Emerging Creativity

by

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Complex systems and patterns arise out of a multiplicity of relatively simple interactions. This phenomenon is defined as Emergence. Emergent systems can act as a guide to the creative process by allowing the artist to institute conditions under which unexpected interactions lead to creative insight.

Emerging Creativity

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Introduction

This body of research stems from the related disciplines of philosophy and the natural sciences, specifically my research into the field of complexity theory or Emergence. Through this creative research, I am attempting to demonstrate that the principle of Emergence can act as a guide to the creative process. Throughout this thesis I use many terms specific to the disciplines of philosophy, mathematics, and the sciences. Definitions for many of these terms are provided in Appendix B. Also, certain terms are, for the purposes of this document, understood as synonymous with one another. The terms Emergence, emergent complexity, and complexity theory, shall be considered equal and shall be used interchangeably.

I first was introduced to Emergence through my study of physics and the history of natural philosophy. Of particular interest to me was the manner in which the principle of Emergence offered a foil to the long held belief of *determinism*, one of the ideological lynchpins of empiricism and the scientific method. Determinism was born in ancient Greece with the philosophy of the *Atomists*; it was the Atomists who first conceptualized of the universe as composed of tiny, irreducible things called "atoms." However, determinism really flourished during the Enlightenment, a cultural movement of the 17th and 18th centuries respectively.

Enlightenment philosophers began to conceptualize the universe as a machine. Isaac Newton, Thomas Jefferson and others believed that the complexity of the natural world could be understood by reducing it to its smallest components, like the gears of a clock. The beliefs of the Enlightenment, including determinism, remain powerful and prevalent today. In fact, modern physics still clings to determinism with its quest for the big *T.O.E.* The big T.O.E.—or *Theory of Everything*—is a theory in which physicists hope to reconcile the laws of quantum mechanics with the laws of general relativity, thereby describing the known universe in one orderly set of equations.

While fascinated by history, science, philosophy, and physics in particular, I have always been a little bit suspicious of determinism. It has always felt too tidy, too conventional, and too rational for my taste. One imagines that in a deterministic universe a computer could be built that would account for everything in the universe and, having done the last of its calculations, give us the meaning of life, the universe, and everything. This makes for compelling fiction (see Adams, Douglas[1]) but even the notion that such a thing is theoretically possible irritates me. I prefer a messy, surprising, wondrous universe, one where the rules don't add up. This is why I celebrate emergent complexity. A universe governed by emergent complexity is constantly in flux. To paraphrase another ancient Greek thinker, Heraclitus, *everything is change.*

Another way of thinking about the distinction between these competing worldviews is to imagine that the universe is a giant puzzle. If the universe were deterministic then all you would have to do is assemble the puzzle and the picture would become clear. However, in an emergent universe simply having all the puzzle pieces in the correct order is insufficient because under Emergence the puzzle pieces are constantly reacting with one another and changing the picture. To put it simply, Determinism says the whole is equal to the sum of its parts, and Emergence says that the whole is greater than the sum of its parts.

Often the creative process mirrors this emergent complexity. Just as an understanding of Emergence can't be reduced to component parts, neither can the creative process. To illustrate this point, imagine a "paint-by-numbers" book. Simply following the instructions set by the book fails to qualify as a creative process…it takes moving beyond the set of instructions to be creative. This begs the question…what is Emergence? Emergence can be defined as the way complex systems and patterns arise out of a multiplicity of relatively simple interactions.[2] Counter-intuitively, in order to demonstrate the value of

[1] Douglas N. Adams, The Hitchhiker's Guild to the Galaxy (New York, NY: Harmony Books, 1979)
[2] Wikipedia contributors. "Emergence." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 8 Mar. 2013. Web. 12 Mar. 2013.

Emergence to the creative process it becomes necessary to create a set of governing conditions—some "paint-by-numbers" guidelines to be documented and hopefully transcended.

Insofar as this research is an attempt to document the creative process, the initial rules (see appendix A), were put in place to provide a framework in which creative exploration and complexity/interest might arise. Complexity, in this instance, references the scientific theory that asserts that some systems display behavioral phenomena that are completely inexplicable by any conventional analysis of the systems' constituent parts.[3]

It has been my habit to work intuitively. I would approach a material and find a method of working that "felt right." In this instance, that approach has been set aside in favor of a more analytical position. Balancing the drives of intuition against the guidelines put in place provides a structure with which to analyze creative decision making and has helped to better understand where my aesthetic biases lie.

