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ARTIST'S NOTE

Mobiles, Molecules and the Coalescence of Processes

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ABSTRACT

The author provides an account of his development and experiences as both a visual (mobile) artist and a chemist. He describes the surprising similarities between the planning of the construction of a mobile and the execution of retrosynthetic analysis used to chemically create a particular molecule. The fusion of these two independently initiated mental processes into a common creative act can be referred to as a coalescence of processes. The present article discusses the consequences of this merging for both artistic and scientific practices, as well as its relevance to the artscience concept of idea translation.

Much attention has recently been directed toward the relationship between artistic and scientific practices, as evidenced by the articles published in the ArtScience special section of *Leonardo*. Although I am the furthest thing from an expert on cognitive theory or the creative and intellectual capacities that can coexist within an individual, I do believe that my experiences may contribute to these ongoing discussions. I refer specifically to my respective activities as a visual artist whose principal activity is the creation of mobiles and as a scientist whose area of expertise is organic and bioorganic chemistry.

MOBILES

I constructed my first mobile over 30 years ago as a college student, after seeing an exhibition of works by George Rickey [1], whose spare and slow-moving constructs first inspired me to explore kinetic art. This led me to study and appreciate the creations of Alexander Calder [2,3], one of the most important sculptors of the 20th century and inventor of the mobile art form. To understand what a mobile is, one simply has to comprehend how a lever or balance scale works. Suspending objects from the opposite ends of a rod results in gravity pulling each of them downward with a force dependent on their respective masses. At a particular point (called the fulcrum) along the rod, these forces (and consequently the two objects) are balanced and, if the entire ensemble is hung from the fulcrum, one has what constitutes the simplest mobile form. I will not dwell on the details of this aspect of mobile design, as a highly technical article dealing with them has been published in this journal by Mooson Kwauk [4]. This author has also applied his rigorous, mathematical approach to the design of geometric mobile components [5]. To a visual artist, the mobile art form offers endless creative possibilities in that it allows for the spatial organization of objects of all sorts in a well-defined, albeit dynamic, manner.

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Article Frontispiece. ***Objet de luxe parmi des ordinaires dont un qui saigne,*** **rock, glass, quartz, agate, carnelian, garnet, brass, silver, music wire, steel wire, 120 cm, 2006. (© S.H. Kawai. Photo: D. Kubin.)**

Figure 1 provides a simple description of how one would go about constructing a hypothetical mobile entitled *Leonardo* and underlines the bottom-up nature of the process. A mobile can be seen as a 3D array of objects (which I refer to as primary elements) whose positions are defined by the wire structure from which they are suspended. One could envision simply hanging objects individually at the appropriate positions from a wire grid; however, this would not constitute a mobile.

In Fig. 1, the pairs of primary elements A and B, and C and D, are first joined to provide the higher level subunit elements (AB) and (CD), respectively. These are then connected to form the (AB/CD) subunit element. It is important to note that from the (AB) level upwards, every subunit element is itself a mobile that increases in complexity as one proceeds up the subunit hierarchy. Even the completed *Leonardo* could potentially be an element within a more complex construct. Calder was likely referring to this theoretically endless construction when he apparently replied, when asked how he knew when a mobile was finished, "When it's time to go to bed." An important consequence of this fundamental aspect of mobile design is that if any primary element in the final piece (e.g. A) were to be replaced with another of unequal mass, all of the fulcra moving up the chain of subunit elements in the hierarchy would be displaced, and the final mobile would be completely altered. This is what imposes the "bottom-up" method of construction.

An alternative route would be to proceed via pairings (AD) and (BC) or (AC) and (BD), which would provide (AD/BC) and (AC/BD) subunit elements, respectively, where the primary elements could easily be disposed in the same manner, only the wire components being organized differently. Likewise, alternate pairings of higher level subunits such as (AB/CD) to (IJ/K) and (EF/GH) to (LM) could also be employed. It should be obvious that the number of possible ways of moving up the hierarchy to the desired arrangement of elements in the final piece is nearly endless. This said, the structure of the network of connecting parts is often central to the visual impact of the work and can be shaped by these types of changes in the organization of the levels.

