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Molecular Dance

THESIS

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MASTER OF FINE ARTS

in Dance

by

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DEDICATION

To my younger sister, Vivian. You are the greatest blessing in my life. It has been an honor to complete my MFA in Dance with you at the University of California, Irvine.

To my grandparents Nana and Da, who inspired this thesis research and are no longer here to read it. I would not be where I am today without your guidance throughout my life.

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ABSTRACT OF THE THESIS

Molecular Dance

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Savannah Reach

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Professor Loretta Livingston, Chair

This thesis describes the investigation of selected concepts in chemistry as prompts for movement invention and new dance composition. The concepts are entropy, chemical kinetics, chirality, resonance, isomers, crystallization, and the chemical properties of water. In this study, these concepts serve as points of departure for choreographic invention and compositional elements. I use the discoveries to fuel and drive new and original choreography resulting in a concert presented to the public at The University of California, Irvine, April 2017.

As a dance maker and artist, I am interested in revealing chemistry culture through the body's movements. For the research, I use science as a basis for movement discovery, investigating, challenging, and ultimately understanding the pairing of chemistry and dance to create a unique performing art. My study of dance artist and movement theorist Rudolf Laban and contemporary ballet choreographer William Forsythe further stimulated my thesis research.

Multiple modes of inspiration for contemporary dance making emerge from a multitude of investigatory concepts in chemistry. Each concept provides distinct parameters for choreographic invention. I further develop my research by subdividing the concepts into terms that connect to both science and the human body in motion. By delving deeper into a topic, I am able to focus on themes in chemistry by exploring movement with dancers. This study provides a

method for choreographers and dance educators to find and form connections between science and art, in particular, concepts of motion and dynamic spatial and temporal relationships found in both chemistry and dance.

INTRODUCTION

As a dance maker and artist, I am most interested in revealing chemistry culture through the body in motion. By chemistry culture I mean the study of chemical interactions, properties, processes, and transformations that occur at the molecular[1] level. With Bachelor Degrees in both Dance and Chemistry, a minor in Computing Technology and Applications, and a Master of Science Degree in Organic Chemistry, I endeavor to form and find connections between my fields of study. Early in my collegiate studies, I realized there is a symbiotic relationship between the arts and sciences. The common thread is the utilization of creativity in both dance choreography and scientific research. This foundation in the arts and sciences has propelled my thesis research, led by my dance training and my curiosities as a scientist. In particular, I am interested in the potential for creative relationships between concepts in chemistry and compositional elements in dance. The purpose of this thesis is to utilize the intersection of art and science to investigate selected concepts in chemistry as prompts for movement invention and new dance composition.

Specific questions guide my thesis inquiry: In what ways might investigating scientific concepts in chemistry provide inspiration for dance choreography for the stage? How might dynamic actions, groupings, and transformations found in chemical processes provide new models for creating choreographic sequencing and composition? How might my own background in a scientific research laboratory translate into developing movement research of the body to aid my choreographic process?

[1] The term molecular refers to molecules, which represent the smallest fundamental unit of a chemical compound. Molecules are formed when two or more atoms form chemical bonds with each other in a specific geometrical arrangement (H_2O). Atoms function as the basic unit of an element. The periodic table consists of atoms such as hydrogen, helium, carbon, and oxygen (Tro 1).

My examination of the intersection between art and science has been stimulated by my growing interest in the work of dance artist and movement theorist Rudolf Laban. As I became familiar with Laban's work I started to make connections between his framework for analyzing movement and the fields of math and science. My understanding of his framework quickly connected to my educational background. The use of math and science to explore and understand human beings in motion and to provide movement pathways fascinated me as a choreographer, dancer, and scientist.

My thesis research has also been motivated through exploring two projects by contemporary ballet choreographer William Forsythe[2]: *Improvisations Technologies – A Tool for the Analytical Eye* and *Synchronous Objects*. These two projects provided examples of collaborative and educational research, which combine the arts and sciences through technology. These cross-disciplinary endeavors instigated a way for visual artists, scientists, dancers, and designers to collaborate and discuss the organizational principles used by Forsythe, such as his use of spatial geometry and complex patterns. Some of Forsythe's choreographic methods are inspired by his study of Laban's work. In particular, Forsythe's ideas about space and the body draw from Laban's space theory (*choreutics*) and the kinesphere (Gilpin 118-121).

Forsythe collaborated with computer programmers, designers, editors, and dancers to create *Improvisation Technologies – A Tool for the Analytical Eye*. Forsythe originally created the program as a training tool for the dancers of the Frankfurt Ballet in collaboration with the Center for Art and Media Technology (ZKM) in Karlsruhe, Germany (Forsythe and Kaiser 64). The interactive CD-ROM system combines Forsythe's dance principles with the integration of animated white lines and traces. Multimedia artist Paul Kaiser interviewed Forsythe to

[2] American dance artist William Forsythe was the artistic director and choreographer of the Frankfurt Ballet in Frankfurt, Germany for twenty years, starting in 1984. Although American born, most of Forsythe's work and choreographies are done in Europe.

understand his "use of geometric and algorithmic thinking to create new forms of choreography in ballet" (Forsythe and Kaiser 64). Forsythe explained his initial inspiration during his dialogue with Paul Kaiser:

> By moving from a point to a line to a plane to a volume, I was able to visualize a geometric space composed of points that were vastly interconnected. As these points were all contained within the dancer's body, there was really no transition necessary, only a series of 'foldings' and 'unfoldings' that produced an infinite number of movements and positions. (Forsythe and Kaiser 64)

I resonate with the passage above as both a choreographer and scientist. I continue to formulate my choreographic concepts inspired by Forsythe's method of visualization.

The website platform *Synchronous Objects* was developed to investigate ways to visualize the organization of Forsythe's choreography for stage. The visual interpretations of *One Flat Thing* were created through a team of researchers[3] at Ohio State University (OSU) using graphics, animations, and computer applications in order to better understand Forsythe's choreographic mind and to further visualize his creation. The collaborative nature of this project and the connections between the arts and sciences provide inspiration on how to present my topics.