I recognize that Wikipedia is not used in academic writing. However, I felt that in this case it was appropriate. Therefore because of the emergent quality of Wikipedia I felt that it was an appropriate source for the definition of Emergence.

[3] "complexity." *Encyclopædia Britannica. Encyclopædia Britannica Online Academic Edition*. Encyclopædia Britannica Inc., 2013. Web. 11 Mar. 2013. <http://www.britannica.com/EBchecked/topic/130050/complexity>.

Process and Technique

In order that the reader may better understand the objects described in the remainder of this thesis it would be prudent to discuss the processes and techniques used in their creation. When beginning these pieces I start by taking a sheet of copper and embossing it in a process called *roller printing.* In order to emboss the copper one must first construct a matrix. Having etched a matrix into the sheet of brass, the next step is to soften the copper sheet in order to prepare it for roller printing.

The process by which the copper sheet is softened is called *annealing.* The annealing temperature of copper is approximately 1100 degrees Fahrenheit. One unfortunate side effect of applying heat to the copper in an oxygen rich environment is that oxides develop within the microcrystalline structure of the metal. These black and umber colored oxides are removed from the surface of the copper through the process called *pickling.*

After pickling, the metal and the embossing matrix are sandwiched between a pair of hardened steel rollers. Using a large crankshaft, the metalsmith rolls the sandwiched plates between the rollers, exerting significant pressure in the process. After the metal has exited the other side, the matrix has embossed its design onto the previously softened or annealed metal.

This is the first process employed in this body of work. The next process is to cut and shape the various species of exotic and domestic hardwoods. The first step is to rough-cut the wood into a cylinder on the *band saw.* The advantage of the band saw is that it allows the artist to cut complex curves. After the cylinders are cut, a 90° wedge of material is cut out of the cylinder. This gives the cylinder the appearance of a "Pac Man ™" shape (fig. 1). This process is repeated again but the 90° cutouts are placed off-center to make a wedge shape of material. After filing and sanding so that the "Pac Men ™" and wedges fit into one

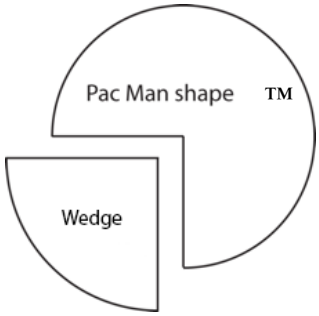

Figure 1: Diagram of shapes

another securely, the pieces are then shaped through the use of the *flexible shaft* or flex shaft. Using the flex shaft, each piece is carved into a gentle dome and then sanded to a fine polish.

After shaping is finished I assemble the mechanisms needed to properly set the wood in place. Sheet metal is cut and joined to the embossed plate through a process called *soldering.* The settings or *bezels* for the wood are soldered to the embossed plate and piece is then pickled.

The next step in the creation of these pieces is the placement and fabrication of *tube settings* for the faceted stones. Nearly all of the tube settings used in this thesis body of work were made by hand in the following manner: to construct a tube I took a rectangular piece of annealed metal and hammered the metal into a series of consecutively smaller U-shaped troughs. Hammering the metal in this way brings the metal into a round cylindrical shape not unlike a drinking straw. When the tube was nearly closed the tube is annealed and brought to the *draw horse* where the material is drawn down into its final shape. Once the tubing is drawn through to the appropriate size the artist solders the tubing closed and proceeds to the next step—*cutting the seat.*

Cutting the seat of a tube setting refers to the process of removing material from the inside of the tubing in order to better conform to the shape of the stone. This is accomplished by using the flex shaft and *stone cutting burrs.* Cutting the seat of a tube for a tube setting requires that the burr be perfectly perpendicular to the edge of the tubing and centered on the tubing. The burr is positioned and lowered into the tubing, cutting away material. Particular attention is paid to the depth of the cut. Too shallow and the stone won't seat properly, too deep and the stone will be covered by metal during the setting process.

After soldering the tubes onto the back plate the settings are ready to accept the stones. When the fabrication is complete and the *patina* is applied the stones are set in place and secured via a *bezel setting punch*. Stone setting takes place as one of the last steps in the creation of the work; before that can happen

a crucial element must be fabricated. Some of the pieces in this body of work contain *die-formed* domes of roller printed metal. These are soldered into place along side the other fabricated elements.

After the fabrication is complete the metal is now ready for *patina.* All of the pieces of artwork in this exhibition underwent a process of rapid oxidation through the use of *Liver of Sulfur* ($K_4O_3S_3$) patina and ammonia. The clean metal is dipped repeatedly into the solution until the desired color is achieved and *burnished* with a brass brush lightly to set the patina.