The degree of complexity of a mobile is related to the number of levels of subunit organization in the hierarchy. For example, if one considers the skull and cluster of small

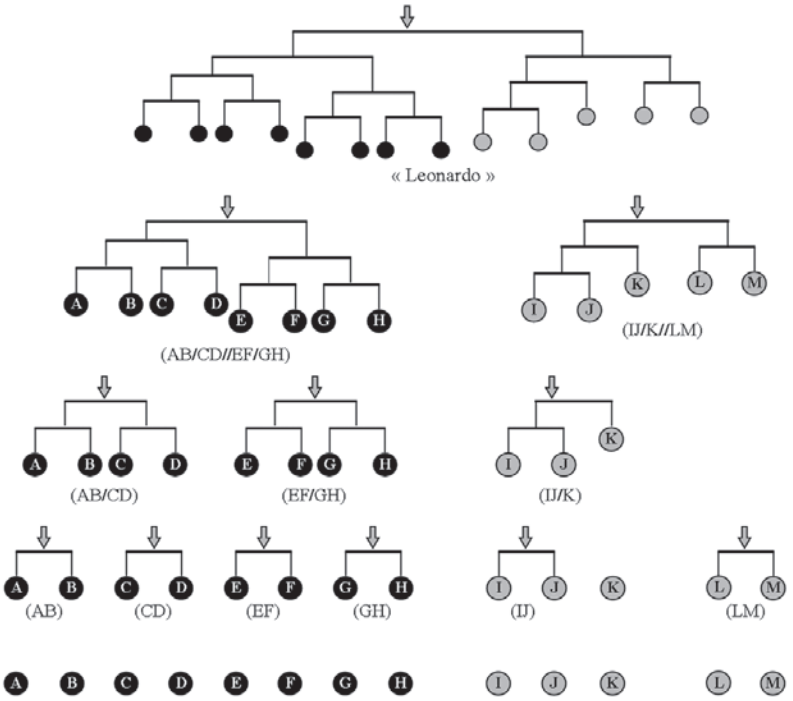

Fig. 1. The process of mobile construction. The hypothetical mobile *Leonardo* can be viewed as a collection of primary elements (A through M along the bottom row), specifically arranged in three dimensions. Construction begins by joining A and B to generate (AB) and finding the fulcrum (grey arrow). (AB) then itself becomes a higher-level subunit element that can be connected to (CD), the product of joining primary elements C and D, which gives the subunit element (AB/CD). Joining of the remaining primary elements and further sequential connecting of higher-order subunit elements results in the completed mobile *Leonardo*, which can be described as (AB/CD//EF/GH///IJ/K//LM) [15]. (© S.H. Kawai)

Fig. 2. *Sentia*, rock, brass, partial opossum skull, music wire, various semi-precious stones (malachite, lapis lazuli, carnelian, agate, etc.), 150 cm, 2010. (© S.H. Kawai. Photo: D. Kubin.)

spheres in the piece *Sentia* (Fig. 2) as a primary element, the mobile is structurally quite simple and constitutes an AB/C//D construct, whose brass spanning bars are crucial to the aesthetic of the work [6]. In *Enantiomeric Snails* . . . (1995) (see Color Plate A), the primary elements and connectors are integrated, each being a cantilever, with the stone being the "fixed end" onto which successive cantilever units are anchored. It could be described as an A(stone)/B//C///D////E assembly. *Objet de luxe* . . . (2006) (Article Frontispiece) has more primary elements but remains relatively simple and can be described as an A/////BC/D////EF/G//HI///JK/L system, in which one of the rocks is not an element but part of a connector. On the other hand, *Premonition* (Fig. 3), which I envisioned as droplets of oil infiltrating rocks (completed a very short time before the U.S. Gulf Coast oil spill occurred) is substantially more complex and incorporates a large number of primary elements organized into an intricate subunit hierarchy divided into many levels—an organization much too complicated to reasonably denote.

What is relevant to the present article, however, is not so much how one puts a mobile together as the process by which a strategy to construct an envisioned work is devised. Once one has a clear idea of how various elements should be positioned with respect to each other, the principal challenge in creating the work is the mental deconstruction of the envisioned piece into sequentially smaller subunits that must ultimately be dissected into the primary elements. This "top-down" analysis must be carried out while keeping in mind the constraints imposed by mass and gravity (positions of all the fulcra) and considering the visual role played by the connecting components. Thus, each downward deconstructive step is carried out with an awareness of the possibilities and limits to moving upward.

While I have always created both starkly minimalist pieces in addition to more intricate mobiles, it is the latter type, such as *Laura's Bird* (Fig. 4), that often seems to attract more attention. I have frequently been asked how one could possibly go about designing something so complicated. Many people, aware that I have a science background, have assumed that the design related to physics or engineering and that my mobiles were products of meticulous weighing and calculation in the same vein as Kwauk's approach [7]. This has never been the

case, and I never use anything more than a short length of thread or string. At the time I created *Laura's Bird*, I was a researcher in the pharmaceutical industry and, while also being very active artistically, I never saw any connection between my chemistry and mobile-making activities. I had never tried to understand in any depth the analysis depicted in Fig. 1; all was carried out intuitively. In fact, the present article constitutes the first time I have described the process in a formal manner.

