Boundary Expeditions:
Strategies for Creative Research at the Interface of Art and Life Science

By:
Gabriel Harp
Bachelor of Arts, Biology, Indiana University, Bloomington, IN, 2000
Master of Arts, Ecology, Evolution, and Behavior, Indiana University, Bloomington, IN, 2003

Thesis Submitted in Partial Fulfillment of the Requirements of the Degree of
Master of Fine Arts
School of Art and Design
University of Michigan
Ann Arbor, Michigan

5/11/2007

Approved by:

____
(Committee Chair's Name), Graduate Committee Chair

____
(Committee Member's Name), Graduate Committee Member

____
(Committee Member's Name), Graduate Committee Member

____
(Committee Member's Name), Graduate Committee Member

____
(Associate Dean for Grad. Ed.'s Name), Associate Dean for Grad. Ed.

____
(Dean's Name), Dean, School of Art and Design

Date Degree Conferred:

Acknowledgements
The culmination of a thesis project and three years of study is the product of many individual interactions. This would not have been possible without the guidance and support of my committee. Allen Samuels cam to my rescue early-on and asked challenging questions throughout. Bobbi Low not only provided careful attention and provoking responses, but she also made her lab available to me along with many resulting opportunity for interaction and community. I am extremely grateful to Satoru Takahashi. His support and belief in my work made it possible for me to press forward. Satoru is also the only person I have known that can anticipate my thoughts. His involvement and precise suggestions contributed to my rapid intellectual development in the last few months of the MFA program. I found Jay Lemke through pure luck–er–well actually someone said that I *had* to take his class. It was the best move I made during my MFA program. Jay was able to bring together many different threads for me and connect them in a meaningful way. For the first time, I started to feel that I had the tools to recognize solutions and respond to my many enduring questions. I am thankful for his supportive belief in my research and candid pragmatism. Indeed, each of my committee members was supportive to the end, and that is a remarkable thing. I thank them for their ability to go out on a limb. We may not have found anything groundbreaking, but that a group as diverse as we were could do it is, in the words of another faculty member, why we came here in the first place.

The only group of people more responsible for this was my cohort of MFA grads. Their willingness to show up, ask questions, and not settle was important for me. Often times, they were the only people keeping me in the game. Their antagonism kept me honest, and I hope that mine kept them honest in turn. Anne Rocklein and Anna Perricci made it worthwhile early-on. Thank you Carrie for being passionate and keeping perspective. To Toby Millman for keeping it real–whatever that means. Breant Fogt was our center–no question about it, and I thank him for that. Jim Leija kept me in my place, and that was a good thing. I wish we had done the marching band project. I particularly want to thank Chris Landau for getting more excited than me and running with it; so much of it was only possible because of Chris. Speaking of which…Alison Byrnes and Zack Denfeld made the entire experience worth doing. Though Alison may call it fighting, I always relied on her for perspective. Good friends are hard to find and I am glad that she is one of them. Zack was just willing to talk it out. So many ideas and Zack made kept reminding me what was important. He is also a good editor for me. Thanks Zack.

The Department of Screen Arts & Cultures provided me a much-needed sense of community and a job in my last three semesters. I am extremely fortunate to have been able to interact with them.

There are many others who deserve credit for doing their jobs and being involved. They affected me directly and indirectly and I thank them for their role. They know who they are, and, if they are still wondering, then they most definitely share that responsibility.

Special thanks to Anuj Kumar for giving me my first big break.

gh 5/11/2007

…

Boundary Expeditions:
Strategies for Creative Research at the Interface of Art and Life Science

keywords: art, design, interdisciplinary, life science, cybernetics, relational aesthetics, boundary objects, network entrepreneurship

ABSTRACT

Using a set of heuristics to suggest new possibilities and modes of action, my goal is to facilitate synthesis among the disciplines of art, design, and biology. I employ a systems approach to art, which seeks to integrate the development of better decision making with creative arts behaviors. I import the concepts of relational aesthetics, boundary objects, and network entrepreneurship from different disciplines as ideas of value, form, and behavioral strategy, respectively. These serve as first approximations for the ideation and implementation of creative work in conjunction with life science research. These design strategies take into account differences among the disciplines and draw from previous work in interdisciplinary pedagogy, cybernetics, organizational strategy, art history, and social semiotics. This work is intended to aid in the formation of educational and organizational objectives and positive solutions at the interfaces of art, design, and life science. After describing and discussing these design strategies, I narrate my experiences with four projects concerned with the integration of multiple disciplines and epistemological traditions (Organelle View, Engaging Evolution, Genomic Cinema, and Sui Generis). These projects formed the basis for my thinking about the aforementioned design strategies and their potential usefulness as heuristics for teaching and learning. I do not provide an analytical reading of my creative work's adherence to these heuristics. Instead, my narrative account is intended as an historical record of the social and methodological factors that influenced the work. I conclude with an exploratory model for the maintenance of art behaviors in dynamic evolutionary contexts.

1. INTRODUCTION

This work aims to set an example for and/or suggest viable strategies for interdisciplinary practice at the interface between the arts and the life sciences. "Interdisciplinary" describes creative work that "draws on disciplinary perspectives and integrates their insights through construction of a more comprehensive perspective" (Klein and Newell, 1998). What do we mean by drawing from interdisciplinary perspectives? What counts as integrative practice in the arts, in science, in academia, and in society? What comprises a more comprehensive perspective? For whom does it matter? These questions are worth considering because the answers are not necessarily straightforward ones. They affect multiple stakeholders, and they can be contentious when traditions, conventions, and other commitments are at stake. These questions are also worth considering because they support basic skill sets for the analysis and integration of difficult problems that require knowledge and cooperation from different groups (e.g. fig 1).

Figure 1. Group collaboration and transdiciplinary problem solving at the Image and Meaning 2.2 workshop at IIT, Chicago, IL. (photo credit: Dan Armendariz)

The question of what comprises a more comprehensive perspective is perhaps the easiest to articulate and the most difficult to implement. A comprehensive perspective ought to take into account the point of view of multiple entities at different points in time, whether they are individuals or computer simulation runs. In the cinema, a comprehensive perspective shows the spatial relationships of the characters and set in the form of an establishing shot. We can recognize that these perspectives are constructed and that an establishing shot could just as easily frame only a few of the many possible characters in a scene. How do we decide how to frame a scene, and how do we know if our current framing allows us to achieve the perspective we need?

Cinematographers do this reframing and will frequently zoom out to reassess what the lens can "see." They may look for relationships in the composition that have been missed on first view. Sometimes the visual field of the frame is worth recording in its own right, but more frequently, the reframing allows the cinematographer to emphasize visual cues in the composition that can help the viewer interpret the narrative. My intent is to use this document like a lens to enlarge the frame of pedagogy and practice. Perhaps it can be used to reassess the potential for new relationships among the existing contexts of creative work. Recognition is the first step.

One can recognize creative interdisciplinary work by the level of integration or synthesis it achieves. Agreement about the definition of integration is rare, but as Wolfe and Haynes (2003) point out, there are a number of ways to reasonably assess this integration including at least three general questions:

1. Does it create common ground?
2. Does it create new holistic understanding and resolve differences between disciplines through the development of a metaphor or other cognitive device (i.e. from concrete to abstract)?
3. Does it apply the new holistic understanding to, for example, an existing problem (i.e. from abstract to concrete)?

A more detailed listing of questions about integration may be found in Appendix 1. These questions serve only as a guide, and I have intended them mainly as a rubric for readers to assess this document and its own level of integration. These questions were developed to assess writing across disciplines, but they can be reasonably applied other creative practices. Other rubrics are available that, although not strictly interdisciplinary, apply to creative research in the arts (Gray and Malins 2004).

One of the pitfalls I hope to avoid with this generalized approach is a reliance on "taste." Taste is one of the factors used historically distinguish successful artwork from that which is less successful. Taste is a kind of selection and a process of elimination and amplification.

"I like only music with a 5/4 time signature."

"I like only 1970's Rococo sculpture."

"This ought to be big, or there should be more of them."

These are preferences, and while there are many reasons why they are important for the ideation and development of specialized creative work, they may be less helpful in establishing good practices and behaviors for long-term creative research. Niklas

Luhmann's analysis of art as a social system (2000) makes a similar distinction–that taste is akin to selection and that genius is related to variation. What I hope to establish with this document is a set of strategies that work to create variation rather than limit it with preference-based attributions and judgments. Variation aims to increase the probability of emergence for creative work (Luhmann 2000). One might contend that these strategies are just another form of preference, and they may well be. However, one can also prefer the absence of preference, and it is in this spirit that I work. This is not to say that benchmarks and standards for excellence are left behind. It is quite the opposite. These strategies promote higher standards of excellence that embrace diversity, richness, and cooperativeness. Making them explicit is the first step.

1.1. Strategies for Creative Research

My goal is to implement synthesis between the disciplines of art, design, and biology. My approach identifies a set of heuristics for this synthesis. These heuristics are situated within a systems approach to art, which seeks to integrate the development of better decision making with creative arts behaviors. In the document that follows, I import the concepts of relational aesthetics, boundary objects, and network entrepreneurship. These ideas of value, form, and behavioral strategy, respectively, serve as first approximations for how to engage in the ideation and implementation of creative work. These design strategies also take into account differences among disciplines. They may therefore aid in the formation of educational and organizational objectives whose aim is to find positive solutions at the interfaces of art, design, and life science.

After a brief outline and discussion of these design strategies, I narrate my experiences with four projects concerned with the integration of multiple disciplines and epistemological traditions. These projects formed the basis for my thinking about the aforementioned design strategies and their potential usefulness as heuristics for teaching and learning. Though I do not provide an analytical reading of my creative work's adherence to these heuristics, my narrative account will provide insight into those factors that influenced the creative work.

1.1.1. Relational Aesthetics

One way to resolve the inconsistencies and differences among individuals is to emphasize the relationships among individuals. Relationships effectively emphasize the nature of interactions and are the product of more than one individual (fig. 2). This suggests a relational aesthetic, which takes into account the range and quality of human relationships and their social context (Bourriaud, 2002). Relational aesthetics relies on a definition of aesthetics as "an idea that sets humankind apart from other animal species." Though human aesthetics are very different from those of other species, it is only the idea that they are different which sets

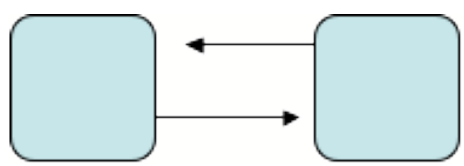


Figure 2 Diagrammatic depiction of a relationship. Each entity is involved in an exchange. This exchange is the area of focus for a relational aesthetic.

humans apart from others. A definition of relational aesthetics can be expanded to include the range and quality of human and non-human relationships as variables.

Instead of setting humans apart from others we can now take into account the numerous interactions and relationships that occur between and among humans and non-humans. If we refer back to the benchmarks for interdisciplinary integration, we are reminded to ask, "How do we create common ground and promote just relationships for each of these interactions?"

George Gessert's work with hybrids of the Iris genus are a good example of relational aesthetics in action. Gessert cultivates iris strains as art (fig 3.). The cultivation and culling of Iris plants strengthens the relationship between Gessert's own aesthetic preferences and the hybrid phenotypes or outward appearance (Gessert 1993). This is a form of artificial selection that has been used for centuries to domesticate and select organisms for human purposes–in Gessert's case, the purposes are aesthetic. The thing to remember about Gessert's relationship with the iris hybrids is that the relationship is, in many ways, the artwork. Rather than promoting an

Figure 3 A bearded iris similar to the kind used by George Gessert in his art practice.

agonistic interaction by simply picking and displaying the flowers, Gessert refers to himself as a "facilitator" which demonstrates that his role is a cooperative one. Raising hybrid Irises is a collaborative artwork involving selective decisions from the artist and developmental decisions the organism. Gessert directly affects floral morphology through cultivation. This raises issues about how human-mediated selection and so-called natural forms of selection might affect plant-pollinator interactions. Correspondingly, other relationships that the plant has (e.g. microbes and fungi in the soil) may implicate other responsive stakeholders.

Examples of human and non-human interactions that promote cooperative relationships are not restricted to the art world. The poultry industry, pressured by the demand for eggs, raises hens in crowded cages to increase industrial efficiency. This crowding increases competitive interactions, mortality, and decreased egg production among the chickens and led to beak trimming as a controversial method of reducing injury. Researchers decided that a better way to decrease mortality and increase egg laying could be accomplished by selecting cages rather than individuals (Muir 1996). In this manner, the relationships among the individuals in the cages were important to the well-being of each individual. Cages with fewer agnostic interactions also demonstrated higher egg-laying productivity. Again, the point of this example is to demonstrate how relationships themselves can be a positive area of interest and lead to a more synergistic response.

Framing the relationship between individuals rather than specific qualities of individuals ensures that individual attributes are maintained in a relationship system, despite whatever value judgments are made. This system might include humans, non-humans, or a mix of both. Mark Thompson creates art installations that allow him to share a space with bees. In Thompson's words, these serve as "models of interaction" while simultaneously creating pollination opportunities outside of the exhibition space (Gessert 1993). My own experience with these interactions comes from looking at host-parasite relationships in an aquatic snail-trematode community. For some of these communities, the levels of virulence, sickness, and mortality are rather low. For other communities, the virulence created by the interaction of the host with the parasite is large. Sometimes the history of the relationship is lengthy and governed by close, local encounters. At other times, infections are infrequent. My interventions in a snail-trematode relationship consisted of technological improvements to a dynamic and buffered ecosystem. This resulted in the ability of this host-parasite system to maintain is cohesion in a different environment–the laboratory setting (fig. 4). The host-parasite relationship that had only previously been sustainable in the wild persisted in a new artificial habitat.

Figure 4 Aquatic snails are shown here organized into several different relationship groups (all male, all female, and mixed). The aqueduct system shown here was one in a number of improvements in the ecosystem technology that fostered the host-parasite relationship in an artificial ecosystem.

Another area in which attention to relationships is important is in the practice of good pedagogy in teaching and learning. Attention to the strength of interactions fosters second-order understanding. Second-order understanding is the understanding that results from recognizing another individual's understanding (Krippendorf 2006). Strong interactions among individuals often promotes the establishment of empathy, a form of second-order understanding. This can result in better design for educational objectives and creative research that springs from strong design. Chickering and Gamson outline seven principles for good practice in undergraduate education (1987; appendix 2) that have a relational component. Three of these seven, contact between students and faculty, reciprocity and cooperation among students, and prompt feedback, clearly suggest a relational strategy. Though less explicitly connected, feedback is a very important relational device for communication and for assessing the quality and range of interactions. Feedback reinforces second-order understanding.

My point in outlining these variables is to demonstrate that relationships (intense/relaxed; local/global; friendly/apathetic, for example) can be attended to, and as all relationships need more than one individual, there may be better opportunities to find common ground between differences. In Gessert's work, an argument can be made that the iris benefits from increased cultivation. Gessert benefits from the pleasure they provide. Attention to relationships can happen through working arrangements in the classroom, lab, or studio. In this approach, the comparison is about those patterns that connect these different levels of organization–biological or otherwise. This also does not presuppose which relationships are better or have more value than others. My intention is only to reframe the boundary of the system to take more perspectives into account. Those that are less frequently incorporated (e.g. non-humans) may gain an increased stake in discussions under this model. Consequently, decision-making that implements a relational set of values would first ask about the kinds of relationships created and what qualities and/or ranges those relationship exhibit.

1.1.2. Boundary Objects

Difficult social problems often require the perspectives and integration of multiple disciplines. Relational aesthetics emphasizes relationships among individuals, but it does not address how to maintain balance or promote a positive relationship. This creates an immediate conflict between aesthetics and ethics. Because an "aesthetic" does not specifically address what the qualities of the relationship are, there is potential for asymmetrical relationships in which the concerns of individuals are subordinated to those of others. One way to resolve this conflict is to borrow a concept from sociology that helps to identify ways in which symmetrical relationships can be developed. Boundary objects:

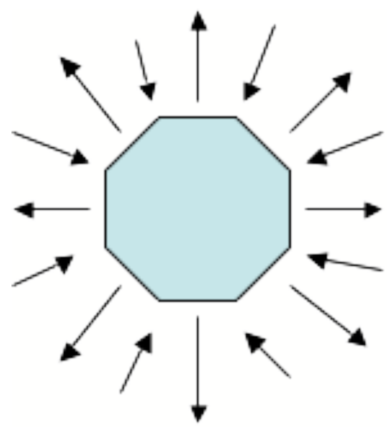


Figure 5 A diagrammatic representation of a boundary object in which the import and export of multiple interests is possible.

