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Form Evolution: From Nature to Polyhedra to Sculpture

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Abstract. This paper written by a sculptor describes a polyhedral generating process from primitive line units that inspires forms of art: A collection of slides and sketches of natural patterns had its beginning more than thirty years ago as a visual aid for teaching drawing and sculpture. As the collection grew, cataloguing became necessary. Spatial patterns were detected that repeated themselves even though a wide range of materials were represented – a drying mud puddle cracked like a turtle's back – like pine tree bark – like cloud systems. These patterns have become a source of information for generating families of polyhedra and for producing many pieces of sculpture.

Key Words: natural patterns, generating polyhedra, sculpture

1. Introduction

During years of comparative analysis of natural patterns (Thompson [4], Stevens [3]), there was a gradual realization that the information about the assembly of patterns was not to be found by focusing upon the solid material but by focusing upon the spaces between the material parts. This research strongly suggested that the patterns are not in the materials but that the materials are in the patterns. The gaps between the parts of a material pattern system is where all assembly and separation takes place. With this conclusion, new assemblage patterns were recognized whose minimal components are interactive lines and their junctions called *"foundation sutures"*. These foundation sutures produce the prime structural components for generating polyhedral lattices.

In this study, the points, lines, planes and solid volumes of classical geometry do not provide the fundamental structural components for the generation of polyhedra; the line patterns that emerge between the parts of material bodies do. The foundation suture spatial lines perform everything the classical components do plus a lot more. Unlike the rigidity of the classical components, the suture lines twist and untwist and form loops that turn inside out as they interact with each other. The conventional faces, vertices and edges in the anatomy of

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classical polyhedra do not exist in the foundation suture polyhedral generating process. It is the lines alone interacting with each other that institute the process of polyhedral assembly. The polygons (former faces) in the bodies of the polyhedra are the last to form. To see the foundation sutures as the alpha components of polyhedra requires a shift of the focus from surfaces to the spaces between. *"The closed-wall, plane-faced-straight line approach to spatial problems has dominated thought about 3-dimensional structures for too long, even in the minds of such masters as Bucky Fuller"* (Smith [2]).

The following text describes the foundation suture polyhedral generating process. Remember that all the lines in the diagrams represent suture spaces.

2. Generating polyhedral lattices

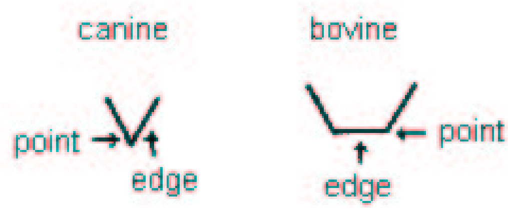

Figure 1: Canine and bovine foundation sutures with point and edge junction sites

In the foundation suture system, all polyhedral lattices are generated from two kinds of incremental line units called *"canine"* and *"bovine"* foundation sutures. As shown in Fig. 1, canine and bovine sutures each have a point and an edge junction site. Later, when the units are replicated and joined together, they will join at these sites.

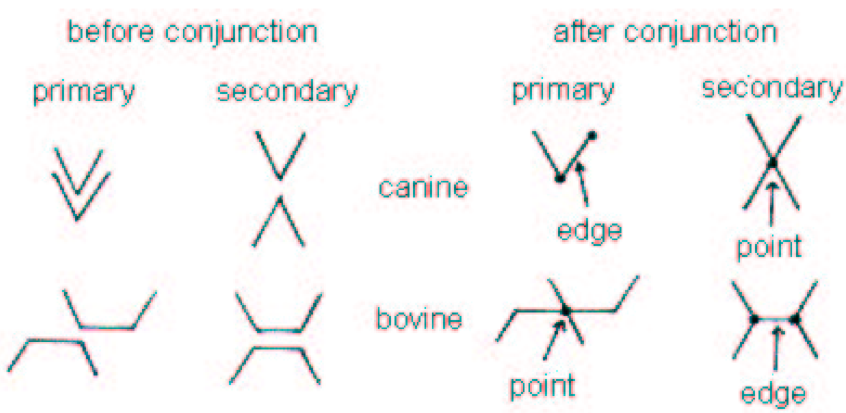

Figure 2: Paired suture units

Replicated (paired) canine and bovine units are shown in Fig. 2. By joining the paired sutures at the junction sites, four pairs of compound suture units are generated. The left position of the figure shows the suture pairs before they are joined and the right shows them after they are joined. Primary and secondary refers to the relationship between the suture pairs after they are joined — primary for alternate and secondary for opposite.

