from that of a confident belly dancer to the shiver of a frightened toadstool. In his studio the works grow as if in a forest or wild garden performing their gyrations as visitors walk in and out. Unlike many other works in this idiom, Tsai's cybernetic sculptures are sensual. Their organic qualities associate them with the world of biology rather than of physics or technology pure and simple, bridging the gap between the technological interests of artists and the more recent developments which are either connected with, or set out to emulate, the world of the sciences of life.

Towards 'green music'

Few artists looking for an alternative life style have succeeded in producing something both new and relevant. Most of those who have rejected object-making as a way of cluttering up the world have failed to engage the imagination of the majority of its audience. Conceptual art with its written messages, empty rooms, and cryptic instructions is not sensual and opulent. Artists making works of earth, manipulating land, stones and carving lines in fields and cutting vegetation into patterns, often do not intend their works to be permanent. The land slides back and the plants grow again, but the only way the public knows about earthen works is through photographs. Even if someone happened upon, in some remote area, a circle made of stones, he might not recognize it as a work of art.

Then there is body art. This deals with the creation of effects through the manipulation of the human body: sometimes through movements like ballet, sometimes with paint, sometimes (once more) through the use of photographs which record the event. In search of alternative life styles, artists have sought an art that could be experienced without necessarily being possessed. Those who have found themselves in this position have understandable difficulties in making a living. The time has not yet arrived for one to know what to do with such a development.

But whether in terms of earthen

works, ecological art or new paintings, the 1970s represent a return to nature as a source of inspiration. There are some artists working, for example, with plants. The variety of their approaches can best be expressed by describing the work of two people, Luis F. Benedit from Buenos Aires and John Lifton of London.

Benedit's work with plants is a part of his total scheme to present the animal and the vegetable worlds in such a way that they can be observed from every direction. To this end, he started off by making animal habitats. These are beautiful, transparent sculptures which are in fact tanks for tropical fish, snail houses, hamster cages and containers for bees and other creatures whose privacy has been sacrificed so that the spectator can see the animal in the context of its habits and social behaviour. In some of the habitats it is possible to indulge in play with the animals by making mazes for hamsters for instance, or building hills for ants. The visual aspect of the habitats is sometimes quite exciting and at other times is compensated for by what one was able to watch inside. At the Venice Biennale in 1970 Benedit exhibited a huge beehive called *The Biotron,* with 4,000 live bees flying inside. The bees could choose between feeding in the nearby gardens or from twenty-five artificial flowers which dripped sugar under the control of an electronic system. These artificial means for observing the behaviour of bees, birds, turtles and fish have angered some and fascinated other spectators.

Art and living plants

Benedit's most interesting work is now with plants. Having worked with botanists, he fills his transparent containers with substances on which plants can feed extremely well but which do not obscure the view. Thus one can see the progress of roots as well as foliage. Rather than concentrate on controlling and recording the behaviour of an animal reacting to the toys and mazes it is presented with, the plants can simply grow. Or can they? Those who play music to their geraniums and talk to their poppies will no doubt use Benedit's experiments to see what sort of light, sounds, and vibrations will bring forth these most exquisite natural sculptures.

Whereas Benedit is still dealing with objects, in as much as plants and containers are objects, John Lifton is concerned with effects. One of the most talented artists in the field of electronics, Lifton has in the past devised cybernetic systems which (through images and sounds) are capable of conducting a dialogue with the passers-by. His hardware, consisting of a computer, amplifiers and projectors, is not in itself the work of art; the work of art does not exist until someone makes a gesture, a sound or gives some other sort of signal.

Again working with effects which do not appear until provoked, Lifton is now preparing to make what he calls 'green music'. In a plant, the chemical properties of cellular membranes generate an electrical potential; the continuous and uninterrupted contact of cellular surfaces is responsible for small electrical currents passing throughout the plant. According to recent research, these currents are largely responsible for co-ordinating the growth and metabolic activity of the plant. Lifton is working on a project to use these small voltages, with amplification and computer processing, to synthesize music.

The artist describes the process as follows: 'Six plants are used in an environmental chamber. In the first stage of processing correlation between the signals separates their response to environmental changes such as temperature, humidity, light and dark, and so on, from their response to internal chemical activity. In the second processing stage, this information is built up in storage by a learning and memory system resembling a multiple threshold neuron model. This stores the information over a period of time so that the relationship of the plants' current activity to their previous activity may be used to control the synthesizer. This provides the overall structural coherence in the music.

'The synthesizer will have both rhythm and tone generation. A type of fugue in which different plants produce different melodic lines, overlaid on an increasingly complex rhythmic base, will build up from silence each time the processor is switched on. When the learning ability of the processor approaches maximum, the unit will automatically cancel what it has learnt and start again. Each variation produced in this way will be different, but related to the inherent theme designed into the processing.'

Not only plants, but animals too

Whether 'green music' will be musical is hard to foretell. Whether it will be an interesting experience is also a matter for speculation, but it is quite certain that the experiment will be worth while. The art climate at the moment is such that work with plants is bound to increase in impetus. The movement follows on the work of Cleve Backster in America which has fascinated artists. Backster has been trying, by means of a lie detector, to discover what stimuli result in an 'emotional' response in plants. (See the description by Tompkins and Bird, writing in the magazine *Harper's*, November 1972.)[1] Sir James Jeans once said that our stream of knowledge is approaching a non-mechanical reality, with the universe looking 'more like a great thought than like a great machine', and his view is echoed by these very developments in art.

Whereas this absolutely new work with plants deals with what is already there, its animal counterpart seeks to add something new. The most ambitious project in this field is planned by Briton Edward Ihnatowicz. It will be a sculpture, or some three-dimensional work of art, which will correspond in its qualities to what we recognize as the essence of animal behaviour. The work perhaps could be like something out of a mechanical zoo in which the inmates, although not belonging to any recognizable species, act like living creatures. Ihnatowicz's system will have a series of interacting input

1. See also P. Tompkins and C. Bird, *The Secret Life of Plants*, New York, N.Y., Harper & Row, 1973.

facilities, and the resulting behaviour will be based on the modification and translation of the input signals.

Ihnatowicz has already made two works which, through their complex responses, engage the viewer's imagination in an elaborate dialogue. Hundreds of people hooted and clapped at *SAM*, a flower-like sound-activated mobile based on a hydraulic system, as its petal-head bent towards those whose voice in frequency, timbre, and volume approximated to the desired optimum. Later, his *Senster* at the Philips pavilion in Eindhoven (Netherlands) entertained crowds by moving around the arena. *Senster* responds to directional sound by moving in a very organic way. Indeed, in the same way as the claw of a real lobster from which the design is derived.

The mechanics of *Senster* are readily visible: actuators, pipelines, and wiring remain undisguised. Quiet, fast and accurate movement is made possible by an electrohydraulic servo-system which responds to the analogue signals emanating from a control unit. What actually happens is this. The input of information, based on the sounds made by visitors, is picked up by a microphone, and their movements are detected by radar. This information becomes responsible for the movements of the claw. Since the claw's movements are co-ordinated by a computer, the input signals are translated into instructions, and the behaviour of the machine is modified according to past experience (stored data) as well as what is happening at the time (real-time data).

The technology-art interface

The problem with the work Ihnatowicz is engaged in now is not only a technical one. It is also one of how and what sort of a body can one build that will be meaningful in terms of art and that will express the complexity of the system which motivates it.

In their different ways, Ihnatowicz, Lifton and Lacey are engaged in a similar pursuit. They attempt to say something about man, in his environment and his predicament, by using the very hardware and technology which brought about the predicament. The cybernetic systems they use and their varying degrees of complexity may seem primitive by the standards of the equipment at the launch pads of Cape Canaveral but the ideas they implement are intuitively in advance of the kind of science-technology of which the layman is aware.

The parallels between what is new in science and what is new in art are sometimes obvious, sometimes not at all. If we are blind to the importance of various developments until after the event, it is because in art as indeed sometimes in science, we don't really know what to look for.

Revitalizing art and humanizing technology: an educational challenge

by Robert Preusser

The trench which has long separated the world of arts and letters from the technical sphere can be, and is being, filled. The natural sciences can provide new impetus, in new directions, in aesthetic form and expression. Yet modern educational processes remain 100 years behind in preparing students on either side of the gap to understand and appreciate what exists beyond that cultural obstacle. Here is described an exciting and successful pedagogical experiment to eliminate the barrier between the 'two cultures'.

Vincent Van Gogh, writing in 1888 about works of art yet to be created, speculated that they would be '. . . beyond the power of an isolated individual . . .' and that '. . . they will, therefore, probably be created by groups of men combining together to execute an idea held in common' [1].[1]

The German painter, Franz Marc, who perceived in the theory of energy '. . . a more powerful artistic inspiration . . . than a battle or a rushing torrent . . .' [2], commented in 1914: '. . . the art to come will be giving form to our scientific convictions. . . . It will be profound enough and substantial enough to generate the greatest form, the greatest transformation the world has ever seen' [3].

Twenty-three years later, Piet Mondrian proclaimed that the consequence of non-figurative art would be '. . . toward the end of art as a thing separate from our surrounding environment . . .' [4].

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1. The figures in brackets correspond to the references at the end of this article.

Although these masters of modern art were deeply committed to painting as a form of personal expression, their visions anticipated a future need for changes in method, form and context of art. Their predictions have come true and now are being reinforced as it becomes evident that interaction between artists and people in other disciplines is necessary to assure the relevance of art to changing human, social and environmental conditions.

As these conditions become more complex, there is growing awareness that the perpetuation of art as means for satisfying perceptual and aesthetic needs calls for radical departures from art's traditional forms. Also recognized is the probability that the physical and applied sciences can give impetus to new directions in visual form, expression and communication.

Fundamental to meeting this challenge is a redefinition and reorientation of the visual arts and their combinations as elements integral to our physical and social environments. Employing scientific and technological advancements in this new scale of tasks requires collective creativity and new modes of performance by artists and technical specialists alike. Creating a climate conducive to collaboration is contingent upon synthesizing a wider spectrum of knowledge and skills than has heretofore been operative in the teaching-learning process.

It is with these convictions that I have attempted to relate science and engineering to art at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts. Having contributed to scientific and engineering advancements for well over a century, MIT in recent years has become increasingly concerned that technology be made more responsive to human needs. Teaching art in a scientific community has led to the conclusion that technology can contribute to the revitalization of art and that artistic perceptions, in turn, have a significant role to play in the humanization of technology.

Technology's implications

The conflicting purposes for which scientific technology may be used require decisions with implications of unequalled magnitude in the history of civilization. Technological advancements threatening annihilation of the human race hold equally astonishing promise for improving man's physical and social well-being. Fears and hopes regarding these alternatives attest to the necessity for new levels of self-discipline and discrimination in the applications of technology we choose to foster. Clearly, man's survival depends upon converting scientific knowledge into technology for constructive purpose.

The tools are now available for solving problems within the physical sphere of human existence. Among the more prosperous nations, limited progress has been made in raising standards of living, curbing disease and lessening the drudgery of labour. The urgency of concerted efforts to attain these goals for all is undeniable. Less recognized is the equally compelling need to enrich man's inner world. Utilizing technology to create conditions that will motivate a renaissance of the human spirit is as important to the future of mankind as the material gains it can provide.

Psychologists, sociologists and philosophers continue to warn that eliminating the stress of physically coping with an increasingly complex world would, by no means, guarantee tranquillity. Their concern about the fate of man should the dream of complete automation become a reality, is not as much with the economic upheaval that could occur as it is with the loss of individual freedom in a society no longer governed by the work ethic.

While it is true that automation has made relatively slight inroads on a global scale, those beginning to be affected show signs of becoming refugees from the more secure world of self-identity with labour they once knew. Lacking inner resources to cope with free time, the tendency is either to submit to a life of conformity dictated by commercialism or to seek new life-styles in defiance of it. In neither extreme is seen the shaping of a pattern for living that will avert Orwellian predictions for 1984 (a year now only a decade distant). In short, the erosion of human values in the wake of technological progress is as much a threat to man's psychological well-being as pollution is to his physical existence.

This threat makes imperative those pursuits that enrich the quality of life and give it meaning. Art has served this purpose in the past, and I believe it has an even greater potential in the future.

Current status of art

A rapid, seemingly illogical succession of changing images and visual sensations has been the dominant characteristic of art for well over a decade. Continuity and the life span of movements as they had existed from Cézanne to Jackson Pollock no longer prevail.

It was assumed that after abstract expressionism had run its course, the next development would be a logical successor, linking to the chain of events initiated with impressionism. In retrospect, however, we know that societal and environmental change then emerging from an escalating technology was destined to affect the evolution of art.

Although the relevance of existing concepts, media, idioms, form and content was beginning to be questioned while Pollock was still living, it was not until after his death in 1956 that erratic departures in the visual arts began to surface. The search for new forms of visual expression since then has resulted in a bombardment of conflicting ideologies. This persistent feature, reflecting contradictory ideas as to the form, function and destiny of art (including the belief by some that art no less than God is dead), has lead to the confused status of art today.

Furthermore, the hypnosis of novelty induced by modern advertising tactics in the promotion of art has compounded this confusion. As a consequence of novelty rather than credibility having predominated in the market-place and museums, there has been little discrimination between idiosyncratic forms of expression and those efforts which have relevance in the twentieth century.

Undoubtedly, time will deal severely with the many transient styles that have been so effectively merchandised as commodities to be consumed rather than contemplated. History may record this period of disjointed developments more as a sociological phenomenon than an artistic one. Nevertheless, there is little doubt that we are living through a period of changing artistic perceptions. The denial of established criteria and pursuit of technological artistic media forecast drastic changes in the vocabulary, organization and anatomy of art.

