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Visualizing the Random, Rare, and Jackpot Nature of Genetic Mutations--A Self Portrait

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Abstract
Many contemporary artists have drawn upon scientific concepts and phenomena as source material and inspiration for their works. This self-portrait is a visual manifestation and expression of the random, relatively rare, and jackpot nature of genetic mutations over time. The highly repetitive and frequent occurrence of cellular replication inevitably allows for mutations, or alterations in the DNA, to randomly occur according to a small statistical probability that is embedded in every juncture of replication. In turn, these mutations are passed on, resulting in a jackpot or concentrated distribution in successive generations.

My grade school pictures stand in for replicating cells, as they document my physical progression in a relatively standard, uniform format. Successive generations accumulate in a linear fashion, from left to right and top to bottom. The content of the images is used to delineate the potentially positive, negative, and neutral effects of innate spontaneous mutations, prompted by a random number generator with a mutation rate of 0.2% for each type of mutation or an overall general rate of 0.6%. The model for positive change includes growth and positive evolution, as illustrated by the next year's school picture. The model for negative change involves regression and deviation from the standard pose, as expressed by an earlier age's formal portrait. The model for neutral change involves an alteration in the image that does not palpably change the visual information, as delineated by flipping the image across the vertical axis. An external mutagen was also introduced by blurring an image every time my phone rang during the production process. As a final piece, it is the random, rare, and jackpot nature of mutations that create the art and visual pattern.

Keywords
Visual Studies, Jackie Tileston, Tileston, Jackie, Paul Sniegowski, Sniegowski, Paul

Visualizing the Random, Rare, and Jackpot Nature of Genetic Mutations – A Self Portrait

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in

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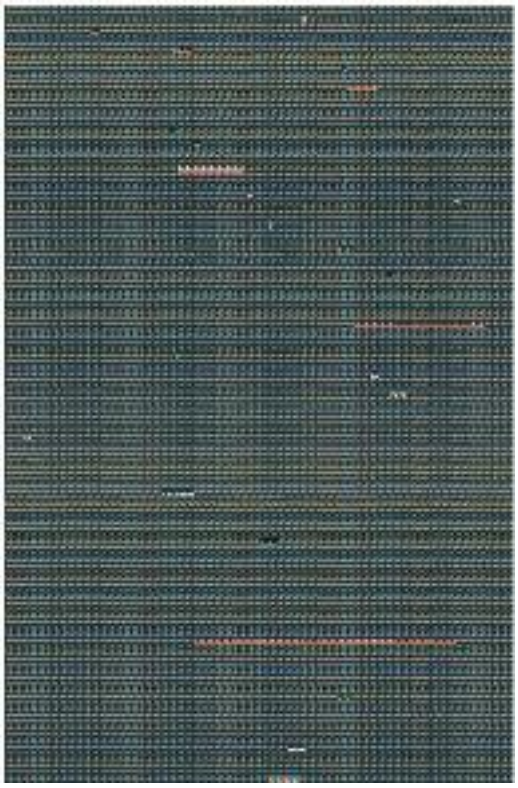
Dr. Paul Sniegowski (Department of Biology)

– Digital print on acetate –

62.5 inch (width) x 93.75 inch (height)

Installation view



Computer document view

Close-up view

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I. ABSTRACT

Many contemporary artists have drawn upon scientific concepts and phenomena as source material and inspiration for their works. This self-portrait is a visual manifestation and expression of the random, relatively rare, and jackpot nature of genetic mutations over time. The highly repetitive and frequent occurrence of cellular replication inevitably allows for mutations, or alterations in the DNA, to randomly occur according to a small statistical probability that is embedded in every juncture of replication. In turn, these mutations are passed on, resulting in a jackpot or concentrated distribution in successive generations.

My grade school pictures stand in for replicating cells, as they document my physical progression in a relatively standard, uniform format. Successive generations accumulate in a linear fashion, from left to right and top to bottom. The content of the images is used to delineate the potentially positive, negative, and neutral effects of innate spontaneous mutations, prompted by a random number generator with a mutation rate of 0.2% for each type of mutation or an overall general rate of 0.6%. The model for positive change includes growth and positive evolution, as illustrated by the next year's school picture. The model for negative change involves regression and deviation from the standard pose, as expressed by an earlier age's formal portrait. The model for neutral change involves an alteration in the image that does not palpably change the visual information, as delineated by flipping the image across the vertical axis. An external mutagen was also introduced by blurring an image every time my phone rang during the production process. As a final piece, it is the random, rare, and jackpot nature of mutations that create the art and visual pattern.

II. INTRODUCTION

Many contemporary artists have drawn upon scientific concepts and phenomena as source material for their works. For example, Eduardo Kac created a transgenic bunny that glowed fluorescent green, and Deanna Deeds made digital weavings based on DNA sequences. On the other hand, scientists often turn to artistic representations to give visual dimension to scientific models. For example, cellular reproduction can be been drawn in a cartoon-like caricature, the double-helix nature of DNA can be described with a 3-dimensional sculpture, and experimental data can be represented with visually appealing and easily accessible graphs and diagrams. For me, art relates to finding the visual aesthetic quality in nature, while science is derived from finding an objective, concrete understanding of nature.

As for my project, the idea first stemmed from my fascination with DNA as the hereditary backbone of life. It is like a book of instructions for all biological processes and structures. In thinking about how frequently DNA replicates (every time a cell divides), I decided to visualize first, the **repetitive** nature of DNA replication, second, the relatively **rare** and **random** occurrence of mutations (spontaneous alterations in the DNA sequence that occur during replication), and third, how mutations accumulate into a **jackpot** or concentrated distribution over time. Jackpot distribution refers to the notion that the original chance mutation is passed down to successive generations, causing an accumulation of that mutation. What resulted is a self-portrait in the form of wallpaper that mimics a laboratory microscope slide.

I used school pictures as my source material to stand in for replicating cells. The genre of school pictures includes photographs that are taken around the same time each year, in standardized poses, with standardized backgrounds. I may have made aesthetic decisions about my hair and clothes on picture days, but each photographer aimed to place me in a neutral, controlled environment in which the documentation and sitting pose were standardized. In the set of images, the main variable is the person within images, not the means of documentation. This references the scientific method which deals with controlled experiments in which variables are isolated in order to be studied.