Emergent Growth Series

The emergent growth series can be read as a direct consequence of the initial conditions but behind those rules are an oblique series of ideas that have inspired them. Drawing inspiration from the formation of cityscapes, travel patterns, chemical and biological interactions, weather systems, and cosmology, I have sought to create work that is the outgrowth of an emergent process and visually represents emergent phenomena in our environment such as the murmuration of birds or the manner in which fish school. I began this work attempting to faithfully follow the rules as I set them down, while actively searching for those insights that transcend the more mechanistic approach.

ex nihilo nihil fit—nothing comes from nothing

Let's assume that everything that is has a beginning. Beginnings are important in our culture. We celebrate them. Buildings have groundbreaking ceremonies, ships are christened, and birthdays are observed annually to commemorate the day of a person's "beginning." I personally believe that beginnings are celebrated because they are powerful reminders of potential but as contemporary philosophers and recording artists *Semisonic* remind us, "…every new beginning comes from some other beginning's end." With this sage wisdom in mind, it was important for me to consider the ramifications of my aesthetic choices, as these choices would continue to influence the work to come.

Beginnings

The first piece in the series is a small brooch of carved Cocobolo wood, a copper and brass structure utilizing roller printed texture of my own design, and 18 k gold. The form and the materials were predetermined by the guidelines but there were other choices to be made. Initially, there was the choice of which wood to employ in the work. After reflection, I chose Cocobolo because of its intricate

patterning and the fact that the Sapwood and the Heartwood were both present in the piece I purchased. The contrast in color and texture between the two halves of the wood was evocative of a sense of potential; the knotty grain structure reminded me of the epithelial membrane that surrounds the ovum, with its complex web of blood vessels nourishing the life within (fig. 2).

Figure 2: Emergent growth series 1
Copper, cocobolo, brass, 18 karat gold,
1" x 1" x .75", 2012

I then chose to carry that metaphor forward by inlaying a dot of gold. Its yellow color, high value, and symbolic importance serve to enrich the symbolism of biological growth and Emergence in my mind. The copper housing for the brooch incorporated a texture abstracted from imagery of cellular mitosis and aerial views of cityscapes, further supplementing the notion of Emergence on both a grand and a miniscule scale.

The next piece of the series was a brooch containing two pieces of wood with a copper support structure—a Cocobolo form with a Bloodwood protuberance, seeming to develop from within the

cocobolo piece. The forms are divided by an architectural element of copper that alludes both to microscopic cell walls and the macroscopic partitions with which we are more familiar (fig. 3).

Figure 3: Emergent growth series 2
Copper, cocobolo, bloodwood
1.5" x 1" x .75", 2012

After finishing this piece I was confronted with a dilemma as this was the first instance where the rules seemed insufficient to describe the complexity I had hoped to reveal. Reflecting on the newly finished piece, I determined that there simply was not enough visual interest. Faithfully following my rules led me to a place where one of my aesthetic biases was revealed—I actively try to maintain a sleek and clean aesthetic. Following the rules I put in place helped me realize that there is a fine line between sleek and lackluster; I was bored with this piece. It was also important for me to push through my dissatisfaction

with the piece rather than simply change gears. This forced me to re-engage with the rules and search for creative solutions to my aesthetic dilemma and required a level of trust that the answer would indeed present itself in time. The realization that I should trust the process was critical and it allowed me to move forward with renewed enthusiasm.

Figure 4: Emergent growth series 3
Copper, cocobolo, bloodwood, pink ivory, paduk, garnet, orange cubic zirconium
3" x 1.5" x .75", 2012

Resolving to regain some of the interest and excitement I felt about the first piece, I moved on to the third and it is in this piece that I believe the sense of Emergence began to reassert itself (fig 4). The third piece introduces two new species of wood as well as tube set gemstones. The introduction of the gemstones was a critical revelation serving both functional and conceptual aims. The addition of the tube settings in the areas between the wood domes helps stabilize the sheet metal that joins the wood sections. Simultaneously, the introduction of the tube set gemstones allowed investigation into one of the outcomes

of complexity theory, namely, "Strange Attractors." Complexity theory defines an *attractor* as a set towards which a variable, moving according to the dictates of a dynamical system, evolves over time. A Strange Attractor is an attractor such that the approach to its final point in phase space is chaotic. The interactions of these elements combine in a structured, balanced pattern of variation that I find pleasing and that echoes the microscopic/macroscopic emergent phenomena I mentioned.