Assault upon the senses

It was 'pop art' that initiated the proliferation of diverse idioms that has so greatly affected the climate of art. Reflecting an affluent society with desensitized values, artists became anti-individual, anti-intellectual, anti-structural, anti-romantic and anti-expressionist. They abandoned their preoccupation with aesthetics, substituting a glorification of the mundane for the traditional artistic concerns. Marked by cynicism, despair, sensationalism and an assault upon the senses, pop art jolted an apathetic public into recognition of its commercially corrupted environment. Its fleeting presence unwittingly challenged us to be concerned with the way things should be rather than passively accepting them as they are.

Whereas the ultimate effect of pop art was primarily that of bringing about a critical awareness of the visually dehumanizing conditions and missing qualities of life, subsequent departures from established modes of visual expression have had more to do with shattering fixed ideas about the structure of art itself. Such explorations as shaped canvases, primary structures, 'op', kinetic and minimal art are justified solely on the grounds of their visual concreteness. Despite the diversity of these idiomatic configurations, all have in common a separation of the visual elements from their customary backgrounds and interrelationships. The assigning of independent functions to isolated visual elements has afforded perceptual experiences unique in the history of art.

Experimenting with optical phenomena in this way makes doubtful that the visual elements ever will be reassembled in a manner conforming to art as we have known it. Nor is it likely that the division between painting and sculpture will survive as each has been assigned characteristics of the other. Although capriciously promoted by the same establishment that made pop art fashionable, credit must be given to these explorations for initiating change in the structure of art.

Simultaneous with this denial of established criteria is the flirtation of many artists (regardless of style) with technology. The attraction to the materials, tools and techniques of engineering and science forecasts not only further change in the organizational structure of art, but radical alterations in its anatomy as well.

Pop artists were among the first to be involved in this inevitable development. Dissatisfied with unorthodox use of traditional fine arts media in attempting to depersonalize their renderings and assemblages, they turned to commercial materials and methods.

Artists of other persuasions, in their bid for attention, resorted to monumentality as exemplified by the so-called *primary structures. Without the aid of* industrial materials and fabrication processes, the scale necessary for their recognition in a visually competitive world could not have been realized.

By contrast, op artists seeking ways to intensify visual vibrations and ambiguities harnessed stroboscopic lighting and electronic devices to moiré patterns and figure-ground components. The degree of visual calisthenics induced by this kind of technological wizardry reached its zenith in the form of the discotheque.

Even computers and lasers

Other applications of engineering ingenuity are to be found in the sculpture of kinetic artists. No longer content with erratic air currents, they employ scientific principles of motion by mechanically generating and controlling some of the forces of nature.

The computer is among the more recent and most advanced tools of technology with which artists have become involved. For them, data processing equipment and the oscilloscope replace easel, canvas and brush. And now looming on the horizon is laser holography. This phenomenal technical accomplishment of modern physics gives further cause for speculation about the future as artists become increasingly tempted to assign artistic objectives to its application.

Although examples such as these indicate an irreversible trend in the relating of art and technology, a fully committed alliance between them has yet to occur. Success in opening new avenues of visual exploration has been the exception *rather than the rule. Just as automobiles* had the appearance of horse-drawn carriages in the beginning, most forms in the initial stages of technologically oriented art are confined to configurations conceived in a previous era.

Difficulty in breaking through traditional barriers is due largely to the fact that historians and artists alike fail to recognize one thing: ever since primitive man exploited the properties of mineral substances (first in the form of cave painting, then in ceramic vessels made possible by processing clay with fire), the manipulative interaction of materials, tools and techniques has played a significant role in the evolution of art. This clue to visual research in the context of modern technology has yet to be examined.

More often than not, the artist today uses technology for the sake of novelty rather than to exploit its unique visual characteristics by capitalizing upon experimental manipulative techniques. The tendency to dismiss media and process, as incidental to the visual forms created, has deterred an imaginative and systematic investigation of the aesthetic vistas inherent in technology.

Rather than allowing technology to play its historic role in the evolution of visual form, the artist persistently imposes preconceived rhetoric upon the vernacular of technics. Having discarded all traditional concepts of art except the concept of the artist himself, he resists sharing his signature with those of other disciplines on the forms they might create in concert. While it is true that the engineer is frequently called upon to assist in technical matters, he is usually an accessory after the fact and rarely encouraged to collaborate creatively in the search for relevant, contemporary visual form. Because of this failure to engage specialists at the conceptual level, the visual potential of many technological territories remains unexplored. Not until the engineer's specialized knowledge and skills are brought to bear on the visual forming process will the artist fully comprehend the profound implications of the search which he initiated.

Engineering responsibilities

Engineers also have been remiss in acknowledging this cultural challenge. Their lack of concern with artistic matters is primarily because of the persistence of self-imposed limitations stemming from inherited attitudes established almost a century ago; at that time, the engineering professions dealt almost exclusively with developing products and services related to man's physical needs. It was practical matters such as extracting the earth's resources, the production of consumer goods and functional devices, the mechanization of farming, and the construction of transportation and utility systems that challenged engineering ingenuity during the formative stages of modern technology.

Having achieved, in large measure, the technical means for making life more comfortable—and because of the changing nature of technological developments—the realm of engineering responsibilities has grown enormously. There is acknowledged concern, of course, about overcoming physically harmful threats resulting from earlier technologies, especially pollution and ecological imbalance. Equally important but less understood in the pursuit of new technologies are awesome responsibilities for their effects upon man's mental, emotional and perceptual faculties.

For better or for worse, the frontiers of technology have profound cultural implications of a non-material nature. Affecting the way we think, feel and see, applications of discoveries in modern science unavoidably change life in ways that were inconceivable fifty years ago. Sophisticated electronics is a case in point. The transistor radio, television, communication by satellite and that invader of privacy—electronic surveillance—have greater influence in altering perceptions than they do in changing the material conditions surrounding man.

Despite the fact that these innovations inevitably affect man intellectually, subjectively and aesthetically, most engineers are reluctant to extend their concerns beyond the technical aspects of their disciplines. When confronted with relating their skills and knowledge to visual form, communication and expression, specialists profess lack of knowledge and inability to become involved. Due to self-imposed limitations and unaware of the influence their technical expertise could provide in bringing about a revitalization of art, they perpetuate the myth that science and art are foreign to one another and that the analytical-technical mind has nothing to contribute in the search for visual potentials inherent in their media. Like artists, they have lost sight of the fact that aesthetic values were integral to the origin of technology and that in science and art, throughout history, their prevailing features have been more parallel than divergent.

Concepts in science having to do with physical phenomena (i.e. light, colour, movement, space and time), as well as those dealing with the human psyche, more often than not have had their simultaneous counterpart expressed in the evolution of art. This becomes evident if one juxtaposes each discipline's theories and practices during concurrent stages of their development. In the late nineteenth century, for example, scientific research in colour perception found almost immediate applications in neo-impressionism; the theory of relativity was conceived during the same period that Cubism was depicting the indivisibility of space and time; psychoanalysis was developing as a science as surrealism was delving into the subconscious.

Pragmatism v. culture

As for the relevance of art and technology, there is ample evidence that man's capabilities in the latter were first realized when he was experimenting with procedures to create visual form. Methods and tools devised by ancient cultures for forming materials were as much the outcome of a desire to fulfil aesthetic needs as practical ones. In fact, applications of technical processes for functional purpose frequently came about subsequent to their invention rather than having been the motivation for them. The unearthing of fragmentary remains from past civilizations presents mute testimony to this contention. In metallurgy, some of the most important processes (that constitute a major industry today) were the experimental results of craftsmen seeking ways to transform materials in the production of ceremonial and ritualistic artefacts.

With these historic perspectives, it is reasonable to anticipate that dramatic scientific discoveries and spectacular technical achievements of this century will prove to be of significance in evolving new forms of visual expression. It is not unreasonable to speculate that scientific knowledge such as that gained from space exploration may revolutionize concepts in art and that materials, tools and processes resulting from space technology could radically alter the anatomy of art.

Although modern technology stems from practical concerns, it holds as much promise for enriching the quality of life as it does for satisfying physical needs. But the opposite side of the technological coin threatens to dehumanize man's physical and visual worlds. Only by interdisciplinary understanding and creative action on the part of scientists, engineers and artists can the perils of technology be thwarted. For the realization of a climate conducive to collaboration between them, it is as essential that the technically oriented begin to exercise aesthetic sensibilities as it is that artists become aware of the visual characteristics and potentialities unique to technological media. Implicit in this challenge is a reappraisal of the crucial roles to be played by both. A sustained, in-depth inquiry regarding objectives and methods of co-ordinating efforts is imperative.

This need was keenly perceived by

Dr J. Robert Oppenheimer in an address [1] given in December 1954 at the closing of the year-long bicentennial celebration of Columbia University. In urging that the differences between artists and scientists '. . . which are the most striking and which raise the problems that touch most on the evil of our day . . .' be overcome, he stated: 'They can, in their work and in their lives, help themselves, help one another and help all men. They can make the paths that connect the villages of arts and sciences with each other, and with the world at large, the multiple, varied, precious bonds of a true and worldwide community.'

A flaw of modern education

The separation of artistic sensibilities from scientific and technical training is largely responsible for the schism between those educated in the humanities and those taught in the scientific tradition. Notwithstanding C. P. Snow's critical focus upon the 'two cultures',[2] the debate he initiated has continued for well over a decade without real progress in resolving the pressing dilemma.

Despite the trend to establish a status of cordial co-existence between the sciences and the humanities, the threads of their diverse disciplines have yet to be interwoven within the fabric of education. Aware of the need to encompass a wider spectrum of knowledge than can be gained in any single area of learning and acknowledging the responsibility for creating a climate conducive to a dialogue between the 'two cultures', scientific and engineering institutions as well as liberal arts colleges and universities have responded with a more permissive sanctioning of each other's disciplines. Nevertheless, false barriers between the sciences and the humanities remain because their disciplines have not been interrelated.

It is curious that the dichotomy between Western science and art born in the nineteenth century educational system did not become an issue until late in the twentieth century. Even more perplexing is the fact that conflict between their modes of learning and understanding has persisted in an era of educational experimentation.

A deterrent to unifying scientific and aesthetic perceptions has been the belief that scientists and artists are incapable of comprehending and performing in the other's discipline: attitudes, personality and temperament identified with one discipline preclude ability to become involved in the other. For this reason, there has not been a concerted effort in higher education to bring about a convergence of these basic disciplines. Overlooked is the prospect that students of each discipline can revitalize those in the other with points of view and concepts seldom considered in their own conventional formats.

Perpetuating the myth that art and science do not mix, professional training in the fine arts pays scant attention to the physical and applied sciences. Consequently, many art students graduate without having had the stimulus of scientific concepts and technological processes. Conversely, most science and engineering

1. Reprinted in its entirety in *The New York Times*, 27 December 1954.
2. That is, science-technology and arts-letters.

students, not having experienced the discipline of art, enter their professions artistically immature although stimulation of scientific curiosity leading to understanding, discovery and invention is frequently dependent upon visual and other sensory awareness and contemplation.

Adherence to established methods of teaching these disciplines in isolation is symptomatic of the specialization syndrome that compartmentalizes knowledge and experiences. This delimiting characteristic of modern education is responsible for the conflict between the outer world of fact and man's inner world of feeling. Correcting this discrepancy requires that intellectual and intuitive methods of performance be integrated in the learning process. Implied in this observation is the belief that similarities in art and science are not adequately understood and that there is need for education to identify and unite those processes of the mind shared by both.

Reliance upon analytical procedures and quantitative measure, without resorting to subjective reasoning sensitive to qualitative values, reduces creative performance in either field. A balanced interaction of conscious intent and subconscious will is as important to science and engineering as it is to art. Also, it is important to recognize that discoveries leading to scientific and technical innovations sometimes occur outside the domain of rationalization. As in art, conceptualization does not necessarily precede discovery but, in fact, often precludes it.

In addition to exercising similar processes of formative imagination, both disciplines rely upon the same sensory fundamentals in comprehending their subject-matter. Although performing different functions, they both perceive rhythm, pattern, proportion and form, responding to the same principles of organization and unity. That they do so in different ways and for different purposes is of less importance than that they are motivated by the same structural orders. Phenomena requiring visual and other sensory classification are no less unique to one than to the other.

Aesthetic response to such phenomena is as important in science as it is in art. As affirmed by luminaries in the world of science and engineering, this faculty of awareness has often led to scientific revelation and technical invention. An investigation of what constitutes the creative process in engineering, carried out by the Institute of Personality Assessment and Research at the University of California, Berkeley, supports this thesis. In reporting their research, Dr Donald W. MacKinnon, director of the institute, stated that its finding '. . . suggests that student engineers need stimulation of their aesthetic interest and appreciation if their creative potential is to be developed' [5].

If these contentions are correct, it is a paradox of our time that education has not extended its function to include a developing of these sensibilities along with scientific cognition. Moreover, with education's responsibility for bridging the 'two cultures', it would seem that relating art to those disciplines polarized around natural science should be a major pedagogical concern. In the final section of this paper, which follows, I describe a programme designed specifically to enhance the sensory perception and appreciation among university-level students of science and technology.

MIT's 'Visual Arts Program'

In an effort to overcome 'visual illiteracy', the Massachusetts Institute of Technology has pioneered in granting visual training a role in the mainstream of general education. The findings of the Committee for the Study of the Visual Arts at MIT provided the impetus for this development. Their report [6] emphasized that due to a neglect of visual education '. . . there is a discrepancy between the average freshman's ability to think and to see. Already scholastically mature, he has yet to learn his ABC's in visual terms.' [1]

The committee advocated a visual-arts programme that would '. . . contribute not only to the efficiency of the technical mind, but also to its scope by providing the student with an insight into non-technical values which he might not otherwise attain'. They conceived the goal to be that of developing '. . . the capacity of the technician to undertake responsibility for the forms that his technical training creates . . .', observing that 'The quality of these forms, as of his own spiritual insight, ultimately affects the social atmosphere and climate of thought of his entire world.'