Next, I reproduced the images in the form of a grid, with each kindergarten school picture dividing into two new identical images (like a cell dividing into two daughter cells during binary fission). I then allowed for mutations to "randomly" occur during reproduction by using a random number generator to dictate which images would become mutated and divide into one normal cell and one mutant cell; the random mutation occurred according to a relatively rare statistical factor of 0.2%. The grid as a whole illustrates the accumulation of mutations in a "jackpot" effect, with an increased presence over time.

To illustrate the idea that mutations can be considered neutral, positive, or negative in their effects on a cell, I created a visual system that differentiated between each type of mutation. I designated a neutral mutation by flipping the image across the vertical axis; this change is one which alters an image but that bears little noticeable effect on the visual information available. I designated a positive mutation by substituting the next year's school picture; I interpreted growth and development as beneficial. Finally, I designated a negative mutation by substituting an earlier age's formal portrait or a portrait which deviated from the standard pose; I interpreted regression and external variants as negative since they deviate from the standardized nature and progression of the grade-school pictures.

Though growth cannot scientifically be thought of as mutation, I extracted the concept to create an aesthetic language. In addition to these innate spontaneous mutations, I introduced an external stimulus that represents a rogue element in causing a mutation: every time my phone rang during the production process, I blurred the image I was currently working on. As a final piece, it is the random, rare, and jackpot nature of mutations that create the art and visual pattern.

III. BACKGROUND ON ART

The intersection between art and science has been an area of great interest to many contemporary artists. As I have thought about my own approach to the intersection, it has been interesting to learn about other artists' conceptions of how science can be used to influence and/or generate art.

1. Eduardo Kac

Edaurdo Kac made a transgenic artwork called "GFP Bunny" (2000), which was a bunny named Alba who glowed a fluorescent green color. By creating a transgenic bunny, he altered the genome of the bunny by inserted a gene that encodes a protein called Enhanced Green Fluorescent Protein, which is the synthetic version of the protein responsible for the bioluminescence of jelly fish. GFP is a popular tool used in biological research to tag various proteins in order to study organelle trafficking, cellular developmental stages, and other processes. Using this technology, Kac proposed a new art form "based on the use of genetic engineering to transfer natural or synthetic genes to an organism, to create unique living beings."[1] In explaining the bunny as a work of transgenic art, not as an example of a breeding project, Kac explains that it "offers a concept of aesthetics that emphasizes the social rather than the formal aspects of life and biodiversity, that challenges notions of genetic purity, that incorporates precise work at the genomic level, and that reveals the fluidity of the concept of species in an ever increasingly transgenic social context."[2]

[3]

"GFP Bunny" (Eduardo Kac)

[1] http://www.ekac.org/gfpbunny.html#gfpbunnyanchor
[2] http://www.ekac.org/gfpbunny.html#gfpbunnyanchor
[3] http://www.ekac.org/gfpbunny.html#gfpbunnyanchor

Another of Kac's works is "Genesis" (1999) which "bestows godlike power to humanity on a microscale."[4] It allows viewers to create real, biological mutations in a bacteria's DNA. With an online version and an installation version, a viewer can focus ultraviolet light on the display of bacteria, causing mutations in the coded message of the bacteria's genome, which in turn causes a change in the proteins that are produced. As Kac says, "the metaphor of art imitating life doesn't apply anymore. This is a situation where art is creating life."[5]

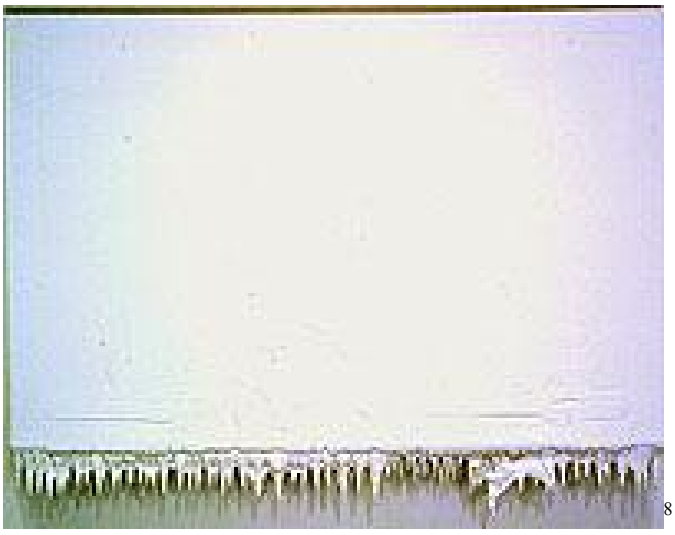
 [6]

"Genesis" (Eduardo Kac)

[4] http://www.ekac.org/thescientist.2002.html
[5] http://www.ekac.org/thescientist.2002.html
[6] http://www.ekac.org/thescientist.2002.html

2. Roxy Paine

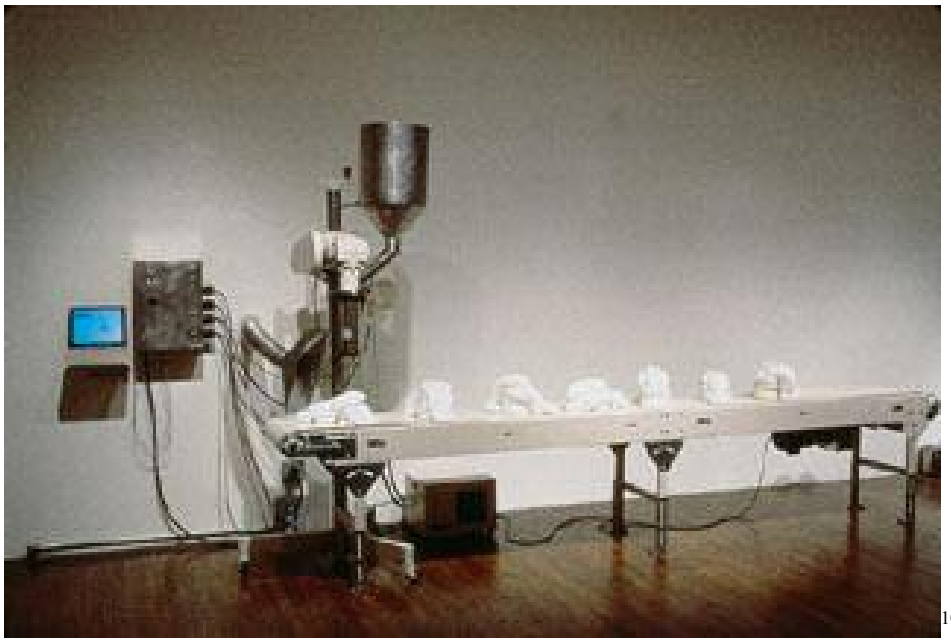
Roxy Paine is an artist whose paintings and sculptures relate to the mechanical and repetitive nature of DNA replication, which is vulnerable to the "chance" occurrence of mutations. As such, his art works are triggered by complex mechanical processes and chance. With his "Paint Dipper" (1997), a canvas was periodically dipped into a reservoir of paint, so that the paint dripped down and congealed at the bottom like stalactites. The machine was fully automated, run by a computer programmed by Paine. In this sense, "the machines do not create works of art; they merely carry out orders in a manner that is lackadaisical, languorous and rigidly scripted."[7] The program is rigid but the final product is subject to the natural tendencies of the paint itself.