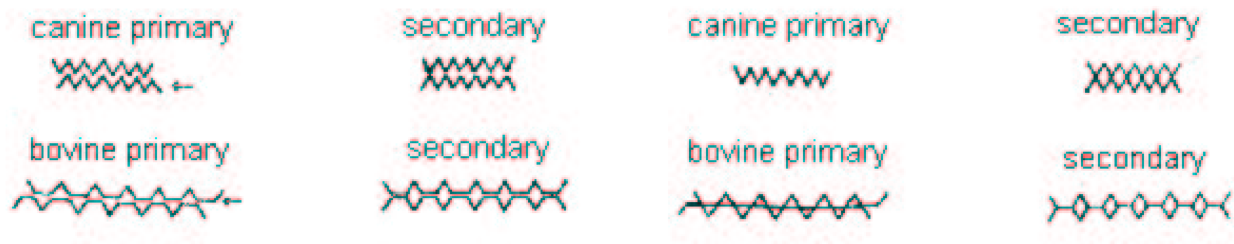

Figure 3: A glide-reflection symmetry transformation

In the next step, shown in Fig. 3, the paired suture units are replicated six times for this example and joined together to produce four pairs of six unit wavy lines. The above portion of the figure shows the point and edge sites of the replicated suture units before they are joined and the below after they are joined. This diagram holds the key to the dynamics of the generating process. It shows a glide-reflection symmetry operation between the pairs of wavy lines. As one line of each pair glides across the point and edge junction sites of the other, they move through the primary and secondary configuration modes.

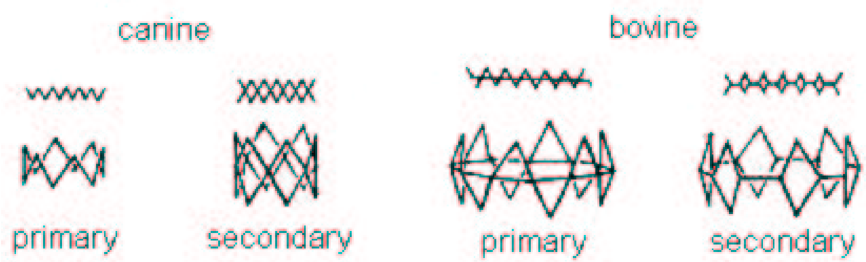

Figure 4: Foundation ring components

In Fig. 4, the joined (compound) wavy lines are wrapped into foundation rings. The foundation rings form the equatorial components in the anatomy of all spherical polyhedral lattices. The lattices in this system have only two structural components – equatorial foundation rings and polar caps. Capping of the rings is necessary to complete the polyhedral lattices.

In a capping operation, each 2, 3, 4, 5 and 6 unit equatorial ring can be closed (top and bottom) with five different caps. The caps are called radial, circumferential and compound. The five caps generate five different polyhedral lattices upon each equatorial ring for both the primary and secondary modes. Fig. 5 shows an example of the 3-unit primary and secondary canine rings with their five caps. The secondary ring is composed of two primary canine rings stacked point to point.

The polyhedral lattices generate in family groups. The families evolve from two through six unit equatorial ring and cap components. In Fig. 6, the family of the cube (primary 3-unit canine) and the family of the twist octahedron (primary 2-unit bovine) demonstrate this form evolution. The members of the cube's family have radial caps attached top and bottom to the rings and the twist octahedron's family has circumferential caps attached top and bottom. The equatorial ring and cap components are connected to each other in the two-dimensional