Aware that the quality and appearance of our changing environment is increasingly determined by scientists, engineers and managers, and that aesthetic insight should be brought to bear on technical decisions, MIT responded to the committee's recommendation that training in the perceiving and structuring of visual form be made available for all students of its twenty-four departments.

Eradicating the grievous physical and visual blight imposed upon the natural and man-made worlds by uncontrolled technological spread is considered a major priority. It is the potential of visual education within this context that has particular significance for the institute. Recognized is the fact that knowledge and skills which have traditionally constituted schools of science and engineering must be reoriented and related to a wider range of concerns; otherwise, the depersonalizing and dehumanizing effects that visually insensitive applications of technology have on man and his environment will be difficult to counteract.

No less a compelling reason for this pedagogical adventure is the growing doubt that the existing methods and content of education are appropriate to cope with the overwhelming and ever-expanding bodies of knowledge that education has inherited. Compartmentalization of disciplines has resulted in a fragmentary, rather than a unifying, educational experience. Scientific cognition and technical skills, acquired at the expense of other primary modes of understanding, fail to develop an awareness of responsibilities beyond professional borderlines necessary to assure a comprehensive approach to human needs. This goal cannot become a reality so long as specializations are pursued in isolation.

In attempting to expand the horizon of students, the MIT Visual Arts Program affords them the opportunity to

1. A freshman is a first-year undergraduate in the universities and colleges of the United States and Canada.—Ed.

relate their disciplines to the theory and practice of art. Serving as a prime example of integrating diverse disciplines, this programme has become indigenous to the intellectual and scientific climate of the institute. From the inauguration of the programme, the artist's studio was considered as essential to the study of art as the laboratory is to the pursuit of science. Whereas analysis of style and content in the context of prevailing sociological, technological, scientific and ideological conditions of each historical period is necessary to appreciate the dynamic impact of visual form upon society, an understanding of art as a basic function of human performance requires the individual's participation in the process. Just as participation without critical study fails to reveal the intellectual and historical significance of art, the verbal/analytical approach without studio experience fails to develop the senses to their fullest capacity.

Aesthetics of our environment

By combining scholarly and studio work, the programme bridges the gap between theoretical and empirical methods of learning; it thus serves as a prototype of both response to and structure of order on all levels. Not only do students gain appreciation for their heritage of fine arts; they take active part, also, in an activity which has as its objective the fulfilment of human needs no less basic than those with which their specializations are identified. This dual approach has particular value for MIT students. Pursuing study of their scientific heritage and acquiring the skills of its application, they have the opportunity to compare theory and practice in these complementary disciplines.

Specifically, theoretical study clarifies perceptual needs and establishes criteria for exercising aesthetic discrimination in selecting and rejecting the man-made shapes of our environment. Practice in manipulating and organizing the elements of design develops ability to play an active role in its formation. Students become aware of the effect which services and products of their specializations have upon a complex extending beyond the confines of professional borderlines.

The studio course is conducted so as to bring the artist's process within reach of the scientifically minded, without diluting the essence of art or encouraging a superficial dabbling in it. Co-ordination of design principles with the interaction of media tool and process is emphasized as a way of evolving form and structure. This method of experimentation, supplemented by examples from the history of art (as well as science), reveals that preconceived ideas do not necessarily preclude discoveries and that artistic (as well as scientific) inventions frequently result from this kind of interaction.

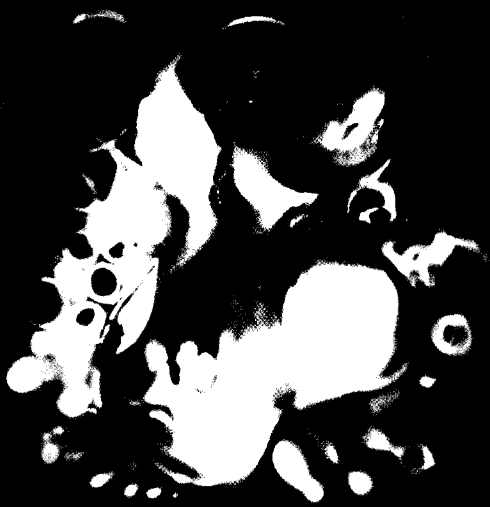
Thus, activity of this kind confirms the compatability of art and science. At the same time, focus upon subjective-qualitative values implicit in the art process serves to counterbalance the inductive-quantitative learning on which scientific education is based during its formative years. Unlike those disciplines, in which a thorough knowledge of their fundamentals and methods of verification is prerequisite to discovery and

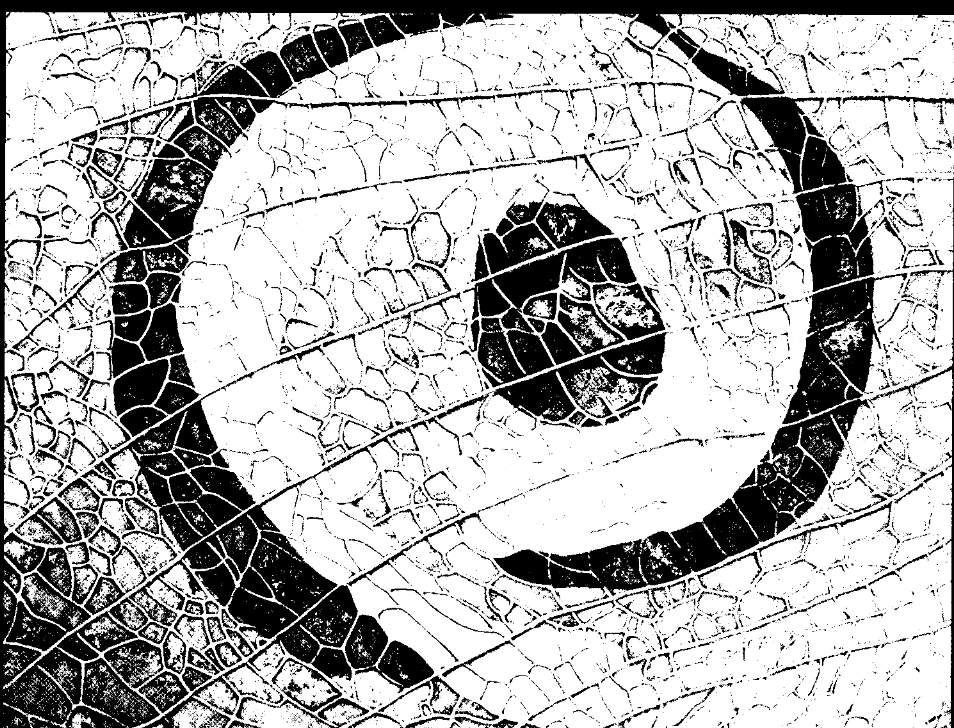
[*continued on page 66*]

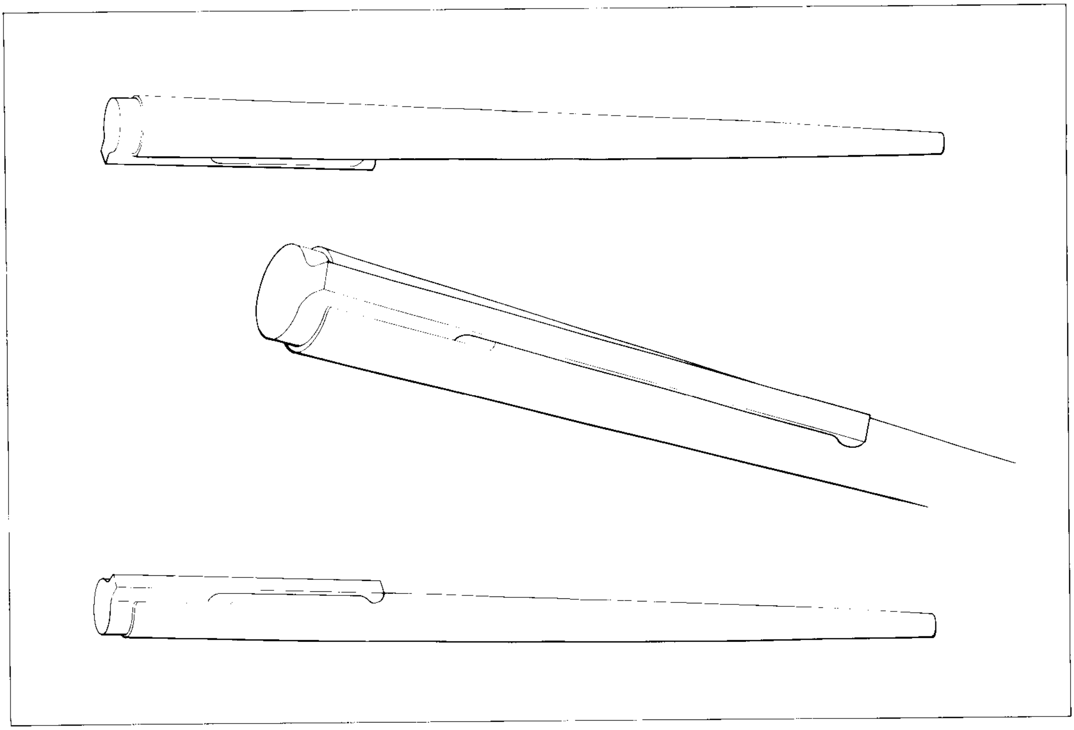
• Joining artistic sensitivity with scientific knowledge and engineering skill is demonstrated by William Parker, a final-year student specializing in physics and architecture at MIT. The photographic rendering depicts how a 'virtual volume' combined with plasma technology would appear on a facade of the Dreyfus Building, MIT campus. A flexible polyvinylfluoride tube is pumped to a low pressure; the rarefied gas within is then excited to a glow discharge by 18,000 volts from a Tesla coil. The flexible tube, or Lite-Line on which a patent is pending, is spun into a virtual volume by means of a special rotary vacuum connexion and a variable speed electric motor. A glass-to-metal seal at the bottom end of the tube is immersed in water, permitting the Lite-Line to gyrate unhindered while maintaining electrical contact. The diameter and number of nodes of the virtual volume can be varied by the speed of rotation and the tube's length. Colour changes can be made by varying the composition of the gas. (Photograph by N. Bichajan, Department of Architecture, MIT.)

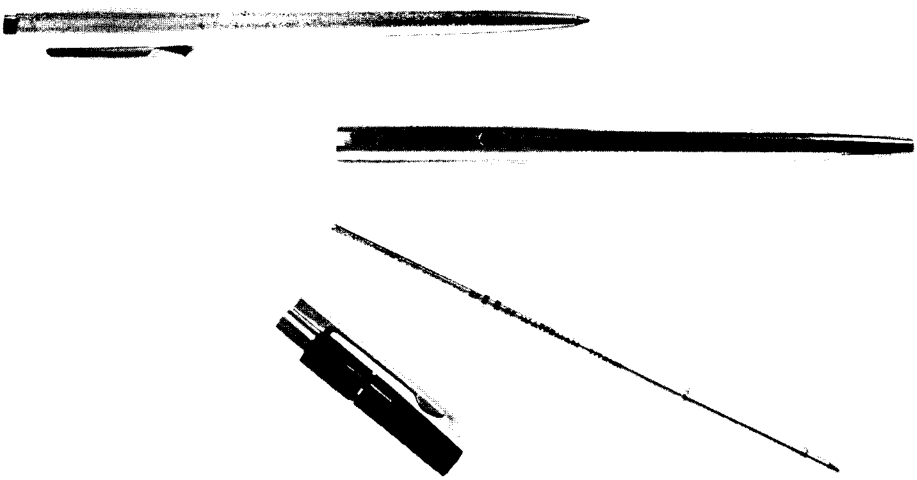
•• Detail of a saddle blanked found under the burial mound of Pazirik, fifth century B.C., from the Altay region of southern Siberia. The blanket is a tapestry made of felt. The technology of felt antedates that of weaving, non-woven felts being accepted generally as the first textiles produced by man. The making of felt involves the use of heat, moisture or friction to mass and interlock fibres of wool, fur or certain animal hair. To this day, felt is produced by tribes of nomads in northern central Asia much in the same way as by their ancestors of more than two millennia earlier and used chiefly as clothing or for shelter. Modern felts are used for decoration, as apparel, and in upholstery; to isolate vibrations, as insulation or padding; to polish, seal, or package; and in the dewatering processes peculiar to the papermaking trade. Photograph courtesy of Vice-Director V. Suslov, Hermitage Museum, Leningrad 191065 (Union of Soviet Socialist Republics).

••• The Japanese artist Masako develops her images in colour from drawings made in India ink or *gouache* on paper. She derives her basic ideas from dreams, often arising in the middle of the night to record her first impressions. The artist then refines her work, painting with oil varnish on plastic sheets separated by a translucent sheet of polyethylene from electrically operated geometric or free-form shadow diagrams —all illuminated by fluorescent lamps. The resulting tableau is one of fantasy-coloured, constantly changing movement. Ms Masako, trained in Tokyo, Osaka and Paris, is an *avant-gardiste* in sketching and painting. She has also created acoustically equipped habitacles, or furniture to live in. She is 'interested in problems of space, especially as they relate to people', and hopes that her interest in kinetic structures will lead to the making of motion pictures.