Utilizing my experiences in both fields along with my study of Laban and Forsythe, I envision a true cross-disciplinary research project as a learning module. I will select concepts in chemistry that have the potential to serve as points of departure for choreographic movement invention and compositional elements. I will use the discoveries to fuel and drive new and

[3] The creative directors were Forsythe, Professor Maria Palazzi, and Professor Norah Zuniga Shaw. Palazzi is a Professor of Design and the director of the Advanced Computer Center for the Arts and Design at OSU. Shaw is a Professor of Dance and Technology at OSU where she continues to collaborate on creative research projects. The rest of the creative team included graduate research associates, faculty researchers from OSU in the Departments of Geography, Statistics, and Industrial, Interior, and Visual Communication Design, Forsythe Company Dance Research Collaborators, and International Collaborates specializing in art and science.

original choreography to be presented to the public in a dance concert at the University of California, Irvine in April 2017.

CHAPTER 1: Where Dance and Chemistry Meet

Introduction

I have selected seven topics in chemistry to serve as points of departure for movement invention. When investigating chemistry concepts, I focused my research on finding topics relating to space, shape, time, patterns, repetition, and three-dimensional motion. The selected chemistry concepts are chemical kinetics, entropy, resonance, chirality, isomers, crystallization, and the chemical properties of water. I am using these chemistry topics as prompts for new dance composition to test the physicality of the selected concepts through movement. In addition, I am using video documentation of my movement explorations in the studio and keeping a journal as a record of my work. I am interested in how dynamic actions, groupings, and transformations found in chemical processes provide new models for creating choreography. My explorations include concepts of motion and dynamic spatial and temporal relationships found in both chemistry and dance. In order to allow for conversations between artists and scientists, I have described each concept in physical terms and chemical definitions. This will allow for both fields to perhaps find the symbiotic relationship in the selected topics.

Chemical Kinetics

"Nobody, I suppose, could devote many years to the study of chemical kinetics without being deeply conscious of the fascination of time and change…" Sir Cyril N. Hinshelwood[4]

For my thesis research, I am interested in exploring the scientific concept of chemical kinetics. Kinetics is the study of motion, from the Greek word *kinesis*, which means movement. The basic definition of chemical kinetics is the study of how molecular motion causes change

[4] Sir Cyril N. Hinshelwood (1897-1967) won the 1956 Nobel Prize in Chemistry for his research on the mechanism of chemical reactions.

over time (Tro 562). Rudolf Laban introduced the term *kinesphere* to define: "the sphere around the body whose periphery can be reached by easily extended limbs without stepping away from that place which is the point of support when standing on one foot" (Laban, *Choreutics* 10). Laban created the word *kinesphere* by combining the Greek word for movement – "kinesis" – and the Greek word for ball – "sphaira" (Groff 125). The concept of chemical kinetics is well suited for dance movement because of the relationship between movement, motion, and changes that occur over time.

In dance movement, it is easy to see changes in the body in motion that occur over time. In scientific research, it is more complicated to examine changes of molecules in motion that occur over time. When molecules are moving, they start to collide and form interactions. Some molecules "like" each other and form new bonds. Other molecules "dislike" each other and their interaction weakens. The forming and weakening of bonds means a chemical reaction occurred. The term *reaction* refers to a chemical process that changes from start to end. These molecular interactions are similar to human interactions and preferences in personality types. Some people interact well together and form a bond. Other people do not interact well together and their bond is either weak or not formed.

Using the concept of chemical kinetics as a departure point, I plan to study varying rates of movement in my choreography. I will examine changes in terms of the interactions between the dancers. The concept of chemical kinetics prompts me to study how the dancers move through space with different approaches to time. This examination of kinetics relates to Rudolf Laban's study of time, which refers to a variation in time between "accelerating and decelerating" (Moore 152). As movements accelerate, there is an increase in the speed of motion that provides "a sense of energetic hurry and activity" (Moore 152). In contrast, when there is

effort to decelerate time, the movements become slower to demonstrate an extension and sustainment of the action. Laban's study of varying time is similar to kinetics because both concepts focus on a change in motion that occurs in relationship to time. Laban discusses in his book *The Mastery of Movement* the connection between motion and change in time when he wrote, "Motion becomes movement in living beings, who possess an inner urge to use time and the changes that occur in time for their own purposes" (89).

Entropy

Electrons, neutrons, and protons are the particles that form atoms. In order to form molecules, atoms bond together. According to Nivaldo J. Tro, author of *Chemistry: A Molecular Approach*, chemistry is the "science that seeks to understand the behavior of matter by studying the behavior of atoms and molecules" (3). Using my knowledge of the ways particles move, I am aligning movement phrases for the dancers based on disorder and dispersion. The increase in chaotic and random movements in the dancers' phrases creates an increase in disorder. These choreographic ideas are based on the chemical process of entropy. Entropy measures the chaotic movements of particles, where disordered or more randomized movements of particles in the system are favorable (Brown, et al. 172). The dancers will start collectively assembled (highly concentrated) and disperse as time progresses to explore a change in the entropy. The concept of entropy is an important choreographic tool for me because my movement vocabulary is usually ordered and structured. I intentionally chose the concept of entropy due to the possibilities of physicalizing randomness and disorder through movement.

Resonance

I am using the theory of resonance as a choreographic tool by exploring how electrons flow freely through a benzene[5] ring. This concept is well suited for movement in the human body. The theory of resonance prompts several departure points for my choreography. For example, I could start with a group of dancers in a large circle connected to one another. Inside the circle, dancers move freely. The dancers inside the circle will physicalize the continually flowing nature of the electrons in benzene. The dancers representing the benzene circle remain static to embody the cyclic structure of benzene.