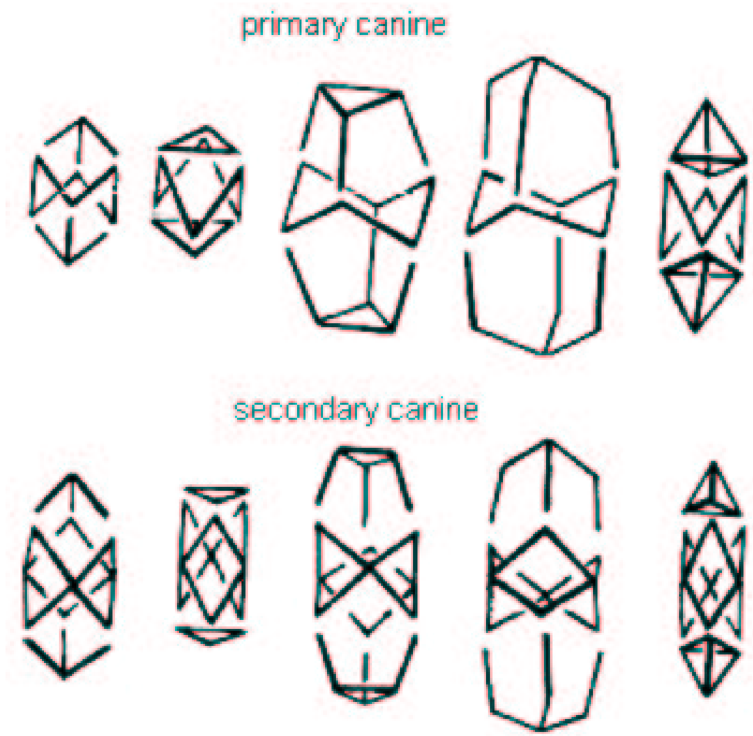

Figure 5: Capping operation

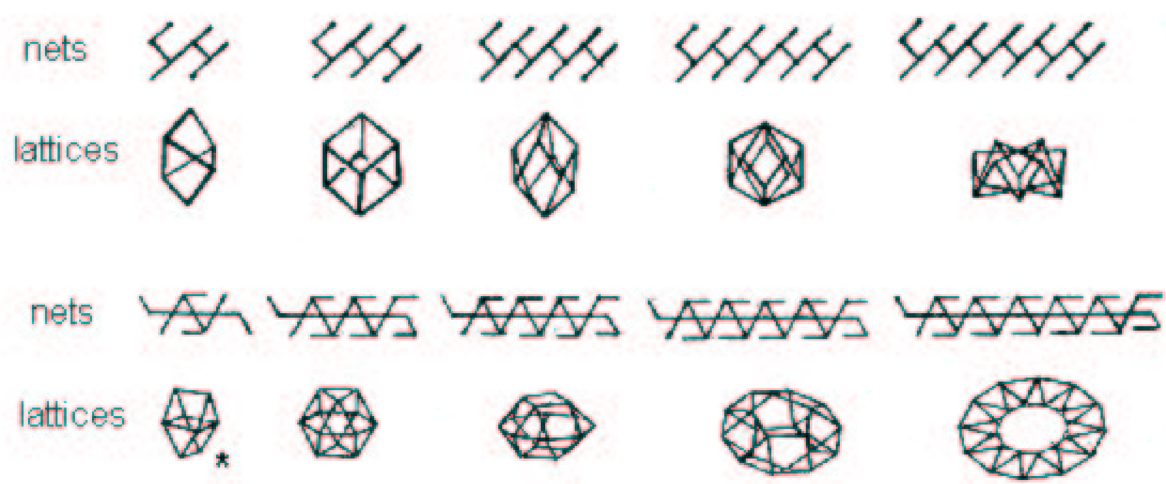

Figure 6: Two polyhedral families:
(top) family of the cube; (bottom) family of the twist octahedron

nets. Many more families of polyhedra generate from this system than can be shown here, including hybrids and the buckyball. The twist octahedron has emerged from the system as a new ninth self all-space filling polyhedron [5].

2.1. Twisted loops

The twisted loop insight was inspired by the foundation rings of the polyhedral lattices. Focusing upon the foundation ring of the regular cube, Fig. 7 shows how to visualize the