Strange attractors in nature are fixed points in systems that arise out of the confluence of factors that surround them. One example of a strange attractor with which we are familiar is the eye of a hurricane. The eye of the hurricane is a fixed point that develops naturally out of the same forces that draw the hurricane into being in the first place. We also find attractors in economic markets, nuclear chain reactions, traffic patterns and the like. What is so compelling in the translation of the strange attractor from nature to art is the manner in which creating art is so eerily similar. Many artists are familiar with the experience of having the work "speak" to them. The work is personified and internalized to such a deep level by the artist that at times the work seems driven by its own force, and that it develops with little effort on the part of the artist. I am not immune to this effect and in some sense the work seemed to "ask" for the tube set gemstones. Within my own creative practice the act of being able to "listen" to the work has been important and while I think that there are many ways in which artists might work I have found the balancing act between concept and technique to be the most fruitful.

Figure 5: Emergent growth series 4
Copper, paduk, bocote, bloodwood, canary, pink ivory, queenwood, african blackwood, garnet, assorted cubic zirconium
5" x 4" x .75", 2013

The next piece in the series continued to evolve according to the guidelines (fig. 5). New wooden growths were added and the tube set gems were placed at the intersections of the larger pieces of wood. Critically, this is the first piece in the series that exhibits rule 5 and has an element extinguished. The original piece of cocobolo is removed and is replaced with a shallow dome of textured metal. The texture applied to the dome is a roller-printed series of arcs with dots at the intersections and is meant to remind one of the chaotic patterns of nature at the atomic level. Formed through the use of a hand-pierced brass plate this process gives the copper dome a texture that references particle orbits. Most of us are familiar with the standard depiction of an electron's orbit. Swirling ellipses chart the path of the electron around the nucleus and the dots present in the piece are symbolic of the electrons' particle-wave duality. This

subtle texture is almost invisible at standard viewing distance and it is incumbent upon the viewer to engage with the work in order to observe its effect on the piece.

Figure 6: Emergent growth series 4 (detail)

Meanwhile, on the back (fig. 6) of the piece, a dome of African Blackwood is strategically placed in the same position. The African Blackwood contains a small sterling silver tube set cubic zirconium and the dichotomy between the extinguished/textured front and Blackwood back sets up a quandary all too familiar to those who have studied quantum mechanics. The problem is superposition. Colloquially, the problem of superposition is understood through the thought experiment commonly referred to as the Schrodinger's cat experiment.[4]

I love this thought experiment because at its core this experiment demonstrates the unlimited potential of

[4] The experiment goes roughly like this. A cat is placed in a box along with a bomb that has a 50% chance of going off. The box is then closed. The principle question of the experiment is whether the cat is alive or dead. Counter-intuitively, quantum mechanics maintains that until the box is opened the cat is both alive and dead. The cat is in a state of superposition between the two extremes and it is the act of observation that forces nature to choose.

emergent systems and the agency of the actors within that system to influence the whole. I have chosen to represent this superposition within the series by presenting the viewer with an element that from one perspective (front) is extinct, yet from another perspective (back) is still vital.

Quantum mechanics follows emergent principles because in order to make any statement about the fate of our pitiful cat one must participate in the experiment and the very act of that participation fundamentally influences the outcome[5]. You have to open the box to resolve the superposition. Taking all possible observers into account—for every potentiality—can quickly result in an unimaginably complex set of scenarios. This complexity is mirrored in the creative process. Every decision influences those to come after and if one were allowed to sit and stew about all of the potential decisions involved one could quickly become overwhelmed. That is why it was so important to come up with a set of guidelines with which to begin. The rules operated as a starting point—a constraint—that liberated me from indecision.

The agency of the actors within an emergent system is similar to the agency I feel as an artist. I have in this experiment set the initial conditions with which to begin my work but am empowered to operate in response to the influences present in the work as they develop. This experience is similar to the manner that a crowd crosses a busy intersection. The majority of people will tend to walk along one side of the intersection but individuals within the crowd will walk across the street as they see fit thereby opening up avenues for others to follow. The sway of the individual decision to walk across the street influences the paths open to those crossing next. In a very similar way the body of work developed characteristics such as tube set stones, African blackwood back pieces, and curvilinear walls that influence the construction of

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[5] *Jones, A. Observer Effect. Jones, A. (n.d.)* Observer Effect. *[online]* Available at: http://physics.about.com/od/physicsmtop/g/ObserverEffect.htm [Accessed: 13 Apr 2013].

pieces to come next. The puzzle changes both as more pieces are added and as I observe their dynamic interactions.