In 2005, I began thinking about *Carbon-Based* (Fig. 5), a piece that makes reference to Primo Levi's magnificent synthesis of literature and chemistry, *The Periodic Table* [8]. I started positioning elements in my head and imagining connections, going through the usual top-down deconstruction, when it suddenly struck me that what I was performing was a *retrosynthesis*—a type of analysis any synthetic organic chemist must routinely carry out and that I describe in the paragraphs below. From this point onward, I referred to this backward planning out of the making of a mobile using this borrowed term, once having made this mental connection between my artistic and scientific thinking.

Fig. 3. ***Premonition*****, rock, hematite, music wire, steel wire, 135 cm, 2010. (© S.H. Kawai. Photo: D. Kubin.)**

MOLECULES

Molecules, whether derived from Nature or designed by scientists, come in an astounding variety of shapes and sizes. It is not surprising that organic synthesis has developed into a vast field that has provided us with the tools to prepare virtually any molecule imaginable. Constructing a particular target structure generally begins with a starting material, normally a simple, inexpensive and readily obtained substance. Through stepwise chemical transformation involving the attachment of other molecules or the cleaving off of bits, the starting material is repeatedly modified until the desired molecule is obtained.

Retrosynthesis [9], as the term implies, is synthesis in reverse—and done on paper; it is an intellectual exercise performed for strategic planning purposes. Keeping the desired target molecule in mind, one progressively simplifies it conceptually (with awareness of the plethora of transformative chemical reactions available) until one arrives at a practical starting material that can then be acquired for synthesis of the target molecule in the lab. At times, what are termed disconnections (the opposite of forming a bond to join molecules together) are carried out, which results in

Fig. 4. ***Laura's Bird*****, rock, hematite, carnelian, Chinese turquoise, brass, music wire, lovebird feather, 90 cm, 2004. (© S.H. Kawai. Photo: D. Kubin.)**

Fig. 5. ***Carbon-Based (hommage à Primo Levi)*****, resin, seashell, hematite, carnelian, cherry amber, quartz, CPK model, music wire, pigeon feather, 120 cm, 2006. (© S.H. Kawai. Photo: D. Kubin.)**

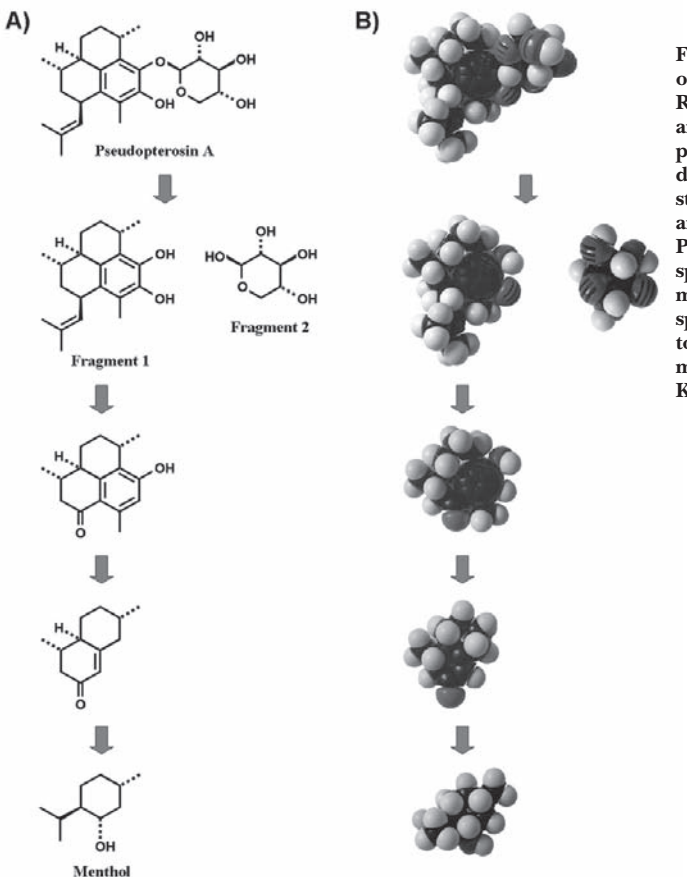

Fig. 6. The process of retrosynthesis. Retrosynthetic analysis applied to pseudopterosin A depicted using A) structural formulae and B) CPK (Corey-Pauling-Koltun) space-filling atomic models, where each sphere corresponds to an atom in the molecule. (© S.H. Kawai)

simpler fragments. Figure 6 presents the retrosynthesis that guided the preparation of a relatively complex, naturally occurring molecule. In the first backwards step, a disconnection is made to generate two fragments. To any chemist, this is an obvious disconnection, since methods to join such pieces together are known and fragment 2 can be purchased in a practical form. Further sequential simplification of fragment 1 ultimately leads to menthol, a simple substance that we all know from chewing gum or smoking cigarettes.