Linus Pauling was the primary chemist who developed the theory of resonance in the 1930s. Based on his resonance theory, benzene can be described as two structures that help contribute to the actual molecular structure. The figure below shows the two contributing resonance structures for benzene. The curved arrows shown inside the benzene ring represent the fluid nature of the electrons[6] moving as some bonds appear and others disappear. When drawing resonance structures, electron pushing is used to show the movement of electrons with curved arrows (Brown, et al. 44).

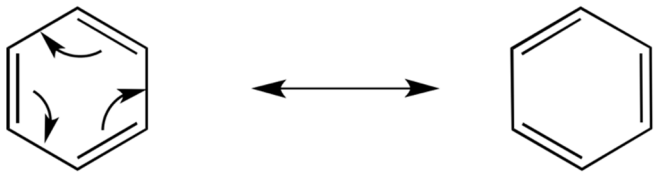


Figure 1.1. Resonance structures of benzene[7] demonstrating electron pushing arrows.

[5] Benzene is a cyclic molecule with 6 carbon atoms and 6 hydrogen atoms.
[6] The electrons are depicted by the extra three lines that are inside the benzene ring.
[7] Benzene is only one example of the numerous molecules that are described by resonance.

The two contributing structures of benzene are needed because chemists are unable to draw the placement of electrons around the ring. This is due to the electrons moving freely in the benzene ring instead of being static. The concept of resonance can be understood by examining the difference between capturing a movement phrase with a series of photos compared to capturing a movement phrase with a video. The series of photos will contribute to the idea of the phrase, but the entire movement phrase is not able to be fully seen without the use of a video recording. Similarly, the actual molecular structure of benzene is a resonance hybrid of the contributing structures because of the fluid nature of electrons flowing within the ring. The resonance hybrid version is shown in the figure below (Figure 4).

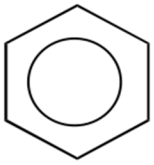


Figure 1.2. Resonance hybrid version of benzene.

The resonance hybrid version of benzene does not depict the flow of electrons using arrows. Instead, a circle is used to represent the circular flow of the electrons inside the benzene ring.

The flowing nature of electrons inside the benzene ring relates to Rudolf Laban's study of flow, which refers to his analysis of the ongoing nature of movement in human motion. According to Laban, the concept of flow varies between freeing and binding. In the flow continuum, the freeing of flow occurs in movements that are fluid and the binding of flow occurs in restrained motions (Moore 151). Laban's explanation of fluid movements in the freeing of flow provides additional insight into the nature of electrons in the resonance structures of

benzene. In particular, Laban's study of flow relates to both electron movements and motions in the body.

Chirality

The concept of chirality requires the ability to visualize objects in three dimensions and understand the relationships between three-dimensional objects. As a dancer, I am equipped to visualize movement in three dimensions and to understand the relationship of my three-dimensional body with other dancers or objects in space. The concept of chirality can be difficult for beginning students in organic chemistry. One reason chirality is challenging for chemistry students is that although they are studying molecules as three-dimensional objects, they are reading and writing the molecules on paper in two dimensions. Dancers have a unique background in the concept of three-dimensional space because of the nature of dance training. Both spatial awareness and bodily awareness in dance are required. The study of chirality provides concepts in three-dimensional visualization and relationships, such as symmetry and mirror images[8], which easily translate into the human body because of its bilateral symmetry.

As a choreographer, I am interested in using the concept of chirality to explore the symmetrical attributes of the body in motion. I plan to utilize the concept of chirality by expanding my ideas of mirroring and symmetry into multiple dancers to explore orientations (locations) and configurations (arrangements) in space. Lastly, I am using the scientific concept of chirality to further develop my understanding of mirror images and symmetry through movement invention.

Chirality is used to describe an object that is not superimposable on its mirror image. Superimposable means to place one on top of the other. To further understand the concept of

[8] A mirror image is simply the reflection of an object in a mirror.

mirror images, observers should imagine the right hand and left hand are without differences. There are not any interesting freckles, scars, or rings on one hand when compared to the other. If the palm of the right hand were placed on the palm of the left hand so that each finger lines up (pinky finger on pinky finger, thumb on thumb, etc.) and a small space between the hands were created, while keeping the same relationship between each finger, the right hand and left hand would be mirror images of each other based on their orientation. In order to demonstrate the opposite concept, one hand placed on top of the other with both palms down makes the hands not superimposable because the thumbs are near the pinky fingers of the other hand. This experiment concludes that the hands are chiral. The term chiral comes from the Greek word, *cheir*, which means hand (Brown, et al. 118).

In comparison, when an object and its mirror image are superimposable, the object lacks chirality. The term for these objects is *achiral*. An example of an achiral object is the cube (Brown, et al. 118). Achiral objects contain one or more elements of symmetry. There are two types of symmetry to look for in an object. The first type is center of symmetry. The center of symmetry is described by Brown et al. as "a point so situated that identical components of an object are located on opposite sides and equidistant from that point along any axis passing through it" (119). For example, the cube contains a center of symmetry.

Rudolf Laban found this center of symmetry in the cube and related it to the center of gravity in the body and the center of the kinesphere[9] (Laban, *Choreutics* 11). Laban describes the cube as "the three-dimensional form composed of height, breadth and depth, which is easiest to visualize" (Laban, *Choreutics* 11). He continues to explain certain properties in the cube, such as oblique lines. The oblique lines, also called diagonals, start in each of the eight corners of the

[9] Laban describes the kinesphere as the "sphere around the body whose periphery can be reached by easily extended limbs without stepping away from that place which is the point of support when standing on one foot" (Laban, *Choreutics* 10).

cube and end in the opposite corner to create four diagonals that intersect at the center of symmetry in the cube. The eight corners of the cube are useful for "mapping movement in the kinesphere" (Moore 117).