Walls and Dividing Lines

Figure 7: Emergent growth series 5
Copper, canary, maple, paduk, zebra, bocote, ash, pink ivory, purpleheart, queenwood, zapote, african blackwood, garnet, assorted cubic zirconium
5.5" x 4.75" x .75", 2013

As I began to conceptulize the 5th piece in the series I was struck by the sense that something was missing (fig. 7). I felt as though the preceeding pieces in the series were failing on some level to communicate the fluid and dynamic quality we so frequently associate with emergent phenomena. Macroscpically, Emergence is often evidenced visually through the movement of the agents within the dynamical system (e.g. the flocking of birds and schooling of fish). In the fifth piece of the series I chose to represent the character of that movement through the creation of a curvilinear wall that flows through the piece. The

wall tapers in height and flows around the piece drawing the eye from the center outward, terminating at one of the five still "living" appendages. The decision of where to place and how to shape the walls was guided by my observations of emergent phenomena in our environment. The walls begin in the center of the pieces and flow through the work, dividing the elements within the work and setting the stage for the next pieces to come. The division of the elements progressed through the pieces in a mathematical way such that each piece would be divided by half, accounting for the number of living and extinct elements that would be present in the next iteration of the series, thereby providing a scenario where the system might eventually reach a natural conclusion. Attention was paid to the path of the walls through the work so that it would convey the character of birds in flight; a character full of sinuous curves that bend and respond to what from our grounded position seems random and without justification, but is likely a response to unseen stimuli—the aggregate of which produces ordered complexity of astonishing beauty. When viewed from above the wall element bolsters the understanding of Emergence as present in the formation of cityscapes. The tube set gemstones have multiplied, clustered at points, and one might imagine them as describing the emergent complexity of a traffic system, with its entry ramps, exits, and bottlenecks. Here the wall takes on the dual roles of obstruction and pathway, alternately blocking or allowing egress. Much to my satisfaction the introduction of the wall helped establish a more fluid movement within the piece. Crucially, and unexpectedly, the evolution of the wall set the stage for the next development in the series—*bifurcation*.

One element of emergent systems in mathematics, as well as in nature, is the property is self-organization. The next piece in the series takes advantage of this self-organization by dividing or bifurcating in the manner mentioned above. Bifurcation has many uses in topology and related mathematical disciplines, and artists are most likely familiar with the Fibonacci series as one example.

Pascal's triangle, a graphic display of the Fibonacci series, is a classic instance of the property of bifurcation within an emergent system (fig. 8). Such an arrangement is emergent because the value of each new term in the system is dependent on the two above it and so on. Bifurcation theory is most commonly applied to dynamical/self referential systems such as has been the focus of this research and which includes the direction and division of the forces that draw together a hurricane and the forking of river systems as two examples.

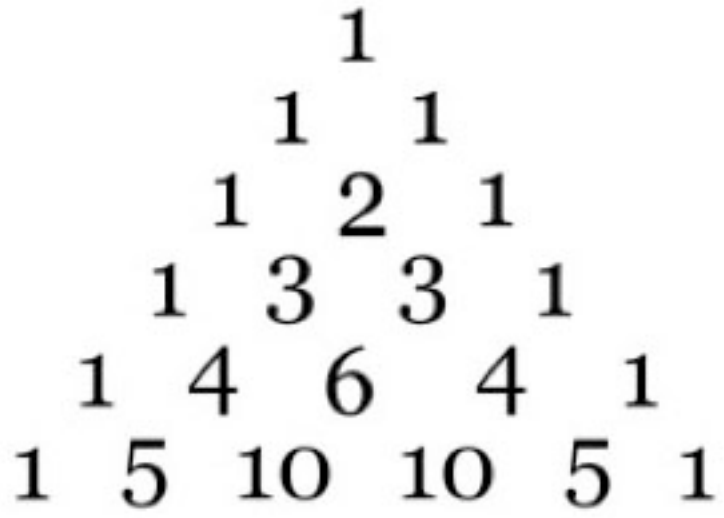

Figure: 8 Pascal's Triangle through 6 iterations

This process of bifurcation also addresses the concerns of functionality and wearability. The pieces were becoming too large and cumbersome to operate as single units. Therefore, in order to continue to make work that fits the criterion of wearability and furthers the aim of revealing Emergence it became clear that the work needed to be divided into smaller components within the system. Bifurcation provided not only the solution to my concerns over functionality but also allowed me to conceive of a display that I believe will allow the viewer to better comprehend the dynamic relationships within elements of an emergent system.