> "... are those objects that both inhabit several communities of practice and satisfy the informational requirements of each of them. Boundary objects are thus both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity

> across sites. They are weakly structured in common use and become strongly structured in individual-site use. These objects may be abstract or concrete... Such objects have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting communities…Boundary objects arise over time from durable cooperation among communities of practice." (Bowker and Star, 1999)

Boundary objects thus mediate cooperation while maintaining heterogeneity among the participants or actors in a cooperative network (fig. 5). In an analysis of a natural history museum community, Star and Griesemer (1989) found four types of boundary objects:

1. Repositories or ordered 'piles' of objects that do not require negotiation on the part of the participants in order to use the objects for their own purposes (e.g. databases, natural history collections, Legos).
2. Ideal types that are abstract and vague but may be adaptable for local needs (e.g. diagrams, flags, stem cells).
3. Coincident boundaries are common objects with the same boundaries but different internal contents. Thus, different perspectives can be shown along with a common referent for cooperating actors (e.g. maps, metaphors).

4. Standardized forms are methods of common communication across dispersed groups. These can be transported over long distances without loosing information (e.g. jargon, species designations).

Because relationships exist among humans and non-humans, we might ask how to create or recognize objects that exist at the juncture of humans and non-humans. Do boundary objects serve the purpose of facilitating ethical relationships between humans and those we identify as "other." To deal with this ethical question and to add yet another ordering scheme for these objects, it is worth distinguishing between objects that members of different communities can *interpret*, and objects *designed* by members of different communities. These designations need not be mutually exclusive. It is probable that objects designed by multiple communities would also be interpretable by multiple communities. The point of the designation serves only to recognize that a single individual can design objects that still resonate with individuals in other communities. In order for this to be effective, those involved in the design process need to be able to empathize with members from other social worlds. Like the relational strategy, the design of boundary objects depends on second-order understanding either at the level of an individual or as a property of a group. As a group property, multiple community members may contribute second-order understanding to the design of a boundary object. This may confer a "multivalent" quality, making it possible to interpret the object across social boundaries and among different contexts. To the extent that boundary objects can be used to communicate with other communities, they serve the ethical function of promoting understanding and empathy, even if only reinforcing the idea of a shared experience. To the extent that boundary objects are made in cooperation with members of multiple communities, they serve the ethical function of making the design process participatory.

For teaching and learning, the generation of boundary objects supplies many opportunities for putting principles of good practice into action. Because it requires negotiation on the part of the participants, making boundary objects encourages active learning and reciprocity among students. Active learning happens when students relate the concepts and processes to their own experience (Chickering and Gamson 1987). Reciprocity is achieved when goals are formed, ideas are communicated, and the boundaries of an object are actively negotiated. Time on task is another principle of good practice (Chickering and Gamson 1987), and it supports the boundary object-making process. The social pressures that come from negotiation, reciprocity, and active engagement help to focus attention on the task of making along with the reception and communication needed to accomplish the task. It also holds students accountable for their roles and responsibilities to a project. If one of the prerequisites for making a boundary object is to identify and empathize with members of different social groups, then the ethical dilemma created by a relational focus is at least partially met by involving others in the process.

Consider what this might mean for the intersections of art and biology and for the relationships of humans and non-humans. Art integrates perception into the communication network of society and demonstrates the compelling social forces of order in the realm of the possible (Luhmann 2000). Making boundary objects presents an opportunity for the communication of biology and life science to open itself to perception. Negotiation among artists and biologists would amount to continuous recalibration of the discourse and practice of biology as an attempt to match socially-desired futures with those being performed out of convention. One expected outcome is greater second-order understanding for biologists seeking to improve their explanatory power and gain a better understanding of how research is perceived. For the relationship between humans and non-humans, making boundary objects is an exercise in establishing concern for each other's concerns. The most obvious benefit comes in the form of what Nobel laureate Barbara McClintock described as "a feeling for the organism" (Keller 1983). If a biologist can empathize with the organism they are studying, then the scientist stands a better chance of making better decisions about what they are looking at and how it should be examined.

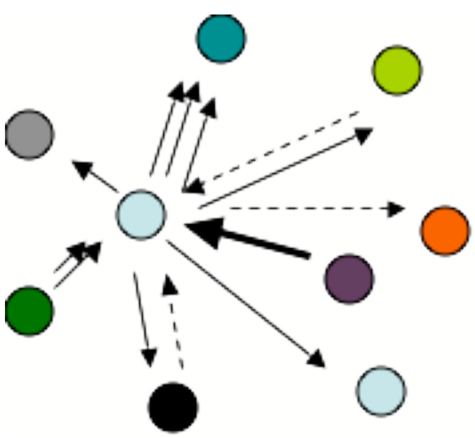


Figure 6 Diagrammatic representation of a network entrepreneur (center) with the network of interactions (periphery). Note the range and intensity of the various interactions.

1.1.3. Network Entrepreneurship

A third heuristic is the concept of network entrepreneurship. A network entrepreneur is someone who brokers ideas across structural holes in organization and networks (Burt 2003). Burt defines structural holes as areas of emptiness or gaps between social groups. The epistemological and methodological gap between the arts and sciences is a good example. According to Burt, individuals (and possibly groups) that provide vision advantages through network entrepreneurship can be thought of and related to as social capital. The work that these types of individuals do is based on the assumption that within group variation and the diversity of ideas is less than the variation and range of possible solutions achievable between groups. Network entrepreneurs are positioned (or position themselves) to draw from these different sources of variation while seeking strategic design solutions (fig. 6). If an individual in involved in designing a boundary object, the degree to which they engage in network entrepreneurship may increase the suitability of that object across different communities.

Burt (2003) recognizes four behaviors of network entrepreneurs who engage in information arbitrage:

1. Making individuals in one or both groups aware of the interests and difficulties of the other(s), and in the process, mitigate misunderstandings and confusion.
2. Transfering practices that have the potential to create value from one group in another group.
3. Drawing analogies between things that are seemingly irrelevant to one another.
4. Synthesizing new behaviors and beliefs that combine the concerns of multiple groups.

One thing to recognize is how similar the benchmarks for interdisciplinary integration are with these brokering behaviors. It seems reasonable to consider the processes of network entrepreneurship in the context of strategies for realizing high quality interdisciplinary creative work.

Examples of network entrepreneurship abound and there are varying degrees of the behavior. Someone directly involved in cinema production may reasonably be called a network entrepreneur. Cinema, by virtue of its techniques and conventions, is a collaborative medium and dependent on the actions of individuals to create a relational aesthetic that facilitates production. Recognizing the corresponding needs of the lighting crew and the camera operators is a function of the director of photography. The motion picture is a sort of boundary object, representing the work and input from a variety of individuals, groups, and organizations. In an industrial setting, producers balance the concerns of directors and distributors. On the side of the spectator, cinema appeals to multiple audiences and provides an exceptional level of empathy for the viewer to attach oneself (Koss 2006). For Soviet filmmaker Sergi Eisenstein, calling attention to the similarity between developing cells in a biological context was akin to his new formalist approach to film editing (Eisenstein 1949). This was a form of network entrepreneurship that facilitated communication and boundary crossing using an analogy.

For students, network entrepreneurship can take the form of an idealized set of behaviors that can facilitate the formation of new ideas. As a principle of good practice (Appendix 2), encouraging network entrepreneurship can communicate high expectations and promote respect for diverse talents and ways of learning. High expectations are reinforced when standards in one group can be related to standards in another. The high currency placed on writing in the sciences, for example, may carry over into the arts if they are networked. Likewise, the emphatic respect for diversity in the arts may also carry into the sciences as multiple perspectives contribute to new ideas.

If the goal is to build bridges between art and biology, network entrepreneurs are a key to unlocking new opportunities. By actively promoting connections and translating across these social boundaries, network entrepreneurs establish relationships and build cohesion within and between individuals.

1.2. Summary

For creative work at the interface of art and life science, attention to the relationships, cross-border objects, and networks of opportunity can bring balance and closure to the work. This opportunity exists because the conflict created by the demands of scientific and artistic modes can bind individuals into impossible situations. The relationship between art criticism and contemporary art is similar; continuously shifting preferences in the "art world" make artistic responses to these preferences a zero-sum game. Reponses that follow preferences may not be recognized because preferences have shifted from earlier positions. In order to move beyond this situation, creative work must precede the existence of preferences. In essence, creative work must exploit opportunities to establish new preferences either through an appeal to the cognitive architecture of the brain or some other mechanism. Importing and exporting ideas, concepts, behaviors, and patterns from other sources is one way to establish so-called novelty because the difference it creates may be an important attribute.

These situations exist in part because the disciplines rely on different criteria for evidence. This is also their strength. These different criteria can expand the context for creative work and enlarge the domain of inquiry. However, for an individual student to make things that are artistically satisfying and appropriately scientific, these different criteria have to be recognized as assumptions before they can be overcome. The first task is to consider the context. In today's social context, scientific knowledge formations hold the upper hand if one intends to advance an argument (though there are counter-examples depending on the local community...global warming for instance). Does scientific reasoning provide answers comparable to those of artistic imagination? Are they symmetrical? Asymmetrical? What forms would a symmetrical or asymmetrical response take? Gregory Bateson proposed solutions to these problems as part of his theory of the Double Bind (Bateson 1972). By expanding the question to take into account each of the participants constraints or assumptions, Bateson suggested that a reframing or recontextualization can take place. From this level of understanding, it becomes possible to identify what tactics need to be used to address or foster a particular relationship. If science makes a particular claim based on the objectivity of its

Figure 7 Jan van Eyck's Man in a Red Turban (1433) connects to the viewer through the gaze. This relationship establishes an opportunity for recontextualizing the image with the viewer as part of the work.

scientists and validates this claim through the assumption that the observations were unimpeded, then an opportunity lies in one's ability to recognize the relationship between the observer and the observed.

Contemporary artists have recognized the relationship between the observer and the observed since at least as early as the fifteenth century when Jan van Eyck painted his Man in a Red Turban in 1433 (Kress and van Leeuwen 1996; fig. 7). The gaze of the man in the portrait establishes a connection with the viewer. In doing so, the opportunity for reframing the relationship becomes possible with each viewer's interaction.

In the methods section that follows, I provide narration for four my projects. These are presented from my personal perspective as creative strategist and network entrepreneur. Instead of viewing the methods section as the logical outgrowth of the preceding section, I would encourage the reader to consider the introduction as an epilogue to this work. To do otherwise would suggest that prescience had played a role in the development of the work. Rather, the summary strategies for creative work were derived from an examination of the concepts, failures, achievements, and processes involved.

2. METHODS

2.1. Organelle View: Networks and Localization

By the time I enrolled in the School of Art and Design in the fall of 2004, I had started thinking explicitly about how genes are represented visually for scientific and public communication purposes. This was stimulated by my interest in multilevel selection. Multilevel selection theory suggests that natural selection[1] can act at multiple levels of biological organization including genes (e.g. Hamilton 1963). I became interested in how individuals perceive genes both as an *indicator* for natural selection and in public *discourse* about genetics. I was also interested in how these two different modes of communication could be merged. This issue of gene representation also came about while studying the statistical methods used to analyze distributions of gene functions. In the yeast genome, duplicated genes have a significantly different distribution of functions compared to other genes (Conant and Wagner, 2003; Harp, unpublished data). I recognized that gene duplication, like other forms of repetition, might have a particular relevance for postmodern critical theory (e.g. Fig. 8) and, correspondingly, the art community.

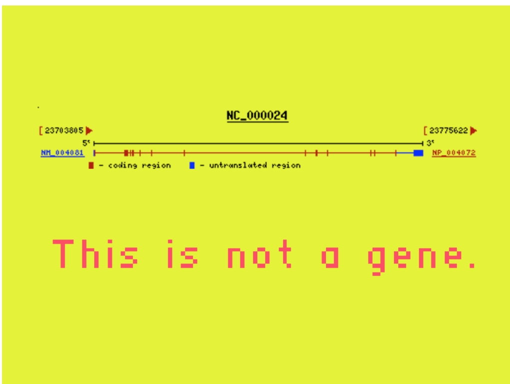


Figure 8 This is not a gene. (Gabriel Harp 2004) makes a comparison between a verbal description and the representation of a gene as a minimalistic, machine-produced image**.**

As I started to explore how to engage both contemporary art and life science, gene functions were an intuitive area to focus on. They were well categorized and had a standard ontology (Gene Ontology 2000). Thus, it was conceivable that a visual vocabulary could be found (fig. 9). I also had a general interest in science education and the relative cognitive accessibility of bioinformatic resources. I decided that

[1] Natural selection is a dynamic process or organic evolution that depends on the existence of heritable variation. Environmental pressures favor differential reproduction based on this variation. As a result of this differentiation, changes occur in the rage of variation.

visual investigations of gene function were warranted and could create some resonance between the scientific research community and the public.

I approached Anuj Kumar at the Life Sciences Institute at the University of Michigan. I thought that perhaps we could have a conversation using the concept of "gene function" as a source of understanding and common ground. Indeed we had a wonderful discussion, and though nothing specific came from the meeting, I sensed an opportunity.

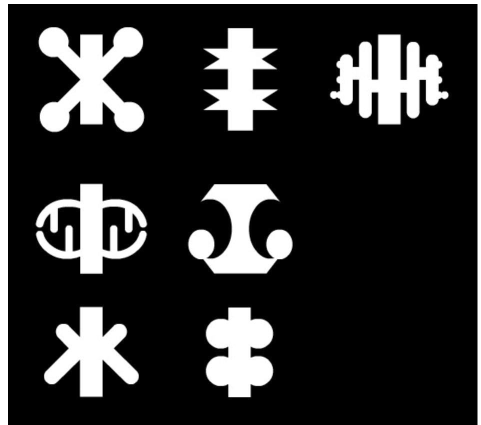


Figure 9 These OntoGlyphs are pictorial representations of gene ontology information. Many of the OntoGlyphs were developed by [the Blueprint Project] although some new ones were designed by the Organelle View team.

Shortly thereafter, the Grants Opportunities for Collaborative Spaces (GROCS) project made its first call for proposals in late 2004. GROCS was looking for rich media projects that were networked collaborative and interdisciplinary. Here is a draft of the letter I wrote to Anuj about the opportunity:

> Dear Anuj, I am thinking about assembling a team to tackle the visualization project we spoke about during our meeting. You thought it might be good to have an interactive visualization of gene products in the subcellular domain- potentially to augment the organelle database. I think I may have found a way to help that happen. The Digital Media Commons and the office of the provost (http://www.ummu.umich.edu/grocs/) have grant monies available to students to support collaborative work in rich media. The grant carries substantial

collaborative and monetary benefits for the students involved. The proposal deadline is Nov. 15th , and the project would commence at the start of the winter term. I wonder if you would be willing to serve as a faculty advisor for the project. So far, the team would consist of myself (an evolutionary biologist and artist) and a colleague (artist/designer) here in the School of Art and Design's interdisciplinary MFA program. We would also seek to fill two key roles with interested undergrads or grad students. I imagine someone from information visualization, bioinformatics, or 3-D modeling would have the most interest and/or expertise, but we would consider anyone interested. The project as I conceptualize it would be to build a 3-d model of a generic cell displaying all relevant organelles. The subcellular locations of gene products would then be built into the model using information obtained from Organelle DB. Users would be able to query their genes of interest and have them appear as part of the model. I am somewhat uncertain about how to go about this. Thus, this would be a true collaboration for those involved. The next step would be to send out a project description to interest groups. I could then develop the proposal to completion if we are able to find collaborators. Please pass the word along if you are aware of anyone that might be interested.