•••• *Pseudocreobotra ocellata* is a carnivorous moth which stalks its prey, the specimen represented here originating in Togo. The illustration is a fragment of wing sheath, or elyptron. The artist, Ms Yvonne Schach-Duc of the Zoology Laboratory at Paris' École Normale Supérieure, works up a first sketch via optical five-power magnification. She follows with a second drawing equivalent in scale to seventy-five magnifications (through a binocular microscope), using indelible ink in three shades of red, two of green, and one each of yellow and sepia. The artist uses a pen exclusively, building features by applying painstakingly a series of dots. The technique makes possible relief, but without the additive process of mixing colours as in painting. This method of illustration also brings out the coarseness of the insect's epidermal chitin, a complex carbohydrate-like substance also found in the shells of crustaceans and in some fungi. The result, although realistic, is the interpretation by a human being (instead of a photographic lens) of what he or she has observed in nature.

••••• Today's techniques and tools of writing, in whatever the language, had their origins as long as 40,000 years ago when early man developed the first means to paint, model or incise representations of both the creatures of nature and objects of his own making.[1] The two-part illustration shows how the manufacture of modern writing instruments adapts technology to the aesthetic presentation of the tool destined to transfer ink to a surface of record. While the simplicity and effectiveness of the implement depend largely on the principles of surface tension and capillary action, the artful presentation of the product is suggested by most modern business analyses of the needs of the market place. Above, industrial designer Alain Carré's proposals for a new model of ball-point pen; below, dissected and complete aspects of the finished product. Original illustrations and pens courtesy of Waterman S.A., Paris.

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1. For more details on writing through the ages, see W. Sandberg, *The Art of Writing*, Paris, Unesco, 1965.

invention, the practice of art permits creative application of its principles while learning them. It is for this reason that art is an ideal experience for gaining insight into the nature of creativity.

Rather than performing with media and skills traditional to the fine and applied arts, our students investigate the possibilities of visual form inherent in their own areas of specialization. When challenged in this way, students of the applied sciences employ industrial materials, tools and techniques whereas those in science and mathematics utilize mathematical concepts, physical processes (including optical phenomena) and natural forces, as well as scientific instruments.

Although the primary objective of extending the physical and applied sciences into the realm of art has been to encourage a merger of artistic sensibilities together with scientific and technical competence, this educational experiment affords an extra dividend. When scientific and artistic perceptions are joined, it becomes apparent that most disciplines fundamental to science and engineering offer aesthetic vistas to be explored. Innovations occur which hold promise of enriching our visual world. New ways of generating and organizing light, colour, texture, motion, rhythm and form are made available for extension of the artist's media.

No less revealing has been evidence that one's commitments to science and engineering do not preclude creative ability in art. Neither previous scholarly or participatory experience nor professional orientation in the visual arts is necessary for imaginative performance. When sensitized to artistic values and order, scientific visual experimentalists exercise unsuspected flexibility and ingenuity. The theory and practice of art, consequently, can no longer be claimed a domain exclusive to liberal arts institutions.

Yet the purpose of the programme is not to make artists out of scientists and engineers; it is, instead, to motivate imaginative thinking and inventive procedures in the linking of their disciplines with art. Hopefully, their experience will enhance the prospect of collaboration with artists in reshaping the environment.

The experience of our programme implies the possibility, too, that discovery and invention in art are not dissimilar to those of science and engineering—that participation in the former can heighten creative ability in the latter. The conjecture that art experience can shed light on the complex psychology of scientific discovery and engineering invention is no less provocative than the prospect that science and technology can be instrumental in revitalizing art with new physiognomy, dimension and scale.

If this prognosis is correct, it can be assumed that a pedagogy will evolve with less discrimination between scientific and aesthetic understanding than now exists in the learning process.

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Beyond the appearances of science and art: some critical reflections

by David Dickson

The extent to which constraints on art and science are determined by socio-political systems is examined. Science and art are cloaked in various guises to legitimize their existing cultural condition. By neglecting the political factors lending to the apparent contradiction between science and art, we support mythical and idealized concepts of how these function in society. Art and science possess surprising intellectual similarity; some of these likenesses are traced, as they affect us all in our daily lives.

Conventional analyses of the relationship between science and art tend to concentrate on what are seen as the parallels and differences between the two. Alternatively they dwell on the direct effects, ranging from the choice of subject-matter to the development of new media or techniques, that the one can be claimed to have had on the other [1].[1] Such approaches are used whether science and art are primarily regarded as intellectual activities or particular spheres of social activity. Yet they already imply certain assumptions about the nature of the analytical categories and the general conceptual framework within which the two can be placed in a way that makes direct comparison possible. Science considered as an intellectual activity, for example, can be fruitfully compared to art only when the latter is placed in a similar intellectual framework. The same is true if we are to consider each as social activities, to the extent that they are carried out by particular groups in

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1. The figures in brackets correspond to the references at the end of this article.

the community, and fulfil an explicit or implicit social purpose.

In an attempt to avoid some of the pitfalls inevitably contained in the above approach, I am taking a slightly different one. Although the points mentioned will enter the discussion, the kernel of the argument will be concerned to show how the apparent contradiction between science and art in contemporary society is as much a function of the way in which these activities are socially interpreted as it is of the nature of the activities themselves.

It is therefore necessary to approach the relationship between science and art in two stages. First, what is the cultural function of science in society, as opposed to its economic or instrumental role? Second, how do we relate this to the contemporary practice of art? In other words, how does the apparent cultural role of science affect the notion of the art object, the techniques and methodology of the artist, and the interpretations placed on art by artists and critics alike? Although this double articulation of the relationship between science and art may not always be made explicit, it provides the general perspective for this essay.

The discussion of the above points will be limited, for reasons of space, to the cultural environment of advanced industrialized societies. Although it is necessary to refer to the major movements of twentieth century Western art, we must omit discussion of related topics that could range from the integration of the practices of science and art in traditional societies to the reactions of artists to the technological innovations of the industrial revolution, and their profound social implications. It does allow us to confront directly, however, the apparent contradictions between the arts and the sciences as experienced by those living in industrialized societies, and to explore the assertion of J. K. Galbraith that 'aesthetic achievement is beyond the reach of the industrial system, and in substantial measure, in conflict with it' [2].

I hope to indicate how the view we have of the apparent cultural value of science is in fact a mythological disguise that masks the political and ideological factors constituting both the form and content of scientific activity. We encounter this myth as the supposed ideological neutrality of science, and its autonomy from political and ideological factors [3]. Contemporary art has attempted to appropriate both the methodological practices and the cognitive categories—such as objectivity and value-neutrality—of science as part of a programme that can be interpreted as the pursuit of transcendental truth. Yet artists frequently confuse the mythological picture of science with its socially experienced reality. They also create a mythology around art that serves the same depoliticizing and fetishizing purpose as that which has been created around science.

Apparent contradictions between science and art appear, not at the level of individual or social practice, but at the level of their respective mythologies. To the extent that the function of these mythologies is a political one, these contradictions can only be resolved through social and political action. This will inevitably involve stripping away the myths through a process of critical self-reflection to reveal the reality that they seek to hide.

Science and our life-style

There is little need to emphasize the importance of science (and in particular its applications through technology) in contemporary society. Not only has it brought about dramatic increases in the standard and quality of life, it has played an important part in creating the life-style of contemporary man. We live in a society in which machines, for example, affect all aspects of our daily lives. The dominant modes of social action and interaction share the same structure as the general design of technology, as experienced through the factors determining the process of technological innovation [4].

Contemporary art has reflected this situation by making full use of the technical potentialities brought by this new scientific knowledge. The technologically derived media introduced into art include plastics, electric lights, optical coatings, fibre optics and miscellaneous electronic techniques. The new techniques of producing art works include vacuum forming, sophisticated casting, magnetic tape-recording, and electric and high-frequency welding; each of these is being used by an increasing number of artists. The appropriation of a new technology into art often has lead to the development of what subsequently becomes identified as a new art form. Some of the most frequently encountered of these include television and video-tape, holography, automata and kinetic art, photography, computer art and aspects of op art [5].

Equally important as its material aspects is the general world-view which science and technology have brought with them. Science has had a dramatic impact on our whole outlook on life, in particular on the image that we have of the world and of the position that we occupy in it. Susanne Langer has emphasized the general importance of ideas in forming our world-view when she writes that 'the formulation of experience which is contained within the intellectual horizon of an age is determined, I believe, not so much by events and desires, as by the basic concepts at people's disposal for analysing and describing their adventures to their own understanding' [6]. In an age where science and technology have replaced religion as appearing to provide the major source of truth about the nature of the human condition (and the possibilities of changing this condition), the basic concepts at our disposal are increasingly taken from a socially accepted interpretation of the practice and methodology of science—and the results that this methodology is already claimed to have revealed. These are taken as the natural categories of social thought, relating to the nature of both its form and its content. To claim, for example, that 'scientists have shown that man is an aggressive animal' or that 'scientists have shown that Blacks are less intelligent than Whites' is to assert the unarguable status of such facts as merely reflecting and expressing a natural state of affairs [7].

How science forms an increasingly important part of our cultural experience in this way is reflected in the activities of artists. Although there is danger in over-generalization, it is possible to suggest one way of looking at twentieth-century art as reflecting a change in the purpose of art from the pursuit of transcendental beauty (that characterized the whole of the Renaissance tradition and its subsequent manifestations) to a contemporary pursuit of transcendental truth. In other words, the concern of artists has moved from attempts to capture a conventionally accepted notion of beauty to parallel attempts to capture a conventionally accepted notion of truth. According to one art critic, for instance, 'the movement towards abstract and non-figurative art can very plausibly be seen as an extension of the ancient mimetic function of art, but directed now towards the representation of underlying truths rather than the superficial truths of appearance' [8].

It would be wrong to ascribe the apparent desire to reveal the truths behind the appearance of natural objects and everyday reality directly to the growing material importance of science. It is possible, however, to suggest that the effects of science on art are reflected in the adoption of a quasi-scientific methodology by contemporary artists as a technique by which these truths can be pursued, discovered and communicated. This in turn reflects an increasing emphasis on rationality and objectivity in all spheres of social experience, and on the relative importance on the methodology, rather than the epistemology, of technique in general [9].

Impressionism and cubism

Impressionism was one of the first contemporary art movements in which technique revealed explicit connexions with science. The early impressionists attempted to depict what they saw as the reality of a visual image considered independent of the material aspects of a solid object. The formalized, analytical approach perhaps was taken furthest by the neo-impressionists (such as Seurat, Signac and Pissarro), whose quasi-scientific painting techniques led, they claimed, to the truest possible images of nature. Many of the impressionists were strongly influenced by nineteenth-century research into the scientific nature of colours, lending weight to their particular interests in the analysis of images purely in terms of colour and light.

Cubism and, subsequently, constructivism were two of the early twentieth-century movements that attempted to provide painting with some form of scientific base. It is misleading to read direct connexions as some have tried to do, between scientific advances and developments in art occurring at roughly the same time. It is easy, for example, to make too much out of the apparent parallels between Einstein's theory of relativity, with its excursions into the fields of four or more dimensions, and the attempts of artists such as the cubists to escape the two-dimensional constraints of the painted canvas. It appears that a general awareness of the potentialities being opened up by science, and the techniques by which this was being achieved, was felt by many of the major artists of the time. According to Naom Gabo, one of the early constructivist artists, 'whether many of us knew exactly what was going on in science, or not, does not really matter. The fact was that it was in the air, and an artist, with his sensitiveness, acts like a sponge. He may not know it, but he sucks in ideas, and they work on him.' [10]

Constructivism itself reveals many of the reductionist and formalist tendencies similar to those contained within a positivist approach to the practice of science.

An explicit acknowledgement of the growing importance of science and technology was made by the Italian futurists. 'From the chaos of the new contradictory sensibility is born today a new beauty, which we futurists will substitute for the former one, and which I shall call Geometric and Mechanical Splendour' announced Marinetti in a typical futurist manifesto of 1914 [11]. It is perhaps significant that the most active period of the futurists was in the years immediately before the First World War, which brought home forcefully the extent to which technology contained the seeds not only of man's salvation but also of his destruction. Marinetti's later flirtation with fascism tends to obscure the extent to which, at the time, a complete identification with the power and promise of technology was a radically progressive stance to adopt. Marinetti greeted Lenin and the Russian futurists in the 1920s with the claim that: 'All futurist movements are autonomous. Each people had, or still has, its own passatism to overturn.' We do not know how, or if, Lenin replied.

Explicit connexions with the methodology of science have been made by many of those working in the field of abstract art. Such art frequently attempts to emulate the scientific method by appealing to the validity of abstracting what are felt to be submerged, formal structures from our experiences of everyday reality and the images that it presents to us.

One of the most important and influential artists who worked in this way was Piet Mondrian. He was originally a cubist, but later developed his own rigidly geometric techniques into the style known as neo-plasticism. 'Denaturalization being one of the essential points of human progress,' Mondrian has written, 'it is one of the greatest importance in neo-plastic art. It is the privilege of the neo-plastic painting to have demonstrated plastically both constructive elements and the manner of composing them. That is why it is genuine abstract painting—to denaturalise is to abstract. By abstraction one attains purely abstract expression.' [12]

The process of denaturalization is thus seen as parallel to the one by which scientists abstract those properties of an object, material or experience whose formal structure will (it is claimed) reveal their true nature. A direct comparison is made by various members of a contemporary British group of constructivist artists known collectively as 'Systems'. Colin Jones, one member of this group, has written that 'the constructive artist rejects the idea of his work as self-expression, seeing it more as a discipline like engineering, architecture, philosophy or mathematics. The programme of his studies is based on knowledge and facts, derived from empirical research, and attempts at the kind of objective reasoning more often associated with the scientific process, than with the "mystical" vagueness of many contemporary artists.' [13]

The observer's objectivity

Other contemporary art movements, if not explicitly claiming the appropriation of methodology from science, appeal to the same concepts of objectivity and the detachment of the observer that our world-view has borrowed from the philosophical presuppositions of the scientific method. A direct instrumental involvement with the art object is denied in the apparent interests of objectivity, claimed necessary for both artist and spectator alike. Art is increasingly justified by its appeal to the intellect, not to the emotions. The spectator is treated as a passive receptor, not as a reflective interpreter who can relate a work of art to his own experience. Andy Warhol, when asked how he would meet the challenge of automation, replied 'By becoming part of it'. He added that 'human judgement doesn't mean anything to me. Human judgement cannot exist in the world of automation. "Problems" must be "solved". Without judgement there can be no problems.' [14]. More directly, movements such as conceptual art, where the necessity of the material existence of a work of art is rejected in favour of abstract discussion of the possibility of its existence, show an attempt by artists to assimilate themselves directly into the field of scientific and philosophical discourse [15].