The second type of symmetry is a plane of symmetry, which is "an imaginary plane passing through an object or molecule" (Brown, et al. 118). The cube contains nine planes of symmetry. Three of the planes of symmetry found in the cube are described by Rudolf Laban as the cardinal planes. The three cardinal planes are the vertical plane, horizontal plane, and sagittal plane. The vertical plane "divides the dancer's space, separating the area in front of the body from the space behind" (Moore 116). The horizontal plane divides the dancer's space above and below the waist level. The sagittal plane, "extends though the kinesphere like a wheel" and "separates the space to the right side of the body from the space to the left" (Moore 116). Laban noted the relationship between the six directions[10] and the concept of symmetry. He described that "our intellect distinguishes between three forms of symmetry in space: up and down, left and right, forward and backward…" (Laban, *Choreutics* 81).

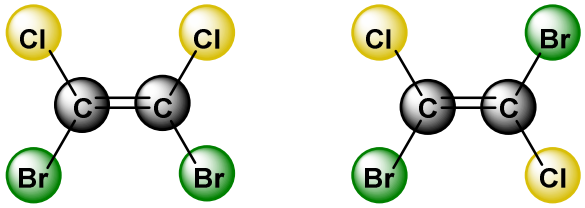
Even though Rudolf Laban did not use the term *chirality* in his work, he did study the concepts of symmetry and mirror images. Laban described the body as a "bilateral organization" with a "mirror-like structure of the left and right sides" (Laban, *Choreutics* 18). The bilateral nature of the human body refers to the external reflective symmetry between the right and left sides of the body. Dancers are familiar with the bilateral reflective symmetry of the body due to

[10] Each plane is two-dimensional, which means they combine two dimensions. The three dimensions are composed of the six cardinal directions. The vertical dimension of height corresponds to the up and down directions. The sagittal dimension of depth corresponds to the forward and backward directions. The horizontal dimension of height corresponds to the right and left directions. The vertical plane is composed of the vertical dimension (up and down directions) and the horizontal dimension (right and left directions). The sagittal plane is composed of the sagittal dimension (forward and backward directions) with the vertical dimension. The horizontal plane is composed of the horizontal dimension and the sagittal dimension. The six cardinal directions are up, down, left, right, forward, and backward.

our technical training when "movement sequences are performed first to the right and then to the left" (Moore 198).

Isomers

In organic chemistry, the term *isomer* describes two or more compounds with the same formula, but a different spatial arrangement of atoms in the molecule. Formula describes the number of atoms of each element in the compound. For example, the chemical formula $C_2Br_2Cl_2$ (2 carbon (C) atoms, 2 bromine (Br) atoms, and 2 chlorine (Cl) atoms) produces two isomers, a *cis* isomer and a *trans* isomer. The terms *"cis"* and *"trans"* are Latin. *Cis* is "on the same side," and *trans* is "on the other side" or "across." The figure below shows the *cis* and *trans* isomers of $C_2Br_2Cl_2$.



cis isomer *trans* isomer

Figure 1.3. The *cis* and *trans* isomers of $C_2Br_2Cl_2$.

The *cis* isomer shows the chlorine atoms on the same side and the bromine atoms on the same side. The *trans* isomer shows the chlorine and bromine atoms on opposite sides, which creates a diagonal between the pair of chlorine atoms and a diagonal between the pair of bromine atoms.

I am using the concept of isomers as a choreographic tool to explore movements where the limbs are on the same side (*cis)* or on the opposite side (*trans*) of a given plane. By exploring

the cardinal planes (horizontal, vertical, and sagittal) there could be many variations of movements using *cis* and *trans*. In addition to two-dimensional explorations of movements in planes, I also plan to utilize less stable explorations of isomers in three dimensions. As previously mentioned, Laban studied the cube and the movement pathways found inside the cubic structure. The cube provides a framework for movement explorations in the three dimensions through the diagonals of the cube. The endpoints of the cube form four diagonals, which all pass through the midpoint. The midpoint of the cube relates to the center of gravity in the body and the center of the kinesphere (Laban, *Choreutics* 11). When used for movement, the diagonals of the cube create the most mobile pathways in comparison to the pathways Laban defined in the other Platonic solids. I plan to combine Laban's study of movement in the cube with the chemical concept of isomers to explore *cis* and *trans* movement possibilities through the diagonals.

Crystallization

Crystallography studies the arrangements of atoms in space that form a unit cell. The unit cell grows to form a pattern in order to create a particular shape. The focus on arrangements, patterns, and shapes fascinated me as a chemist and also as a choreographer. My study of crystallization in the research lab was the topic I originally investigated as a choreographer during my undergraduate experience. My examination of the merge between movement and crystallography was further developed during my research of Rudolf Laban's crystalline forms.

Rudolf Laban dedicated a section of his research to scientific crystallography. In particular, he related scientific crystallography to the kinesphere and the human body in motion. He explained that the "crystallography of human movement in which spatial tensions and

transformations are scientifically examined in a way similar to that undertaken when investigating those which occur in the building up of matter" (Laban, *Choreutics* 103). Laban refers to the body as a "crystalline structure" because it is "built up according to the laws of dynamic crystallization" (Laban, *Choreutics* 105). Laban uses the word *dynamic* because he uses the simplest crystalline form of the tetrahedron (4-sided) to transform into new forms (Laban, *Choreutics* 103).

In addition to the tetrahedron, Laban studied other crystalline forms, such as the cube (6-sided), octahedron (8-sided), dodecahedron (12-sided), and icosahedron (20-sided). Laban used these five Platonic solids to "describe pathways through the territory of the kinesphere" (Moore 112). The five Platonic solids are defined as *regular* polyhedra because all the the sides (faces) are the same size and shape. The angles between the edges of each vertex (corner) are identical and the edges of each side are the same length (Moore 113). The term *polyhedra* is plural for polyhedron, which comes from the Greek words *poly* meaning "many" and *–edron* meaning "face."