[8]

"Paint Dipper" (Roxy Paine)

[7] http://www.grandarts.com/exhibits/RPaine.html
[8] http://www.grandarts.com/exhibits/RPaine.html

Another of Paine's work is titled "SCUMAK" (1998). It is a machine that spurts out a series of sculptural blobs. As noted, "Paine's art producing machines are custom-made to administer the precise amount of a controlled substance over time, a kind of pharmacological delivery system that injects us with a hallucination, a thing repeated, a flawed copy whose flaws are hard to see. All errors ultimately refer back to their perceiver." This notion of a repetitive mechanical process which incorporates the inevitable flaw is similar to DNA replication. Because the products of the mechanical process are sculptures, the art work also brings into question the idea of aesthetic choices. Who decides whether the variations ("mutations") are positive, negative, or neutral? Is there an equivalent of beneficial/detrimental or good/bad mutations in aesthetics?[9]

 [10]

"SCUMAK" (Roxy Paine)

3. John Cage

John Cage is an artist who composes what he calls "chance music" in which he sets up opportunities for sound in which some elements are left to be decided by chance. As Cage describes, "When we ignore it, it disturbs us. When we listen to it, we find it fascinating. The sound of a truck at 50 m.p.h. Static between the stations. Rain. We want to capture and control these sounds, to use them, not as sound effects, but as musical instruments."[11] In his work titled "I Ching," Cage explores the concept of chance by consulting the I Ching to choose various rocks and areas of placement on a grid of 64 lines. He then "poses questions relating to the materials to be used, and in this way the composition is decided."[12] Even though Cage leaves the ultimate sound results up to chance, he makes artistic "aesthetic" decisions when deciding which materials to use in the first place. Similarly, I have chosen the materials and the means of documentation, but I am leaving the final result (the pattern of mutation distribution) up to chance.

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[9] conversation with Jackie Tileston, 9.27.05
[10] http://www.grandarts.com/exhibits/RPaine.html
[11] http://www.bbc.co.uk/music/profiles/cage.shtml
[12] http://www.cyberchiks.com/cage_interview.htm

4. Gene(sis): Contemporary Art Explores Human Genomics [13]

Gene(sis) was an exhibition that presented artwork that reflected recent developments in genomics. As Robin Held, the Curator of Gene(sis) asks, "What can an art museum contribute, through its exhibition and public programs, to the larger discourse about the implications of human genomics?"[14] She continues, "[the exhibit] examines artistic activity that addresses the potential implications of recent human genome projects on our daily lives."

A. Catherine Chalmers

Catherine Chalmers produced a series of photographs titled "Transgenic Mice" (2000), which documents the production of genetically-engineered mice. The mice are "programmed from birth to develop tumors, inherit glaucoma or produce milder pathologies, and are currently produced at a rate of approximately 50 million a year."[15] She is drawing attention to the subjects of study who are literally living the effects of various genetic mutations. One example is "Transgenic Mice: Obese" (2000).

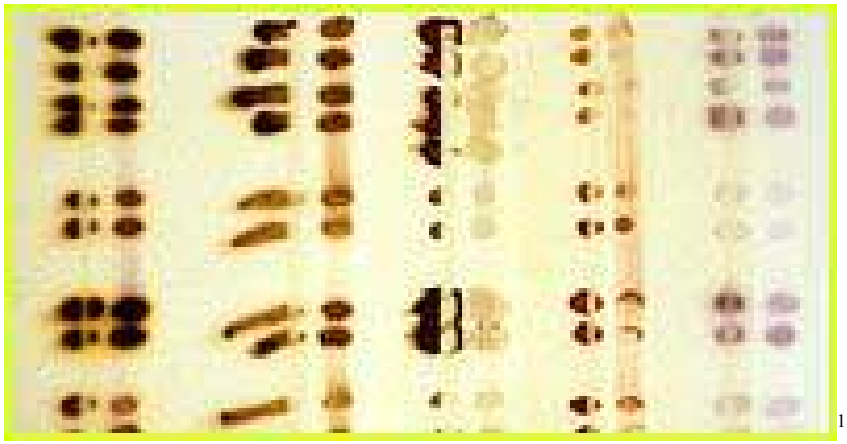
[16]

"Transgenic Mice: Obese" (Catherine Chalmers)

[13] Mary and Leigh Block Museum of Art, Northwestern University, 9.10.04 - 10.28.04.
[14] http://www.gene-sis.net/overview.html
[15] http://www.gene-sis.net/artists_chalmers.html
[16] http://www.gene-sis.net/artists_chalmers.html

B. Jaq Chartier

Jaq Chartier explored scientific methods through experimentation with paint and process. The website describes that "through experimentation, observation, and notation, Chartier's paintings provide commentary on both the visual culture and everyday practice of scientific investigation by highlighting similarities between artistic and scientific practice."[17] Many works were treated like "tests" to discover something about the materials and how they behave. For example, "Blots and Dilutions" (2000) was inspired by images of gel electrophoresis. He explored the migration of pigments, inks and photo chemicals through layers of acrylic gels and gessos, similar to DNA mapping. He builds the paintings layer by layer, separating layers with coats of gels.