Figure 9: Emergent growth series 6
Copper, maple, redwood, canary, holly, zapote, black palm, ash, cocobolo, paduk, garnet, citrine, assorted cubic zirconium
7.5" x 5" x .75", 2013

Beginning with the 6th piece in the series, I reached the conclusion that the work had reached a critical mass and that bifurcation must begin (fig. 9). The decision of where to begin the process of bifurcation was based on the placement and orientation of the wall within the 5th piece. Continuing the pattern of growth previously established and taking into account the extinction phenomenon, the two halves were divided roughly equally with two extinct elements per grouping.

Installation

With the development of the bifurcation and in thinking about ways in which to combine the best elements of a dynamic installation with the constraint of producing a physical, wearable, piece of artwork, I reached the conclusion that a wall mounted display of cut vinyl periodically interspersed with jewelry would be best. The other insight I reached was that within the constraints of the gallery space permitted me I could create an installation that conveyed the grand scale of Emergence in 15 iterations. The gallery space my exhibit inhabits approximates an 8ft by 16ft hallway of sorts, with moveable walls arranged together and the outer gallery wall opposite these. The largest display occupies the gallery wall and the remaining work occupies the moveable walls.

The display itself contains numerous bifurcated elements arranged in a grand, sweeping visual display of Emergence (fig. 10).

Figure 10: Diagram of installation

However, the walls delineating my area of the gallery make it difficult for the viewer to take all of it in at once. Instead the gallery arrangement forces the viewer to look askance at the installation if they are to see the whole picture. This is important because this arrangement obliges the viewer to engage with the work in a manner that mirrors the dilemma facing those that study Emergence. Just as scientists are only beginning to bring complexity theory into focus and frequently understand either the particular or the grand instance of Emergence, but fail to understand the connection between them, so too is the audience forced to look indirectly for this connection. If they choose to square themselves to the display and begin to look more closely, the installation consumes their field of vision and only what is directly in front of them remains clear.

Conclusion

In thinking about the roles of the scientist and the artist I am struck by the manner in which they complement one another. Both professions seek clarity—the quality of coherence and intelligibility—but their approaches differ and there are limits to the understanding that each can impart alone. The authority of the artist lies in his or her ability to translate the reasonable into feeling, sensible into the intuitive, practical into the impossible, concrete into the ethereal, and the deliberate into the spontaneous. The rules set forward in this document were a necessary and important beginning. Without them this process would have been much like the orchestra without the score—a senseless and jumbled barrage of sounds with awkward starts, stops, and no synchrony. Perhaps, the flitting back and forth between processes and media that had been the hallmark of my early graduate career might be understood as an artist lacking a score.

With my rules in hand, the challenge was to interpret the score in a way that conveyed something of the deep truth behind Emergence and this is where the task was most difficult and rewarding. Each new piece in the series brought with it the challenge of communicating the sense of hidden order that makes Emergence so fascinating. How does one convey the miraculous way that order springs from seeming chaos? How might one approach the creative process in a manner that allows for both careful rigor and carefree extemporaneity?

I believe this thesis has shown that the creative process is one of constant vacillation between these poles and that in order for creativity to flourish one must simultaneously ground oneself in structure and yet remain open to hidden possibilities.

By rule, each new piece carried an influence over those to come after and my creative process was aided when I freed myself to accept that reality on an intuitive level as well. This perspective allowed me to

begin to make connections that were less obvious but more true to the spirit of Emergence as I understood it. One of the most intensive areas of study within the field of complexity theory deals with the inner working of the brain. After all, thought itself is an emergent property of the synchrony neurons. This process has changed my thinking and allowed me to the conclude that Emergence acts as a guide to the creative process by providing the conditions under which rules join with play, order joins with disorder, and synchrony leads to clarity.

Portfolio

Figure 11: Emergent growth series 7
Copper, ash, wenge, pink ivory, purpleheart, amboyna burl, ebony, garnet, citrine, lemon quartz, assorted cubic zirconium
5” x 3.5” x .75”, 2013

Figure 12: Emergent growth series 8
Copper, wenge, cocobolo, holly, bloodwood, pink ivory, purple heart, garnet, citrine, assorted cubic zirconium
4.75” x 3.25” x .75”, 2013

Figure 13: Emergent growth series 9
Copper, ebony, amboyna burl, black palm, zapote, garnet, citrine, assorted cubic zirconium
4” x 3.5” x .75”, 2013

Figure 14: Emergent growth series 10
Copper, purpleheart, pink ivory, bocote, bloodwood, garnet, lemon quartz, citrine, assorted cubic zirconium
5” x 4” x .75”, 2013