These five regular polyhedra relate to Laban's study of the kinesphere because they are "three-dimensional, they encompass space, as a sphere does" (Moore 113). Laban used these geometric concepts to map movement pathways and encourage greater spatial range in the dancers with whom he worked. Out of the five Platonic solids, Laban determined that the cube, octahedron, and icosahedron were helpful in "capturing characteristic pathways used in dance and other movement arts" (Moore 113). He used the cube, octahedron, and icosahedron to define three sets of linear pathways established in the kinesphere as dimensions, diameters, and diagonals. Within an octahedral form, Laban aligned the six cardinal directions of up, down, forward, backward, right side, left side with the upright posture of the human body. His

correlations of geometric dimensions to the shape of the octahedron form establish "a set of three intersecting lines perpendicular to one another" (Moore 114). By lines he meant possible trajectories for movement.

With increasing complexity due to the twenty faces and multiple resultant meeting points of sides and corners of the octahedron, Laban found more expansive movement possibilities. The icosahedron has twelve corners composed of twenty triangular faces compared to the octahedron, which has six corners and eight triangular faces. Utilizing corners and faces, planes and dimensions, Laban developed movement patterns rich in spatiality for dancers.

The final Platonic solid with which Laban worked was the cube, which I have discussed in the previous sections of **Chirality** and **Isomers**. The cube contains eight corners and six square faces. The most salient features of the cube for the purpose of movement explorations were the four diagonal pathways, connecting opposite corners and intersecting at the center. In Laban's opinion, the diagonal pathways of the cube provided the mover with maximum mobility.

I am combining my knowledge of crystal formation from my scientific research with Rudolf Laban's study of bodily movement inspired by the five Platonic solids. I will start by exploring the formation of a unit cell through interactions between dancers, which represent the atoms in the crystal. Once the unit cell is formed, the arrangement grows to form a pattern in space. This is how a crystal forms in chemistry. I am also interested in utilizing the concept of diffraction, which is how the crystal structure is determined. Some examples of crystal structures are the five Platonic solids Laban researched.

Chemical Properties of Water Molecules

"Water is easily the most common and important liquid on Earth. It fills our oceans, lakes, and streams. In its solid form, it caps our mountains, in its gaseous form, it humidifies our air. We drink water, we sweat water… the majority of our body is water. Life is impossible without water…" (Tro 487).

Water is made up of two hydrogen atoms and one oxygen atom. Together these atoms create a water molecule (H_2O). There are three transitional states of water: solid (ice), liquid, and gas (vapor). As a dance artist and educator, the fluid nature of water is an important tool for visual imagery. Eric Franklin discusses basic movement images and imagery exercises in Chapter 1 of his book *Dance Imagery for Teaching and Performance*. I was interested in studying his section on whole-body sensation to use three states of water as visual imagery for movement exploration and improvisation.

I am connecting my knowledge of the chemical properties of water with Franklin's approach to whole-body sensation through visual imagery in order to explore new movement investigations with dancers through guided improvisation. The dancers will approach chemical changes and interactions between water molecules by exploring the three states of water. I will start by explaining that water is made up of two hydrogen atoms and one oxygen atom. Together these atoms make a water molecule (H_2O). I will invite dancers to explore the three transitional states of water by starting in a compact position to embody frozen water (ice). In this solid state, the water molecules are trapped without freedom to move outside of their contained space. I will add a layer of description by asking the dancers to reflect to a time in their life where they felt trapped within a situation or a relationship. I will ask the dancers to add those feelings to their current movement improvisations.

The compacted and constrained embodiment of ice transitions to the liquid state through my description of warmth covering their bodies. The dancers will suddenly start to have more

freedom in the space, but they still have some restraint based on their container. I will describe to the dancers that their liquid state could be in a bowl or a glass, which allows for more freedom of movement compared to the frozen form.

The final state provides the most freedom for the dancers through their improvisation. This is the gaseous state of water, which can flow through space freely. This occurs by heating the liquid form of water to a boil. I will describe this state by relating it to a time in their life where they felt free and able to go wherever they wanted to go.

After the dancers finish their improvisations through the three states of water, I will explain that their bodies are a molecular mass. Water molecules make up a large percentage of their body. I will utilize the dancers' improvisations to inspire movement for the opening dance of my thesis concert.

Dancers have an instinctive knowledge about the movement of molecules since their bodies are a molecular mass. I selected water molecules instead of another molecule because the dancers are very familiar with the idea of water. I will use water as visual imagery to explain concepts such as gracefulness and flow. Introducing this simple water concept to dancers is an example of breaking down the divide between the arts and sciences. This can be done by finding, analyzing, and challenging the connections between chemistry culture and dance movement.

Concluding Thoughts

The chemistry concepts I selected will be used to shape my choreographic explorations in the studio. The next chapter discusses how the examination of these chemistry concepts further developed my choreographic process by using science as a basis for movement invention. My thesis research is not focused on directly translating a chemistry concept from the page to the stage, but rather the use of these concepts as departure points to create movement.

CHAPTER 2: Choreographic Process

Introduction

The chemistry concepts within my thesis were utilized as departure points to construct choreography for my movement research. My movement research investigates creative relationships between concepts in chemistry and compositional elements in dance. As a movement researcher, I focused on my approach to movement and challenged my choreographic methods as a dance maker. My process began with determining the number of dancers needed to demonstrate complex concepts such as crystallization and entropy. For example, in order to explore a crystal formation, I needed at least eight dancers. Next, I determined the amount of time needed for each dance in order to portray the chemistry concepts fully. Another important part of my process was selecting music to compliment my choreographic ideas. Music has always created an initial spark for my movement invention. When I started selecting music for my thesis concert, I searched for music that connected to my choreographic ideas.

A Cluster that Gradually Scatters: Entropy

The music drives the rhythm and boosts the flow of energy in every part of this dance. The composition entitled *Elements* by Ludovico Einaudi starts with a quick pulse that continues throughout the score to maintain the tempo. This musical composition progresses in intensity and becomes more layered as instruments are added. A change in tempo or an addition of an instrument occurs every 30-40 seconds. The music inspires dynamic and progressive movement changes in the dance that allow a correspondence to entropy's increase in randomness and disorder.