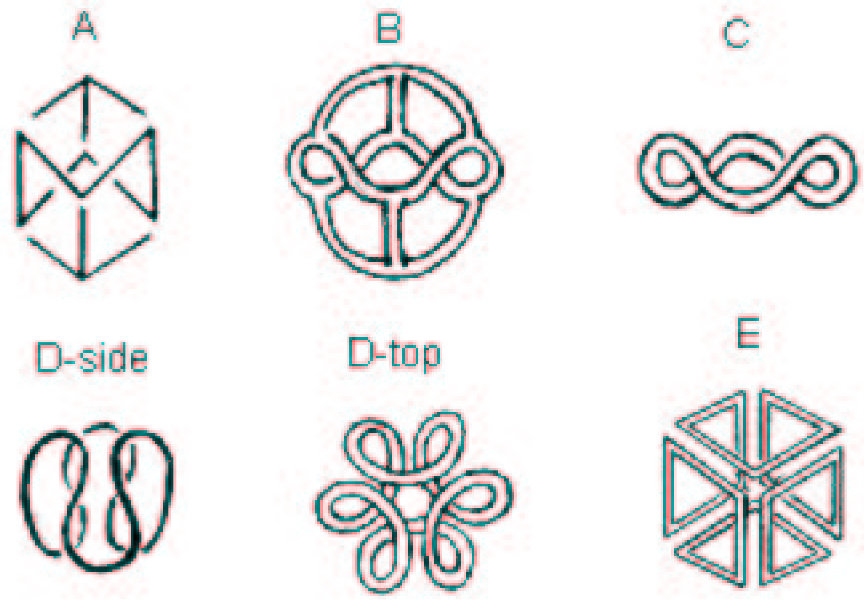

Figure 7: A twisted loop transformation

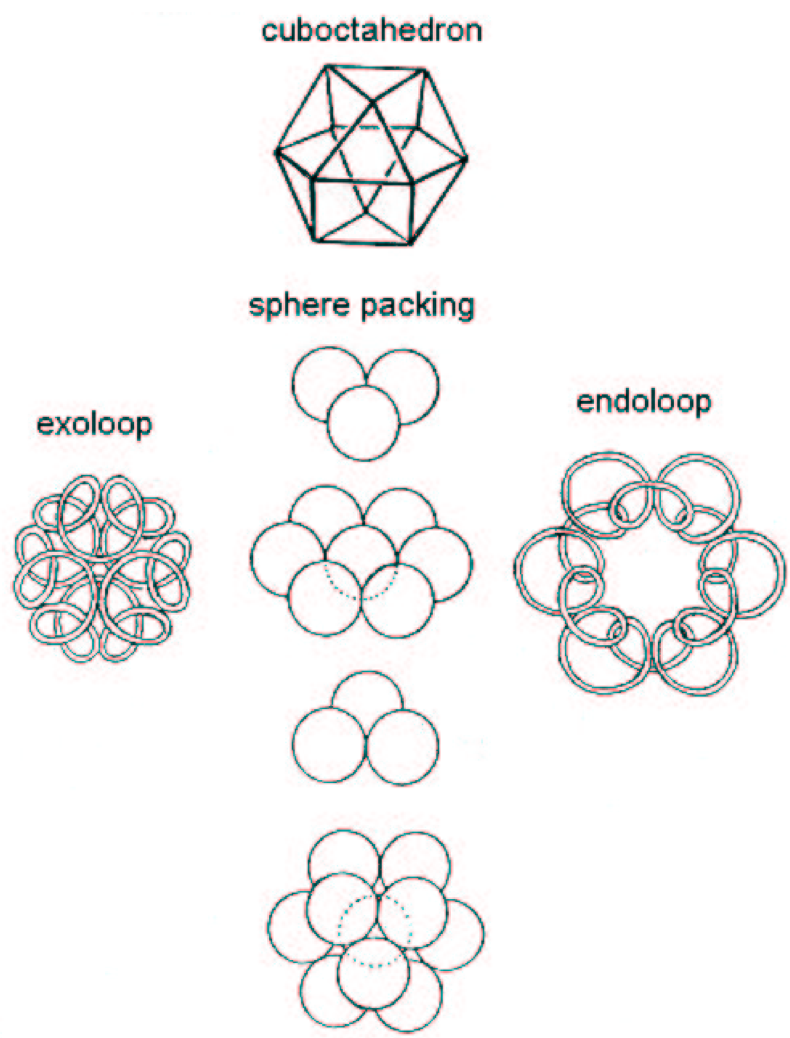

Figure 8: Cuboctahedral loops

transformation of the cube lattice into a twisted loop form of the cube. The angular foundation ring of the cube A changes into a curvilineal ring in the round cube B. The curvilineal ring C is isolated by removing its caps. If the six crests of the curvilineal ring (three above and three below) are elongated and squeezed into a spherical form they produce side and top views of the curvilineal twisted loop D. Finally, the regular cube lattice is transformed into the angular twisted loop form of the cube E.