Thus we can see how, beyond the merely technical level, science has provided us with an interpretation of the world, and with a set of techniques (by which the nature of the world can therefore be revealed) that have been readily taken up by artists. It is important to retain a dialectic, rather than a deterministic, view of this process. For it is just as possible to argue that one view of the world, derived for example from religious traditions, has made science possible as it is to claim that this view of the world has been directly derived from science. Yet it is in the sphere of the supposedly objective, abstract formulations of the nature of reality that a major link between contemporary art and science is to be found.

The interpretation of science by non-scientists in any field inevitably involves a degree of social mediation. In other words, the choice of the categories by which science is interpreted is determined by extrascientific factors, two important examples being provided by the sociology of science and the philosophy of science. This is particularly true of how artists have interpreted science (and, conversely, the way in which scientists have interpreted art). Before we can discuss the implications of the respective categories applied by both sides, however, we must refer briefly to the nature of both science and art as social activities, that is as activities fulfilling a certain social function and carried out by some sectors of the community according to the contemporary division of social labour.

Whether we look at either science or art, it is not difficult to see the extent to which the form of the activity reflects its economic and material role in society. The rapid increase in expenditure on science in the past twenty-five years, for example, is directly related to the growing importance of its applications. Research and development in almost all industrialized countries are dominated by military and industrial interests, hence directed toward the creation of machines of destruction or the innovation of new products. This indicates the extent to which science is linked intimately to the interest of the major institutions in such societies. Science, by virtue of its need for economic support, is increasingly channelled into serving the political interests of its paymasters. It has lost its status as an independent institution, to become simply one more industrial enterprise requiring vast amounts of organization and resources. Scientific research yields to economic imperatives that are determined by the political form of the contemporary state [16]. This process reflects on the very content of science. Ideological features have frequently become constituent of the content of scientific theories, not only in the social sciences but in many of the natural sciences such as biology [17].

Artists and the social order

The same is true of art. The great majority of artists are compelled by both social norms and economic necessity to align themselves with the interests of the social order in which they work. They find these interests interpreted through the financial interests of the gallery system—hence, as a reflection of the values of a wealthy élite of art buyers. This is so if they are to retain their status as pure artists, or by the educational system if they wish to teach, or by the industrial system if they are concerned with the applied arts. Any art which attempts to exceed the limits of social acceptance finds itself rapidly deprived of an audience. Art, like science, can never be considered as politically neutral, either in form or in content [18].

A consequence of this is that both scientists and artists suffer an alienation that results from a loss of control over the nature of the work they are required to do, and the way in which their work is subsequently used by society. Such decisions are taken out of their hands and placed in the hands of those who provide them with financial support. Although it may be possible superficially to select which master to work for, the fact that educational, governmental and industrial institutions are increasingly linked, sharing the same values, priorities and social goals, makes the outcome of their selection relatively insignificant [19]. These shared values and priorities are directly related to the distribution of power and the pattern of social control in society; they are, in other words, political issues.

To make this suggestion frequently raises quick objections from both scientists and artists, who point to the apparently disinterested and socially autonomous nature of their work. If science and art are determined by political interests, it can be asked justifiably, why it is that scientists and artists, the people who actually carry out these activities, are unaware of this fact. Here we must refer to the relationship between practice and social experience and the socially accepted notion of a given activity. Every individual constructs his own social reality by ascribing a particular significance, or cognitive validity, to those elements which make up his environment [20]. Science and art are two of these elements. And the significance attached to both of them makes them appear as primarily intellectual, politically neutral activities—science being interpreted as the pursuit of objective truth, and art as some direct or indirect form of mental stimulus.

There are strong parallels, for example, between the concept of pure science being justified in its own terms as the disinterested pursuit of knowledge, and the similar concept of art for its own sake, or *l'art pour l'art.* Each notion supports the idea that it is not only possible, but indeed desirable, to isolate intellectual activity from social interests. The concept of abstraction, having an intrinsic cultural value, has been legitimated by powerful traditions of philosophic idealism, in particular by the German philosophers of the early nineteenth century [21].

The neutrality of both science and art, as the supposed freedom of the scientist and artist, is a myth. Yet the myth serves an important social function, for the important thing about myths is that they are taken as truths by those for whom they appear to provide an explanation of particular aspects of our social experience. Myths provide a comprehension, and thus they legitimate both the natural and the social phenomena that make up our everyday world [22]. The myth of a 'sun-god' riding across the sky, to take a very simple example, is sufficient to explain why the sun moves across the sky daily, and to reassure us that it will do so again tomorrow, without any prior knowledge of the circular motion of the planets or the spherical nature of the earth. 'Myth has the task of giving an historical intention a natural justification, and making contingency appear eternal', claims the French literary critic, Roland Barthes [23].

The role of scientism

Scientists will tell us that there is no such thing as final, objective truth, but only working hypotheses and concepts that are, at best, a partial and temporary representation of aspects of reality. But the socially accepted notion of science ignores this distinction. It places a positivistic interpretation, furthermore, on the methodology and conceptual presuppositions of science. And it is frequently this interpretation—which can be referred to as scientism, to distinguish it from the true critical practice of science—that is appropriated by artists.

'Scientism means science's belief in itself,' claims Jürgen Habermas, 'that is, the conviction that we can no longer understand science as *one* form of possible knowledge, but must rather identify knowledge with science.' [24] In a secular and materialistic society that appears to have left notions of romantic idealism far behind, the apparent neutrality and objectivity of the scientific method as mediated by this scientistic interpretation frequently appeals to artists as offering to reveal the truths of the human situation. According to an opinion in *New Scientist,* 'Science is a discipline, a state of mind. A kind of morality, even. As an artist, I find this discipline the only effective and honest key to self-denial—without which the artist can offer no information.' [25]

A tendency towards self-denial, towards denying the subjective response to natural objects and images in favour of a quasi-objective understanding of their nature, appears to be one of the main currents of contemporary art, as noted earlier. This is not to argue that all contemporary artists necessarily display these tendencies. Many of those who become socially accepted as the leading artists of our time (and here one can refer to Oldenburg, Warhol, Lichtenstein, Hockney, Bacon, Caro, Paolozzi, Vasarely, Soto, Agam, Bury and a host of others), inevitably share in some way a common set of values. Hence, there is a common interpretation of our outlook on reality, as those values are conventionally accepted by society. Compared with virtually all major art movements up to the end of the last century, contemporary art displays a form of clinical detachment that maintains the importance of scientistically based concepts of objectivity, rather than subjective and critical self-reflection.

There are two important implications of our acceptance of scientism. First, we tend to interpret the world through what we take to be the objectified categories of science, in particular dividing our notion of reality into the independent domains of the subjective and the objective, what A. N. Whitehead has called the 'bifurcation of nature'. Second, methodology becomes accepted as replacing self-reflection, as providing the technique by which the supposed truth about man, nature and society is to be obtained. Correctness of technique thus replaces correctness of meaning, and ethical discussion is eliminated from social practice.

Habermas has suggested that the theories of knowledge which characterized nineteenth-century philosophy have been directly replaced by positivistic interpretations of the philosophy of science. This, by concentrating on the supposedly objective nature of its methodology, has eliminated consideration of the status of the knowing subject and has thus created a general severance between knowledge and the human interests which is represents [26]. Although this process takes place outside the domain of science, it reflects on science by clothing it in the mythological disguise of political and ideological neutrality. The process extends similar interpretations and legitimations to cover the practice of art.

Four questions to ask

If the socially accepted notion of science is, then, one of the myths of industrialized society, then there are four questions to ask. The first is why should the myth that ascribes objectivity and political neutrality to science have been selected rather than a different form of myth. The second, which relates to this, is why, if we are, as we like to think, rational human beings, are we prepared to accept a mythological explanation of a situation rather than facing its objective reality. The third question is how does the myth relate to the way in which we see the relationships (in terms of both the parallels and the differences) between science and art. And finally, we must ask what must be done to identify and do away with this myth if, as is suggested, it imposes a repressive force on man's potential as a human being. These four questions are dealt with in the remainder of this paper.

First, why this myth?

We return here to a direct consideration of social and political issues. We have observed how the development of science is inevitably linked to political considerations reflecting the distribution of power and the practice of social control. Yet we tend to look upon science as an autonomous, self-propagating activity that works according to its own methods, rules and social norms. It may be that the purpose of the latter as a mythical (even mythological) explanation is that it leads us to accept the existing state of affairs, not only about science but about society in general, as being natural and unarguable. We cease to question the activities of scientists or of scientifically trained experts, and are compelled to accept that the scientist knows best because his methodological practices are the right ones, i.e. because they are scientific, rather than because he has a particular insight into human or social problems.

This deference to expertise and the passivity that it breeds runs through all our social experience. Barthes writes that 'bourgeois ideology is of the scientistic or intuitive kind, it records facts or it perceives values, but refuses explanations; the order of the world is seen as sufficient or ineffable, it is never seen as significant' [27]. The function of scientists becomes not to change the world, but merely to interpret it, to provide an explanation of why it is natural that the social environment should be as it is. It legitimates, in this way, patterns of domination over both man and nature [28].

Science may contain the potential of being transformed into a materially progressive force; but under the mythical disguise of scientism, it seeks to obscure the possibility of individual and social emancipation. It is in fact used to suppress such a possibility by preaching the natural order, and hence the inevitability of the existing system, and the patterns of domination and exploitation which this system maintains. It is at the same time able to dismiss as irrational or unscientific any attempts to challenge the authority of science in terms of the class interests which it maintains by arguing the separation of science and politics.

We must now ask why it is that by adopting a neutral conception of science, people are prepared to accept what is, in fact, a false interpretation of a particular shared experience. This applies specifically to scientists who, so we are led to believe, are trained to distinguish falsehood and prejudice from truth. Such questions can be approached only by turning to the workings of the unconscious mind. We can suggest that Sigmund Freud, without necessarily realizing it, indicated how an answer might be formulated by his interpretation of the social functions of religion and art. The first, suggests Freud, provides us with the internal security that we require in order to identify and establish our place in the world; the second offers a means of gratifying those instinctual needs that have been suppressed by the society in which we live, in other words with a means of sublimating these needs.

Freud realized that religion provides a mythological interpretation of the world of our experience. Civilization, he proffered, is required to assist man in three ways in defending him against the forces of nature. 'Man's self-regard, seriously menaced, calls for consolation; life and the universe must be robbed of their terrors; moveover his curiosity, moved, it is true, by the strongest practical interest, demands an answer.' [29] Freud argues that religion developed in response to these three needs.

Science and religion

Adopting an evolutionary, model development (popular among anthropologists at the time at which he was writing), Freud suggested that the needs previously filled by religion had now been surpassed through the real knowledge of the world that we have gained through science. He admitted that religion had performed a great service in the taming of asocial instincts, but claimed that the advent of science had clearly shown religion to be an illusion. By placing such faith in the explanatory and emancipatory powers of science, however, Freud seems to have overlooked the extent to which the three tasks of civilization which he outlined still remain important to the individual, oppressed as he is now by the complexity and apparent overwhelming nature of his social, rather than his natural, environment.

Science has not replaced, but has transformed, religion. Science in many ways has become a religion in its own right, performing those legitimating and interpretive roles which, as Freud points out, have traditionally been the responsibility of religion. 'I hereby swear and affirm. Affirm. On my . . . honour? By my belief in . . . in . . . the technological revolution, the pressing, growing, pressing, urgent need for more and more scientists, and more scientists, for more and more schools and universities and universities and schools, the theme of change, realistic decisions based on a highly developed and professional study of society by people who really know their subject . . ., stutters the lawyer in John Osborne's play *Inadmissible Evidence* [30].

Science, seen from a cultural perspective, is more than just a belief system. The contents of science and the activities of scientists are fetishized into cultural achievements, and often claimed to possess intrinsic value. The particle accelerators at the European Organisation for Nuclear Research (CERN) have been compared to the mediaeval cathedrals, representing the highest cultural achievements of our age: a grotesque, but possibly appropriate, analogy. Theories are described as elegant or beautiful, referring usually to their comprehensive simplicity, but appearing to the non-initiated as mere austerity. Here we see happening the reverse process of the one described above, namely the appropriation by scientists of the concepts and categories usually associated with art. This is done in an attempt to identify, not the objective value of science, but its claims to be evaluated against other socially accepted cultural norms [31].

If we look closely at art, however, we see that it too has its mythology. In contemporary society, this claims the validity of a distinction between the cultural—or 'spiritual'—needs of man from his material requirements, and of substituting the notion of transcendental value for the direct expression and communication of experience of the senses. The myth is explicitly articulated in debates on artistic form, style and general aesthetics. These frequently seek to legitimize particular developments in art *post facto,* and to draw them into the acceptable mythology of art, often providing a very different interpretation from the original intentions of the artist [32]. The concept of the Renaissance, for example, was virtually created by nineteenth-century art writers.