My choreography opens with dancers in a tight cluster facing the audience. The dancers start by moving their right shoulder forward and backward to each beat with the quick pace of the music. After eight movements of the right shoulder, the dancers add bending and straightening of the right leg. These direct and quick movements of the right shoulder and right knee grow into a flow of both the arms and legs. This flow occurs through a weight shift by bending the right leg and then the left leg. As the right leg bends the right arm flows forward and backward, which is followed by the same movement on the left. Utilizing this flow of energy from the weight shifts and sway of the arms, the dancers switch the direction of their arms across their right, center, and left side. Once the dancers start the flowing arm gestures, their movements look similar to seaweed moving in the ocean.

To demonstrate entropy, the dancers begin by scattering randomly once the music shifts in intensity through the addition of a new instrument. The change in the music cues one dancer to leave the cluster as the cluster shifting ninety degrees to the dancers' left. The solo dancer explores a movement idea with the intention of opening and unfolding her arms over her head as she leaves the cluster. The progression starts small and grows as the solo dancer's distance increases from the cluster. Next the cluster faces stage left (audience's right). The dancers' legs in the cluster alternate bending the right leg forward for four counts to shifting the weight between both legs for another four counts. This is repeated for six 8-count phrases. The ten remaining dancers in the cluster were given a number from 1-6 to explore the same phrase as the solo dancer with their upper bodies. The solo dancer outside of the cluster begins the progression with opening her arms as the dancers inside the cluster stay stationary as they correspondingly open their arms on the designated number from 1-6.

This idea of a solo dancer scattering from the cluster with each musical shift plays out through time to result in a leaving and changing within the group. There is a visual effect of flowering as the solo dancer leaves the cluster and initiates change in all the dancers' movements. The cluster resembles a blooming flower, and the solo dancer is a petal that fades and falls away from the flower center.

The second solo dancer progresses from the cluster with movements involving the unfolding of her arms from a starting position of her hands on her shoulders. The first solo dancer that left the cluster watches the new unfolding figure then joins her exploration of movement as it progresses around the cluster. The remaining dancers in the cluster shift their orientation another ninety degrees to their left so that they are now facing the back of the room. The shift in orientation is initiated by another petal released from the flower. They keep their original numbers 1-6 and now explore the unfolding of the elbows from the shoulder. This pattern of ninety degree shifts continues as each dancer comes out of the cluster.

The third dancer leaving the cluster explores bending of the right arm followed by bending of the left arm by moving her torso from side to side. This exploration occurs when the music changes, but before the six 8-count phrase ends. The outside two dancers watch her once and then join her movement investigation in their own moving freely through the space. This movement exploration has a rocking effect on the dancers' torso that resembles movements of a seesaw. The dancers inside the cluster stay facing the back until the six 8-count phrase is completed.

The fourth dancer comes forward out of the cluster once the six 8-count phrase ends and there is another change in the music. Her movement exploration involves crossing the right arm in front of the left arm in front of her chest. The three dancers outside of the circle watch her

once and then join in the progression of the movement phrase. The dancers inside the cluster shift ninety degrees to the left and now face the right side of the room (audience's left). They continue their pattern until the six 8-count phrase is completed.

Growing in complexity and intensity, the music continues to match the scattering of the dancers outside of the cluster. Two dancers now leave the cluster swinging their right arm in the sagittal plane. This movement idea was inspired by the movements of a windmill. The dancers outside the cluster watch them once then explore the new movement phrase. There are five dancers left in the cluster, and they shift back to the front facing the audience. The music accelerates, and the dancers respond by moving away from the cluster towards the outer edges of the space. Two of the remaining dancers leave the cluster during the next change in tempo. Their movement exploration includes moving their chest forward and backward and then jumping forward, switching their stance.

The pattern changes when there are three dancers left in the cluster. All three dancers scatter, which ends the cluster formation. The eight dancers outside the cluster watch and then follow each other in two walking patterns around the room. This section creates two swirls that resemble the idea of the flower petals being caught in the wind. As the dancers move around the stage, they finish in a straight line from the right to the left side of the stage. This idea allows for returning and restoring of the dancers as entropy spreads into space and a new order is established.

The line forms to the dramatically changing music. The music continues with a soft melody and slow tempo as the dancers rearrange their places in the line with flowing movements. The dancers use their breath as the initiation of their movement.

The music gradually grows in intensity, and the pace becomes quicker as the dancers step forward out of the line one at a time. As each dancer steps forward, she showcases the movement she explored independent of the cluster. In this section, every dancer comes forward one at a time to demonstrate her precise movement. After the last dancer moves forward, the group begins a ripple movement from stage left to stage right. As the dancers' energy starts to expand, each dancer breaks into one of two walking patterns around the space. These walking patterns are quick and use both circular and linear pathways. After a few patterns have been completed, all of the dancers exit the stage besides a solo dancer.

Improvisation Methods for a Solo Dancer

The solo dancer breaks out of the group and explores four movement ideas through improvisation. Two of the movement explorations develop from Laban's study of effort, which include four motion factors – flow, weight, time, and space. Moore explains that "each motion factor represents a different sort of inner intent: flow is the effort exerted to control movement; weight is the effort exerted to apply the right amount of force; time is the effort exerted to pace movement adroitly; and space, when used as an effort term, is the effort exerted to aim movement accurately" (151). By combining certain qualities within each factor, two movement characters will evolve, which Laban describes as the fighting side and the indulging side. The fighting side involves bound flow, quick time, direct space, and strong weight. Movements explored with the combination of these efforts create a fighting character, which resembles a ninja or a warrior. The indulging side involves the opposite qualities of the spectrum: free flow, sustained time, indirect space, and light weight. These movements would resemble the leaves of a willow tree swaying in the wind. Once these movement qualities were described to the solo

dancer, she explored the fighting side and the indulging side created by Laban and felt the contrast of these two ideas. Another movement idea she explored involved a geometric description of improvising movements that formed crosses and Xs. The last idea she explored was described as blooming and breaking, such as a flower that blooms and glass that breaks. This particular movement idea causes an abrupt dichotomy in the solo dancer's body.

