THE BEAD GAME CONJECTURE

CHRISTOPHER ALEXANDER

'Das Glasperlenspiel,' the bead game, is Hermann Hesse's great imaginary game, in which all structures — musical, mathematical, historical, social, political, physical, chemical, biological, and visual — can be represented in a single way; so that players of the game can see all these fields at once, from a single point of view, and can make the contents of these many fields act on one another within the framework of the game.

The game does not exist. But, the possibility that such a game might be created is so tantalizing, and the game, if one exists, so badly needed, that it seems to require a deliberate conjecture: 'It is possible to invent a unifying concept of structure within which all the various concepts of structure now current in different fields of art and science, can be seen from a single point of view.'

This conjecture is not new. In one form or another people have been wondering about it, as long as they hove been wondering about structure itself; but in our world, confused and fragmented by specialisation, the conjecture takes on special significance. If our grasp of the world is to remain coherent, we need a bead game: and it is therefore vital for us to ask ourselves whether or not a bead game can be invented.

The first three volumes of "Vision and Value" edited by György Kepes, contain 41 papers which deal with a particular facet of the bead game conjecture: they deal with the connection between visual structure, and the structure of natural phenomena.

Kepes has dealt with this subject before. Five years ago, he published "The New Landscape," a beautiful visual demonstration of the pervasive analogy between structure in art and structure in science. The book contained 450 photographs. Half of them were photographs of natural phenomena, at every possible scale: photographs taken from miles above the earth, photographs of plants, and X-ray diffraction photographs of crystals. The other half were photographs of twentieth century works of art. The effect was overwhelming. As far as these 450 images are concerned, structure is the same in art and science.

However, just because "The New Landscape" is such a beautiful book its lesson has become commonplace today. We know that it is possible to make analogies between art and science. It is therefore not enough for a new collection of papers to present more and more of these analogies. The papers must ask questions: How deep do these analogies go? How far can we trust them? How far can we develop them? And what do they illuminate? Is the bead game conjecture correct; and within what limits is it correct?

Though the conjecture itself is very complex, the steps we must take to find out whether it is correct, are simple.

— We must give a clear description of the kinds of structures which we find in nature.
— We must give a clear description of the kinds of structures which are accessible to visual cognition, and,
— We must give an account of the various relations between these two kinds of structures.

To do this, we must answer certain questions. The following eleven questions, though not exhaustive, are typical of the kinds of question we must answer.

1. Describing the structures which are found in nature, is the task of science, and is too vast to be easily incorporated in a bead game. Are there any general principles of structure in nature?
2. What is the range of structures which are accessible to visual cognition?
3. What kinds of structure do artists consciously believe themselves to use, in their attempts to form visual languages?
4. To what extent is it possible to recast scientific statements of natural structure in more readily visualisable terms?
5. To what extent have visual analogies or metaphors helped scientists in their discoveries?
6. To what extent have natural structures shed light on, or inspired, the invention of visual structures?
7. Are there any concepts of structure which can encompass both specific natural phenomena, and specific artistic or visual phenomena?
8. Which natural structures are 'not' accessible to visualisation?

10. Are there any borderline structures which cannot be regarded as purely natural, or purely visual?
11. To what extent can feeling and thought about structure be integrated?

Though these eleven questions are far from exhaustive, they do form a kind of backbone for the conjecture. Until we know something more about the answers to these questions, we can say nothing further about the validity of analogies between art and science.
Unfortunately, by no means all the papers in these volumes try to answer these questions. Many of the papers are by world famous authors who have been content merely to summarise their achievements. If I tried to describe all these papers, it would be impossible to make them seem coherent. Instead, at the risk of bias, I shall describe only those twenty odd papers which do form a coherent whole, and which give the volumes their coherence and direction. Each of these papers deals with one or another of the questions I have named, so I shall take the questions one by one.