Cheers, Gabriel

One of the people I contacted was Barbara Mirel. Barbara teaches information visualization for the School of Information. I met her while shopping for classes in my first semester of the MFA program. Now that I think back, the Organelle View project (as it came to be called) was my second "backup" proposal. I had asked Barbara to be an adviser for my first project–a semantic network of research about the evolutionary maintenance of sex and recombination. I wanted to see if the primary methods used (population genetics, game theory, and quantitative genetics) were hubs of activity in the network and if so, how they were connected. Barbara suggested one of her former students as a possible collaborator.

I developed two proposals. The following is text excerpted from the proposal we developed for Organelle View:

> "Organelle View is a project to create an interactive visualization of subcellular protein localization data. The bioinformatics tool, Organelle DB, already represents the data as text-form resource. This project will take those data and transform them into 3-dimensional cell model, complete with the cell's component structures. Users will be able to query the data to obtain their locations on a visual cell map. The project will be distributed via the web, but opportunities such as the CAVE, Geowall, or 3-D printing may enhance the value of this project for a wide audience of specialists and laypersons. The team comprises a faculty member in the Life Sciences Institute, two graduates students in the School of Art and Design, and a graduate student in the School of Information.
>
> Organelle View is a collaboration-based project aimed at building an interactive resource for the visualization and discovery of organelle proteins and subcellular structures. The project takes its lead from an existing resource, Organelle DB <http://organelledb.lsi.umich.edu/> (Appendix 3). Organelle

DB is an online database that compiles protein localization data from organisms spanning 154 organisms with emphasis on the major model systems: S. cerevisiae, A. thaliana, D. melanogaster, C. elegans, M. musculus, and human proteins as well. These data indicate where proteins are located in the cell. It presents an organized catalog of the known protein constituents of more than 50 organelles, subcellular structures, and protein complexes.

We will use the existing data from Organelle DB to build a protein localization network based on the spatial (and possibly temporal) architecture of a eukaryotic cell. The current interface for Organelle DB queries the database using form fields and returns text descriptions of cell localizations for gene products. Organelle DB is similar to many bioinformatics tools because the visual language is restricted to text fields, menus, and lists. We view these text-based tools as a constraint to discovery and association with the data. We envision a three-dimensional model of a eukaryotic cell that allows a user to see data in its relationship to cellular space. This cell model would represent common features of the data (e.g. subcellular locations or functions) while deemphasizing the specific morphological characteristics of different organisms. Despite these basic functional characteristics, we would also like to examine conventional representations of the cell. Interactive visualizations allow users to determine the dataset(s) they wish to view. They can also have chance interactions with the data by mining through large datasets. Depending on user interests, he or she could enter sets of gene names

> that correspond to a particular hypothesis. They could see the distribution of those genes in a cell. They could also test, for example, if those genes are distributed in the same fashion across multiple taxa for a comparative view.
>
> The intended audience is quite broad. We predict that highly specialized researches will benefit from the expanded functionality of Organelle View. The freedom to make visual associations as opposed to textual associations provides an opportunity to discover subtle variation in the data. Because this dataset is a part of the central dogma of biology (DNA>RNA>Protein), the dynamic Organelle View visualization could easily become an important presentation tool for communicating results and classroom teaching. However, Organelle DB will be a fairly simple tool to use, accessible to many via the web, and abstract enough so that fundamental connections between cellular structures and nomenclature can be made. We predict that this simplicity will appeal to secondary school students and teachers that require a greater sophistication of practical biology without the extraneous complexity of text-based symbols."

Networks and localization were two important concepts for the content and the creative process of the Organelle View project. Networks were emphasized in the development of relationships that could help to advance project goals and make visible the semantic network of relationships in the database. Localization provided the other side of networks. Much of the work for Organelle View took place in the

GROCS design lab. Having a neutral territory to explore the issues related to the project was an important opportunity. The experiences of our working group crossed with other groups in the GROCS lab. This provided additional opportunities for growth and reflection, particularly during occasional design reviews of our project concepts and strategies. As the creative strategist, I wanted to create a project that would have a measure of conceptual symmetry between the concept and processes of implementation. Our primary interest in the visualization was to identify the localizations of gene products in the cell during the yeast cell cycle.

In addition to a working implementation of Organelle View, the project yielded a research paper describing the project (Wiwatwattana et al. 2007) and a new partnership between two of the project team members based on their experiences. I consider this partnership the most important aim for my own future projects. My involvement in future projects should directly or indirectly create self-sustaining opportunities for others. This is a fundamental principle of good design that serves as an objective for future endeavors.

2.2. Endless Forms: Engaging Evolution

Towards the end of summer 2005, a situation was starting to emerge as an opportunity to bridge activities in the School of Art & Design with activities in other parts of the university. A few of us had been discussing metaphors for biology while anticipating the upcoming evolution theme semester sponsored by the College of Literature, Science, and the Arts. We recognized that little, if any, presence would be given to the visual arts as a way to engage with the topic of evolution. We also recognized that the School of Art & Design was in a unique position to make a gesture to the community with its WORK gallery space on State Street. The location was perfectly situated between the commercial and academic spaces of the university and downtown Ann Arbor. We thought that perhaps a link could be made between the visual arts, the scientific activities, and public outreach during the semester. Funding was sought and a call for work broadcast to the local and international community. The call asked for creative work that addressed the concepts and themes of natural selection, sexual selection, genetic drift, mutation, and migration. These decidedly microevolutionary metaphors and themes would serve to link together artistic work and scientific concepts.

The exhibition entitled, "Endless Forms: Engaging Evolution" brought together artists from varying educational levels and communities to create and stimulate dialogue within and among communities and disciplinary affiliations (Appendix 4). For the community, my goal was to provide access to visual narratives of evolutionary mechanisms rather than evolution writ large using verbal narratives. According to Evans (2001), "The dissemination of evolutionist and creationist beliefs…is a testament not only to their public availability but also to their cognitive appeal." My thinking was that if the cognitive appeal of an often-misunderstood field like evolutionary biology could be increased through art and good design principles, then perhaps some of the negative perceptions associated with these ideas could be revisited and revised.

I was always interested in how visual art could work as a metaphor and support discussions about evolutionary biology. Having the exhibition at the semicommercial, semi-public, and semi-academic space meant that people from many different walks of life could participate. This was an effort to increase the frequency with which different points of view would encounter each other. During the exhibition, a case was being decided in Federal District Court that concerned the teaching of intelligent design in schools. Evolutionary biology was in the news and a topic of public discussion. I had hoped that different communities might find some common ground in the work presented and find opportunities for stimulating discussion.

2.3. Deconstructing the Genome with Cinema

Deconstructing the Genome with Cinema (hereafter Genomic Cinema) is a project that I started to think about in 2003. It began as a question about the similarities between art systems and biological/genetic systems. The concept linking the two systems was repetition. I am interested in how repetition is used in "art" systems as a possible signal and/or indicator of biological factors. Repetition writ large was an unmanageable concept to employ in an analytical context, and somewhere along the way, I was able to limit the scope of the investigation to a comparison of cinema and genomics.

> "Evidence from language, history, and form suggest an analogy between the cinema and the genome. [I describe] relationships between cinema and the genome and point to opportunities for discovering unmarked categories within the genome and new methods of representation. This is accomplished by evaluating existing metaphors presented for the understanding of genetics and

> revealing how current scientific understanding and social concerns suggest a cinematic alternative. The formal principles of function, difference, similarity, unity, and development mediate discussion and serve as heuristics for investigating creative opportunities." (Harp, 2007; © ISAST; Appendix 5)

Jay Lemke's course, Nature, Culture, Justice, in the School of Education helped me to contextualize this work within critical theory and social studies of science, technology, and epistemology. As a result, I developed a greater recognition for the roles that metaphors play in cognitive development, education, and discourse. Making these metaphors explicit is one step towards understanding how scientific ideas inform public perception. This project is one component of a long-term research endeavor that continues to investigate the constraints and possibilities for representing genes.

2.3.1. Formalism and Complex Systems

More recently, I have started to wonder if repetition, as a boundary object or bridge between genetics and cinema, is an indicator of how form-based characteristics can be translated into systems with mathematical descriptions. The formal principles used in my comparison of cinema and the genome are taken from discourse in film and other arts. There is a correspondence between these formal principles and other systems. For example, the formal properties of similarity and difference are analogous, respectively, to the homogeneous and heterogeneous characteristics of agents in other systems. The correspondence of other formal properties and systems characteristics is less clear, but we can recognize how formal systems change over time to attain equilibrium–or not. Suzie Gablik (1977; 1984) eloquently argues for the presence of stable equilibria in art systems over time and views particular style

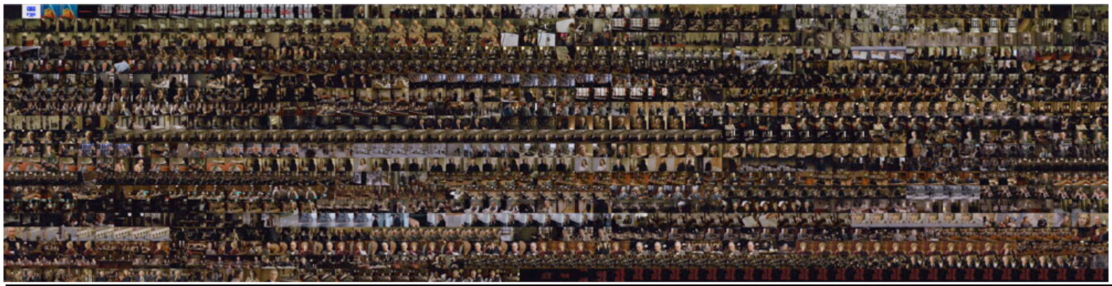


Figure 10 Development and organization in The Verdict (Lumet 1982). Using the Cinema Redux (Dawes) method in the Processing environment, a single frame was captured for each minute of screen time. Much like the the hierarchical view provided by various genome projects, the resulting image reveals visual motifs and structure in the organization of the film.

systems as evidence for the ongoing development of art behavior. We can identify factors such as market forces or preferences that regulate stability through feedback. Formal systems, particularly in time-based art, have a developmental schema (figure 10). Formal systems are also characterized by their unity, which may come from the overall color scheme, as in Sidney Lumet's The Verdict (1982; figure 10). Different levels of organization are also present. An impressionist or pointillist painting suggests emergent or hierarchical levels in the system (fig. 11). Such hierarchies are an important pattern in biological systems from genes to individuals, families, populations, and communities.

Other characteristics do not appear to have analogs to each other. Function in formal systems describes the purpose that a particular element serves within the organization of a creative work. Agents in adaptive systems mix randomly and non-randomly. One question I am left with is the extent to which relational strategies, boundary objects, and network entrepreneurship promotes non-random mixtures of agents in a system.

What are the interpersonal consequences for genomic cinema and how does it create opportunities? One of the consequences of a new analogy for the genome is that cinema suggests ways to promote empathy for things that humans have difficulty perceiving. Genes are as good an example as any. If someone can create a form that establishes the point of view of genes as similar to that of human, then the outcome is familiarity and resonance between them. As the differences between humans and genes decreases, this kind of empathy becomes important for establishing the natural rights of individuals that may be mixtures or hybrid forms. As perception allows us to recognize genes and genomes in new forms, many more opportunities are created for us to lie about ourselves and each other. In the process, the mechanisms of evolution will act and react to these displays serving up new creative opportunities for biological form and function.

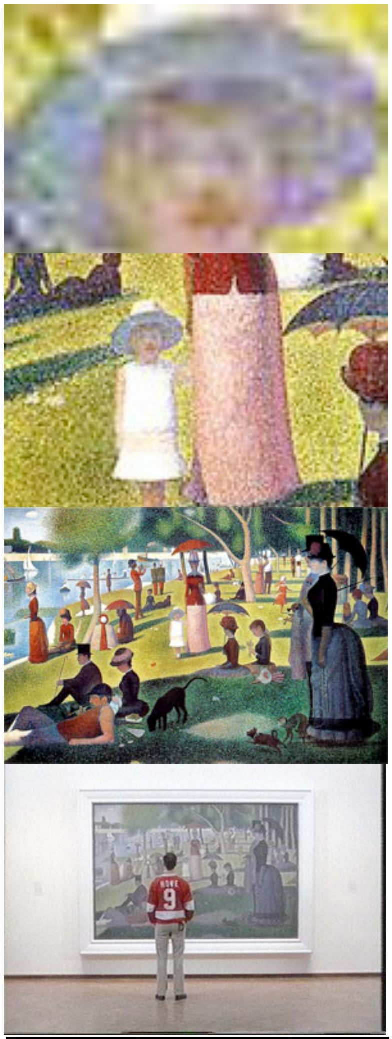


Figure 11 Extreme close-up of Georges Seurat's *Un dimanche après-midi à l'Île de la Grande Jatte* (top). A medium shot follows in which social relationships become more evident. The full composition starts to reveal relationships among all of the individuals. Finally, a macro view of Seurat's painting in the context of the Chicago Institute of Art and the film, Ferris Bueller's Day Off (Hughes 1989)

2.4. Systems Analysis: *Sui Generis*

2.4.1. Systems Art?

Early in my MFA program I developed two systems models for the work I was doing at the time (Appendix 6). Rather than create an un-contextualized set of relationships, I wanted to understand if there were any symmetry between molecular genetic processes and social ones. I also wanted to create something that could bridge information between molecular biology and art. Creating a systems diagram was one way to explore these possibilities and produce a document that could ostensibly be used for discussion across groups. By making the direct comparisons between components of each project, I was looking for similarities and differences between the processes. This analysis was directed as a method for communicating the core of my creative practice, strategy, and interests. Much later, these notions became know to me formally as systems art. Systems art, according to Francis Halsall (2005), has "an interest in the aesthetics of networks, the exploitation of new technology and New Media, unstable or de-materialised physicality, the prioritising of non-visual aspects, and an engagement (often politicised) with the institutional systems of support (such as the gallery, discourse, or the market) within which it occurs."

I recognized the connections between my work and systems art very late in my MFA program sequence. By that time I had already started to develop a project based on my early intuitions that would combine my interests while responding to local social pressures for acceptable "art" projects. Two assumptions helped determine what was acceptable. That art holds a separate place in the social sphere was one assumption ("I know it when I see it."). Another assumption was that the art had to be a physical form, based in part on the prior history of art in Western traditions. These assumptions were implicit; they came from within the local community that was attempting to undergo a transformation from modernist and post-modernist conceptions of art and design to more dynamic prospects and larger contexts.

2.4.2. Morphogenesis

Sui generis, which means "of its own kind", began in late autumn 2005. At that time, I was frustrated by my inability to make lasting connections with members of the school's art and design community. I suspect that my frustration came from my inability to clearly communicate to others the commitments I maintained during the process of art making. My commitments came from many different sources, though few, if any, directly related to my own emotional history and desires. My commitments were analytical, and they were bounded by my personal experience and desire to make integrative work. These commitments were partially the result of my training in biology, which meant that I was often unable to find solutions to visual problems because the solutions available to me held internal contradictions. One of the things I still hope to discover is a sense of how artists and designers make decisions that either allow them to maintain or dissolve such contradictory commitments. For me, these decisions are important to the maintenance and integrity of varied interests. How does one identify expert behavior and decision-making in art and design? In my biology training, I was accustomed to the frequent interactions and crosstalk that transpired during the normal course of the day in a shared laboratory space. These informal communications resulted in the transfer of information about the culture of the lab group and the organization of the discipline as a whole. In the art studios, I found these interactions to be a different sort. Meetings and crosstalk happened in a common space, away from designated workspaces. Sources of information about art and design came from fellow students. While this was valuable in other ways, it was difficult to identify those behaviors that would be valuable over a long time period and could lead to a successful engagement (e.g. a faculty position) in art and design. This situation had a large impact on my decisions during the art-making process.

The first instance of *Sui generis* came in the form of a list (Appendix 7). This was a list of the most important and relevant work I had been thinking about, had made, or was in the process of making up to that time. Some of it was finished; most of it was not. It was a collection of my past and present memories, ideas, and concepts and their basic instructions for how to make them into what I understood as "art." Though the list is itself a very abstract rendering of the concepts and ideas, it served one very important purpose. Because I had been frustrated by my inability to bring many of the differentiated projects to completion, the list served as a sort of developmental checkpoint or bounding tool for connecting the diverse project trajectories. This became a process of pathogenesis (Whoops...Freudian slip...literally…I typed *pathogenesis* when...). What I meant was morphogenesis. This process of bounding and relating initiatives and concerns is at the center of my daily practice.