Similarly the label 'impressionism' was coined by an art critic, describing the first show of the group of artists we now refer to as the impressionists. Even attempts to challenge the fundamental conceptions of art soon find themselves neutralized by becoming rapidly assimilated into the general art mythology. Duchamps' ready-mades are now revered and evaluated as art objects; it has been pointed out wryly, about William Morris, that he became 'not only the progenitor of the arts and crafts movement in Europe and America, but also one of the founders of design for industry, which he hated' [33]. As Herbert Marcuse has written, 'the anti-art of today is condemned to remain Art, no matter how "anti" it strives to be' [34].

Art and our material life

To return to Freud, it was he who pointed out the extent to which society is prepared to accept the fetishizing of the art object precisely because it fulfils a sublimating role, it allows us to avoid considerations of the material aspects of our own existence. John Berger has recently gone even further to describe the extent to which the images used in art are used as substitutes for the real object, the oil painter reminding the art patron of what he possesses, the advertisement reminding the consumer of what he does not own [35]. Like religion, art offers us a glimpse of security that appears to lie above the uncertainties and deprivations of the everyday world. 'Art offers substitutive satisfactions for the oldest and still most deeply felt cultural renunciations,' suggests Freud, 'and for that it serves as nothing else does to reconcile man to the sacrifices he has had to make on behalf of civilization.' [36]

Freud himself extends this analysis to indicate the way in which science can be interpreted as a means of fending off reality, as providing an escape into the world of repressed desires and their apparently legitimate expression [37]. Perhaps mathematics, man's most successful attempt to shake himself free of the constraints of reality, presents at the same time the most sophisticated form of this sublimation. 'Knowing lots of brilliant mathematicians, I don't *really* want to be one. Some of them are *insane*', recently complained a leading chess player, at present reading mathematics as an undergraduate at Cambridge [38]. The tortured paths into which mathematics can lead the soul are vividly illustrated in Bertrand Russell's autobiographic memoirs, a complaint often reiterated in a less literary fashion by many scientists.

Yet because science can, for scientists at least, function successfully as a sublimating agent, its sublimating role appears to become part of its predetermined social function, legitimated in terms of the value of the pursuit of knowledge for its own sake. As Alfred Sohn-Rethel has written, 'philosophical idealism can in the main be identified with the fetishisms of intellectual labour in its divisions from manual labour; spiritual values are glorified and enhanced as against all others and appraised as the substances of the value of man' [39].

Having seen the way in which art and science are individually articulated within the terms of contemporary culture, we can return to the relationship between the two, or rather (since we have seen the need to distinguish between objective practice and the legitimation of that practice) to the way in which the relationship between the two is generally interpreted.

By maintaining that there is a clear distinction between science and art, our culture is able to sustain and legitimize the division of our experience of reality into the separate categories of the objective and the subjective. In science, this is expressed through an emphasis on the necessary objectivity of the scientific method, where the scientist finds the relevance of his own experience denied in the interests of a supposedly objective interpretation of the phenomenon which he is studying. The development of subjective knowledge, he is told, remains the responsibility of the humanities, if he is in a university, or the museums, concert halls and theatres if he is not. The importance of art is not denied, but merely placed in a different compartment. 'Science and art are as closely bound together as the lungs and the heart,' claimed Leo Tolstoi, 'so that if one organ is vitiated, the other cannot act rightly.' [40] Yet this still presupposes a separation between the two. Art is held out to the scientist or the engineer as the civilizing influence that will humanize his outlook on life. 'The Arts—Antidote to Technical Malaise' is the title of a typical essay expressing this point of view [41].

The real aims of science

Maintaining this distinction between subjective and objective experience allows society to attribute complementary but mutually exclusive roles to science and art. Science, seen in an uncritical capacity as purely interpretive description, is taken to represent the act of abstracting a formalized pattern from our experiences of both the natural and the social world. This is expressed in notions such as the task of the scientist being to uncover the hidden laws of nature or of society. According to one scientist, for example, 'the whole aim of theoretical science is to carry to the highest possible and conscious degree the perceptual reduction of chaos . . . the most basic postulate of science is that nature itself is orderly . . . all theoretical science is ordering' [42]. The basic theoretical tools of science are those derived from abstract logic and mathematics, in each of which the concept of ordering plays a central role.

Art, again seen in an uncritical capacity, can be interpreted as a process of ordering. It can in fact be suggested that if science is taken as the internal, abstract ordering of externally experienced phenomena, art plays the complementary role of the external, material ordering of internally—i.e. subjectively—experienced phenomena. The ordering process in art is perhaps best grasped through the attempts of critics to elicit the meaning of a work of art through formal analysis of what are taken to be its basic structures or the way in which the painting 'works'. These may be interpreted as being mathematical in the case of Renaissance painting, conceptual as with the impressionist, expressionist and other schools of abstract art, methodological as with the constructivists, psychological as with the surrealists, or even as being anti-structure, as with the futurists and dadaists [43]. The main working concept is that meaning is conveyed by a system of coding, and the possession of a formal structure is a functional necessity of any such code [44].

The interpretation of both science and art as ordering, and indirectly as coding procedures, carries some attractive implications. The act of creation, for example, can be interpreted as the discovery of an appropriate code to fit a particular experience or situation, thus explaining the observed similarities in the act of discovery encountered in both science and art [45]. Similarly the tasks of searching for an appropriate code among a mass of uncoded data, and of translating a message once the code has been discovered, are both comparatively lengthy mechanical tasks; this is manifest in the everyday activity of both art and science. Almost every major artist, for example, has a number of assistants who carry out this aspect of his work, while in science this activity has been referred to by Thomas Kuhn as 'normal science' [46].

One can go on to argue that an artist abstracts, in a similar way to the scientist, those aspects of an object, idea or situation which he requires for his formal interpretation. In other words, he abstracts those aspects which he considers meaningful in terms of his artwork—or scientific theory. An artist's reputation is very occasionally built on a single work, but more frequently on a succession of works, each of which gives a particular articulation to his central theme, and which together summarize his activity as an artist. The scientific research paper plays the same role for the scientist. There are a few rare examples of scientists who have made their name on a single paper outlining a radically new theory, but the average scientist builds both a reputation and a career out of a lengthy succession of papers, the quantity of which often appears as important as the quality in determining his status as a scientist.

By describing the practice of both art and science as an ordering process, one is able to bring out the complementary aspects of their supposed social roles, and at the same time the parallel aspects of their working procedures, at least prior to any intellectual formalization. One might even expand the ordering model to suggest that culture in general represents the ordering of our social experience. We might identify the natural sciences, the social sciences and the arts as those aspects of this ordering process which apply to our experiences of the natural world, the social world, and the world of our subjective experience respectively. This process might in fact be compared with Weber's concepts of rationality in the organization of human affairs, and taken to be its intellectual counterpart.

Seeking a sense of order

Yet the danger of this interpretation, attractive as it might seem, is that the act of ordering, although apparently a creative one, is frequently done in a passive and uncritical manner. We seek to find an order which (it is implied) already exists so as to interpret it rather than challenge it. A sense of order gives a sense of stability, a sense of purposiveness. Perhaps as a leftover from the Platonic idea of perfect form, we feel that once order has been found, then this in itself is significant. The fact that a structure or pattern is hidden seems to give it a greater significance than the facts or experience behind which it hides. The act of ordering is implicitly a step away from reality. Without a superimposed progressive intention, both art and science become reactionary activities, confirming the divine purpose and stability of the status quo.

If science and art are so closely linked in terms of practice, why is it necessary to discuss their relationship as a problem? We must refer back to the discrepancy between the nature of any social activity as it is practised, and the socially accepted interpretation of this activity in our culture. The contradictions that arise are not those between the practice of science and the practice of art, but between our notion of the practice of science—the pursuit of pure, objective truth—and our notion of the practice of art as equally pure, subjective emotion.

It is part of our cultural inheritance that the two, while playing complementary roles in society, are nevertheless directed towards separate and clearly identifiable ends. The art critic Ernest Read has suggested, for example, that 'between the objectivity of science and the subjectivity of art there is this difference; the one aims to inform, the other to please' [47]. One could list, endlessly, scientists who have done science because they enjoyed it. (In the nineteenth century, elementary experiments were common drawing-room diversions.) Who cannot say that information about the world is not discovered through art? The apparent contradiction between the two, however, is still another articulation of the general mythology of contemporary culture that obscures the nature of the political and ideological factors which inevitably determine the form of any cultural activity.

The contradiction has been given a reified or fetishized existence, for example by reference to the 'two cultures debate' started by C. P. Snow [48]. It helps to frame the cognitive codes into which, it is suggested by Basil Bernstein, we are socialized very early in our lives; it is these codes which discourage connexions between acquired knowledge and everyday realities [49]. In other words, society has certain historically determined categories of individual and social activity which it labels either art or science. These categories are passed down, through our educational institutions, from one generation to the next. Whether we are prepared to accept something as either art or science depends, instead of on our experience, on the extent to which we are able to fit it into our preconceived notion of the factors defining inclusion in either category.

Those who seek to bridge the gap between the arts and the sciences without acknowledging the political and ideological factors which influence the definition of these categories, and the reasons why these categories are maintained as distinct, have met with little significant success. Art movements which have sought to do this merely by appropriating scientific techniques or methodology into new art forms, while admittedly establishing an apparent link between art and science and often affecting the nature of the activities carried out within art, have been unable to break down the barriers that separate the one activity from the other. Such attempts almost invariably land squarely within the conventional boundaries of art; the artistic and technical or scientific aspects of a particular work remain clearly distinguished [50].

A shared sense of purpose

We must ask what we can do in order to rid ourselves of the myths surrounding both science and art, to overcome the apparent contradictions that appear to exist between the two in 'advanced' societies.

There are no simple replies. It is relatively easy to point, in a Utopian sense, to what should be done. Tasks include breaking down the distinction between manual and mental activity, between abstract theory and concrete practice, between different categories of social experience and, indeed, all those artificial barriers which seek to divide one form of individual and social activity from another. More particularly we must seek to revive the concept of both science and art as forms of critical inquiry into the nature of the world confronting us. And both scientists and artists must see their roles as being those to change the unacceptable elements of this reality, rather than merely to legitimate them. A shared sense of purpose will do more to bring art and science together than any amount of abstract theorizing is ever likely to achieve.

Before, however, both science and art must divest themselves of their disguises. This can be achieved only through a process of critical self-reflection, by scientists and artists, of the true nature of their activity and its function in society. This is a process which, as Habermas points out, Freud promoted under the title of psychoanalysis as a way out of the problems of neuroticism but the general importance of which, Habermas claims, he was unable to recognize in his attempts to establish the scientific validity of psychoanalysis in the conventional sense [51].

We have seen the extent to which the pressures on both science and art are determined by the very nature of the social and political systems in which they take place, and the way in which these activities are given a disguise in order to legitimate the existing state of affairs. To neglect the political dimension of the factors giving rise to the apparent contradiction between the arts and the sciences is to support a mythological and idealistic concept of each activity that does not coincide with the way that it is practised or socially experienced. To say that the problem is simply one of the name in which the system is run, and that both science and art as we now experience them are little more than bourgeois mystification is to take a grossly simplified view of the nature of culture as an expression of individual and social experience.

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TO DELVE MORE DEEPLY

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Art, technology and sense perception[1]

by Rolf-Dieter Herrmann

Efforts in recent years to combine technology with art have overturned previous attitudes toward man's conception of artistic imagery. The classical distinction between the viewer (subject) and the viewed (object or art work) no longer holds true. We need to let the art object become manifest as to its role in our life, its place in our universe. As does a game, an art work has a power of its own. Some prominent Western philosophers of the past century provide clues to a new understanding of the art-science relationship.

In 1965 William C. Seitz organized *The Responsive Eye*, an exhibition at the Museum of Modern Art in New York. In the exhibition's catalogue, Seitz explained what the projects, contributed by artists from more than fifteen countries, had in common:

This is an art of appearance, not factuality. Like the apparatus of a stage magician these objects do not exist for their true physical form but for their impact on perception.

They do not ask that the spectator be a rapt admirer but that he be a partner in reciprocal perceptual experiences. They try to make use of the newest methods and materials that industry has made available, the newest principles established by science, and even of mass production and distribution. They speak of the elements of their works as 'information' and their compositional arrangements as 'programming' [1].[2]

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1. This is the enlarged version of a keynote address presented at the annual meeting of the American Society for Aesthetics at the University of Colorado in Boulder, 1970.
2. The figures in brackets correspond to the references at the end of this article.

The works shown in the exhibition were, on the one hand, impressive because of their physical properties, that is, their lines, colours, hues and shapes; but on the other hand, these properties suggested movements, rhythms, waves and produced stimuli exciting our eyes and our brain to the extent that we were overwhelmed and sometimes even thrown into a kind of hypnotic trance. That is to say, they not only affected our immediate sense experience but also provoked after-images. It sometimes seemed as if they were aggressive, as if they wanted to hurt our eyes, and as if they were able to make us depressed and sick.

It seems to me impossible to understand the works of the artists represented in *The Responsive Eye* exhibition in terms of subject and object, i.e. according to the traditional subject-object-separation. These artists' conception of art arises within the whole of the world, a world that is prior to every separation between subject and object and even prior to an analysis, which only amounts to a single statement given with the help of language. What matters to them is experience. We must open ourselves to these works of art and allow them to appear, to become manifest as what they are. Being led by them, we enter a foreign universe, a universe divorced from the subjectivity of our private existence.

