> ~~elements) which will, as abstract schemes, fall into the three categories of the formation principle, distribution principle and set principle. These can be manipulated and applied to an unordered set of elements, so as to produce what we perceive macro-aesthetically as complex and orderly arrangements, and micro-aesthetically as redundancies and information. (Bense 1971)~~

~~Following Shannon, both Moles and Bense equated high degrees of order with simplicity, and high degrees of disorder (i.e., randomness) with complexity. However, as much as information theory has its place in the analysis of communication channels, it does not correspond very well with our experiential sense of complexity in the world generally, or in art specifically. To the extent it equates complexity with disorder, information theory breaks down as a general model of our experience. This is where contemporary complexity science has fashioned a response in the form of *effective complexity*.~~

Effective complexity

Considered as a system, a crystal is made of atoms arranged in a highly regular lattice forming planes and facets. What emerges at human scale is a high degree of order that is easy to describe and easy to predict; in this sense, crystals seem simple. Because of their highly ordered nature any one crystal seems quite similar to others.

By comparison, molecules that make up the gas in our atmosphere could not be more different. As a system, gas molecules are in constant motion, each with a random direction and momentum, and they are all constantly bouncing off each other without any discernible structure at all. Nevertheless we experience gasses as simple systems at human scale. Gas is easy to describe and predict, and a cubic foot of air in one place seems no different than a cubic foot of air in another.

Things we think of as complex systems defy simple description and easy prediction. Many would agree that the most complex systems we encounter are other living things. Life requires a mix of order and disorder: order to maintain integrity and survival; and disorder to allow flexibility and adaptation.

It was this kind of intuition that led physicists Murray Gell-Mann and Seth Lloyd to suggest the notion of effective complexity (Gell-Mann 1995). As illustrated in Figure 5.1, Shannon's information complexity increases with disorder, but effective complexity peaks where there is a mix of order and disorder.

To underscore the contrast, where Shannon would consider white noise or a display of random pixels as being highly complex, Gell-Mann and Lloyd would likely point out that all white noise sounds alike and all displays of random pixels look alike, and as such we perceive them as having low complexity.

Effective complexity as a framework for generative art

Effective complexity introduces a paradigm where high degrees of order and disorder both create simple systems, and complex systems exhibit a mixture of both order and disorder (Figure 5.2). Given this understanding, we can classify forms of generative art as simple-ordered, simple-disordered, and complex systems. Going beyond classification, however, is the discovery that the history of generative art roughly follows the history of our culture's understanding and embrace of these different system types.

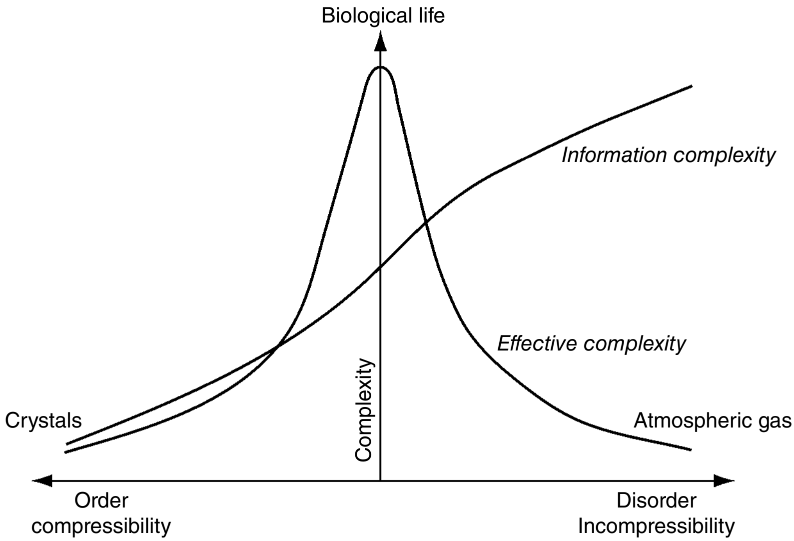

FIGURE 5.1 Order/disorder relationships for information complexity and effective complexity.

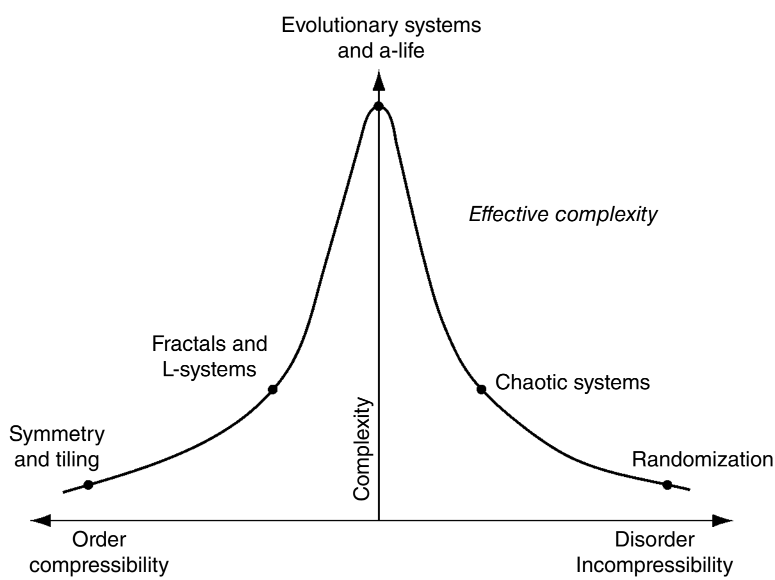

FIGURE 5.2 Systems used in generative art identified by effective complexity.

~~*Highly Ordered Generative Art*~~

~~Every time and place for which we find artifacts yields examples of symmetry, tiling, and pattern in art. These artifacts provide evidence that simple, highly ordered systems were the first systems applied to art (Hargittai and Hargittai 1994). As noted earlier, samples of generative art over 70,000 years old have been found (see Figure 5.3), establishing that generative art is as old as art itself (Balter 2002).~~