After the solo dancer explored these four ideas through improvisation, the order was structured. She started by exploring Laban's idea of the fighting side, followed by the geometric idea of crosses and Xs, which lead to blooming and breaking. The music fades and ends while the solo dancer explored Laban's idea of the indulging side.

Symmetry and Mirror Images: Six Dancers

This section includes six dancers paired in three duets. The dancers' movement phrase travels from stage left to stage right. The first two dancers move through the phrase one behind the other, as if one dancer is copying the other. The second pair begins one dancer at a time. Each dancer in the second duet begins after the first duet passes them in space. The second pair has side-by-side movements. The third pair starts off stage and slowly walks towards each other as the first two duets start the phrase. Once the third pair move closer together, all three groups begin to dance together in unison. This phrase ends with the dancers facing each other in pairs.

The second half of the dance explores the idea of mirror images between the pairs. There is a center of symmetry found between the dancers as each group explores the same gestures facing each other. They mirror each other through these gestures with each dancer orientated differently in space. The dancers' basic gestures in each group match their movements exactly, as if they were looking at themselves in the mirror. Even though all the dancers are doing the

same gestures, each duet demonstrates an individuality, which resulted from their exploration together.

Walking Patterns in Space

During my first full cast rehearsal for my thesis, I was interested in exploring two walking patterns with shifts in direction and a small level change. Each pattern started with the feet parallel and hip-width apart. The first pattern included taking two steps forward followed by a shift of the body to a new facing in space. When the body shifts to a new direction, the feet come back to the starting stance. The arms naturally swing while walking, but without added force or energy. The second pattern takes one side step followed by the another step that crosses over. There was a shift in the direction of the body by 180 degrees as the legs uncross. These two walking patterns take the same amount of time to complete, so that two dancers can walk together in a different pattern and finish in eight counts. The level change started from the neutral stance. The dancers go up to parallel relevé[11] and then come down to straight legs followed by a small bending of the knees in parallel. This level change can also be done starting with a small bending of the knees and finishing with the relevé.

During this exploratory work section, the dancers were shown the two walking patterns with shifts in directions and small level changes. The dancers explored these patterns together with changes in sequencing. This gave me the opportunity to see the dancers together and how they moved and occupied the space as they improvised within the patterns.

The dance begins with one dancer on stage in a neutral stance. She remains still while four dancers enter the space with the walking patterns. The dancers use travelling flexibility

[11] The term relevé comes from ballet vocabulary and describes a movement in which the dancer rises on the tips of the toes.

during the patterns by using both spatial and bodily awareness. This is similar to pedestrians walking across the street using a crosswalk. Every person has the same amount of time designated to cross the street; however, they have freedom to decide how much space is between them and when they start to walk across the street. Once the fifth dancer has completed three patterns, the still dancer joins in as the tempo increases. Instead of taking eight counts to complete a pattern, the dancers now take four counts. The last four dancers enter in a diagonal formation from stage left. They perform walking patterns in an ordered arrangement with the slower tempo.

Dispersion of a Circle

One dancer stands inside a circle created by eight surrounding dancers. The dancers switch places with each other around and through the circle. The switching becomes faster until the dancers disperse into weight sharing poses.

Diagonal Line Section

The dancers slowly create a diagonal line across the stage by moving through a repetitive phrase. They continue this phrase until all nine dancers have formed the diagonal line facing the downstage right corner. Once the dancers have formed the diagonal line they move together with increasing intensity. The moment of highest intensity leads the flow of energy into a balanced pose as the dancers close together in the diagonal line. This diagonal line occurs as the music softens and the dancers come together.

As the diagonal line moves together, one dancer runs from off stage in front of the line. She finishes her running path at the end of the diagonal line in the downstage right corner. The

supporting dancers in the diagonal line unwind from their pose as they watch the solo dancer move freely and quickly to the music. The entrance of the solo dancer occurs as the music starts to pulse, which matches the tempo of her running steps. Once her solo has finished, the diagonal line dancers join her to start the next section.

Solo and a Supporting Duo

While I was still in the process of selecting chemistry concepts to use for my MFA thesis research during the summer break of 2016, I explored the idea of isomers with a few MFA graduate dance students. My explanation to the graduate dancers included describing a molecular structure with *cis* meaning same side and *trans* meaning opposite side. I showed them a few examples with my arms and legs. I explained that their movements choices in the cardinal planes (horizontal, vertical, sagittal) could provide many versions of movements using *cis* and *trans* isomerization. Although my explanation was elementary compared to the full topic of isomers, I was interested in their interpretation of isomerization through movement. This exploration helped me as a movement researcher to visualize movement phrases created by advanced dancers. After this preliminary movement experiment, I wrote observations from their guided improvisations. I used video footage of their improvisations as a tool to further investigate their movement choices when I constructed the dance for my concert. The dance I constructed consisted of a solo and a supporting duo.

While creating movements for a solo dancer, I used an approach to movement invention based on exploring the planes with the intention of *cis*-*trans* isomerization through the body. Her movement vocabulary included a range of extended, elongated movements and narrow, contracted movements. The opening phrase was slow, which allowed her to find balance while

exploring stretched positions in the planes. As the music quickened, it became clear that the solo consisted of three sections. The first section (A) was a simple exploration of slow movements with an intention of balanced and counterbalanced extensions with her body in the cardinal planes, which developed into a complex investigation through a fast and direct phrase (B). The final section (C) transitions to explorations on the floor with slow movements similar to A.

Even though the solo dancer was showing the relationship between *cis* and *trans* isomerization through her movements in the planes, I realized that another level of investigation could be made by adding two dancers. In chemistry, isomerization is understood through the relationship between atoms in a molecule. With dancers representing atoms, I explored the idea of isomerization based on the spatial and temporal relationships between the three dancers.