The synthetic strategy devised through the retrosynthesis depicted in Figure 6 was successfully applied to prepare pseudopterosin A using menthol as the starting material [10]. Nearly a decade later, a different retrosynthesis was devised by the same research group and used to construct the molecule from a different starting material [11]. This underlines an important fact; just as the sequential deconstruction of a mobile into subunit elements can follow many branching paths, retrosynthesis can also generate a branching tree of chemical strategies. It is not surprising that terms such as "art" and "creativity" are often applied to organic synthesis, and many complex molecules have been prepared by very different routes (arising from divergent retrosynthetic analyses), each strategy possessing its particular advantages and, in many instances, elegance.

THE COALESCENCE OF PROCESSES

Only recently did I become aware of the artscience canon through a short article on Le Laboratoire [12], which eventually led me to David Edwards's book [13]. In this context, I sought to understand more about my belated epiphany regarding the common application of retrosynthetic thinking to both my artistic and scientific work and its possible impact on these practices. For well over a decade, both my mobile-making process and my activities as an organic chemist were clearly drawing from the same pool of knowledge/experience without my awareness of it. The deconstruction of complex arrays of objects as an integral part of creating them (whether they be molecules or mobiles) was a mental activity I was regularly engaged in. While the practice had two very distinct origins, I unconsciously merged them at some point during this period of time into a common process. I refer to this fusion as the *coalescence of processes.*

Edwards describes artscience as arising when aesthetic and scientific methods combine and provides many examples of individuals who apply concepts, notions, techniques, etc. derived from one domain to another. He refers to this breaking down of creative barriers as "idea translation" and sets out an "idea translator" paradigm wherein a practitioner of the arts makes a conscious decision to educate him- or herself in a scientific discipline to augment their creative process (or vice versa in the case of an art-savvy scientist) and ultimately produce a novel or important result. Now, how can we view coalescence of processes in the context of my work?

A fact central to this discussion is that the growth of my skills as a kinetic artist and my education and development as a chemist took place more or less concurrently, but in a manner entirely independent from each other. I saw visual art of any sort as a soothing break from chemistry and had no intention of drawing from my scientific practice to influence my artistic explorations. While my experience clearly does not adhere to the idea-translation paradigm, what arose was an integrated method applied to two distinct practices where the notion of translation is very relevant. An important consequence of becoming aware of this coalescence of processes was a clear and immediate appreciation of the many striking parallels between a mobile and a molecule, extending beyond how their respective constructions are planned out.

An essential aspect of mobiles that I have neglected to mention thus far is the manner in which they move in response to air currents or contact. These movements are often complex and unpredictable; however, mobiles inevitably return to the same resting configuration. Molecules behave in a surprisingly similar manner. This prompted me to build on the common vocabulary that began with "retrosynthesis." I started applying chemical terms such as "local energy minima" and "steric congestion" with regard to the kinetic aspects of a mobile's behavior. Chemistry-related themes in general became frequent in my artwork immediately following *Carbon-Based*.

By the late 1990s, I was very interested in the internal movements of molecules (the manner in which molecules bend and contort themselves and certain portions of them rotate as they move through water) and the role of this dynamic behavior in biomolecular recognition phenomena and ligand design [14] (simply put, the floppiness/rigidity of a molecule can have a great impact on how well it sticks to other, much larger molecules). Was my understanding of how mobiles move "translating" itself into insights into the behavior of molecules? In any case, by the time *Carbon-Based* was completed, the clear connection between the internal motions of mobiles and molecules had also firmly established itself in my thinking.

Finally, it may be simply that the coalescence of processes that I describe above tends to arise in situations where independent practices draw on a particular innate capacity. Both organic chemistry and sculpture require that an individual possess proficiency in visualization in three dimensions. Since I apparently have an aptitude for this type of visualization, it is perhaps not surprising that my scientific career eventually oriented itself toward organic chemistry and that, after much time devoted to drawing and painting, my artistic life centered itself around mobiles and mobile installations. This may have given rise to circumstances ripe for the merging of initially distinct mental processes revolving around the mental deconstruction/construction of 3D arrays. Had I directed my 3D skills to dentistry and soapstone-carving, the outcome would have no doubt been very different.

Acknowledgments

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15. In this system of notation, the connection of subunits beyond those composed of two primary elements is denoted by an increasing number of slashes as one moves up the hierarchy. Each slash or group of slashes thus corresponds to a fulcrum within the structure.

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