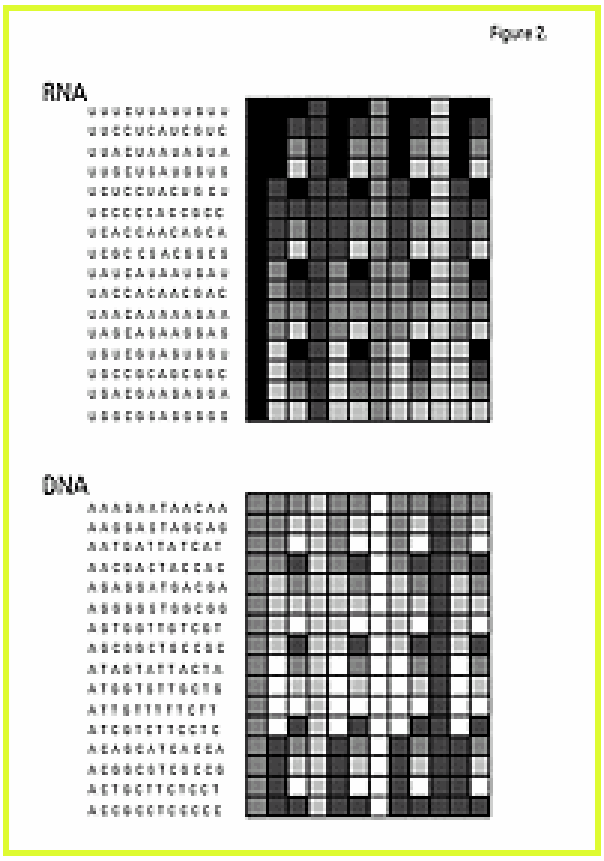
 [18]

"Blots and Dilutions" (Jaq Chartier)

[17] http://www.gene-sis.net/artists_chartier.html
[18] http://www.gene-sis.net/artists_chartier.html

C. Gregor Mobius

Gregot Mobius proposed a visual alternative to the linguistic model most often used to signify the five nucleotides that comprise the human genome. The five "genetic letters" are A (adenine), T (thiamine), G (guanine), C (cytosine), and U (uracil) which refer to the type of base on the nucleotide. One example is his piece "RNA/DNA" (2001) which assigns a different shade of black and white to each letter as he translates a genetic sequence.



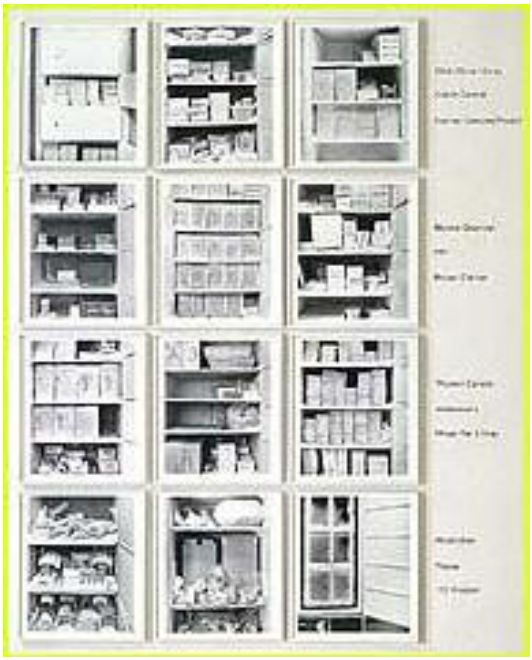
[19]

"RNA/DNA" (Gregor Mobius)

[19] http://www.gene-sis.net/artists_mobius.html

D. Catherine Wagner

Catherine Wagner composed photographs to "highlight the activity of managing and controlling the data of the Human Genome Project by revealing the process of archiving and storing of specimens."[20] Her work "-86 Degrees Freezer (Twelve Areas of Concern)" (1995) is a collection of conceptual still lifes of evidence found in -86 degree freezers containing the archival samples of Alcoholism, Alzheimer's, Bipolar Disorder, Breast Cancer, DNA Synthesis, HIV, and other research from the Human Genome Project. As described by Paradise Now: Picturing the Genetic Revolution, "This freezer typology confronts the new millennium. It forces us to ask how, in the future, we will construct our individual and cultural identities."[21]



[22]

"-86 Degrees Freezer" (Catherine Wagner)

[20] http://www.gene-sis.net/artists_wagner.html
[21] http://www.genomicart.org/wagner-pn.htm
[22] http://www.gene-sis.net/artists_wagner.html

E. Daniel Lee

Daniel Lee creates digitally altered photographs in which animal spirits transform human subjects. "His artful blending of human and animal characteristics provokes dialogue on the future of biotechnology and genetic engineering at a time when boundaries between humans and animals could become blurred."[23] His work brings to attention the idea of evolution and how mutations and changes are passed on and incorporated over time. "Judgment" (1994) is one example which also shows an influence of Buddhist mythologies.

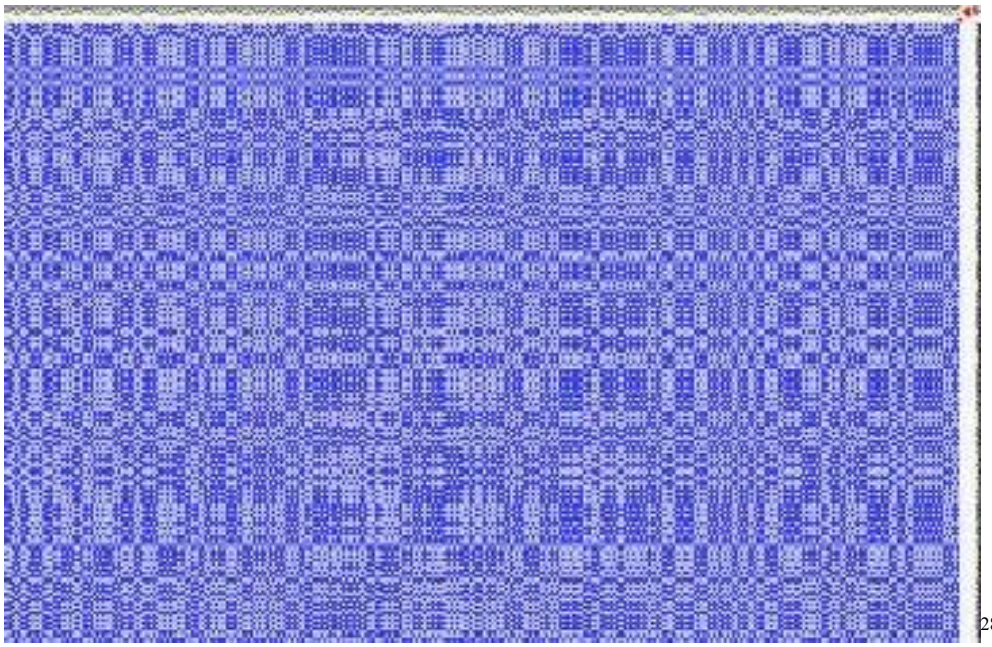
 [24]

