QUASICRYSTAL ARCHITECTURE

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The big news in patterns is that there exists a wholly different class of patterns --Quasicrystals. Two dimensional quasicrystals, often called Penrose Tessellation after Roger Penrose who discovered them in the mid 1970's, are made up on only two shapes or "tiles" -a fat and a skinny rhombus. Three dimensional quasicrystals --made up of a fat and a skinny rhombohedra--are only a few years old. What is new about them, what has escaped 30,000 years of previous pattern making, is that they are non-repeating patterns. Quasicrystal patterns have astounding visual and structural properties that make them ideally suited for applications to architecture.

Imagine a car's tire track in the snow. Perhaps it is a few rows of "w's all nested and interlocking. If the snow was fresh and there was gas in the car, one could make a 500 mile track of millions of little 'w's. Three hundred mile down the track one could find exactly the same sequence as in the beginning; 492 mile down the track the same sequence, because the entire track is made by the same wheel going around, again and again. This is the very essence of what we mean by patterns; one or just a very few elements repeated in a regular way. If there is a pattern then there must be repetition, and if there is no repeat there can only be randomness. No doubt E. Gombrich and R. Ornstein are right about patterns, and the eye and right brain work together in an especially efficient, non-verbal way to precisely confirm these regular intervals. True, one could imagine a completely random tiling: a crazy-quilt of irregular shapes with no regular intervals add up to no line-of-sight structures. But such a crazy-quilt is not a pattern; it is not captivating or satisfying and is only charming as a frustration of our natural inclination to see regular patterns.

A non repeating pattern, then, is an apparent paradox. The perfect stacking of just two quasicrystal elements over and over again looks and feels like a pattern. Recognizable parts of a quasicrystal do repeat, but not in a regular way. It is even possible when given the position of some elements to predict the location of others, but like an irrational number there is not the regular repeat of sequence that we are so conditioned to seeing. There are also many line-of -sight concurrences. There are even rotations which leave the pattern essentially unchanged, in that unit cells are still oriented in one or another of just a few directions. And yet, the patterns are not exactly the same after rotation, only essentially the same. Although quasicrystals frustrate our common pattern recognition systems, we intuit that there is some kind of structure and pattern really there. Even when first encountered, they quickly become endlessly fascinating. As a geometry of flux, rich ambiguity and subtle order they seem elegantly to express our modern experience of space.

The history of quasicrystals is the development of more and more powerful mathematical techniques to generate them, techniques that allow more and more of their subtle symmetry to emerge. Nicholas deBruijn's genius was to discover a global (long range) structure in quasicrystals at the time when every one else though of them as having a purely local, and quite random, structure. A global structure implies a computational algorithm to generate perfect quasicrystals, without trial and error, that can be mechanized to be a computer program. Once quasicrystals became computer generated, rapid progress is being made in using them.

Quite by accident D. Shectman and his collaborators discovered in a rapidly cooled sample of an aluminum-manganese alloy properties of both metallic crystal structure and glassy random structure. These samples had the fivefold (pentagonal) symmetry that had been disallowed for patterns until the discovery of quasicrystals, and P. Steinhardt suggested that they may be serendipitious quasicrystals. Initially there was debate on the part of scientists as to whether these small, early samples might have only the illusion of five-fold symmetry or whether they had only a few atoms in such an arrangement and could not be expanded into whole crystal lattices. Now that large, flawless samples have been made, and it is clear to all but a few researchers that they are truly quasicrystals. Research can now focus on their electrical and chemical properties, possibly with quite startling results.

There is still a major philosophical debate about what it means that these quasicrystals can be formed. If Steinhardt is correct that he has found a new set of matching rules -step by step local operations -that is foolproof, then it is possible to imagine some physical implementation of these rules. Quasicrystals would form when atoms connect to one another according to the local forces described by these rules. If Penrose is right then no such foolproof set of matching rules exists, and perfect large scale quasicrystals can only form by reference to a global and algorithmic system. But what do little atoms know about the big picture? For Penrose that is precisely the point, they do know about the big picture just as quantum theory suggests particles "know" about other places and other times. Thus quasicrystals are macroscopic quantum effects and as such are a model of everything. Penrose's theory, discussed in his book "The Emperor's New Mind", is a breathtaking leap into speculation. No one thinks so highly of quasicrystals: they are the model of the working of the human mind; they will be the basis of new quantum effect computers. While all this may yet turn out to be true, I think Steinhardt is right and a foolproof step by step system exists for making quasicrystals so that it is not necessary to see them as macro quantum effects.