Figure 15: Emergent growth series 11
Copper, bocote, wenge, paduk, zebrawood, garnet, citrine, assorted cubic zirconium
4” x 2.5” x .75”, 2013

Figure 16: Emergent growth series 12
Copper, cocobolo, zebrawood, ebony, paduk, zircote, thinwin, garnet, citrine, assorted cubic zirconium
4.5” x 4.25” x .75”, 2013

Figure 17: Emergent growth series 12.2
Copper, black palm, thinwin, pink ivory, purple heart, garnet, lemon quartz, citrine, assorted cubic zirconium
3” x 2.75” x .75”, 2013

Figure 18: Emergent growth series 13
Copper, bloodwood, holly, wenge, black palm, garnet, citrine, assorted cubic zirconium
7.75” x 3.5” x .75”, 2013

Figure 19: Emergent growth series 13.2
Copper, bocote, wenge, bloodwood, zircote, garnet, citrine, assorted cubic zirconium
3” x 3.25” x .75”, 2013

Figure 20: Emergent growth series 14
Copper, purpleheart, diseased redwood, garnet, lemon quartz, assorted cubic zirconium
3” x 2.75” x .75”, 2013

Figure 21: Emergent growth series 14.2
Copper, holly, bocote, garnet, assorted cubic zirconium
4.5” x 3” x .75”, 2013

Figure 22: Emergent growth series 15
Copper, zircote, pink ivory, lemon quartz, assorted cubic zirconium
2.5” x 2.5” x .75”, 2013

Figure 23: Emergent growth series 15.2
Copper, thinwin, queenwood, garnet, lemon quartz, citrine, assorted cubic zirconium
4.5” x 3” x .75”, 2013

Figure 24: Emergent growth series 15.3
Copper, queenwood, holly, garnet, citrine, assorted cubic zirconium
3.5” x 2.5” x .75”, 2013

Figure 25: Diagram of installation with layout

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APPENDIX A: Guiding Conditions for the Emergent Growth Series, (amended)

1. All pieces shall be wearable.
2. All pieces in the series shall combine wood/metal.
3. The circle shall represent the beginning of the series.
4. Each successive piece will follow a constant pattern of exponential growth though x iterations.
5. Individual elements within a piece will be allowed two generations of iteration before extinction of the element occurs.
6. Extinct elements will be characterized visually as smaller in scale and with a greater proportion of chemically blackened metal than wood. Extinct elements should give the appearance of being static, calcified, and cemented in place.
7. Iterative elements will move along a vector path such that each successive element moves perpendicularly to the preceding elements vector.
8. Iterative elements will move either up or down in accordance to the line of symmetry created by the centerline of the first element.
    a. All growths above the line move up/left or up/right if free to do so and all elements below the line of symmetry move down/left or down/right if free to do so.
9. In the case of elements "running" into elements that are still vital—preference of place will be given to the more established/older element.
    a. Should this happen the younger element will move in another Left/Right direction.
10. In the case of vital elements running into extinct elements–the vital element subsumes the extinct element's place and takes on a portion of its material characteristics
11. In the event that an element is "boxed in" by still vital elements that element must move forward in space to allow for continued growth
12. All guidelines are subject to change

APPENDIX B: Glossary of Terms

Annealing: The process of softening metal. Annealing works because of the crystalline microstructure of metal. When force is exerted on metal the crystalline structure compresses and makes the metal more rigid, less ductile, and at extreme levels more susceptible to fracturing. In order to resolve this issue metalsmiths have learned that at certain temperatures the crystalline microstructure of metals will expand and relax, thereby allowing the metalsmith to continue working the piece without the risk of damaging the work. That temperature is called the *annealing temperature* and different metals will anneal at different temperatures. A side effect of annealing copper in an oxygen rich environment is the formation of oxides on the surface of the metal. These black and umber colored oxides are primarily cupric oxide (CuO) and cupric dioxide (CuO2) and are removed from the surface of the copper through the process called *pickling.*

Atomists: One of the theories the ancient Greek natural philosophers devised to explain the universe. The atoms, from the Greek for "not cut" were indivisible.

Attractor: a set towards which a variable, moving according to the dictates of a dynamical system, evolves over time.

Band Saw: A tool used in wood and metal working for cutting.

Bezel: A bezel is thin strip of metal that encases an object, usually at or just around the base of the object in order to capture it.

Bezel Setting Punch: A tool used by a metalsmith to aid in the setting of circular bezels. The tools are steel mandrels of varying sizes that have a shallow concavity milled into one end so that they can be placed over the bezel material to push the bezel closed.