"Judgment" (Daniel Lee)

[23] http://www.gene-sis.net/artists_lee.html
[24] http://www.gene-sis.net/artists_lee.html

5. Deanna Deeds

Deanna Deeds is an engineer by vocation with a passion for weaving. She has "always been fascinated by the connection between weaving and math."[25] At the suggestion of her brother, she started introducing an element of biology into her patterns, looking at the application of genetic sequences to weaving patterns. For example, she created a weave pattern based on mapping the nucleotide sequence for hemoglobin, a protein carried by red blood cells to pick up oxygen in the lungs and deliver it to peripheral tissues in the body. Hemoglobin is composed of two similar proteins which stick together, both of which are coded for with a specific DNA sequence.[26] The normal sequence is ATG GTG CAC CTG ACT CCT **GAG** GAG AAG TCT GCC GTT ACT. Sickle cell anemia results when the hemoglobin protein structures do not fold properly, due to a mutation or change in one nucleotide of the sequence to ATG GTG CAC CTG ACT CCT **GTG** GAG AAG TCT GCC GTT ACT.[27] In her weaving pattern, she assigned each of the nucleotide base letters in a normal hemoglobin sequence to one of four blocks in a block crackle (twill form).

 [28]

"Untitled" (Deanna Deeds)

[25] http://home.earthlink.net/~djdeeds/mathtex/sequences.html
[26] http://sickle.bwh.harvard.edu/hemoglobin.html
[27] http://carnegieinstitution.org/first_light_case/horn/lessons/sickle.html
[28] http://home.earthlink.net/~djdeeds/mathtex/sequences.html

6. Critical Art Ensemble

Critical Art Ensemble is a group of five artists who explore the intersections between art, technology, critical theory, and political activism. Within this sphere, they have focused on biotechnology for the past seven years. They "propose to give people reliable information and direct experience of the routinised processes of science so that individuals can come to understand that biotech is within their power to think about and actively influence."[29] A *New York Times* article titled "ART; The Artists in the Hazmats Suits" (Randy Kennedy; July 3, 2005), explained how bioart "can credibly claim to have made a more revolutionary break with tradition. Instead of finding ways to represent and distill life using paint or marble or pixels, the artists use life itself - bacteria, cell lines, plants, insects and even animals - as the medium to ask the questions that art has always asked."[30] The article continues, "occasionally the work is playful, verging on silly - serenading a strain of E. coli bacteria with Engelbert Humperdinck's greatest hits to see if that causes increased antibiotic production. (It appeared to.) Other artists are simply trying to find new ways to do old things - creating portraits on leaves or in swaths of growing grass by using photosynthesis. But much of the work is provocative and, depending on your Brave New World tolerance, disturbing: creating 'victimless' meat by growing tiny steaks from biopsied frog cells and then eating the steaks."[31]

7. Do-Ho Suh

Do-Ho Suh is an artist I turned to in thinking about how to visually manifest my ideas. Do-Ho Suh created a floor to ceiling wallpaper, titled "Who am We?" (2000), composed of thousands of Korean high school yearbook portraits. As described by Art21, "When viewed as large-scale installation, the individual portraits are lost among the crowd."[32] In the case of his wallpaper, the many different individual people get lost amidst the crowd, the photos appearing to all be of the same person. I am taking the opposite approach, exploring various dimensions of one individual person (myself), represented at different stages in my life. While each of Do-Ho Suh's images is an individual who is part of a collective whole, in my project, each stage of my life becomes one part of my collective life.

[33]

"Who are We?" (Do-ho Suh)

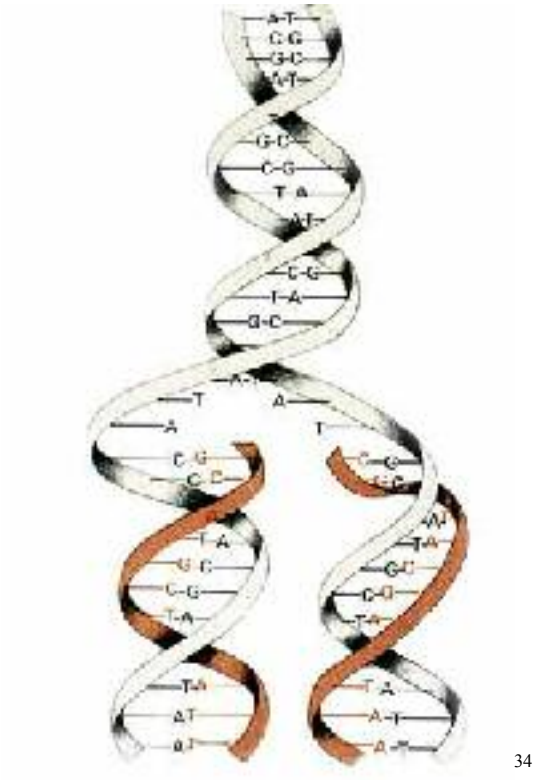
[29] http://greenmuseum.org/c/enterchange/artists/cae/
[30] http://rhizome.org/thread.rhiz?thread=17844&page=1#34133
[31] http://rhizome.org/thread.rhiz?thread=17844&page=1#34133
[32] http://www.pbs.org/art21/education/teachingmaterials/img/art21_s2guide_stories.pdf
[33] http://www.pbs.org/art21/education/teachingmaterials/img/art21_s2guide_stories.pdf

IV. BACKGROUND ON SCIENCE

1. DNA

Deoxyribonucleic acid (DNA) is a nucleic acid which serves as a set of instructions for the biological development of all cellular forms of life and most viruses. It is a double helix structure made up of a sequence of smaller units strung together. Each nucleotide unit is made up of three components: a phosphoric acid, a single sugar, and a nitrogen base. The only difference among the four DNA nucleotides is the nitrogen base, which can be one of four: adenine (A), cytosine (C), guanine (G), and thymine (T). A and T are purines, and C and G are pyrimidines.