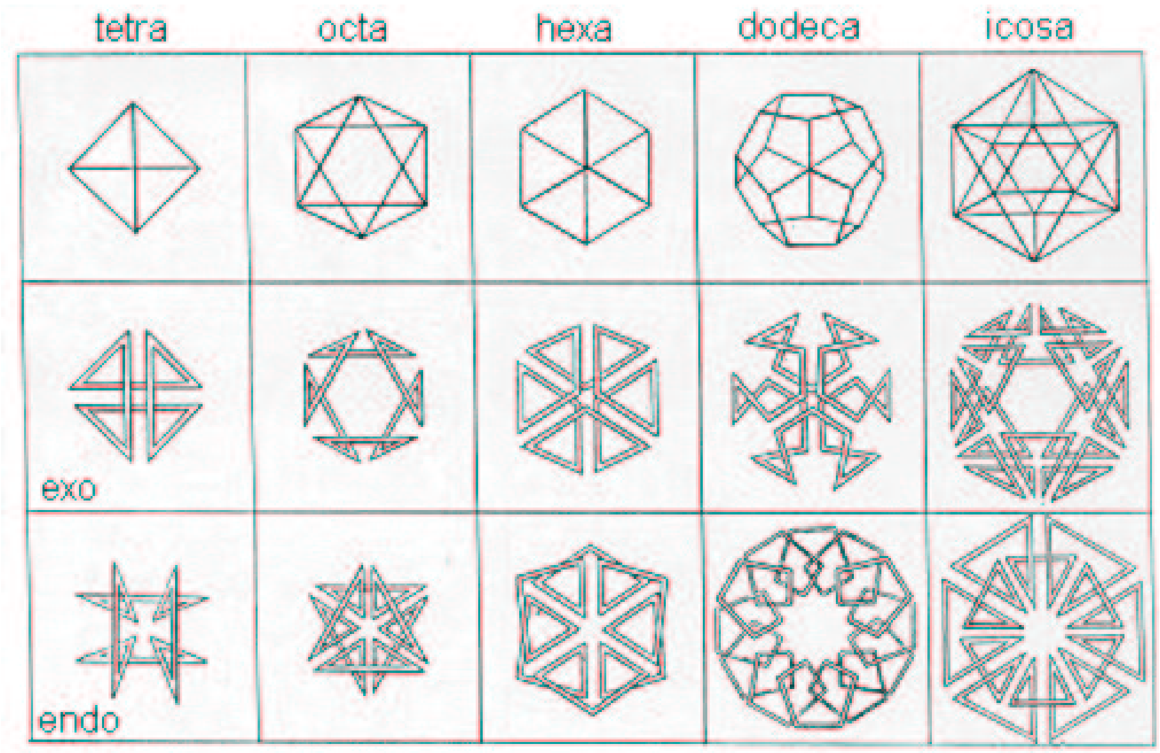

Figure 9: Twisted loops of the Platonic solids

One of the most interesting polyhedra for the twisted loop treatment is the cuboctahedron in Fig. 8. Buckminster Fuller (1975) called it the vector equilibrium because in the close packing of twelve equal spheres around a thirteenth nuclear sphere, they all touch the nuclear sphere. On the 4-fold axes, each outer sphere touches exactly four outer spheres and the inner sphere, thus its center is equidistant to the centers of these touching spheres. On the 3-fold axes, there are four groups of three touching spheres and they all touch the inner sphere. Its center is also equidistant to the centers of the fouir 3-fold sphere groups. The center points of the twelve spheres are the vertices of the cuboctahedron: three at the top, six around the equator and three at the bottom. In the twisted loop forms of the cuboctahedron, the twelve vertices are replaced by twelve continuous twists. The two twist modes, outside-in (exo), and inside-out (endo), can oscillate back and forth into each other on the same loop.

The twisted loop configurations can be seen circumnavigating between the polygons of many spherical polyhedra. Fig. 9 shows how it applies to the five Platonic solids in both the exostructural (outside-in) and endostructural (inside-out) modes.