1. Are there any very general principles of structure in nature?

Two papers deal with this question.
Smith, in a paper on crystallography, called "Structure, Substructure, Superstructure", draws attention to a particular kind of unifying concept which science lacks. The concepts of structure which exist in science today are all at some specific level of scale. There are no comprehensive concepts which tie together structures at widely different levels of scale. It is possible that art, traditionally concerned with the complex, may be able to help in the formation of multi-level concepts of structure which are complex enough to span many scales.
L.L. Whyte begins by outlining some of the major properties a general conception of natural structure would need: — (among others it would have to cover the phenomena of order and disorder, stability, symmetry, hierarchy, vibration). What is most interesting though, is his belief that an adequate unifying concept of structure could come from our contemplation and analysis of visual form. As he says "No comprehensive and radical analysis has been made of all spatial forms".
This comprehensive analysis of the varieties of visual form is of course, just what question two is about.

2. What is the range of structures, which are accessible to visual cognition?

Held does not try to answer the question; but he clarifies it by stating it very clearly: Since the retinal image undergoes considerable neural processing before it becomes a percept, and since in the course of this processing it undergoes transformations, the only structure in the real world which we can 'see' is that structure left invariant by these transformations. What are these transformations, and just what do they leave invariant? Clearly, this is a fundamental question. The particular aspect of the bead game conjecture being discussed in these volumes, the equivalence of structure in nature and in visual art, cannot be evaluated until we know the answer to this question; and indeed it will stand or fall, according to the answer. Whatever structure in the world is left invariant by these transformations, may be captured in visual terms; whatever structure these transformations destroys, cannot be faithfully expressed in visual terms.
Wallach is more specific. In a simple and beautiful paper on visually perceived motion, he shows in detail that relative motion between two perceived objects makes a more fundamental contribution to perceived motion, than the motion of a single object relative to the observer.
Finally, Hayter describes the assymetries of the visual field which give rise to an illusion of motion; this paper too, is beautifully specific.

3. What kinds of structure do artists consciously believe themselves to use, in their attempts to form visual languages?

The most explicit answer to this question is Richey's outstanding analysis of the kinds of visible motion which can play a part in a kinetic work of art. He hames all the kinds of motion which are possible, and discusses their effects and combinations.

Maki and Ohtaka describe two sorts of structure which can generate urban form — Magastructure, a broad skeleton of major elements which, once laid down, allows any kind of minor pattern to develop around it, and Group form, a set of elements which may be arranged in any with respect to one another.
H.C.L. Jaffe, in his paper, "Syntactic Structure in the Visual Arts", shows that Seurat, Gris, Kandinsky, and the de Stijl painters all tried deliberately to create sets of elements and rules from which to make pictures. Hans Richter dexcribes his own attempts to find a language of elements and rules adequate for the portrayal of movement. Margit Staber tries to describe what "structure" as a concept has meant to the various different painters who have used the concept.
4. To what extent is it possible to recast the concepts of science in a more readily visualisable form?
Arnheim's paper is called, "Visual Thinking". He begins with an example of a simple problem which can be solved either intellectually or visually. The visual solution is both more elegant and more direct. He goes on to show that many of our thoughts are visual in origin — laboriously translated into verba terms only when we set them down. Unfortunately most people have now come to regard the abstract and verbal form of thought as more immediate, and have thereby sacrificed all the natural sense of structure which the visual process can provide. The very fact that thoughts are so often visual in origin, makes it clear that scientific concepts could often be recast in more explicitly visual terms. Buckminster Fuller's paper is a living example. His argument is simple and clear: "The Cartesian system of three orthogonal coordinates x, y, z, which you learn in school, is an arbitrary and unnatural way to look at the world. Many things in the world are made of close-packed, equal-sized, roughly spherical elements. Since spheres pack naturally in tetrahedral complexes, the Cartesian system is a laborious and unnatural way to describe these packings and it is much more natural to think directly in terms of tetrahedral arrangements. This conviction led Fuller to the invention of geodesic domes.
Scientists and teachers far too rarely look for the most natural, and most easily visualisable solution of problems. Even the simple geometry of curves is still taught to schoolboys in terms of Cartesian coordinates. The intrinsic equation of a curve, which defines it in terms of its intrinsic (and visualisable) properties — curve length, curvature and tersion — is often not taught until the post-graduate level.