In 1968 and 1969, an exhibition called *Air Art* was shown in several places in the United States. The exhibition was organized by Willoughby Sharp; it offered a multimedia presentation. The inflatable and immaterial works shown were intended to restructure our technological world entirely and to intensify the consciousness of our own human existence. As Sharp said:

> The present technological age occurs in a new environment, an electric environment, which has reconfigured our senses. Seeing is no longer the primary means of knowing. Hearing, tasting, touching and smelling have become more important. Our five senses are rapidly becoming more completely integrated. We now demand greater participation in events. We have reached the end of contemplation, impartiality and disinterestedness. We are embarking on a new phase of artistic awareness in which participation, partiality and interest are the chief characteristics. There is an increased participation in the physical environment that results in an open-ended experience which can only be completed by the participant. Involvement mitigates the inside and outside split. It destroys the subject-object duality [2].

Once this 'subject-object duality' is called into question, there is room for exchange between our perceiving body and the world in which we live. As Robert Morris put it:

> A certain strain of modern art has been involved in uncovering a more direct experience of these basic perceptual meanings and it has not achieved this through static images but through the experience of an interaction between the perceiving body and the world which fully admits that the terms of this interaction are temporal as well as spatial, that existence is process, that the art itself is a form of behavior that can imply a lot about what was possible and what was necessary in engaging with the world while still playing that insular game of art [3].

It is not by accident that Morris associates a work of art with a game. A game is not based on the human subject playing outside and above the world but, rather, it has a power of its own, a power that is independent of oneself, that involves the individual as soon as he enters into its structure, and that includes his body and his whole organism.

Beyond sensual involvement

Such a closer, more intimate encounter with a work of art, however, does not happen on an exclusively sensual basis. Whenever an experience takes place, we are already beyond the immediacy of pure sensual involvement. As Gyorgy Kepes said:

> An artistic form . . . is more than a pleasant tickle of the senses and more than a grasp of emotions. It has meaning in depth, and at each level there is a corresponding level of human response to the world. The artistic form strikes directly at the senses but reaches beyond them and connects all the strata of our inner world of sense, feeling and thought [4].

When we encounter a work of art, we experience something 'as' something. That is to say, we accomplish something through our thematization in one way or the other: we turn our interest to something, and we leave out something else. If such a thematization is really to imply anything at all, it must lend a meaning to the work of art which was not present before. This meaning-giving activity emerges directly from our place in the world, because each time we comprehend something 'as' something, our meaning-giving activity is part of an interrelated whole of meanings which we have gained in the course of our own individual life history. Admittedly, we select certain aspects in looking at a work of art, and we relate and order them; but this fundamental process of thematization, although it depends on our choice, is historical and grounded in the whole of the world.

Once we have decided to consider a work of art in this light, we may understand better those artists deeply concerned with art and technology projects during the last few years. Nicolas Schöffer, for instance, has been concerned with providing the viewer with a wide variety of effects caused by light, sound, colour and movement, effects familiar to anyone who has seen his luminodynamic and chronodynamic constructions. The idea occurred to Schöffer that he should associate his work with architecture and town planning. He built a tower at the Parc de Saint-Cloud, in the Paris suburbs, in 1954; in 1961, he constructed a light-and-sound tower at Liège; and again, he began to plan a new centre for Paris, a 'cybernetic' tower 347 metres high. His plans included even a whole cybernetic city, with all kinds of facilities for modern living. His basic aim in these projects is to 'impress' us:

> It no longer suffices to give impressions to the public, but it is necessary to impress it profoundly.
>
> In order to arrive at this end, the products of artistic creation must enter into the vital circuits of society. The totality of informational networks, networks of exchange of all kinds, must be opened to real aesthetic still playing that insular game of art [3].

Victor Vasarely, too, is not concerned with promoting the century-old subjectivism present in art. He writes, in a private communication, 'I reject the traditional subjectivism'. In 1970, he opened a cultural centre in a Renaissance castle at Gordes, France. He had three major plans: first, fundamental research; second, development of projects oriented to city planning and architecture; and third, an interdisciplinary encounter of all kinds of people—painters, sculptors, architects, urbanists, sociologists, psychologists, industrialists and others. Vasarely is motivated by the belief that an artist in today's technological world is obliged to enrich man's life—to strive for what he calls a 'new humanism'.

A new humanism: 'give something to be seen'. The social being is no longer content to assure men material goods, it adds intellectual and sensitive goods: sciences and arts [6].

Another example is provided by the organization Experiments in Art and Technology (EAT) in New York. The activities of this group began in January 1966, when a small band of artists and engineers met to prepare a series of performances to be given in an armoury hall the following September under the title *9 Evenings: Theatre and Engineering*. In one project, John Cage brought into play sounds from all over New York, even from outer space, sounds

which are in the air at the moment of performance, picked up via the communication bands, telephone lines, microphones, together with, instead of musical instruments, a variety of household appliances and frequency generators.

In another project, Lucinda Childs worked with the help of a Doppler sonar in order to make audible the energies involved when someone is dancing. She wrote:

I do not feel that dance should be limited to the display of physical exertion alone; anything that can exist in a non-static state for a certain duration of time is of interest to me [7].

In another of the EAT projects, Robert Rauschenberg presented the stage as a tennis court. Two men, whose rackets were equipped with radio transmitters, played tennis. When a racket struck the tennis ball, the audience heard a loud sound, and one of forty-eight displayed lights went out. When all the lights on the stage had gone out, the game on the court was over. At that moment some hundred people entered the hall, which by now was completely dark. The people could not be seen; only their images were visible because the entire hall in which the performance took place was filled with infra-red beams; sensitive television cameras then picked up the activities of the people on the stage and projected their movements on large screens in the hall. Rauschenberg's intention in this project was to penetrate the darkness by means of technology in order to make visible the invisible.

During the *Art by Telephone* show at the Museum of Contemporary Art in Chicago in 1969, artists were asked to dictate the essence of their projects by telephone, and employees of the museum had to execute them according to the instructions given by the artists. The task of the viewers was to implement these given works by means of their experiences. Jan van der Marck, director of the museum, explained the process thus:

The viewer is subjected to an experience, rather than presented with an object . . .

He went on to say:

The interest these works generate does not reside in their form, construction or composition, but rather in their reason for being, their relationship to surroundings and in the audience response they elicit [8].

Emphasis on sense perception

In so far as we can generalize about these art and technology projects, we can say that the artists involved attempt to do more than to close the gap between art and technology. Their real effort is concerned with an interaction with the public; the art and technology projects make sense for them only in terms of the stimuli penetrating the senses of those who become involved in them. The demonstrations attack the senses and thus break down the subject-object contrast on which are based traditional aesthetics and art criticism. A philosophical understanding of this breakdown and of the new emphasis upon senses and perceptions of the senses in these projects could, it seems to me, be provided by Dilthey, Heidegger, Gadamer and others within the movement of phenomenology.

Wilhelm Dilthey was one of the earliest to regard art experience as a subject of phenomenological research [9]. He reacted against the so-called 'historical school' of nineteenth-century Germany. An historical event, or any other event in the human world, he thought, should not be analysed in a positivistic way oriented toward the methodological ideal of the natural science; rather, it should be described in its uniqueness and as an expression of the same world in and through which we move. This approach became the basis for his understanding of the *Geisteswissenschaften.*

In his book, *Einleitung in die Geisteswissenschaften* [Introduction to the Human Sciences], Dilthey argues that we cannot have a firm, absolute, and fixed principle above and outside history according to which we can judge something *a priori.* To accept such a principle, we would perforce begin with a given axiom and arrive at constructions which Dilthey would oppose.

> This is the deepest understanding at which our phenomenology of metaphysics arrived, in contrast to the constructions of the eras of mankind. Each metaphysical system is only representative of that situation in which a soul perceives the mystery of the world [10].

We always find ourselves within the whole of the world; when encountering something, whether it be a work of art or any other man-made object, we need to understand it within the context of our individual historical heritage and our own existence. But just as we are part of the whole of the world, so is a work of art. We should not start with an already given abstract principle. Our understanding of a work of art should become a disclosure of the world itself. Only later, when searching for scientifically valid knowledge, should the object of our actual sense perception turn into a matter of reflexive thought.

Yet even while accepting the prereflexive realm of experience as the foundation of the *Geisteswissenschaften,* Dilthey remained, more than he was aware, dependent upon the ideas of his predecessors. On the one hand, he overcame the scientism of the 'historical school': he recognized a work of art as an expression of life, as an objectification involving man's inner nature in time and history. But on the other hand, he was still tied to the philosophical tradition of modern philosophy since Descartes: he regarded a work of art as an object existing over and above an object, and still aimed at some kind of objectively valid knowledge.

> Their relation to life is not like that of thinking to other intellectual conditions, *but that of living to the consciousness of that which man witnesses,* experiences, perceives in its totality, and in the relation of his own life and world. *Because the world as an independent unit is a mere abstraction.* The object is only in relation to the subject, as its correlate. This may be taken for granted [11].

Phenomenology, not methodology

A similar discrepancy faces us when we look more closely at Edmund Husserl's phenomenology. The basic assumption made by Husserl in his *Logical Investigations,* and then in his *Ideas,* was that our attitude towards science must be grounded in a transcendental, constitutive phenomenology. Husserl did not question the validity of science, its methods, and its techniques. What he criticized about the methodological ideal of science was its most artificial character. Science, he held, has a preconceptual background: it is founded in our sense perception, and the fundamental procedure used to analyse this sense perception in all its facets is the 'phenomenological method'. This method opens up everything registered in the human consciousness, be it a dream, memory, or reflection. As Husserl said in his *Ideas* when discussing 'Intentionality as the Main Phenomenological Theme':

> It is intentionality which characterizes *consciousness* in the pregnant sense of the term, and justified us in describing the whole stream of experience as at once a stream of consciousness and unity of *one* consciousness [12].

Husserl holds that there is not a being or an absolute truth behind and beyond the appearances of phenomena. In relation to a work of art, this means that we perceive its physical presence, something that is admittedly transcendent of our consciousness; but this work of art has no meaning unless we are there to perceive it with our senses and attribute a meaning to it in the constitutional act of our ego. We arrive at such a meaning-giving activity through the transcendental consciousness by carrying out in ourselves a radical procedure of suspension. All phenomena of our natural world, strange, alien and obscure as they are, must be eliminated. Only after doing so can we really start from the very beginning and regard these phenomena as transcendental correlates, as something real and familiar. This kind of transcendental phenomenology makes it no longer possible to view a work of art in opposition to life. There is not, on one side, the work of art, and on the other, the reality of life. Both art and life are parts of ourselves, of our sense perception, and of our consciousness as defined by intention.

The encompassing character of the phenomenological method can preserve the primordial forms of sense perception. But the method depends on the human consciousness: it sets everything, even the facticity of being, in a context of transcendental subjectivity, and it does this in a basically scientific manner. These were the problems Martin Heidegger faced in writing *Being and Time.* The fundamental ontology he developed in this book implied, first, a radical critique of Husserl's subjectivism and of the subjectivism of modern philosophy since

Descartes. Second, Heidegger demonstrated that the scientific approach is not the proper philosophical means for discovering the significance of man's being-in-the-world. This point of departure seems to be so important for the understanding of art and technology projects during recent years, and of the subsequent emphasis on senses and perceptions of the senses that we should discuss it in a more detailed way.

Let us begin with a comparison of Husserl's and Heidegger's attitudes towards time. Husserl followed the trend of subjectivizing in modern philosophy. Consequently, his lectures on 'The Phenomenology of Internal Time-Consciousness' did not deal with the objective time, i.e. the time of phenomena in a transcendent world, but rather with apparent time and its apparent duration as experiences of time-consciousness. It was in this context that he spoke of

> the phenomena of temporally constitutive consciousness, that consciousness in which temporal objects with their temporal determinations are constituted [13].

This means that what we regard as time-objects are a matter of constitution in the phenomenological sense: we must intend them, and we have to do this through our consciousness whether the objects exist within a short phase of time (perhaps merely within the present, now) or within a time-duration.

> It is indeed evident that the perception of a temporal object itself has temporality, that perception of duration itself presupposes duration of perception, and that perception of any temporal configuration whatsoever itself has its temporal form. And, disregarding all transcendencies, the phenomenological temporality which belongs to the indispensable essence of perception according to all its phenomenological constituents still remains [14].

We can neglect certain details here of Husserl's conception of time-consciousness and ask instead how and on what terms it was attacked. Heidegger, himself a pupil of Husserl, formulated his own philosophy by means of transcendental phenomenology; he was sceptical, at the same time, of his teacher and of all those who accepted the universal claim of the transcendental approach. His criticism was that Husserl's and his predecessors' method of phenomenology was nothing but another version of the subjectivism implicit in modern philosophy. Consequently, Heidegger assumed that the only way of bypassing this subjectivism was through the development of a fundamental ontology. This would avoid the concept of transcendental subjectivity as Husserl had proposed, and would recognize the human existence as a part of the world.

Interpretation: part of our being

The interesting aspect, as far as the experience of our art and technology projects is concerned, is Heidegger's interpretation or hermeneutic of existence. In the published portions of *Being and Time,* Heidegger tried to put an end to the exclusively subjective character of interpretation which depends upon our individual terms, concepts, and points of view forced by us upon the surrounding phenomena. Instead, it is the business of an interpreter to open up the realm of phenomena and let these manifest themselves as what they are. 'In interpreting, we do not, so to speak, throw a "signification" over some naked thing which is present-at-hand,' he argued, 'we do not stick a value on it.' Rather, interpretation is part of man's being in the world. Thus,

> when something within-the-world is encountered as such, the thing in question already has an involvement which is disclosed in our understanding of the world, and this involvement is one which gets laid out by the interpretation [15].