The process first started to manifest into *Sui generis* as a factor analysis. Wikipedia describes factor analysis as "a statistical data reduction technique used to explain the variation among observed variables in terms of fewer unobserved variables called factors." I already had a full list of "observed variables" in the form of current, future, and past projects, and I started to group them according to recognizable factors: chapel, laboratory, nursery, and carnival. These categories were determined beforehand and thought by me to be important epistemological variables. By this I mean that they were more closely related to each other, historically and conceptually, than any of the individual observed variables. Appendix 8 contains a table that coordinates these connections as abstract relationships. Column headings describe the domain specificity for each set, while entries along the rows are similar to eigenvectors in a covariance matrix. Eigenvectors are like translation tables that allow one set of relationships to be reframed into another set based on some scaling (f)actor. Covariance describes how two or more sets of variables vary in response to each other. My introduction to these relationships and scaling came from trying to understand how an organism's physical form varied in response to its genetic constitution as the result of environmental influences.

One method that was important for me was work in plant community ecology that involved the measurement of gradients. In order to understand how a species is distributed relative to other species and environmental factors like rainfall or elevation, the locations of individual plants are plotted along a spatial transect. In this way, comparisons can be made to distinguish what factors are most important for the distribution of the individual plants. Some methods may suggest that the dominant

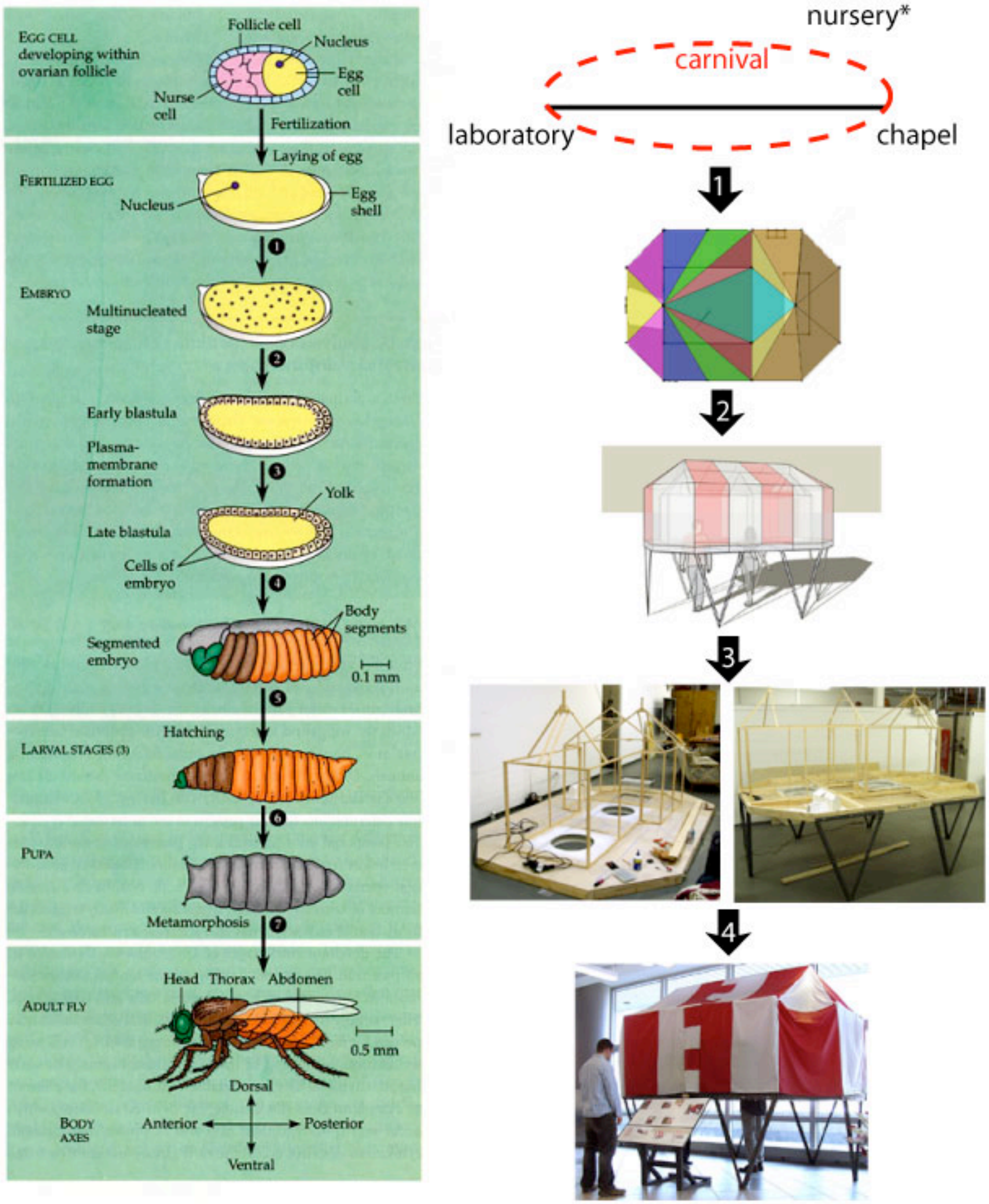


Figure 12 Narrative diagrams depict the development of form in biological (left) and artistic (right) systems. Developmental changes in both cases proceed as distinctions in form indicate qualitative differences. For the Sui generis installation the first instances of form materialized as a set of important factors in the conceptual focus of the work (1). Subsequent body plan formation (2) and three-dimensional design (3) set the stage for the transition from internal structure to tectonic installation (4).

species has a strong effect. Others may indicate an environmental effect. What I recognized and started to compare was the similarity between these community-level ecological gradients for plants and the cellular-level molecular gradients that form during organismal development.

The development of form has long fascinated biologists. Developmental biologists have traditionally taken a holistic approach to biology by training their attention on morphogenetic fields which are collections of cell that form a particular organ (Gilbert 2006). When molecular biology and genetics eclipsed developmental biology in the mid-twentieth century, these fields fell out of fashion, but there has been a resurgence in the concept since the 1990's because of its ability to link together th actions of genes an evolution (Gilbert et al. 1996). In a developing organism, it is thought that the patterns of gene expression start to organize into distinct fields or gradients in the embryo. In this way, distinct forms begin to emerge and structure the organism (fig. 12). The identity and timing of gene expression differs for different fields (e.g. anterior-posterior/dorsal-ventral). However, at some early point in the development of an organism, the information and entities involved share a certain unity. The factoring and refactoring of this initial set is what gives structure and diversity to a particular form.

When I started to organize together many different ideas, projects, and concepts into a set of reduced factors: chapel, laboratory, nursery, carnival, I arranged these four factors along axes (fig. 12). "Chapel" and "laboratory" occupied an axes with each at one polar end. The arrangement of these factors as opposites was due to their reliance on different standards for truth. Chapel, being a religious construct, relied on faith. Laboratory, being a scientific construct, relied on reason. "Carnival" and "nursery" performed different functions and had no axes, per se. The "carnival" factor bound together the rest of the elements and provided the initial sensory cues for perceptual recognition. "Nursery" was a scalar factor that regulated the others and had an interest in the formation of perception and cognition. The physical embodiment of these ideas is illustrated in Appendix 9.

Suzi Gablik took up these ideas of a scaling factor and cognitive development in her book, Progress in Art (1977). Gablik employed Jean Piaget's stages of cognitive development to describe historical changes in the style and form of art. Her approach applied Piaget's explanations of genetic epistemology, which attempts to explain changes in knowledge in an evolutionary context, to the history of art. According to Gablik (1977), Piaget's idea is that common laws of development organize cognition among individuals and constrain the evolution of knowledge in fields as different as art and science. From a methodological standpoint, Piaget sets out a "common denominator" that facilitates comparison. The idea that individuals undergo developmental changes in cognitive ability during their lifetimes is easy to recognize, as are the stylistic and formal changes art has undergone during its historical progression. What is less clear is how individual-level stages of development scale to population-level symbolic changes. There does not appear to be any evidence that the evolution of human cognition underwent a developmental series similar to that of an individual–that is, an analogy of all human development to a single lifespan. Nonetheless, Gablik's argument remains persuasive. One reason for this is that art is a form of symbolic inheritance that maintains its formal structure across generations. Biological forms typically respond to environmental pressures. This is not to say that the environment does not affect artistic forms. Indeed, the environment may affect perception of artworks by occluding a high-fidelity reading of the symbol or by even changing the meaning of the symbol through shifting social or contextual clues. The fact that art provides a stable form and transcends generations may be a clue to some sort of scaling or feedback that takes place between individuals, cognitive changes, and population-level processes. This would be a form of feedback that biological forms, by themselves, would not be able to generate.

As a final note, establishing symmetry was important part of the project. The aesthetic and perceptual value of symmetry is well documented. One example of my implementation was that the total number of factors had to be four. This number led to other sources of meaning, and it became a source of cognitive bias that allowed me to judge the artistic decision as a sound one. Subsequent readings of the work made the instance of "4" more significant while facilitating connections to other sources of meaning. I could also reasonably conclude that the number was a form of boundary object that, due to its abstraction, provided the opportunity for multiple interpretations. It was, in essence, a convention shared by many people and used in varying circumstances. Many other examples of this symmetry can be found in the conceptual design of the project–too many to explore in detail. Nonetheless, each symmetrical pairing was formed out of a concern for relationships and that each factor ought to have some dimensional companion.

2.5. Future Directions: an epilogue to the epilogue

The previous examples aimed to incorporate a systems perspective in the development of the creative work. In many cases, relationship-based variables provided creative restraints and opportunities. A systems analysis of art within the context of human evolutionary biology suggests some compelling directions for future study. Coupled with non-human systems, the functional role of art in society has the potential to stimulate a unlocked diversity through the interaction and coordination of relationships. Establishing the relationship between creative behaviors and reproductive success should one aspect of this project. Another is to identify sources of symbolic variation and stability among different cultures that can possibly provide evidence about the reproductive value of contemporary art either now or in th recent past. Gablik's argument suggests that art, like other humans behaviors, is subject to the constraints of biological evolution. What is the role of signal/receiver bias relative to latent preferences in humans? That is, do people prefer particular forms unconsciously? How are genes recognized as symbolic forms or as discrete indicators of biological variation? What role do boundary objects play in this process? Are they possible sources of cognitive bias because they facilitate many readings? How does the environment and learning influence these readings? If supported, an evolutionary hypothesis for the maintenance of art would resolve many long-standing conflicts in art criticism including debates about the intrinsic value of art as well as its role in maintaining biological diversity among humans.

References

Bateson, G. Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology. University Of Chicago Press. 1972.

Bourriaud, N. Relational Aesthetics. Trans. Pleasance, S. & F. Woods. Les Presses du Reel. 2002.

Bowker, G. C., and Star, S. L. Sorting Things Out: Classification and Its Consequences. Cambridge, MA: MIT Press. 1999.

Burt, R. S. Structural Holes and Good Ideas. American Journal of Sociology. 110: (2004). p.349–399.

Chickering, A. W., and Gamson, Z. F. "Seven principles for good practice in undergraduate education" American Association of Higher Education Bulletin. (1987). p.3-7.

Conant, G.C., Wagner, A. GenomeHistory: a software tool and its application to fully sequenced genomes. Nucleic Acids Research. 30 (2002). p.1-10.

Eisenstein, S, The Cinematic Pronciple and the Ideogram in Film Form. New York, NY: Harcourt Brace Jovanovich. 1949.

Gablik, S. Progress in Art. New York, NY: Thames & Hudson,Rizzoli. 1977.

Gablik, S. Has Modernism Failed? New York, NY: Thames & Hudson,Rizzoli. 1984.

Gene Ontology: tool for the unification of biology. The Gene Ontology Consortium. Nature Genetics 25: (2000). p.25-29.

Gessert, G. "Notes on Genetic Art," Leonardo Vol 26, No. 3 (1993).

Gilbert, S. F. Developmental Biology, 8th ed. Sinauer Associates, Sunderland, MA. 2006.

Gilbert, S. F., J. M. Opitz, and R. A. Raff, "Resynthesizing Evolutionary and Developmental Biology," Developmental Biology, Vol. 177, No. 2, 357-372 (1996).

Gray, C. and J. Malins. Visualizing Research: a guide to the research process in art and design. Ashgate Publishing Limited. Aldershot. 2004.

Harp, G. Deconstructing the Genome with Cinema. Leonardo 40:4 (2007).

Halsall, F. Observing 'Systems-Art' from a Systems-Theoretical Perspective. Proceedings to the 21st CHArt Annual Conference. Vol. 8, Theory and Practice. London. 2006.

Keller, E. F. A Feeling for the Organism: The Life and Work of Barbara McClintock. New York: W. H. Freeman and Company, 1983.

Kress, G. and T. Van Leeuwen Reading Images: The Grammar of Visual Design. London: Routledge 1996.

Klein, J. T. & Newell, W. H. “Advancing Interdisciplinary Studies.” In W.H. Newell, Ed., Interdisciplinarity: Essays from the Literature (pp. 3-22). New York: College Entrance Examination Board. 1998.

Koss, J. On the Limits of Empathy. The Art Bulletin. 88: (2006). p.139-57.

Krippendorf, K. The Semantic Turn: a new foundation for design. CRC Press. Boca Raton, FL. 2006.

Luhmann, N. Art as a social system. Stanford University Press. Stanford, Calif. 2000.

Muir, W. M. Group selection for adaptation to multiple-hen cages: selection program and direct responses. Poultry Science 75: (1996). p.447-458.

Star, S. L. and J. R. Griesemer. Institutional Ecology, 'Translations,' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-1939. Social Studies of Science 19: (1989). p.387-420.

Van Leeuwen, T. and C. Jewitt eds. Handbook of Visual Analysis. SAGE Publications Ltd. London. 2001.

Wiwatwattana, N., Landau, C.M., Cope, G.J., Harp, G.A., & Kumar, A. Organelle DB: an updated resource of eukaryotic protein localization and function. Nucleic Acids Research. 35 (2007). D810-D814. PubMed fultext article

Wolfe, C. R., and Haynes, C. Interdisciplinary writing assessment profiles. Issues in Integrative Studies 21: (2003). 126–169.

Appendix 1

1. Does it Create Common Ground? (Category 1)
    - Present a clear rationale for taking an interdisciplinary approach.
    - Assumptions from more than one discipline are made explicit and compared.
    - Compares and/or contrasts disciplinary perspectives.
    - The problem is explicitly defined in neutral terms that encourage contributions from more than one discipline.
    - Creates a common vocabulary that can be applied to the object of study.
2. Does it Create New Holistic Understanding? (Category 2)
    - One or more novel models are presented.
    - A preexisting model is used or applied in a novel way.
    - A new theoretical interpretation or understanding is presented which explicitly draws on more than one discipline.
3. Does it Apply the New Holistic Understanding? (Category 3)
    - The new metaphor, interpretation, or model is applied to a new situation or phenomenon.
    - The new metaphor, interpretation or model is applied in a novel way to an established "text," situation or phenomenon.
    - The new metaphor, interpretation, or model is explicitly tested through observation, data collection, or lived experience and reflection.
    - The new metaphor, interpretation, or model is used in a significant way to guide inquiry.
    - The new metaphor, interpretation, or model is tested by using it to solve a problem.

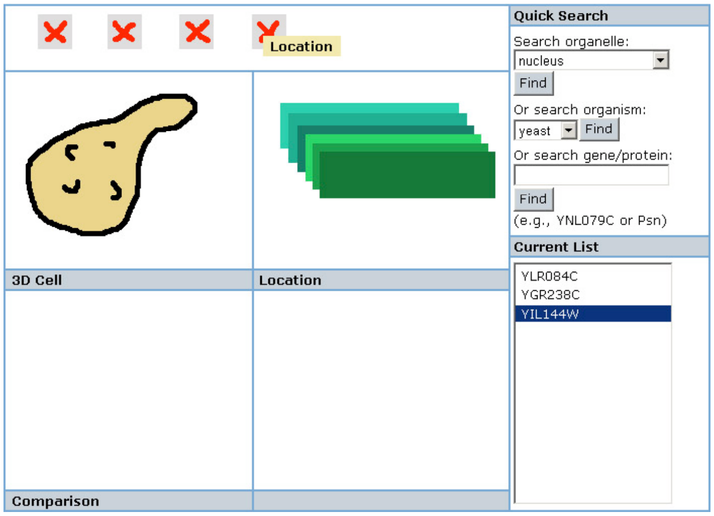
from: Wolfe, C. R., and Haynes, C. 2003. Interdisciplinary writing assessment profiles. Issues in Integrative Studies 21, 126–169.