5. To what extent have visual analogies or metaphors helped scientists in their discoveries?
Gordon gives three examples, from his experiments on metaphoric thinking, showing how students manage to grasp difficult concepts when they think them through in terms of personal, visualisable, metaphors.
Ehrenzweig's paper is one of the best in these three volumes. He discusses the potential looseness and temporary ambiguity of visual images, dreams and metaphors. While artistic training often helps to develop a tolerance for ambiguity and an unconscious mastery of images that seem incoherent at the conscious level, (Ehrenzweig gives a number of interesting examples), scientific training too often kills it. Yet tolerance for ambiguity is as essential as precision, in the search for new hypotheses.
There is classic example of the part an incoherent image can play in an inventive process. For fifteen years before his invention of relativity theory, Einstein was fascinated by the question, "What would happen if I caught a beam of light and ran with it?" This image is senseless if taken literally. Yet it is only because he dared stare it in the face for fifteen years instead of ignoring it, that he could finally refine it and restate it in mathematical terms.

7. Are there any concepts of structure which can encompass both specific natural phenomena, and specific artistic phenomena? In other words, are there any truly valuable analogies between the two? This question is not discussed in general terms, but three papers deal with specific examples. Ackerman deals with evolution; Bronowski with topology; and Gerstner with statistical mechanics. Ackerman compares Darwinian evolution with the evolution of artistic style, and gives a very careful and accurate account of the simi-

larities and differences between the two.
Bronowski's paper says that both mathematics and art have recently focussed their attention on fundamentals. Topologists concern themselves with more global properties of spaces than the earlier geometers did; Henry Moore concerns himself with more global properties of the human figure than earlier sculptors did (However, these properties are 'not' topological as Bronowski says — the aspects of the human body which we find interesting, and which Moore captures, are not purely topological properties, but also depend on curvature and rate of change of curvature).
Finally Gerstner presents a series of patterns, each one a square arrangement of black, white, and grey squares. It turns out that only very few of the possible configurations have much perceptible structure (just as the low entropy configurations of statistical mechanics are both rarest and most highly structured); and these few that do have perceptible structure are related to one another by simple transformations.
11. To what extent can feeling and thought about structure be integrated?
Hesse's bead game allows people to deal with structure in thought and with feeling, simultaneously. It is a terrible poverty of our time that we have no vehicle which allows people to think about structure and to feel it simultaneously. We need a way of doing it. Kepes has said this over and over again — he says it in each of his three introductions — and it cannot be said too often. But there is very little said that can be taken as an explicit answer to the question.
None of the papers answer questions 6, 8, 9, or 10.
How far do these papers go towards validating the bead game conjecture?
First, let me again remind the reader that I have deliberately sharpened the conception of what these books are driving at. At the risk of bias and unfairness I have deliberately ignored the 20-odd papers which shed no light at all on the conjecture. This is the first time a serious attempt has been made to examine the bead game conjecture closely. It is a challenging and daring attempt: if we lost sight of its central theme, we should belittle it.
In terms of their effect upon the reader, the books are magnificent. They are beautifully produced. They are exciting and suggestive. Anybody who himself lives on the boundaries of art and science is certain to find things in these volumes which trigger trains of thought in his own mind. They are stimulating. They are inspiring. Yet above all these books are exciting because they confront the reader with the difficulty of the subject, and with their own inadequacy. When I leave aside enthusiasm, and ask myself how much substantial contribution has been made towards the validation or refutation of the conjecture, I must confess it to be slight.
There is still a split between art and science. The split is smaller than it used to be: the growing tendency on both sides, to talk in terms of 'structure', gives the papers a superficial uniformity which they would not have had ten years ago. The papers, whether they are written by scientists or artists, make equal sense from either point of view. (This is great progress: twenty years ago what artists wrote made little sense to scientists, and what scientists wrote came nowhere near the artists problems). Yet the split is still there, at a deeper level. Though there are the beginnings of a common language now, and though there is more overall similarity of concepts than there used to be, 'there is still no paper in this collection which gives new insight simultaneously, in both art and science'.
A scientist who was not interested in art would learn nothing from these papers; an artist who was uninterested in science would learn nothing from them. There are no papers with authority in both; even the best papers are still searching, and speak without authority. Until we educate a generation of artist-scientists there will be no people who have authority in both, there will be no work which gives insight in both directions simultaneously, and the bead game will remain, as it is now, a challenging but ungrasped hope.