Of course, we intend this thing. We give a meaning to it and, consequently, our meaning-giving activity depends (at least to some degree) on our will. But our will is prestructured: it is based upon what we have in advance, our presuppositions, and our basic prejudices which guide us whenever we do something. These presuppositions and basic prejudices, as part of our being in the world, were the topic of the fundamental ontology Heidegger developed. The explication of this ontology was his way of avoiding the threat of subjectivism in interpretation. As he explained it,

> whenever something is interpreted as something, the interpretation will be founded essentially upon fore-having, fore-sight, and fore-conception. An interpretation is never a presuppositionless apprehending of something presented to us [16].

If we take interpretation in this sense of being dependent upon a 'fore-having', 'fore-sight', and 'fore-conception' as Heidegger emphasizes, then it must be conceded that phenomenological research does not have its basis in transcendental consciousness, that is, in the subject throwing his own visions over the phenomena encountered. This research is then grounded in 'phenomenal' experience; and this 'phenomenal' experience is grounded in the way phenomena reveal themselves to us. If so, the primary act of interpretation is to let phenomena become manifest as just what they are, and what we call our involvement is thus guided by these phenomena and the extent to which they disclose themselves.

From this point of view, interpretation is not a problem that can be solved merely through the human subject. We are like participants, and what counts most and provides something like a measure for interpretation is the world of the phenomena as such. It is our task to bring them out of secrecy into light, 'to let that which shows itself be seen from itself in the very way in which it shows itself from itself. This is the formal meaning of that branch of research which calls itself "phenomenology".' [17] This part of Heidegger's thought is interesting with regard to the experience of the art and technology projects mentioned above. We cannot merely comprehend them as objects; we cannot merely understand them, that is to say, if we are guided by the traditional subject-object relationship. Rather, prior to such efforts, lies the world which is already there and which demands of us a high degree of responsiveness.

It was Gadamer who in his book, *Wahrheit und Methode* (1960), developed the consequences of Heidegger's conception of interpretation as analysed in *Being and Time*. Gadamer was not concerned with the previous orientation of interpretation toward method and methodology; instead, he was concerned with 'understanding' in general and specifically with the understanding of art as related to man's totality of being in the world.

As Gadamer argued, perceiving a work of art is not so much a matter of pleasure. When seen in this aspect, art functions within the context of the subject-object model, and art then becomes an aesthetic object completely at the disposal of a subject. The subjectivism implicit in this approach depends on a kind of abstraction which cannot be maintained. 'What we call a work of art, and what we experience aesthetically, thus rests on a performance of abstraction. In looking away from all those things within which a work in its original context of life is rooted, from every religious or profane function in which it stood and in which it possessed its meaning, it becomes visible as the "pure work of art".' [18] Gadamer argues here that art is not something that is 'pure' or something that is isolated from the world in which we live; he contends that it has its place and function in our world, and that we have to view it as a world in itself, a world in which we participate and which reveals itself in concrete encounters.

How true is a work of art?

When seen in this light, we do not ask such questions as, 'How is something made?' or 'What kind of material did the artist use?', or 'How did he form this material?' These questions concerning the creation of a work of art and its form and content are of secondary importance and merely touch it externally.

> One does not admire the art with which something is made as one does regarding a virtuoso. This is only of secondary interest. What one really experiences in a work of art, and toward what one is directed, is rather how true it is, that is, how much one finds and recognizes something and oneself in it [19].

It is evident that Gadamer wants us to ask primarily how true a work of art is, how it challenges our responsiveness to being, and how (through our individual involvement) it furthers our self-understanding in the world. While all the questions mentioned above require a certain distance between ourselves and a work of art, it is a distance with which Gadamer is no longer concerned.

It is interesting to see how Gadamer drew, in *Wahrheit und Methode,* and in the light of this conception, an analogy between the being of a work of art and a game. A game, according to him, is not based on the human subject and the pleasing activity which this subject enjoys outside the world in which it exists; rather, a game has its own autonomy independent of those playing. It

> has its own being, independent of the consciousness of those who play. Game is also there, really there, where no being-in-itself of the subjectivity limits the thematic horizon and where there are no subjects who behave playingly [20].

Gadamer puts the game in an ontological context. It is something that happens in and through us and gives us the feeling of entering a self-contained, autonomous world that is open to our sense perception.

It seems as if this phenomenological understanding of art experience provides some common ground on which the art and technology projects mentioned earlier can be understood. These projects strike us because of their physical presence; they stimulate our sense perceptions and elicit our direct participation. It is obvious that when faced with them, we are not supposed to look for values as some of us are accustomed to doing because of our long-lasting exposure to the Western tradition of idealism. Instead, we should have a puritanical distrust toward those values and should experience those projects primarily on a preconceptual level [21]. That level can perhaps best be understood within the context of phenomenology.

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Letters to *Impact*

Preserving our cultural heritage

Man's history and his works of art react mutually to throw light one upon the other. With the technical capabilities we possess today, we owe it to future generations to register faithfully the arts and crafts of the contemporary human scene.

I should like to put forward a few ideas on the solutions which may be found, thanks to modern technology, to the various problems involved in preserving our artistic heritage.

The documentary art film seems to be acting as a tremendous catalyst for several new movements in contemporary culture; three of these growing centres of interest are worth mentioning: (a) works of art seen in their historical perspective; (b) empirical exploration of the sources and effects of modern art; and (c) integration of all artistic techniques in present-day artistic performances.

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The various aspects of the art documentary share the distinctive feature of tending towards an all-round presentation of works of art; they point the way towards the integration of such works with mankind, society, history and other techniques and means of artistic expression. Socio-cultural analysis appears to confirm the presence of these characteristic features, since the three new trends (mentioned above) in modern artistic culture are visibly contributing to the various types of art documentary.

Historical integration

We know that the scientific and technical revolution is having positive effects nowadays in the sphere of artistic culture, because cultural documents can now be very widely distributed and brought before hundreds of millions of people, thanks chiefly to television. It can also have adverse effects, for the old sources of local or regional cultural tradition are running dry; the rural populations which converge on the urban and industrial ant-heaps often go through a dangerous phase of alienation before they are ripe for involvement in a more universal cultural tradition.

Interest in the great human tradition is constantly increasing, however, among these anonymous crowds. It often takes the form of a growing taste for the works of art of past pages but, nearly always, history and art seem mutually to reinforce each other. Works of art appear to shed the clearest light on history, especially as these works have always represented the most beautiful combination of aesthetic and moral values. Conversely, history seems to be the best means of bringing works of art to life; they gain by being set off against other documents of the time, and individual biographical descriptions enhance their value still more.

The role of television seems particularly important in this connexion. By means of a carefully thought-out policy and meticulously chosen programmes on art, it is able to set an example and prove that contemporary civilization is capable, by an almost mechanical process, of fitting together again the traditional values which it tears apart.

An experimental exploration

Public interest in the historical integration of works of art is fostering the development, on television and in the cinema, of several types of documentary, three of which are very widespread, although, unfortunately, they can seldom claim to be masterpieces. These are the biographical documentary, the documentary on the artistic culture of a period, and history as seen through art.

Let us now consider, in turn, two different aspects of the growing interest in an empirical exploration of the sources and effects of art.

Exploration of the sources of art

Sociologists have recorded a strange phenomenon: a growing interest on the part of twentieth-century man not only in works of art but also (sometimes especially) in the mystery of creation and in all the 'roots'—psychological, sociological and cultural—of modern art. The psychological roots seem to be of particular interest. Man in the age of mechanization and standardization, in which the consumer ideal reigns supreme, longs to see in the artist a great hero of his time, someone whose works do not divide human society but unite it.

At the same time, the very prevalent scientific turn of mind is encouraging another trend. There is a desire to explore more and more empirically the sources and mechanisms of artistic creation, to explore and come face to face with the personality of the artist, and to become familiar—through discussion or observation—with his philosophy of life and of art. All this may be combined in a detailed reportage, the true portrait or modern self-portrait of an artist. Good reportage, thanks to the cine-camera and microphone, makes it possible nowadays to conduct a sort of empirical-artistic exploration of the acts of creation, working techniques, and other similar phenomena.

Exploration of the social effects of art

For sociologists, educationists and artists, sounding out public reaction (as revealed in gestures, behaviour, conversation and spontaneous discussion) is becoming a more and more interesting activity. This interest is growing among an increasingly large number of spectators.

Museums, books and photographic reproductions can show works of art only outside the context which produced them and in which they have their being. We see the flowers without the earth from which they sprang and in which they were originally sown as new seed. The screen reverses this age-old state of affairs. It shows us art as a total phenomenon.

Integration of all art techniques

In the twentieth century we are observing a phenomenon of rapid integration of various artistic techniques, especially in the present-day dramatic performances. Various forms of art, still practised in the nineteenth century (naturalistic theatre, painting and music) are finding in such a performance—even when not screened—a new line of development and opportunities for collective co-operation. The performance is beginning to take the lead in our artistic culture.

The integration of traditional techniques of expression in the performance is further strengthened by the use of the cine-camera (used especially for television) which generally accomplishes a two-fold task: a technical one, by imprinting the performance on tape for reproduction, and an aesthetic one, by giving the performance a new form, based essentially on editing and camera work.

The aesthetic operations create a kind of superstructure for the filmed performance. Nevertheless, although the recording of a performance may strive to be as 'objective' as possible, and even ascetic, if it is intended primarily to fulfil the needs of the history of the theatre, music, ballet and folklore, then its cultural value is priceless. Only through the different facets of such a documentary record will future generations be able to recognize the living portraits and the creations of today's great masters of the performing arts.

A few brief conclusions

In our time, two cultural problems appear to be of overriding importance: the spiritual drawing together of the nations, and the education of man. In both these tasks, the role of art has always been very important, but it has taken on remarkable proportions since television has shown itself capable of disseminating art on an international—and soon on a planetary—scale.

Television programmes in this field cannot therefore be subjected to commercial restrictions or be held in reserve to fill gaps in other broadcasts which are considered more serious. Art documentaries, while retaining their entertainment value, must be accorded the same prestige as top-level educational programmes.

The fact that art documentaries are becoming an increasingly common feature of television programmes must by no means entail the decline of the cinema's role in this field. This role remains pre-eminent, and will perhaps gain still more importance, provided that modifications in distribution are made. In several countries (including Poland) the role of the art film, distributed as a short accompaniment to feature films in the major cinema chains, has been seriously challenged.

Screening documentaries on television, although more frequent, also has a few drawbacks. Forms and colours are always shown to better effect on the cinema screen, and only in specialized cinemas can very useful discussions among the audience be organized in this connexion, stimulating an active and critical social response. These disadvantages will certainly not be removed by the technology of the private videotape recorders (for television cassettes) which are now being produced.

Under these circumstances, it would seem necessary to adopt the solution of delimiting the functions of the cinema and television screens in a reasonable fashion. Although television may continue to be the main wing of this new imaginary museum which we are sketching here, the annexes have still to be built or enlarged. Hence the new horizons opening for film theatres in schools and in art education establishments, as well as a fine opportunity for cinemas attached to museums, in which the future of the documentary seems particularly promising.

Those responsible for programmes and the making of documentary films for television must be highly competent. The customary stipulations for recruitment of television staff seem inadequate in this instance. Over and above a passionate personal interest in art, the authors of documentary portraits and frescos must have a knowledge of the special technique of television and a general knowledge of art, and should be very familiar with contemporary culture.

It is difficult to plan an up-to-date programme for the development of the art documentary on television without solving another problem of special importance, which has seldom been discussed hitherto. All kinds of art films must be given a scientific basis, if only a very unassuming one, through the creation of specialized sections in general training establishments or organizations. Such a basis will permit the development of the history, theory and precise documentation of this type of broadcasting; no systematic attempt to do this has been made hitherto.

Another problem is that of setting up documentary archives, governed by all the rules of public archives, in all television organizations. For the most part, television archives are in a sorry state. In some countries, extremely valuable broadcasts (such as silhouettes of great artists, or authentic folklore phenomena which are dying out) are either not recorded, or else the existing tapes are spoiled by being used as material for further editing.

International exchange and distribution of art films has remained almost at the same level as a few years ago, when, at an international symposium on Eastern European art films, held in Cracow in 1963, several general recommendations were voted. True enough, since that time, the television networks of several countries have organized exchanges, mainly on a commercial basis. But political and cultural requirements seem to be bringing pressure to bear in favour of research into new methods which might make a more effective contribution to improved understanding between peoples. It is, perhaps, time to carry out investigations, under the aegis of Unesco, with a view to finding new regional, continental and international solutions.

Judging by those rare masterpieces which exist today, the art documentary has a great future in store. Even by taking brief stock of everything to be seen on television at present, it is easy to imagine the organization of several public television/cinema film libraries which would bring together flawlessly made documentaries from different countries on the art of the past and the art of the present. One might then propose collections of 'golden series' of great reportages and documentaries, from which the most eminent artists of our time would not be excluded. A new pantheon of the heroes of mankind might thus be born on television.

Zbigniew CZECZOT-GAWRAK

Bodily function and behaviour

I found the contents of your issue 'Bodily Function and Behaviour—2' *(Impact of Science on Society,* Vol. XXIII, No. 3) remarkable as well as interesting. Such a wide-ranging approach is especially needed in this age—too often!—of over-specialization.

Man can remain man while transcending himself, realizing new possibilities of and for his human nature. Once there are enough people who can say honestly that they believe in *transhumanism,* as I call it, our species will be on the threshold of a new direction. Only by following this will mankind be fulfilling its real destiny.

Julian S. HUXLEY

Sir Julian Huxley, FRS, biologist and writer, was first Director-General of Unesco (1946–48). He published, among his numerous works, an article titled 'Transhumanism' in the Journal of Humanistic Psychology *(spring 1968), and here briefly returns to that theme.*

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