When the double helix strand is unzipped, a strand of messenger RNA is made based on each strand, and the genetic code is read in a triplet codon form, with every three nucleotides read together to produce one protein. Proteins in turn are essential to the structure and function of all living cells and viruses. DNA is often referred to as the molecule of heredity because it is responsible for the genetic propagation of most inherited traits, such as hair color and disease susceptibility. The following diagram illustrates DNA as a double helix as it undergoes replication.

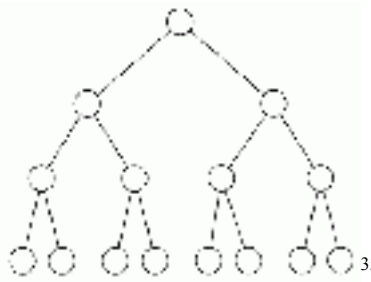
 [34]

DNA double helix

[34] http://www.genelex.com/paternitytesting/images/dna-molecule.jpg

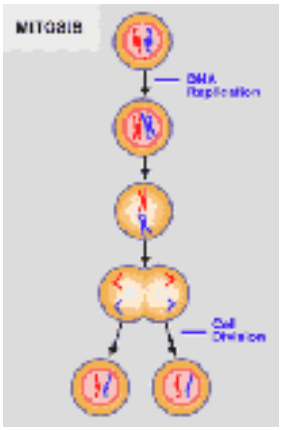
2. DNA Replication and Cell Division

Bacterial and somatic (body) cells divide through a process called binary fission. Binary fission is a form of reproduction in which two cells divide into two equal or near-equal parts. The following binary tree shows four generations of such cells.

 [35]

Binary tree

In bacteria and somatic (body) cells, DNA is replicated through a process called mitosis after which a cell divides through a process called cytokinesis. The single DNA molecule (the set of instructions) first replicates, and then attaches each copy to a different part of the cell membrane. The cell begins to pull apart and the original chromosome and replicate are separated. The cell then splits, and the result is two cells of identical composition (except for the rare chance of spontaneous mutation). The following diagram illustrates mitosis and cytokinesis.

 [36]

Representation of mitosis

Within an individual organism, every cell contains the same sequence of "instructions," though each cell only uses a subset of its DNA instructions according to its specific form and function. For example when dealing with somatic (body) cells in a human body, brain cells utilize a different part of the same DNA sequence compared to nerve cells and skin cells. DNA can be thought of as a book of instructions, from which each cell reads only the appropriate chapters.[37] During development, the DNA sequence is preserved unchanged, as the cells alter their behavior through controlled changes in their pattern of gene expression.

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[35] http://www.gigaflop.demon.co.uk/comp/fig3_2_3-1.gif
[36] http://genetics.gsk.com/graphics/mitosis.gif
[37] http://www.koshlandsciencemuseum.org/exhibitdna/intro02.jsp

3. Mutations

Any change in the DNA sequence is considered to be a mutation. A mutation can either be due to a mistake during DNA replication in cell division, or it can be due to damage from environmental mutagens such as ultraviolet light, radiation, and other agents. Mutations are unavoidable (even in an environment free of radiation and other external mutagens), and they occur spontaneously at an estimated rate of about 10^{-6}, or one out of a million, mutations per gene per cell division. In the course of a lifetime of a human being, about 10^{16} cell divisions take place; every single gene is likely to have undergone mutation on 10^{10} separate occasions. The vast majority of mutations, however, are eliminated by DNA repair.[38]

The different types of mutations include:

a. Point mutations occur when there is an exchange of a single nucleotide for another, such A for G or C for G. If these mutations occur in a protein coding region of a gene, the mutations can be classified into three kinds:
    i. Silent mutations which code for the same amino acid
    ii. Missense mutations which code for a different amino acid
    iii. Nonsense mutations which code for a stop; this leads to early truncation of the protein.
b. Insertions occur when extra nucleotides are inserted into the DNA. Unless the number of insertions is a multiple of three, they will cause a frame shift in the reading of the DNA.
c. Deletions occur when nucleotides are removed from the DNA. Like additions, they may also altar the reading frame of a gene.

Such mutations can either produce negative effects on health, positive advantageous effects on health, or produce no significant changes in protein functions.[39]

4. Study on the Random Nature of Mutations

In 1943, Luria and Delbruck design an experiment which would test the two main competing hypotheses at the time regarding the random nature of genetic mutations. They studied Escherichia coli cells to determine whether exposure *caused* resistance to a viral agent or whether the exposure simply *selected* already resistant cells. They had previously observed that if a drop of antibiotic were dropped in a flask of E. coli, the flask would become clear as though all the bacteria were killed, but later, the solution would become cloudy again with renewed bacterial growth. The key was to figure out whether some E. coli cells were able to actively change their genome in response to the selection factor (such as by becoming resistant to the viral agent after being exposed to it), or whether the mutation happened to already be in place before the selection arose (an earlier chance variation which enabled the bacteria to resist the agent). As described in a paper by Dr. Paul Sniegowski:

[38] Alberts, Bruce; Bray, Dennis, et. Al. *Essential Cell Biology*. New York and London: Garland Publishing, Inc., 1998. p 620.
[39] http://en.wikipedia.org/wiki/Mutation

> The "acquired hereditary immunity" hypothesis supposed that each bacterium has a certain small probability of surviving exposure to the virus, and survival confers immunity that is inherited. In contrast, the [spontaneous] "mutation" hypothesis supposed that each bacterium has a small probability of mutating spontaneously to viral resistance even in the absence of the virus, and that each descendant of a resistant mutant is itself resistant.[40]

Another way to phrase it is:

Hypothesis 1: There is a finite and small probability that each cell in the culture might survive the phage attack, and all subsequent progeny from survivors will be resistant.

Hypothesis 2: There is a finite and small probability that a mutation from susceptible to resistant will occur at a constant rate.