With Steinhardt's help and using de Bruijn's powerful dual method, I have written computer programs which generate, rotate, slice 3d quasicrystals, and which demonstrate the visual behavior of these structures as seen from different angles. Sometimes they seem to have fivefold symmetry and are pentagons and star pentagons. Other times they appear to have three fold symmetry, and appear to be made up of triangles, hexagons, and 60 degree parallelograms. Still other rotations reveal them to have the two-fold symmetry of squares and diamonds. This icosahedral symmetry is a characteristic of all quasicrystals. It is thrilling to see this structure transmute before your eyes, in real time, becoming one thing and then another, dissolving cells at one place and re creating them elsewhere, becoming one moment a dense thicket and the next a transparent lacework-- and all the while knowing that the structure is not really changing, that only a rotation of a fixed, rigid, structure is being observed. IT is a though three different structures were hidden in the same structure.

I am convinced, based on these programs and the large scale models I have made, that quasicrystals will be a major contributions to architectural structures. Imagine the delight of seeing a structure that transforms as you walk around the outside of a dome, or underneath a quasicrystal ceiling, or even by just turning your head. Quasicrystals are exquisitely and magically responsive to both changes in light and the viewer's movement. Buildings could become effervescent, and seeming alive.

I am also convinced that quasicrystals have novel structural properties, and that these building would be interesting for their engineering, alone. Because they are non-repeating patterns, quasicrystals are structurally deferent from anything yet built. Forces are not translated directly as with other structures; rather loads are instantly diffused in all directions. Yet these resilient and flexible structures can be stiffened by tensile membranes, by new materials, or by open plates.

It is well known from before the time of the Eiffel tower, that truss structures can be made that are stiff by assembling triangles. It is not difficult or novel to introduce rigidity into these structures; what is hard to accomplish and necessary to do on many occasions is to introduce flexibility without loosing strength. Quasicrystals were originally thought of by Steinhardt as a model for an idealized fluid, and pressing on one part of a quasicrystal structure dislocates many other parts of the structure in directions that are greatly different from the original force. It is like pressing on a balloon filled with water- the force in not translated trough the balloon to come out of the structure on the opposite side basically unaltered, as would be the case in a truss. Rather the force is diffused in all direction and absorbed by the structure as a whole. The structure, like the balloon of water, is only as weak as the stress skin resists tearing.

When maximum flexibility is required, in earthquake prone area for example, even large scale quasicrystal structures can be built using new spring concrete that can flex. When build with rods and nodes, quasicrystal structures can be thought of an complicated three-dimensional springs that "spring" in many directions at once. Quasicrystal architecture can also be build with open plates which still maintain all the visual properties mentioned. Plates have many practical advantages: any three plates meeting at a corner form a rigid unit, the edges of the plates carry the load and the nodes are structurally unimportant, only two plates make every quasicrystal structure, units can be prefabricated on the ground and hoisted into place, and the partially completed roof has more structural integrity than with other structures.

If we adopt the Gombrich-Ornstein pattern thesis (that pattern matching is the work our right brains do, is the basis of our unconscious creativity, and is the source of our mystical connection to nature) then the discovery of quasicrystals is a tremendous challenge to and opportunity for consciousness. Non-repeating patterns are extraordinarily hard to visualize- they do not match a template already in the right brain storage racks. But if we can learn to work with them, to think in them, who knows? Maybe magical and magically constructed building are just the beginning.

The author wishes to tank Paul J. Steinhardt for his many kind consultations on the mathematics and computer programing of quasicrystals.

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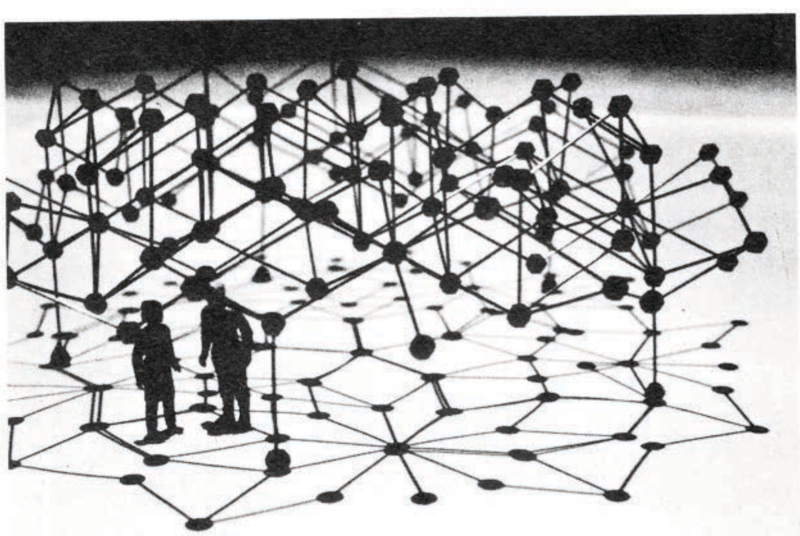

A Quasicrystal Spaceframe casting a shadow of a Penrose Tesselation, Model in BRASS, 30" diameter.