Appendix 2

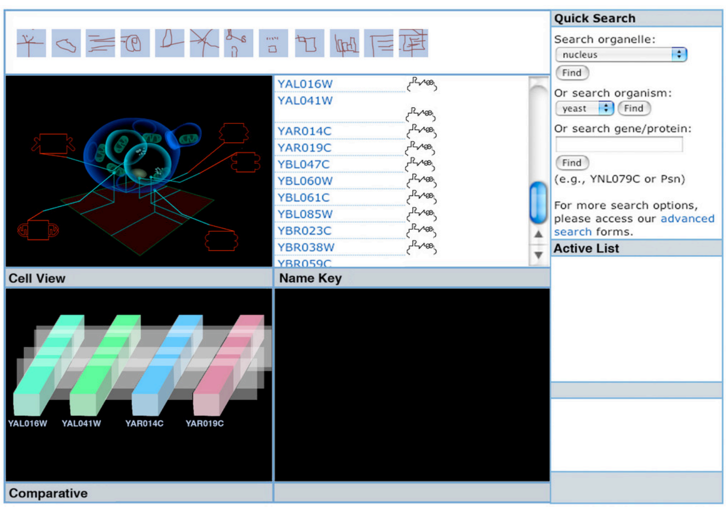
Seven Principles of Good Practice.
Arthur W. Chickering and Zelda F. Gamson (1987) "Seven principles for good practice in undergraduate education" American Association of Higher Education Bulletin pp.3-7

1. Encourages Contact Between Students and Faculty
    - Frequent student-faculty contact in and out of classes is the most important factor in student motivation and involvement. Faculty concern helps students get through rough times and keep on working. Knowing a few faculty members well enhances students' intellectual commitment and encourages them to think about their own values and future plans.
2. Develops Reciprocity and Cooperation Among Students
    - Learning is enhanced when it is more like a team effort that a solo race. Good learning, like good work, is collaborative and social, not competitive and isolated. Working with others often increases involvement in learning. Sharing one's own ideas and responding to others' reactions sharpens thinking and deepens understanding.
3. Encourages Active Learning
    - Learning is not a spectator sport. Students do not learn much just by sitting in classes listening to teachers, memorizing pre-packaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences and apply it to their daily lives. They must make what they learn part of themselves.
4. Gives Prompt Feedback
    - Knowing what you know and don't know focuses learning. Students need appropriate feedback on performance to benefit from courses. When getting started, students need help in assessing existing knowledge and competence. In classes, students need frequent opportunities to perform and receive suggestions for improvement. At various points during college, and at the end, students need chances to reflect on what they have learned, what they still need to know, and how to assess themselves.
5. Emphasizes Time on Task
    - Time plus energy equals learning. There is no substitute for time on task. Learning to use one's time well is critical for students and professionals alike. Students need help in learning effective time management. Allocating realistic amounts of time means effective learning for students and effective teaching for faculty. How an institution defines time expectations for students, faculty, administrators, and other professional staff can establish the basis of high performance for all.
6. Communicates High Expectations
    - Expect more and you will get more. High expectations are important for everyone -- for the poorly prepared, for those unwilling to exert themselves, and for the bright and well motivated. Expecting students to perform well becomes a self-fulfilling prophecy when teachers and institutions hold high expectations for themselves and make extra efforts.
7. Respects Diverse Talents and Ways of Learning
    - There are many roads to learning. People bring different talents and styles of learning to college. Brilliant students in the seminar room may be all thumbs in the lab or art studio. Students rich in hands-on experience may not do so well with theory. Students need the opportunity to show their talents and learn in ways that work for them. Then they can be pushed to learn in new ways that do not come so easily.

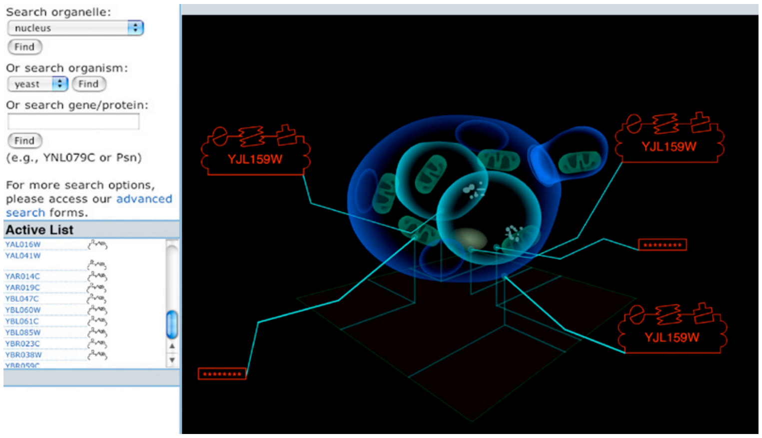
Appendix 3



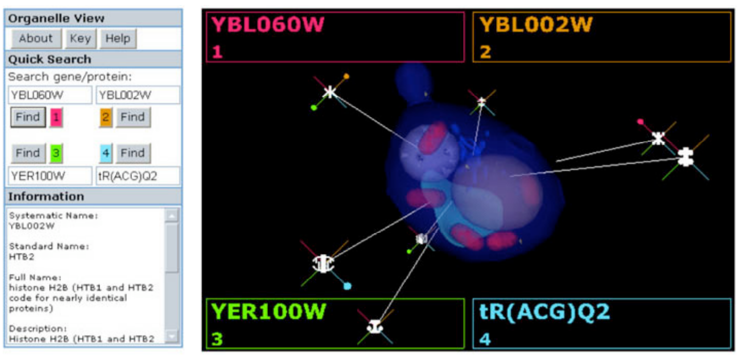
One of the earliest mock-ups of the Organelle View interface. Early commitments to search functions, "cell-as-navigation", and other conventions are evident.



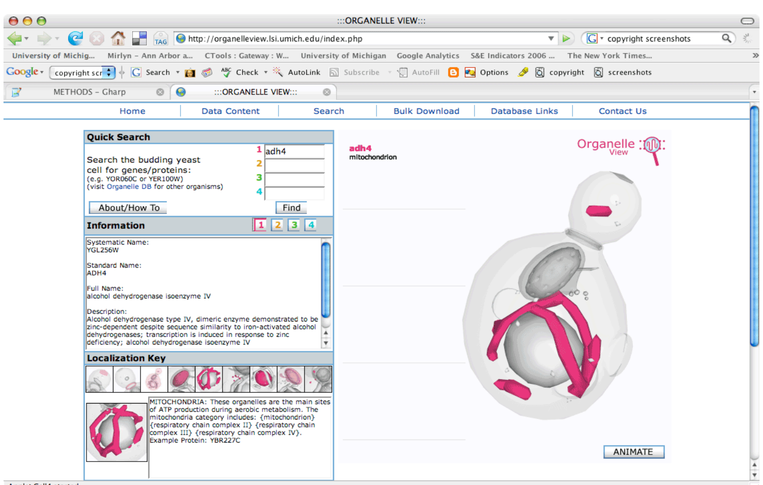
The yeast cell visualization takes form as Flash sketches. OntoGlyphs serve as early shorthand for communicating gene functions.



The cell becomes the primary interactive and information component. Unfortunately, the database form field conventions remain.

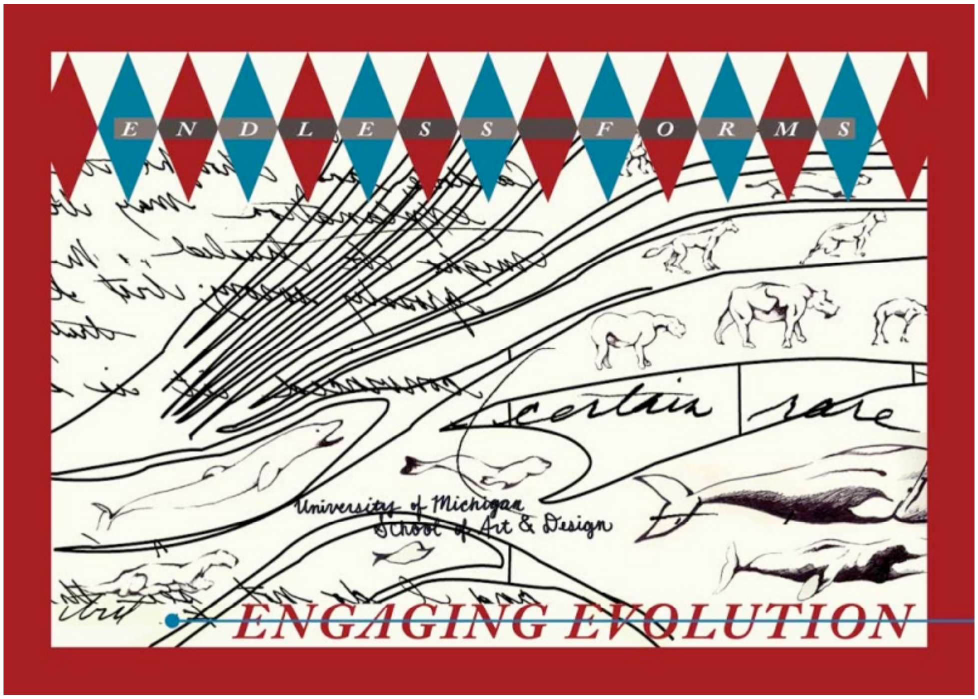


Full implementation of the cell animation in Virtual Reality Markup Language (VRML). The database is now visually dynamic.



Visual look-and-feel redesign. Organelle View graduates from GROCS and becomes the project of *nformation design.*

Appendix 4



The exhibition announcement used carnival-like motifs combined with illustrations from early texts about evolution.

Unwrapping one of the artworks.

View of the exhibition from inside WORK.

Community members visit the exhibition and take in the work. Objects were submitted by artists from six countries and included amateurs, students, faculty, and established professionals. Image © Samara Perlstein

Appendix 5

Deconstructing the Genome with Cinema

Abstract
Language, history, and form suggest an instructional analogy between cinematic and genomic forms. Here I describe these relationships and point to an opportunity for discovering unmarked classes in the genome and new methods of representing the "genetic unseen." Along the way, I take into account preexisting metaphors and reveal their inadequacy in light of current scientific understanding and social concerns. This analogy affords the familiarity of a cinematic model to structure our investigations of "the genome."

We create and identify new forms of meaning through cinema, but because art and genetic systems share similar aesthetic properties and functions [1], perhaps we can interpret biological patterns using film as a discovery tool. Here I describe an approach to film form that uses an organism's genetic sequence (hereafter, the genome) as a template for the creation of conflict and meaning in the filmic language. The goal is to use the cinematic form to explore the genome by extending an analogy between them. I seek these formal comparisons as an analogical tool to derive similarity between patterns in the genome and the language of films. Genomics (the study of the genes and their interactions) and cinematic practices refer to natural objects and processes. In the cinematic mediums, these may be realized as films, analog or digital video, or video games, and for genomics, the mediums often range from molecular to digital objects.

I motivate the following comparison with competing metaphors used to describe and animate the genome in public discourse. Historical relationships suggest convergences that have occurred in the field of representation to make this analogy possible. Finally, I make formal comparisons between cinema and genome, structure and grammar, and discuss their implications.

Modeling Life

Concerned with how to represent their ideas, discoveries, and scientific models to specialists and a non-technical public, biologists, designers, artists, and journalists turn metaphors to integrate and describe natural processes (e.g. fig. 1). These scientific models are often judged on their appeal to consistency with other belief systems, models, and metaphysical commitments [2]. This search for consistency leads some biologists to recognize that creative media, like living organisms, are sources of information for studying life. Computer simulations, for example, allow biologists to test their assumptions *in silico* and demonstrate life processes using structured mathematical languages. Yet around the time these computational tools began to emerge as a tool of biology, influential embryologist and art critic C.H. Waddington emphasized the similarities among forms created by people and those created by nature. As a comparative biologist, Waddington used static objects like bones and fossils to infer biological causality, but he implicated film's unique ability to record change as an observational tool for studying growth and form.

> "When, or if, cinema becomes the most important technique of artistic creation, and movement one of the fundamental raw materials out of which beauty is created, then, perhaps, we shall have to turn our attention to the aesthetic characteristics of developmental processes." [3]

Waddington's concern for aesthetics was representative of many biologists, including Charles Darwin, who based their standards of evidence for evolution on comparatively similar structures among organisms. However, unlike many, Waddington looked beyond organic forms for scientific inspiration. In film, Waddington recognized an "organicist holism" [4] that characterizes irreducible complexity in an organism. Since these early comparisons, elements of film have been further articulated, as has the genetic basis of organismal development. Consequently, we can build on the success of these descriptions and recognize that the cinema and the genome share structural similarity.

Analogy and reconfiguration are rich sources of new hypotheses. Analogy (and its younger colleague, metaphor) provides a scaffold of natural experience to support and extend our understanding of a concept, create similarities, and transform reality [5]. The use of this analogy (that the genome and genomics is equivalent to film and cinema; e.g. fig. 2) is consistent with other uses of analogy; it has the potential to reconfigure both domains because it allows for the identification of otherwise unmarked classes without the restrictiveness of a literal translation [6]. However, there is a key distinction in this choice to suggest an analogy rather than a metaphor. Attributing a certain amount of homology to structures that are otherwise dissimilar, analogy implies deep connections and/or causative relationships that come with practical description and understanding. When we use an analogy as opposed to a metaphor, we take the first step towards an analytical synthesis of differences in a comparison of seemingly unrelated structures. Indeed, the cognitive stage seems to be set for a systematic comparison between the genome and cinema.

Language foreshadows this post-genomic-cinematic comparison. Metaphors such as editing, splicing, and sequencing permeate molecular biology and cinematic discourse as the first clue. Computational tools for investigating genomic sequences use such names as CINEMA and THEATRE [7] to project themselves as holistic tools for comparing and discovering hidden sources of meaning while further suggesting the broad applicability of this analogy as a bioinformatics tool. In evolutionary biology, analogy substantiates claims of convergent evolution– when, for example, the spines of succulent Euphorbias of Africa and the Cacti of the Americas have comparable morphology without being closely related (fig. 2). Wing structures in bats and birds also demonstrate how similar functions have arisen independently from similar evolutionary pressures or developmental constraints. Just as we can ask what forces or constraints give rise to and maintain structures in birds, mammals, and plants, we can ask how similar sources of meaning are made using film and the genome.

Genomic Metaphors

It is necessary to recognize that several persistent metaphors guide popular (mis)conceptions of the genome. In the years surrounding the "revelation" of the human genome sequence, many critics have counseled the application of metaphor in public discourse and discussed the social and scientific implications of their uses [8]. Since then, cultural, media domain, and metaphor analyses have examined the outcomes of scientific and political discourse about the genome with the public [9].

The most enduring metaphor appears as a "map", which serves the useful function of being applicable to a range of situations across wide swaths of time. Maps appeal to our visuospatial cognitive abilities– though not always equally across the sexes [10], and yet maps are invoked anytime significant unknown conceptual territory looms on the horizon. Genetic maps are fetishized objects [11], post-genomic artworks, useful for displaying and intervening in the processes that spawned their production, and for strategizing impending invasions into unknown lands or, in this case, bodies [12]. Hall interprets the spatialization effects of genetic maps as the organization and structuring of sets of “truths” which tend to exclude alternative biological processes and social contexts [13]. Ultimately, maps may be useful tools for those doing the research, but for generalized public understanding, a diversified array of representations may be more appropriate and engaging.