It is like trying to figure out whether the light is on in the refrigerator when the door is closed. The light is the mutation of being resistant to antibiotics, and opening the door is the selection factor of exposing the cells to antibiotics. The question is whether the light (mutation) was "on" before the door was open (it met the antibiotics.)[41]

Test:

In order to test the hypotheses, the researchers studied the distribution of resistant mutants after exposing E. coli cells to a viral infection which would ordinarily kill the bacteria. They made many independent cultures which each started with a few sensitive cells. They then let the cells replicate by binary fission in which each cell replicates its DNA and divides into two theoretically identical cells. At the end of many generations of replication, they exposed each culture of cells to a selective viral agent to kill all the cells except for the mutants which were able to resist it.

They expected that each hypothesis would predict a different distribution of resistant mutants among independent cultures. According to the acquired immunity hypothesis (hypothesis 1), each cell would have a low probability capacity to respond to the agent by changing, so we would expect an even distribution of mutations across cultures. According to the spontaneous mutation hypothesis (hypothesis 2), the mutations would have to have occurred during growth of the culture by chance, so at the end, some cultures would demonstrate **jackpot immunity** due to chance (with large numbers of resistant clones after replication over generations) while other cultures would not have any.

Results:

After plating each independent culture, the researchers found a jackpot distribution, which was in accordance with the later hypothesis of spontaneous mutation. The mutations that led to resistance to the lethal agent were spontaneously produced at earlier times and passed on to successive generations by DNA replication and reproduction, rather than occurring only in the last generation in response to the viral agent.

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[40] Sniegowski, P. D. and Lenski, R. E. "Mutation and Adaptation: The Directed Mutation Controversy in Evolutionary Perspective." Annual Reviews Inc., 1995. p557.

[41] Conversation with Dr. Paul Sniegowski, October 28, 2005.

V. PROJECT DESCRIPTION

This project explores the random, rare, and jackpot nature of genetic mutations. It is a visual manifestation and expression of the potential for a mutation to occur, which is embedded in every juncture of replication.

1. Random nature refers to the idea that mutations can spontaneously occur by chance during reproduction of a DNA sequence.

2. Rare nature refers to the relatively small probability of such a chance to occur.

3. Jackpot distribution refers to the notion that the original "spontaneous" mutation is passed down to successive generations, causing an accumulation of that mutation within the population.

I wanted to create first, a repetitive process with a potential for chance alteration; second, a means of documentation of the mutations as they are passed on from generation to generation; and third, a means of representation to illustrate whether the mutations were positive, negative, or neutral in their effects on the cell.

Repetitive process and its documentation:
My kindergarten school picture is repeated 15,625 times in the form of a grid (125 x 125 images). Over time from one generation to the next, each picture replicated into two new identical pictures, assuming that image's reproduction is "normal." Overall, about 14 generations are depicted. The grid accumulates from left to right and top to bottom, with each image having replicated into two new identical images. The following grid explains how successive generations accumulate in a linear structure; each lesser number produces two new numbers; like numbers refer to a single generation.

1	2	2	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7																						

Opportunity for mutation:
A random number generator computer program was used to dictate which images would reproduce normally, and which would produce a mutant progeny. A list of 15,625 numbers was created, with the program selecting from the numbers ranging from 1-500. Each number on the generated list corresponded to an image in the grid, beginning in the upper left-hand corner.

All images with the numbers 1-500 (except 100, 101, 102) were designated as normal reproduction; they automatically gave rise to two new identical pictures. However, each image that corresponded to 100, 101, or 102 on the randomly generated list was considered a mutant and gave rise to one normal image and one mutant image. Thereafter, each mutant image gave rise to two more identical mutants, accumulating the mutation over time.

Documentation of mutations:
Out of the set size 1-500, every time the numbers 100, 101, or 102 came up, the normal image gave rise to a normal image and a mutant image. Thereafter, the mutant picture automatically reproduced two new identical mutant pictures. The number 100 indicated a ***neutral*** mutation, and the picture was flipped across the vertical access so that the change bears little noticeable effect on the visual information; the change did not really harm or benefit the image, just altered it. The number 101 indicated a ***positive*** mutation, and the picture was replaced with the next grade-level school picture; growth and development were used as a model for positive change in this project, even though they do not scientifically represent mutation. The number 102 indicated a ***negative*** mutation, and the picture was replaced by an earlier age's picture or one which includes props and is less neutral than the grade-school pictures; regression in age and deviation from the stand school-portrait pose were considered negative in this project, even though it is not necessarily the case scientifically. The designation of growth as a positive change and regression as a negative change are artistic decisions and do not exactly reflect scientific study.

Probability and randomness:
Numbers were selected from a total set-size of 500 numbers (1-500). Because there were 3 opportunities for mutation, the probability of getting a mutation overall was 3/500 (0.6 %). The probability of getting each specific mutation was 1/500 (0.2 %). The randomness and relative rarity of getting a spontaneous mutation is visually evident in the final result due to the small scale of the images and the large scale of the work; the mutants are like "specks" amidst a sea of identical images. The jackpot effect and accumulation of mutant images are evident as large groups of mutated images that have accumulated over time. It is the random, rare, and jackpot nature of mutations that create the art and visual pattern.

The mutation rate of 3/500 is based on the inherent probability of a change occurring by chance during the reproduction. However, in real life, there are also mutations that can arise based on external influences (such as by radiation, carcinogens, etc). This project also allows for such external "rogue" elements – each time my phone rang while I was making the grid, I blurred the image that I was working on as a mutation. This generates a mutation beyond the statistical rate.

Medium:
The grid of images was printed on two sheets of acetate, each measuring 31.25 inch wide x 93.75 inch tall. They hang vertically; a hook and grommet mechanism was used to hang them from a metal rod, 3 inches away from the wall. The scale of the piece not only creates a large visual field referencing wallpaper, but the overall dimensions of 62.5 x 93.75 inches of the grid are in the same relative proportions as the dimensions of each individual picture (0.5 x 0.75 inches). The size of the overall work is therefore derived from the relative size of each image. The grid then becomes square with regards to the number of pictures, with 125 images both across and down. The acetate was selected because it serves reference to specimens on a microscope slide, which are often used in the study of cellular genetics.

Procedure:

1. Start with one cell in the left-hand corner

2. Click for random number to be generated

    a. **Normal progeny**: cell gives rise to two normal cells
        - number generated 1-500 other than 100, 101 or 102.

    b. **Mutant progeny**: cell gives rise to one normal cell and one mutant cell
        - number generated is 100, 101, 102.