Christopher Alexander

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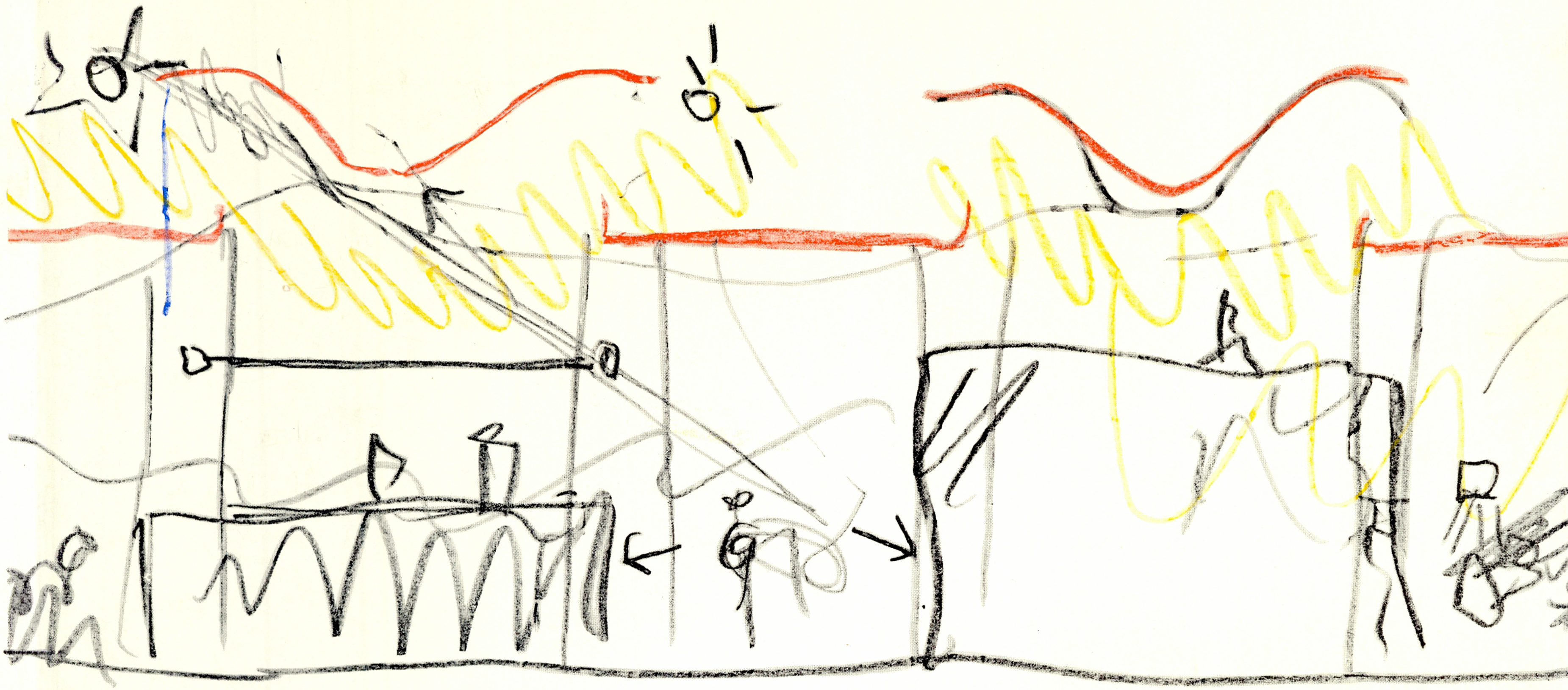

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