Bifurcation: In a dynamical system, a bifurcation is a period doubling, quadrupling, etc., that accompanies the onset of chaos. It represents the sudden appearance of a qualitatively different solution for a nonlinear system as some parameter is varied.

Burnish: The process of smoothing or polishing something as if by rubbing.

Cosmological: Pertaining to the study of the origins and eventual fate of the universe.

Determinism: A metaphysical philosophical position stating that for everything that happens there are conditions such that, given those conditions, nothing else could happen. Determinism was born in ancient Greece with the philosophy of the *Atomists*; it was the atomists who first conceptualized of the universe as composed of tiny, irreducible things called “atoms.” However, determinism really flourished during the enlightenment, which was a cultural movement of the 17th and 18th centuries respectively.

Die-Forming: The process of giving dimension to metal through the use of a hydraulic press and a die matrix. The metal is placed atop the die, layers of soft, “squishy” material are laid over them, and the

whole sandwich of materials is placed inside of a hydraulic press. The hydraulic press is raised and the metal is then pushed into the cavities of the die. This method is particularly useful when the artist desires to add dimension to a form that has already been textured.

Draw Horse: The draw horse is a machine that provides the artist with a mechanical advantage by utilizing a series of gears to aid in pulling metal through a piece of hardened steel full of holes of various sizes called a *draw plate*.

Dynamical System: A mathematical formalization for any fixed "rule" which describes the time dependence of a point's position in its ambient space.

Emergence: The manner in which complex systems develop through the interaction of relatively simple component parts.

Etching: The process of removing metal through chemical action. The process of etching involves placing a *resist* on a plate of metal and placing the metal in a bath of acid, will dissolve away the material not covered by the resist. The resist and acid used in this work are iron-based copier toner and ferric chloride, respectively.

Flexible Shaft: An electric rotary tool with interchangeable heads used to cut and shape materials.

Heracliteans: Followers of the early Greek philosopher, Heraclitus, who maintained that strife and change are the natural conditions of the universe.

Macroscopic: Visible to the naked eye; not microscopic.

Natural Philosophy: The philosophical study of nature and the physical universe that was dominant before the development of modern science.

Patina: Patina is a surface treatment for metal that changes the color or appearance of the metal and typically results from chemical reaction. Furthermore, though the process of annealing has the effect of changing the color and appearance of metal it is not generally thought of as being a patina unless it is used intentionally for its decorative effect. When annealing is used in this way we refer to the treatment of the surface as having been given a “heat” patina.

Pickling: The process of removing oxides from the surface of a metal. Pickling is important for the removal of oxides from the surface of a metal, which is necessary if the piece is later to be soldered. In this case, the work is put in a solution of Sodium Bisulfate (NaHSO3) and water, which forms mild acid. The term “pickling” likely refers to the acid baths of previous centuries where a metalsmith would submerge his piece in a solution of vinegar and salt, much in the same way vegetables are pickled.

Resist: A barrier placed atop metal to prevent the etching process from occurring.

Roller Printing: The process by which metal is embossed through the use of mechanical rollers and an embossing matrix. In order to emboss the copper one must first construct a matrix. In this instance, the matrix used is a sheet of brass which has been etched.

Soldering: Soldering is a process used in metal fabrication that joins metals together by way of a filler metal. This process relies on the relative difference in melting temperature between the metals to be joined and the filler metal. In order to join metal through soldering the filler metal must have a melting

temperature lower than the metals to be joined. In the jewelry field soldering is referred to as silver soldering, but other fields typically refer to this method of soldering as "hard" soldering and it is quite distinct from the "soft" soldering that the general public might be more familiar with.

Stone Cutting Burrs: Stone cutting burrs are carving attachments of fluted steel that come in a variety of sizes and are shaped to mirror the angles found in brilliant cut stones.

Tube Setting: A type of setting used in metalsmithing for the capture and display of faceted stones. In order to fabricate a tube setting one must take into account the structure and size of the stone to be set. Round, brilliant-cut, faceted stones are composed of five major areas. Those areas are as follows, from top to bottom: the *table* or top of the stone, the *crown*, the *girdle* or the widest part of the stone, the *pavilion* or the material between the girdle and the culet, and the *culet* or the bottom of the stone. To begin the process of creating a proper tube setting an appropriately sized tube must be selected or made. The outside diameter of the tubing should be at least .5 mm larger than the girdle of the stone and the inside diameter must be at least .5 mm smaller than the girdle of the stone. Tubing that meets these specifications are referred to as "*thick walled"* tubing.