3. Record the appropriate two new pictures, accumulating the images left to right followed by top to bottom, rather than as a pyramid shape.

4. Continue with cell replication; each cell divides into two new cells.

    a. **Normal cell**: click on the random number generator to determine what makes up the cell's progeny (2 normal or 1 normal/ 1 mutant)

    b. **Mutant cell**: mutant cell automatically divides into two new mutants (because the mutation is genetically passed on), thus accumulating a jackpot.

5. As a rogue element to mimic an environmental mutagenic agent, the image that I am working at time my phone rings is blurred; this creates a mutant image that deviates from the statistical rate.

[Please see figures for images]

VI. CONCLUSION

I have set up a visual system that is both a self portrait and an objective illustration of the relatively rare and random nature of spontaneous genetic mutations that accumulate in a jackpot pattern of distribution over time. In thinking about the interchange between art and science/medicine, I depicted the wonder of the human body on the microscale of genetic reproduction, the artistic form of the human body itself on the macroscale, and the amazing nature of reproduction of populations over time on an even larger macroscale. The overall aim of the work was to create a visually stimulating work of art which allows for the observer to understand the relatively rare, random, and jackpot nature of mutations, while getting lost in a sea of images.

With the ever growing body of scientific knowledge and the ever growing sphere of contemporary art, the two fields are offering more and more to each other in terms of how they can complement and influence each other.

VII. ACKNOWLEDGMENTS

Thank you to my advisors, Jackie Tileston (Assistant Professor of Fine Arts) and Dr. Paul Sniegowski (Associate Professor of Biology), who each used her/his field of expertise to help guide me in my attempt to integrate the fields. Thank you to Renata Holod, Gary Hatfield, and Julie Schneider for making the Visual Studies Major a reality. Thank you to Chris Pastore for coordinating all of the logistics. Thank you to Dr. Linda Robinson for providing me with biology lab-based consults and materials. Thank you to Greg Finnson for help with printing. Thank you to Aelon Porat for creating the random number generator. Thank you to my parents for their continued support in my pursuit of both art and science.

VIII. REFERENCES

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IX. IMAGES

Visual Studies Senior Thesis Exhibition
University of Pennsylvania
Philadelphia, PA

April 24 – May 17, 2006

Figure A – Exhibition Space

Figure B - Installation

Figure C – Computer document

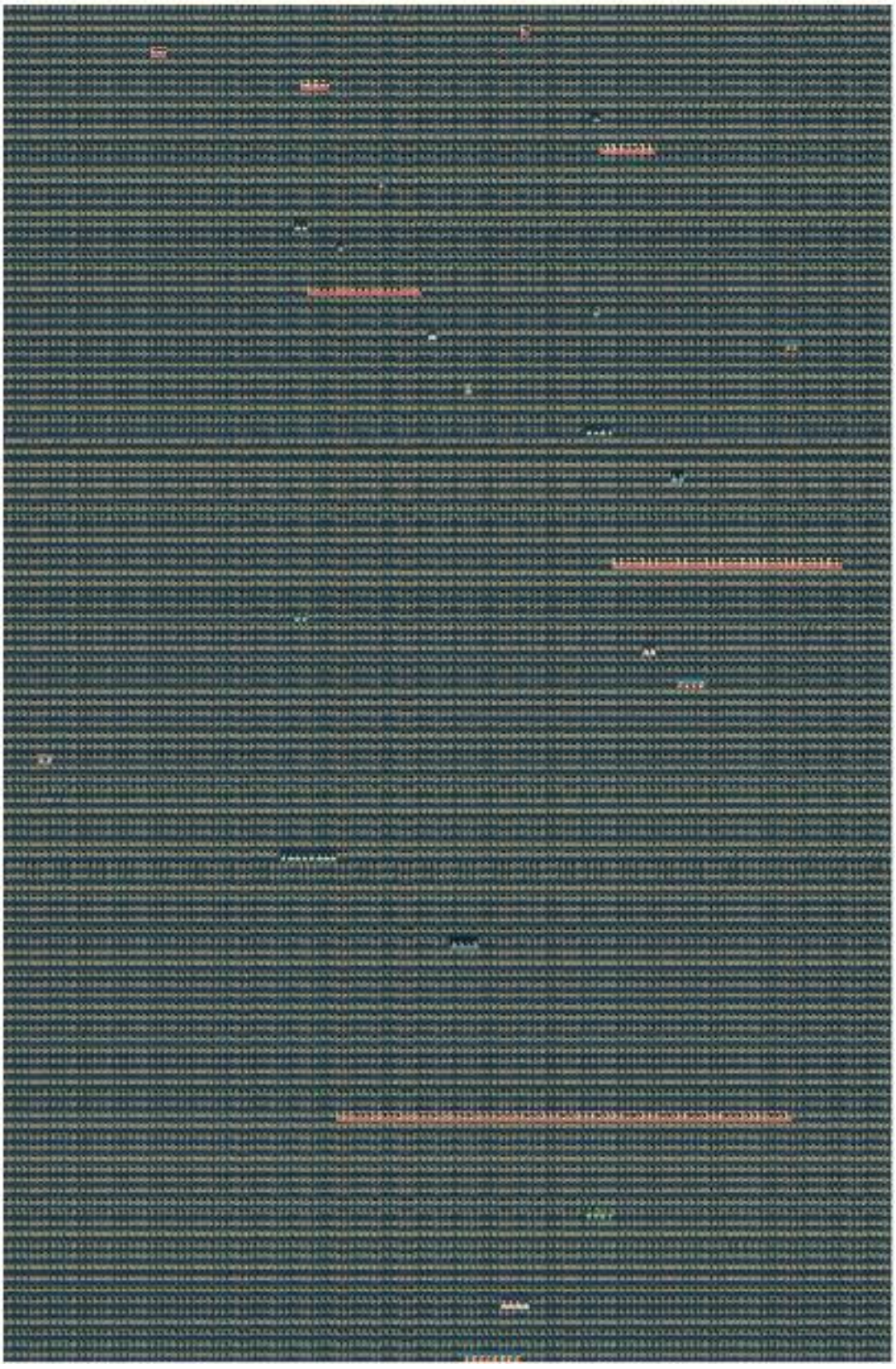

Figure D – Detail