Two dancers started with A to represent two atoms *cis* to each other. By *cis* to each other, I mean that their movement phrase was the same. The third dancer started with B and C to demonstrate movements *trans* to the other dancers (atoms). By *trans* I mean that the third dancer was exploring opposite phrases compared to the other two dancers. Once the two dancers completed A and transitioned into B, the third dancer transitioned into B so that all three dancers were now performing the same movement phrase. As these three dancers move together, the speed increased and changed their spatial and temporal relationships. This final transformation demonstrated the switch from oppositional movements between the two dancers and the third dancer to all three dancers moving in unison.

There were numerous relationships occurring during the trio. Each individual dancer explored the relationships between *cis*-*trans* isomerization in the three cardinal planes. In the beginning of the dance, the two dancers were *cis* isomers and the third dancer had a *trans* relationship to them. Overall, the first section showed *trans* isomerization because the three

dancers were not performing the same movement phrase together. The switch to *cis* isomerization occurred when the three dancers connected to explore B and C together at the end of the dance.

Concluding Thoughts

Throughout these choreographic explorations, I noticed repetitive spatial and movement patterns. As a choreographer, I rarely create dances where the dancers improvise their movements or spatial arrangements. However, most of the dances in my thesis concert rely on improvisation as the dancers complete the work with their own interpretation of my descriptions. Repetition is layered throughout the concert as the dancers revisit movements with new musical cues, patterns, and relationships.

As I was envisioning chemistry concepts, I realized that my movement inventions were developed from repetitive processes found in nature, such as crystallization. These repetitive patterns found in nature are caused by chemical processes at the molecular level. As I created my thesis concert, repetitive movements and spatial arrangements manifested throughout my dances. This was the first time I allowed repetition to be a main theme in my choreography. The process of repetition challenged me as a dance maker to form new connections between the dancers, music, and space.

CONCLUSION

Even though my MFA thesis research started approximately two years ago, my fascination with finding connections between the arts and sciences began seven years ago as a sophomore at the University of Alabama. The symbiotic relationship between my two fields of study are creativity and beauty. I realize that beauty is subjective; however, my research in both chemistry and movement has challenged my perspective of beauty. There is beauty to be discovered at the molecular level.[12] In chemistry, I find beauty in chemical processes through motion, transformations, arrangements, and dynamic actions. There is also beauty in the arts. In dance, I find beauty in movements that explore new patterns, spatial arrangements, and dynamic temporal relationships with the music. There are parallels between the arts and sciences, which can lead to further discovery in both fields by utilizing creativity.

My own background in a scientific research laboratory translated into developing movement research of the body, which aided my choreographic process. I noticed that my preparations for choreographing in the studio and researching in the lab are similar. Just as I wrote a detailed set of guidelines in my chemistry research notebook before starting a reaction, I also wrote descriptions of movement ideas and formations for choreography before working with my dancers.

In addition, I realized that my choreographic approach is similar to my scientific research approach. In scientific laboratory research, fluctuations occur frequently. Even when preparations have been made for a reaction, alterations are typically made from the initial skeleton. I discovered a related method in my choreographic process. I came into the studio with

[12] For a visual reference to many beautiful chemical processes, visit these websites to view multiple video examples: http://www.beautifulchemistry.net and http://www.beautyofscience.com. I utilized some of these videos as visualizations for my thesis concert.

prepared choreography for each dancer. However, just as an effective science researcher needs improvisation skills, an effective movement researcher needs to make adjustments until the choreographic vision is clear. My investigation of scientific concepts in chemistry provided inspiration for my dance choreography for the stage.

Through my explorations of chemistry at the molecular level, I found new freedom as a dance maker. My perspective was altered through the creation of my thesis concert as I formed connections between chemistry and dance to create a unique performing art. This thesis research challenged my approach to creating movement through developing my fascination of finding links between the arts and sciences. I started to see my dancers moving through space as both artists and molecular beings.

Out of the selected chemistry concepts, crystallization challenged my choreographic process. The concept of crystallization was the initial inspiration for my thesis concert. I was able to immediately visualize how I could use my knowledge of laboratory crystallization research and implement it into my choreographic process. My usual approach as a choreographer is to arrive with set movements assigned to every dancer with specific spatial patterns arranged. However, my process was dramatically altered once I approached my role as a choreographer and a researcher. Using crystallization as a choreographic tool, I became interested in the analysis and problem solving aspect of my role as a movement researcher instead of the setting of specific movements in space. By problem solving, I mean using movement prompts for the dancers, which gives control over their actions and decisions. In a sense the dancers become researchers in their phrasing as they problem solve their route through space and their approach to the movement vocabulary and descriptions I provide for them. The analysis of this type of

movement research involves linking my knowledge of chemical processes with dance vocabulary in order to provide new movement pathways and ideas for my work.

The concept of entropy was the most significant tool for me as a choreographer, teacher, and scholar. I knew that entropy would challenge me chorographically because the nature of entropy is the polar opposite of my approach to movement invention. Before starting this thesis project, I would describe myself as a structured, deliberate, and analytical choreographer. The scientific concept of entropy evolves to a state of disorder, randomness, and chaos. I specifically selected entropy because I wanted to use this opportunity to develop those aspects of my choreographic process. I used the music as my calculated and steady guide. The movements were entirely based on the ideas of entropy, which provided a heavy emphasis on movement exploration of the dancers in order to fully analyze and understand a state of randomness. At first, the process felt as if I was trying to write with my left hand for the first time. As I started to trust the dancers, I realized the importance of this method as a teacher. Finding the balance between control and giving students the opportunity to explore their bodies is very important for the creation of new knowledge for both the students and the teacher. In the case of my MFA thesis research, my dancers had the role of the students. By analyzing their choices and challenging my choreographic process, I noticed the balance between order and disorder. There is something to be learned in moments of chaos that could not be discovered in a completely ordered system.

In the future, I plan to use my thesis research to educate artists and scientists in the relationship of space, time, patterns, repetition, and three-dimensional motion. I plan to implement as a teacher the ways creativity in both the arts and sciences enhance each other. My thesis research provides methods for choreographers and dance educators to find and form

connections between science and art, in particular, concepts of motion and dynamic spatial and temporal relationships found in both chemistry and dance.

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