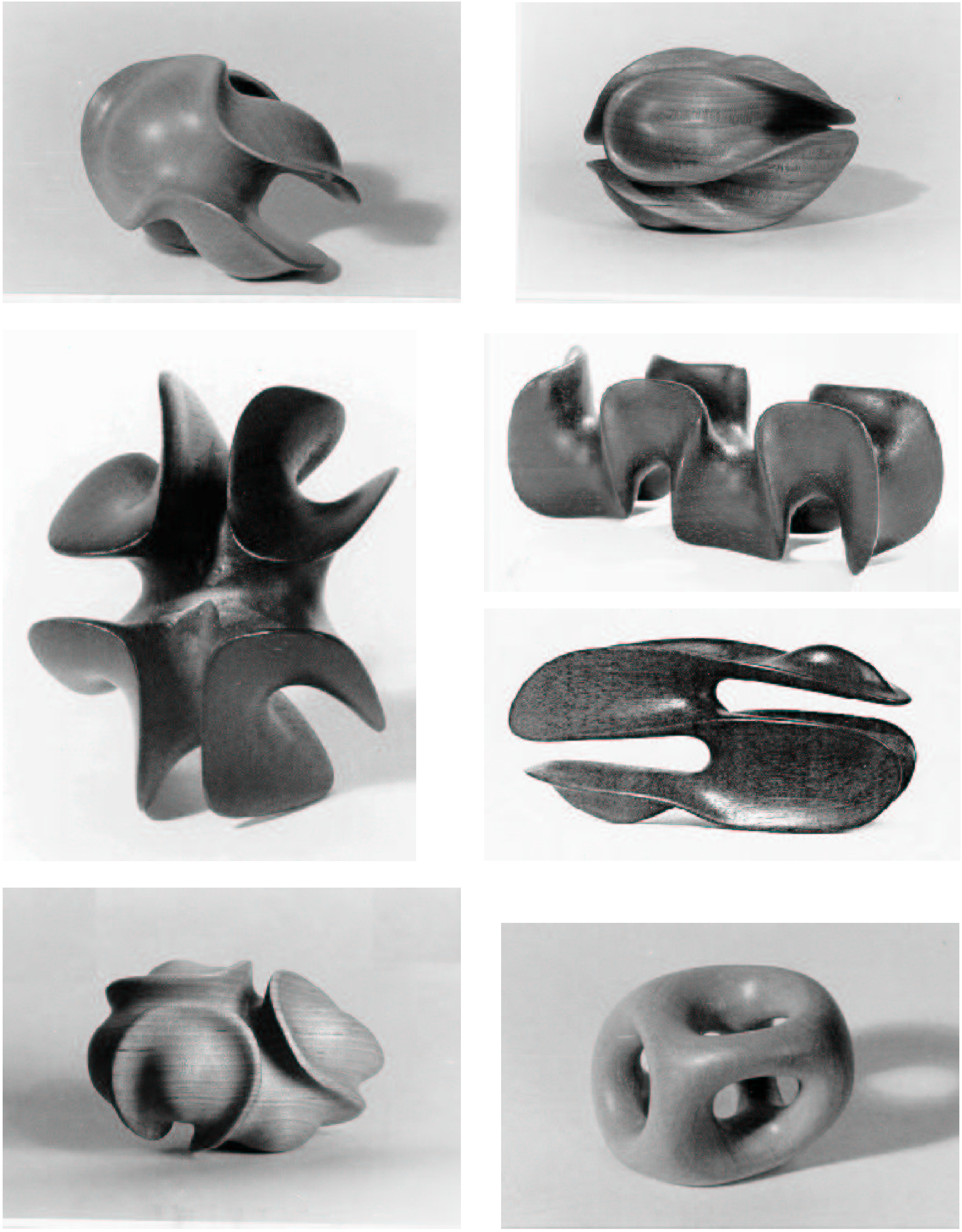

Figure 10: Seven pieces of twisted loop sculpture

3. Twisted loop sculpture

The foregoing text and diagrams show how primitive line units replicate, wrap into rings, generate polyhedra, transform into twisted loops and turn inside-out. A loop, in addition to its twisting capacity can stretch, stack to form tubes and redefine recognizable objects. For a sculptor this is a perfect physical and conceptual vehicle for both the study of natural systems and for creating forms of art. The loop is at once a very simple idea but with the twist it has the potential for structural complexity. Fig. 10 shows examples of the sculpture that came from this study.

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