Another metaphor suggests that genetic maps are “intelligently designed” to guide us during a journey complete with twisting paths and moral judgments. When it comes to describing the genome in its biomedical research context [14], the “Holy Grail” is the Grail of Christian journey metaphors. However, like other navigational metaphors, this one has its limitations because it does not refer to anything inherently spatial [15]. This specific legend implies a search bound by moral fortitude, focused on an elusive object, and motivated by revelations of God’s divine message through promises of eternal life [16]. Perhaps we ought to take from this or any “journey” metaphor is the notion of process, whereby we are constantly in the process of constructing “the genome” from a complex meeting of physical, cultural, and mental representations.

Still, if God’s messages populate the “mapped genome”, how can we read and interpret them? The notion that the genome is a code to be solved, cracked, translated, and deciphered is a pervasive metaphor of science and public discourse [17]. “Codes” can be easily extended to include languages that need to be translated from or into blueprints, recipes, and books. “Translation” permeates molecular biology in reference to processes that assemble protein molecules from messenger RNA. Book and blueprint metaphors have turned the genome into an object rather than an ongoing series of questions.

Metaphors are used to account for divine revelations “told” to humans, but what if they also refer to God’s incarnation within humans? Van der Weele reveals some sources of metaphor that situate DNA as *the* causal mechanism for organismal development, and argues that these metaphors exclude the effect of the environment as a causal mechanism for biological development while impeding a more nuanced and complete understanding of nature [18]. When DNA is placed in this role, it contributes to masculinist, power, and control metaphors that sustain a worldview in which someone has to be in charge– all despite the fact that DNA is a relatively inert molecule [19].

The difficulty with these metaphors is that, for some, these paths point to an intelligent designer. Offering implicit promises of fulfillment, proclamations touting codes, maps, and “holy grail” language do as much to situate intelligent design with the public as any school board-ordained middle school textbook ever could. Even without religious undertones, codes and books imply that a single author has written them. The pressing question remains, “Who wrote the book of life?” How does a public resolve these mixed messages from a scientific community that is complicit with these metaphors when it benefits biomedical research funding and aghast when intelligent design proponents challenge contemporary evolutionary theory and funding? These examples expose the genomic metaphors and their affiliations with intelligent design arguments.

Precedents: New Opportunities

Despite these historical precedents, many creative individuals have developed alternative methods for communicating the genome’s complexity in a pluralistic society. Music continues to be a welcome departure from traditional genomic metaphors with explanations rooted in jazz [20] and software-mediated translations of genetic sequence data into aural representations [21]. Still, music relies on a text or code that, again, only a skilled group can translate. Music employs repetition to achieve basic functions of meaning, and in that sense it is more akin to the genome than any of the aforementioned metaphors. Ohno and Ohno conceptualized the transdisciplinary meanings generated by viewing genomic repetition as a source of inspiration and novelty.

> "'Whereas ordinary mortals are content to mimic others, creative geniuses are condemned to plagiarize themselves' is my shorter, albeit inarticulate, version of what Van Veen said in Ada by Vladimir Nabokov. Indeed, it seems that vaunted geniuses seldom invented more than one modus operandi during their lifetimes, and even civilization has largely been dependent upon plagiarizing a small number of creative works; e.g., the multitudes of Gothic churches can be viewed as pan European plagiarism of the abbey church of St. Denis and/or the cathedral at Sens. This is not surprising for new genes *sensu stricto* have seldom been invented. Evolution rather relies on plagiarizing an old and tested theme; the mechanism of evolution by gene duplication. ... this principle of repetitious recurrence pervades both the construction of coding sequences in the genome, which can be regarded as being representative of nature, and musical composition which can be regarded as the most abstract and therefore the most intellectual expression of nature." [22]

In joining the concepts of linearity and plagiarism, Ohno and Ohno ignite a relationship between two of the most ancient and derived expressions of nature and humanity, that of the genetic code and music composition. Both of these forms demonstrate contemporary awareness of disguised originality– that repeating existing forms provides the substrate for all new meaning. This is a basic feature common to both cinematic and genetic systems.

Metaphors for the genome include visual arts processes. Plant developmental biologist Enrico Coen compares gene organization and structure to the steps involved in the development of a painting [23]. Similarly, McMeekin [24] has shown how Diego

Rivera's *Detroit Industry* (South Wall) and "Healthy Human Embryo" in the courtyard of the Detroit Institute of Arts compares the industrial and collective development of an automobile with the embryonic development of a human being. Avise [25] concludes that the functional collaborations characterized by "an interactive community…may be especially useful and stimulating at this time." Because we are searching for new working metaphors for the genome [26], the social collective seems to be finding a niche as an *ad hoc* committee [27] or a cast of characters [28]. These new metaphors emphasize cooperation and point again to the ideas of process, interaction, and context.

We are unlikely to unhinge ourselves from previous metaphors that rely on a text, but we can incorporate new insights and scientific concepts. What began as a map, a text, and a journey, can now be complemented with sound, visuals, and cooperation among individuals and groups. Of all cultural forms, few bring these elements together as well as cinema.

Historical Convergence

By 1929 the study of embryos and their development foreshadowed genomic biology. Scientists sought alternative explanations for a gene concept that was rapidly being incorporated (and ultimately confirmed) by Darwinian evolutionary theory [29]. Soviet biologists were at the heart of the debate, and it was in 1929 that Soviet filmmaker Sergei Eisenstein made the comparison that, "The [cinematic] shot is a montage cell (or molecule)" and "just as cells in their division form a phenomenon of another order, the organism or embryo, so, on the other side of the dialectical leap from the shot, there is montage [30]." This was a telling analogy using well-established observations from embryology to describe his new approach to cinematic form. As Gilbert and Faber have pointed out [31], the filmic language used by Eisenstein was similar to those of his contemporary embryologists who were consistently making comparisons across developing cells. Indeed, embryology has a set of visual preferences distinct from other forms of biology [32], and with film, it shares an aesthetic similarity.

Hannah Landecker [33] also considers Eisenstein's analogy along with the statement by Walter Benjamin [34] that the cell is, "more native to the camera than the atmospheric landscape or the soulful portrait." Like Waddington, photography is recognized as the appropriate domain from which to study embryogenesis. Landecker goes on to reveal how the "teeming presence" of the cell in early cinematic culture was part of scientific and cinematic concerns over how to represent life. Recalling Kracauer's [35] connections between the gaze of cinema and its origins in scientific filmmaking, Landecker describes how early scientific films became critical to the development of the cinematic form. She illustrates the shared desires of scientists and filmmakers to describe the shape of life and its minute relationships using film, and maintains that Kracauer's kinship model of science and the cinema is not borne out of any shared attempt to record "objective" reality. Early cinema and life science was forged through its shared, changing visual and written languages to share the reality of another dimension, based on the psychological representation of language processes rather than representation of objects such as the cell or genome [36]. It was from these early relationships that new artistic and scientific ideas were generated.

Genomic Cinema

The principles of function, repetition, difference, development, and unity promote structure and provide the grammar for film [37] and genetic languages. Here I give just a few examples as a brief orientation to this formal comparison.

Function

Genomics is divided into two areas. Structural genomics is concerned with the DNA sequence organization, while functional genomics identifies the roles that individual genes play and their interactions within the genome as a whole. An example of a gene's function is its role during cell division or in the transport of materials. Gene functions are indicative of their cooperative roles during the life of a cell or organism, and they may serve multiple functions. Some heat shock proteins are involved in metabolism, DNA repair, stress responses, and a cell's sensing of its environment.

Similarly, shots in a film perform various functions that drive the story. In Victor Fleming's The *Wizard of Oz* (1939), sequences of Toto motivate Dorothy's journey to and from Oz, but Toto's grey color also provides a counterpoint to the bright color of Oz and provides a link to the black and white beginning and end scenes of Kansas [38]. The Ferrari sequences in *Ferris Bueller's Day Off* by John Hughes (1986) provide a means of transportation to and from the city as well as the source and resolution of conflict between Cameron and his father. Functions are descriptions of the tasks that sequences or shots play in the overall plot, be it genome or film.

Difference (with a slight aside):

Playing with repetition and using the concept of difference, Sergi Eisenstein created cinematic meaning within the philosophical framework of dialectical materialism. Dialectical materialism is the philosophical idea that the physical processes of the natural world regulate conflict and synthesis between opposing or different forces. This view was extremely important for embryologists in the 1920s through the 1950s [39] and implicit for some evolutionary geneticists [40]. Eisenstein held the belief that art is conflict and arises from the "evolutionary synthesis" of an interaction between two contradictory opposites. This s*ynthesis* of opposites is an essential concept because it recognizes that benchmarks, thresholds or, at least, endpoints, demarcate the unfolding story [41]. A story for developmental biologists is an organism, and to filmmakers, it is the cinematic experience for the viewer. Likewise, contemporary evolutionary and developmental biology recognizes that conflicts in an unfolding organism stem from the relationships and interactions with its historical past, physiological present, and ecological futures. As such, dialectical materialist methods have been and continue to be advantageous for understanding dynamic relationships in nature and evolutionary processes [42] because they allow for multiple comparisons among many different sources of meaning.

Development

We can think of development as the change or progression of a story or organism. Developmental change is dependent on the patterning of repetition and difference in the genome. Homeotic gene regions organize pattern formation in plants and animals as complexes that reside in close proximity on the chromosome [43]. These loci are thought to have diversified from multiple chromosomal duplication events (i.e. repetition), while their role in development is temporally and spatially collinear. This means that gene expression (when it is turned on or off) is correlated in time and space with a gene at the "beginning" of the complex expressed in one region of the body early in development, while a gene at the "end" of the complex is expressed both late in development and in another body region. This would seem to indicate that gene expression is linear with respect to the location of genes along the chromosome [44]. These homeotic loci demonstrate modular repetition that, due to temporal changes in the timing and organization of their expression, can yield expansive diversity in form and function. Thus, it is rare for genes involved in pattern formation to take part in only one developmental decision.

Pattern formation happens similarly in cinema. Interestingly, both biologists and film analysts use segmentation in an organism and a film, respectively, to analyze patterns of development. Bordwell and Thompson [45] describe how, in the *Wizard of Oz*, Professor Marvel furthers the development of the film. At the beginning of the film Dorothy tries to visit him, while at the end he visits her. He is also present as the Wizard of Oz, representing her hopes to return home. Thus, in the development of the film from journey (away from home) to search (for the Wizard) and finally mystery (Who is the Wizard of Oz?), Dorothy basically encounters the same individual. This development happens because that individual is expressed differently according to other repetitions (e.g. relationships with family) happening in the film as well as temporal (story progression) and spatial differences (Kansas vs. Oz). The resulting interplay of function, similarity, and difference create dynamics that contribute to the development of the cinematic form.

Discussion

These examples emphasize similarity of form (e.g. fig. 4). Framing genomic architecture against the cinematic form suggests that the creation of meaning in artistic domains can transgress the constructed boundaries of science and vice-versa. The benefits are partially perceptual, allowing us the opportunity to recognize gaps in our knowledge. For genetic counselors, public health practitioners, biologists, politicians, artists, and others, genomic cinema can be a useful analogy for communicating knowledge, addressing public concerns, and building empathy among individuals.

Like all analogies, this one has its limitations. As a film instructor, I can attest to the difficulties that many students face when first learning about the systematic interpretation of cinematic form and meaning. However, the success of the medium clearly demonstrates how easily communication can occur at some level. Genomic cinema also creates the possibility of uncertain futures that may be as problematic as those we currently face. Genetics and visual media are currently experiencing a shift towards digital encoding, storage, and control. Synthetic biologists have begun to explore these issues with microorganisms and their genetic architecture acting as genetic switches or devices. As these experiments unfold, questions need to be asked about how we translate the genome and turn its stories into a visual and/or mechanistic vocabulary.

Ultimately, the goal of using cinema to deconstruct genetic architecture is to reveal structures and relationships that become suppressed by the static uses of metaphor.

By supplanting filmic repetitions, layers, and interpretations in place of existing genomic metaphors, an expanded set of representations may be found in a direct appeal to the range of human sensations (fig 5.). Furthermore, when current cultural debates use metaphors that contribute to religious and scientific misunderstandings, we ought to examine our uses of language and suggest alternatives. The genomic cinema analogy suggests such an alternative and provides creative research opportunities for investigating dynamic grammars in the cultural context and hopeful vision of our time.

Figure Captions and Images

Figure 1
László Moholy-Nagy, *The Machine of Emotional Discharge,* 1920. (© The Moholy-Nagy Foundation <http://www.moholy-nagy.org>)

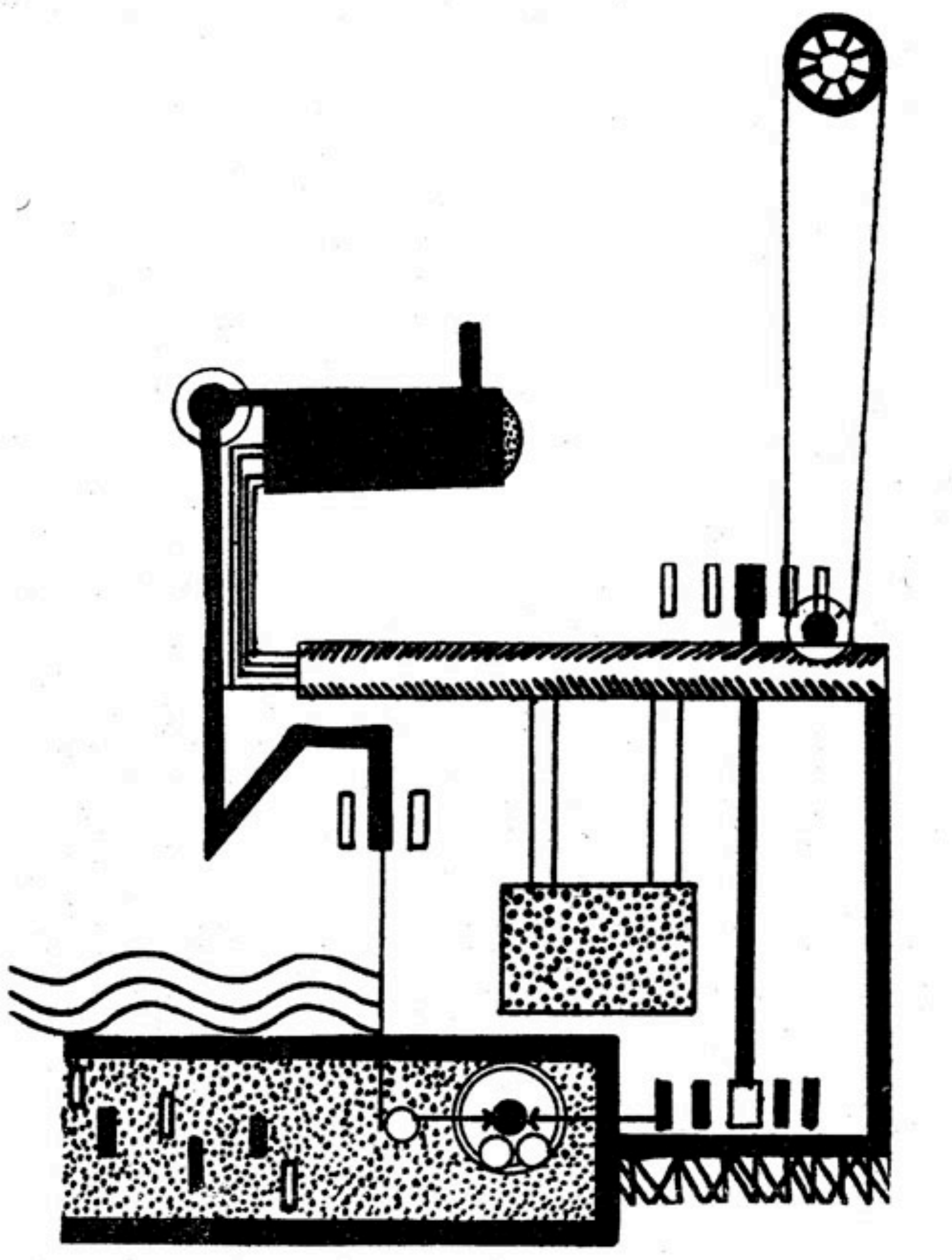


Figure 2
Gabriel Harp, *Chromosoma*, 2006. (©Gabriel Harp) In this installation view, a visual analogy is made between folded lengths of 35mm movie film and chromosomal structure. New pairings of unrelated images may be found in accidental crossovers of the film with itself.

Figure 3
A visual comparison is usually the indicator of convergent evolution. A new world variety of succulent Cacti (left) and an old world variety of Euphorbia (right) have similar spine and stem morphology.

Figure 4
A visual comparison demonstrated by the minimalist database representation of the human mitochondrial genome (National Center for Biotechnology Information Map Viewer) and a digital video-editing track copied from Final Cut Pro (Apple, Inc.). Even though both sequences can be linear, they are often compiled and realized non-linearly.

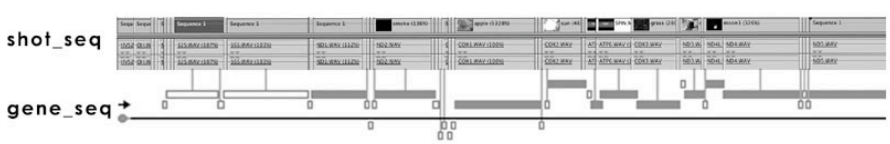
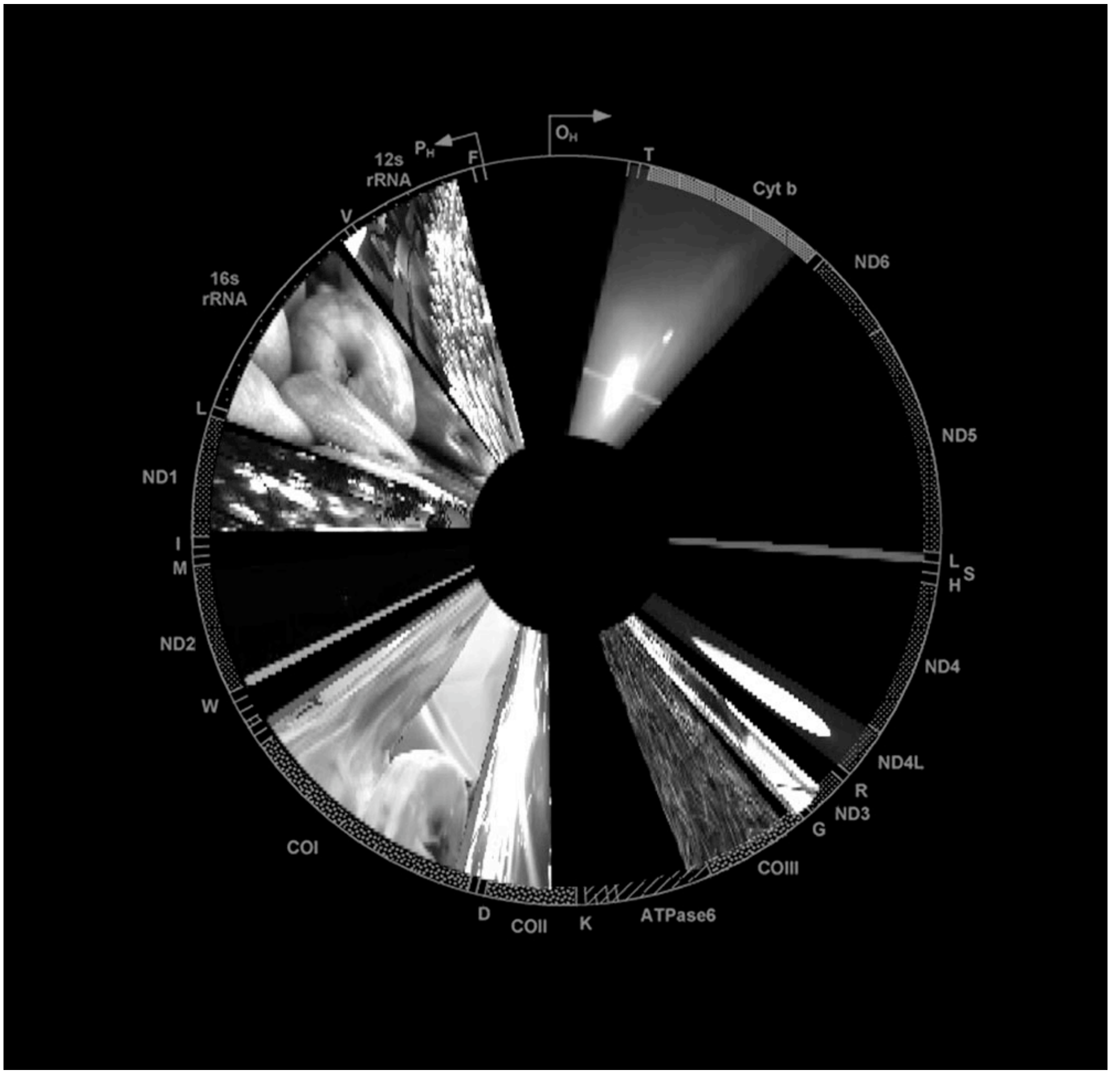


Figure 5
Gabriel Harp, *mtMAP*, 2004. (©Gabriel Harp) In this video, the human mitochondrial genome is used as a template for the creation and organization of symbolic images.



Works Cited

1. Levy, E. K., "Repetition and the Scientific Model in Art," Contemporary Art and the Genetic Code, Art Journal, Vol. 55, No. 1, 79-84 (1996).

2. Cartier, J., J. Rudolph, and J. Stewart, The Nature and Structure of Scientific Models: Working Paper (Madison, WI: The National Center for Improving Student Learning and Achievement in Mathematics and Science, 2001) p. 5-6. Available at (http://www.wcer.wisc.edu/ncisla/publications/reports/Models.pdf).

3. Waddington, C. H, “The Character of Biological Form” in Aspects of Form. L.L. Whyte ed. (London: Lund Humphries, 1960) p. 44.

4. Gilbert, S. F., and M. Faber, “Looking at Embryos: The Visual and Conceptual Aesthetics of Emerging Form” in Aesthetics and Science: The Elusive Synthesis, A. I. Tauber, ed. (Boston, MA: Kluwer Academic Publishers, 1996) p. 138-139.

5. Lakoff, G. and M. Johnson, Metaphors We Live By (Chicago, IL: The University of Chicago Press, 1980) p. 117, 145-155.

6. Elgin, C. Z., "Creation as Reconfiguration: Art in the advancement of science," International Studies in the Philosophy of Science, Vol. 16, No. 1, 13-25 (2002).

7. Parry-Smith, D. J., Payne, A. W. R, Michie, A. D. and Attwood, T. K., "CINEMA - A novel Colour INteractive Editor for Multiple Alignments," Gene, Vol. 211, No.2, 45-56 (1997 and Edwards, Y. J. K. , T. J. Carver, T. Vavouri, M. Frith, M. J. Bishop, and G. Elgar, "Theatre: a Software Tool for Detailed Comparative Analysis and Visualization of Genomic Sequence," Nucleic Acids Research, Vol 31, No.13, 3510 - 3517 (2003).

8. See Petsko, G. A., "The Rosetta Stone," Genome Biology, Vol. 2, No. 5, 1-2 (2001); Kay, L. E, Who Wrote the Book of Life? A History of the Genetic Code, (Stanford, CA: Stanford University Press, 2002); Condit, C. M., B. R. Bates, R. Galloway, S. Brown Givens, C. K. Haynie, J. W. Jordan, G. Stables, and H. M. West, "Recipes or blueprints for our genes? How contexts selectively activate the multiple meanings of metaphors," Quarterly Journal of Speech, No. 88, 303-325 (2002); and Keller, E. F., Refiguring Life: Metaphors of Twentieth-century Biology, The Wellek Library Lecture Series at the University of California, Irvine (New York, NY: Columbia University Press, 1995).

9. See New Genetics and Society Vol. 24, No. 3 (2005) and Ceccarelli, L, "Neither Confusing Cacophony Nor Culinary Complements: A Case Study of Mixed Metaphors for Genomic Science," Written Communication, Vol. 21, No. 1, 92-105 (2004).

10. Halpern, D., and M. Collear, Sex Differences in Spatial Abilities: More Than Meets the Eye, Cambridge Handbook of Visuospatial Thinking (New York, NY:

Cambridge University Press, 2005) p. 170-112.

11. Haraway, D. J., Modest_Witness@Second_Millennium.FemaleMan©_ Meets_OncoMouse™ (New York, NY: Routledge, 1997) p. 135-137.

12. Larsen, E., and S. Millner, "Mapping the New World," Art Journal, Vol. 59, No. 3, 54-58 (2000).

13. Hall, E., "Reading Maps of the Genes: Interpreting the Spatiality of Genetic Knowledge," Health &Place, Vol. 9, No. 22, 151-161 (2003).

14. See Gilbert in Lewin, R., "Proposal to Sequence the Human Genome Stirs Debate," Science, No. 232, 1598-1600 (1986).

15. Montello, D. R., Navigation, Cambridge Handbook of Visuospatial Thinking (New York, NY: Cambridge University Press, 2005) p. 257-294.

16. Critical Art Ensemble, "Body Invasion and Resistant Cultural Practice," Art Journal, Vol. 59, No. 3, 48-50 (2000).

17. See, for example, Kay, L. E. and Petsko, G. A. [8]

18. Van der Weele, C., Images of Development (New York, NY: State University of New York Press, 1999) p. 19-45.

19. Lewontin, R. C., "In the Beginning Was the Word," Science, Vol. 291, No. 5507, 1263-1264 (2001).

20. Porta, M., "The Genome Sequence is a Jazz Score," International Journal of Epidemiology, No. 32, 29–31 (2003).

21. Dunn, J., and M. A. Clark, "Life Music: The Sonification of Proteins," Leonardo, Vol. 32, No. 1, 25-32 (1999).

22. Ohno, S., and M. Ohno, "The All Pervasive Principle of Repetitious Recurrence Governs not only Coding Sequence Construction but also Human Endeavor in Musical Composition," Immunogenetics, Vol. 24, No. 2, 71-78 (1986).

23. Coen, E., The Art of Genes: How Organisms Make Themselves (Oxford, UK: Oxford University Press, 2000) p.

24. McMeekin, D, Diego Rivera: Science and Creativity in the Detroit Murals (East Lansing, MI: Michigan State University Press,1985) p. 29-33.

25. Avise, J. C., "Evolving Genomic Metaphors: A New Look at the Language of DNA," Science, Vol. 294, No. 5540, 86-87 (2001).

26. Turney, J., "The Sociable Gene," EMBO Reports, Vol. 6, No. 9, 808-810 (2005).

27. Moss, L. What Genes Can't Do (Cambridge, MA: MIT Press, 2003) p. 188-190.

28. Pappas, G., "A New Literary Metaphor for the Genome or Proteome," Biochemistry and Molecular Biology Education, Vol. 3, No. 1, 15 (2005).

29. Gilbert, S. F., J. M. Opitz, and R. A. Raff, "Resynthesizing Evolutionary and Developmental Biology," Developmental Biology, Vol. 177, No. 2, 357-372 (1996).

30. Eisenstein, S, The Cinematic Pronciple and the Ideogram in Film Form (New York, NY: Harcourt Brace Jovanovich,1949) p. 37.

31. See Gilbert, S. F., and M. Faber [4] p. 139.

32. See Gilbert, S. F., and M. Faber [4] p. 125

33. Landecker, H., "Cellular Features: Microcinematography and Film Theory," Critical Inquiry, No. 31, 903-937 (2005).

34. Benjamin, W., "Little History of Photography," Selected Writings vol. 2, trans. Rodney Livingstone et al., ed. Michael W. Jennings et al., (Cambridge, MA: Harvard University Press, 1999) p. 512.

35. Kracauer, S, Theory of Film: The Redemption of Physical Reality (New York, NY: Oxford University Press,1960) p. 20, 50, 52.

36. See Landecker, H. [33] p. 903-937.

37. Bordwell, D., and K. Thompson, Film Art: an Introduction, 7th ed. (New York, NY, McGraw Hill, Inc., 2004). p. 59-65.

38. See Bordwell, D., and K. Thompson [37] p. 60.

39. See Gilbert, S. F., J. M. Opitz, and R. A. Raff [29] and Gilbert, S. F., and M. Faber [4] p. 135.

40. See Levins, R., and R. Lewontin, The Dialectical Biologist. (Cambridge, MA: Harvard University Press, 1985).

41. See Gilbert, S. F., and M. Faber [4] p. 139.

42. See Levins, R., and R. Lewontin [40] and Clark, B., and R. York, "Dialectical Nature: Reflections in Honor of the Twentieth Anniversary of Levins and

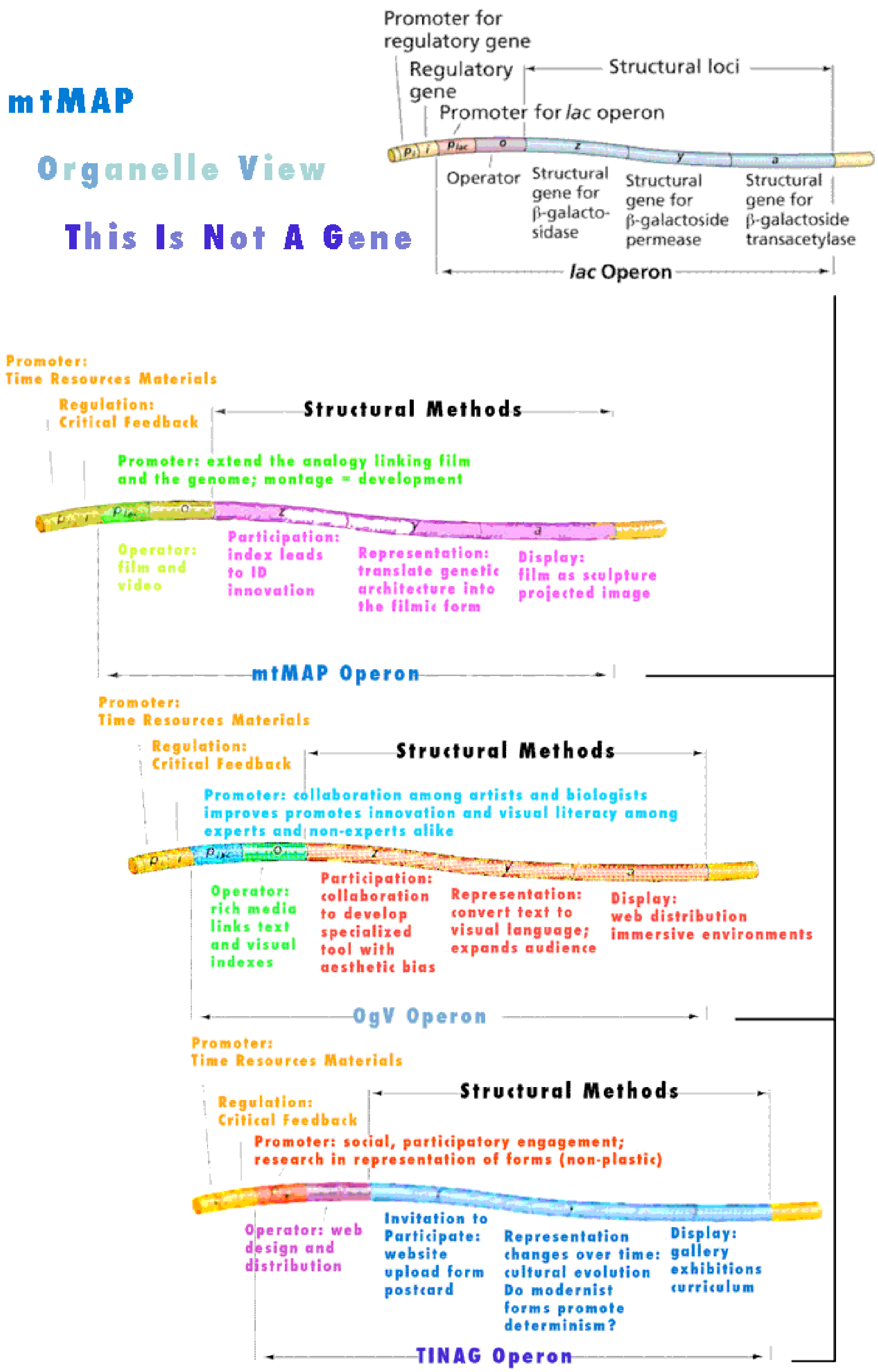
Lewontin's The Dialectical Biologist," Monthly Review, No. 57, 13-22 (2005).

43. Freeman, S., and J. C. Herron, Evolutionary Analysis (Upper Saddle River, NJ: Prentice Hall, 2001) p. 588-589.

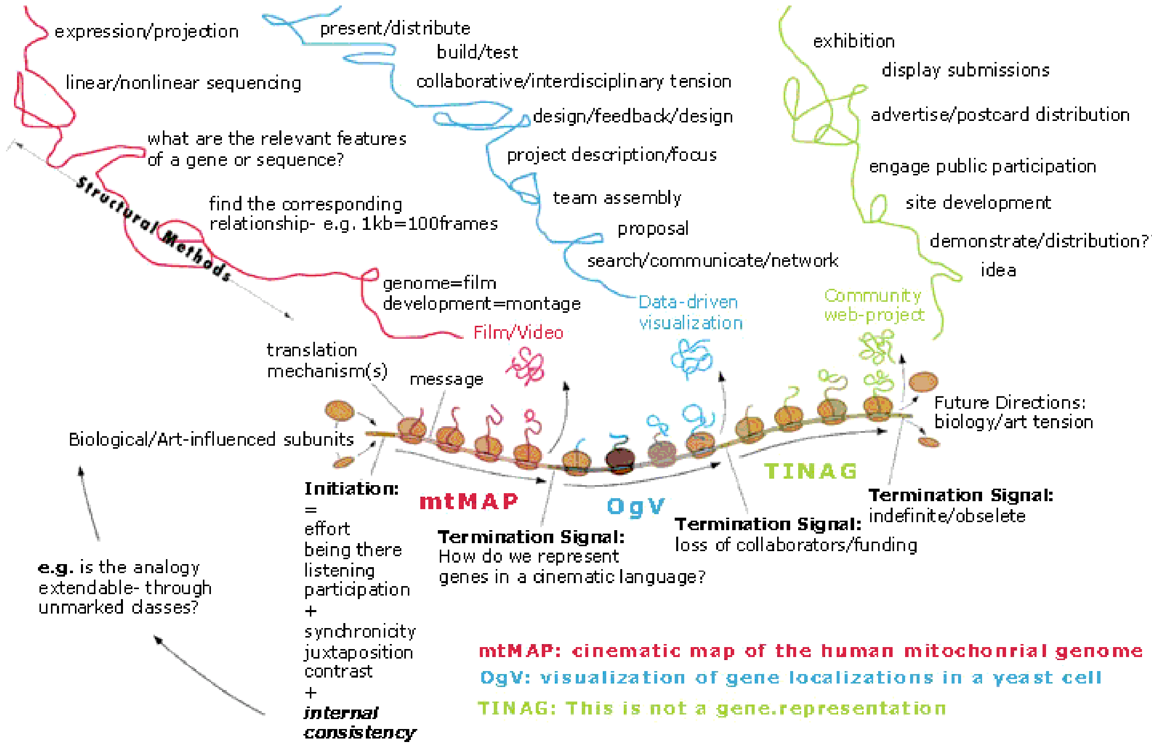
44. See Freeman, S., and J. C. Herron [43] p. 589

45. See Bordwell, D., and K. Thompson [37] p. 64-65.

Appendix 6



Systems diagram of creative processes in which different works are explained within the dynamics of a gene operon system. © gharp 2005



Systems diagram of creative processes explained within the system dynamics of a gene/protein translation from a strand of mRNA. © gharp 2005

Appendix 7

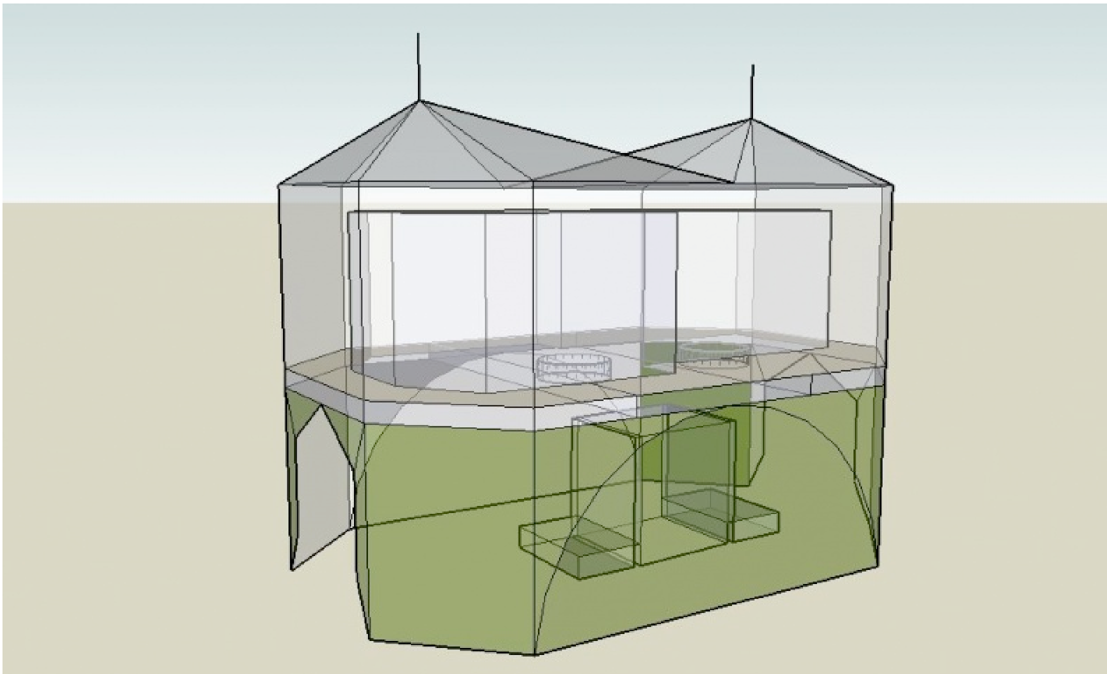
* Nursery
1. Jigsaw Peg Puzzle (lac operon)
2. Chairs (abstinence at the fertility clinic II)*
i. ***musical chairs
1. Beads on string (BioBricks)
i. ***taking the beads on and off
1. Punnet square 7 traits (diallelic pea cross)*
    1. Color
    2. Wrinkled
    3. etc
2. Sandbox (w/family images?)
3. Organelle View*
4. Princess Detector* (ART)
5. Evolution Children's Book
6. T-shirt hooks/experiment
7. Rorschak tests
* Lab
1. This is not gene*
    1. Genomic cinema
        o Sickness
    o Lab
    o Informatics
        + Representation
1. Website*
    2. Painting*
2. Faith in a testube*
3. Mitosis/meiosis
4. Fridge magnets (biobricks)
5. Meiotic anti-drive 2005*(ART)
6. A&D Life*
* Carnival
1. Dolly crane game (ART)
2. Sperm competition shooting game
3. Evolution show*
4. Marching band
5. Life begins at conception road signs
6. 7 deadly sins
        o gluttony*
    o envy
    o etc
* Chapel
1. Versi-christ* (ART)
2. Average Jesus tabernacle
3. High alter: sacramental biology
4. Virgin of the rocks
5. Intelligent design spaghetti/thanksgiving/pancake breakfast dinner
6. Pedigrees of world religions and reproductive behaviors

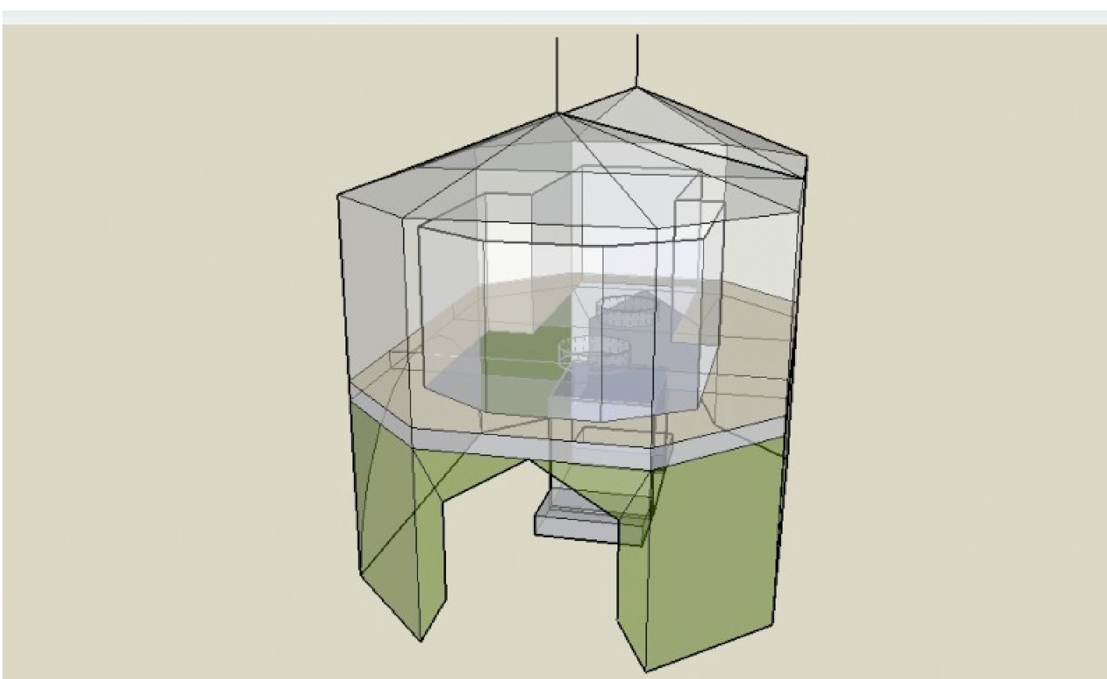
Appendix 8

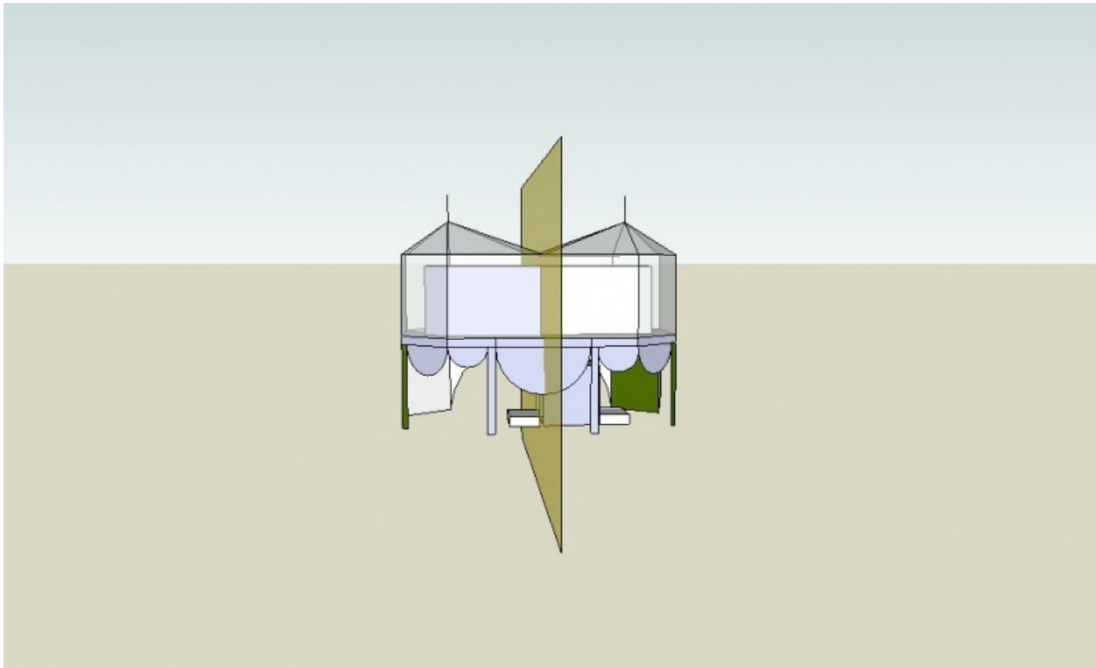
INSTITUTIONAL or RELATIONAL	**PSYCHOLOGY of ART**	**REQUIREMENTS for DEMOCRATIC FUNCTIONS (Latour 2004)**	**MATHEMATICAL FUNCTIONS (via wikipedia)**	**GENERAL ORDER (Foucault 1970)**	**COGNITIVE DEVELOPMENT (Piaget)**
CHAPEL (THE LOWER HOUSE)	RITUAL	INSTITUTION: Investigation into the means to to be used to stabilize the inside and the outside of the collective.	TOPOLOGICAL: Topology begins with a consideration of the nature of space, investigating both its fine structure and its global structure. Topology builds on set theory, considering both sets of points and families of sets.	SIGNS	CONCRETE OPERATIONAL: Intelligence is demonstarted through logical and systematic manipulation of symbols related to concrete objects. Operational thinking develops (mental actions that are reversible). Egocentric thought diminishes.
CARNIVAL	PERFORMATIVE	PERPLEXITY: Investigation into the best way of detecting propositions that are candidates for existence, making them visible, and getting them to talk.	PIECEWISE LINEAR : The absolute value function $f(x) = \| x \|$ is a good example of a piecewise linear function. Other examples include the square wave, the sawtooth function, and the floor function.	SIMPLE NATURE	SENSORIMOTOR: Intelligence is demonstrated through motor activity without the use of symbols. Knowledge of the world is limited (but developing) because its based on physical interactions / experiences.
LABORATORY (THE UPPER HOUSE)	CONFESSIONAL	CONSULTATION: Investigation into the best means for constituting the jury capable of judging the effects of each proposition on the habits of others.	DIFFERENTIABLE: A positive or negative relation between the dependent variable and the independent variable (as measured by the value of the derivative, whether positive or negative) at a given value of the independent variable.	ALGEBRA	PRE-OPERATIONAL: Intelligence is demonstrated through the use of symbols, language use matures, and memory and imagination are developed, but thinking is done in a nonlogical, nonreversable manner. Egocentric thinking predominates.
NURSERY	ETHICAL	HIERARCHY: Investigation into the contradictory scenarios that gradually make it possible to to compose an optimal hierarchy.	COMPLEX: A function in which the independent variable and the dependent variable are both complex numbers.	COMPLEX REPRESENTATIONS	FORMAL OPERATIONAL: Intelligence is demonstrated through the logical use of symbols related to abstract concepts. Early in the period there is a return to egocentric thought.

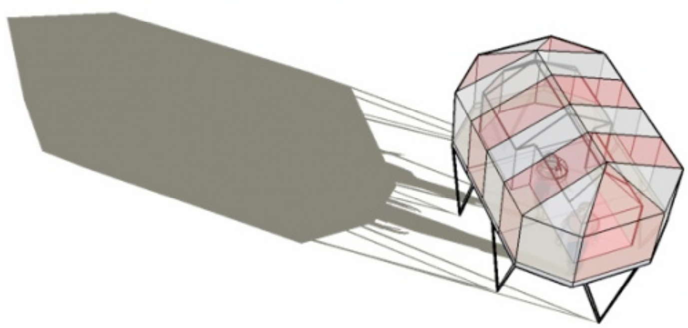
Appendix 9

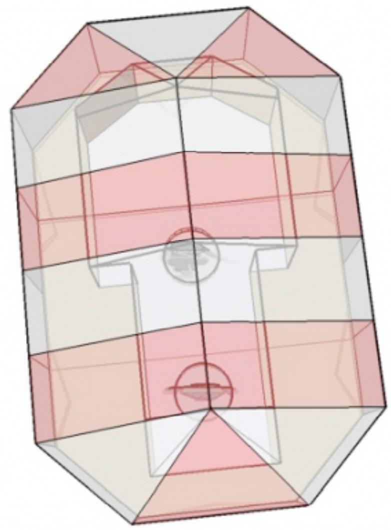
Gallery of images from the Sui generis installation project ranging from early model development to final "readings."












Ceci est mon corps.
prenez-le et mangez-en tous.
Ceci est mon sang.
prenez-le et buvez-en tous.
hurts
Totally.


your love is
more pregnant
than mine