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Photomicrography as an artistic medium

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ABSTRACT

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This thesis investigated the problems associated with artistically photographing patterns that exist within the microscopic world echoed on a larger scale throughout nature. Photographing these patterns at a microscopic level presented a number of difficulties not associated with photographing patterns through traditional photographic means. This thesis explored the problems associated with photographing subjects on a microscopic level, specifically the issues presented by lighting subjects. Experimental techniques with multiple light sources as well as light spectrum were explored. Also explored was the history of microscopy and popular processes for modern microscopy.

Images were created utilizing either a compound microscope or stereomicroscope in conjunction with a digital single-lens reflex (SLR) camera and a microscopy lens attachment. Subjects for images consisted of a variety of live and dead coral specimen, algae, saliva, blood, marine vertebrates and invertebrates, and terrestrial insects. Recommendations for further studies of the microscopic world and patterns are also presented.

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I am fortunate in that this thesis has presented me the opportunity to express my appreciation to the individuals who have made such a lasting impression on my life. First, thanks must be given to my family for giving me the guidance and encouragement that allowed me to believe in myself. Thank you to the art and design community here at the University of Northern Colorado for making my time at school a wonderful experience. Special thanks to Dennis Morimoto, Mike Lemke, Tom Stephens, and John Tonai for their guidance and friendship. Thank you to Jon Garnett, a good friend and mentor. Finally, thank you to Nicole Cowan, the love of my life and my inspiration.

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PREFACE

The decision to compose my thesis on the subject of photomicrography was reached as a direct result of my job field for the past six years. Aquarium keeping began as a hobby but quickly became an obsession. In an effort to slow the amount of money I spent on my hobby, I turned it into a means of income and began working at my local tropical fish store. Working with marine life on a day-to-day basis allowed me to witness a beauty that often goes unseen. Corals that possess pigment more vibrant than any artist's paint inspired me to put forth my best effort in capturing and sharing their beauty.

Initially, I began photographing the corals I worked with using a macro lens so that we, as a company, could accurately catalog them for sale on our website. In the coral hobby, a great deal of emphasis is placed upon the accuracy of the images a retailer provides of the corals they are selling. If the color of a coral differs from the image provided, or the size is not accurately portrayed, there is a good chance the customer will be unhappy and, potentially, no longer a customer. That being the case, I was forced to put a great deal of thought into the composition, proper white balance, focus, and other aspects of the images I was producing. I quickly realized the artistic value of the images and soon after began photographing the corals with the intent of creating works of art. When a co-worker brought in his microscope so that we could

diagnose a sick fish for a customer, a new world of photographic potential was revealed to me. Soon after, I purchased my own microscope and a lens attachment so that I could capture the images I saw. Everyday objects soon became subjects of interest when viewed on the microscopic level. The simplest of things were now capable of creating some of the most interesting and complex images. The process of selecting subject matter transformed from what did I see of interest to what I did not see of interest.

CHAPTER I

INTRODUCTION

Historically, photomicrography has been utilized for scientific means. The microscope was created with the intent of gaining a greater understanding of how subjects functioned on a level previously unable to be observed. However, recent developments in microscope technology seem to be creating opportunities for subjects to be viewed in a more artistic light. Varying techniques are capable of yielding a wide variety of visual results for the same subject matter. Nikon's annual photomicrography competition, Nikon Small World, showcases the many styles of imaging currently possible through the use of a microscope. Photomicrography, being a relatively new branch of photography, presents a great deal of room for expansion and exploration as an artistic process.

Statement of Purpose

This thesis investigated the problems associated with artistically photographing patterns that exist within the microscopic world, which are echoed on a larger scale throughout nature. The presence of these patterns at various scales creates the potential for a variety of interpretations when viewing images that have been de-contextualized. By photographing microscopic subjects in a manner that empha-sizes these patterns, it is possible to mentally distance the microscopic subject from the

object it represents. This mental distance has one of two effects upon the viewer: either the viewer appreciates the subject from a purely formal point of view and gives no thought to what the subject represents, or the lack of a defined subject causes the viewer to extend their viewing of the image in an attempt to discover what object is being shown.

Photographing these patterns at a microscopic level presents a number of difficulties not associated with photographing patterns through traditional photographic means. This thesis explored the problems associated with photographing subjects on a microscopic level, specifically the issues presented by lighting various subjects. Different microscopes create different sets of problems.

Anticipated Problems

Two types of microscopes were used for this thesis: a compound microscope and a stereomicroscope. In the case of the compound microscope, the only light source provided is located underneath the stage to provide backlight for subjects. The stereomicroscope is also backlit, but also has a single overhead lamp for lighting subjects. Some of the work being attempted requires a more complex lighting set-up involving the use of multiple lights to illuminate the subject from the sides and above in order to capture the three-dimensionality of some of the objects being viewed. The most noticeable deficiencies present while exploring simple forms of microscopy artistically lie within the forms of lighting being utilized, specifically:

- The number of lights provided by the microscope.
- The mobility of the lights provided by the microscope.
- The color temperature of the lights provided by the microscope.

Microscopes tend to be designed for a specific purpose, and as a result the lighting can be very limiting when attempting to use that microscope for creating art. As previously stated, the compound microscope used for this thesis was only equipped with a backlight. A single light source greatly limits the possibilities when photographing subjects. Add to that the fact that the light source is a backlight, and the subject matter is restricted to only transparent and semi-transparent objects.

While the stereomicroscope that will be used to create images is equipped with a backlight, as well as a single top-light, having only one frontal light is just as limiting as only having a backlight when it comes to creating artistic images. A single source of illumination can result in harsh shadows and portions of a subject, which are simply unreachable by a single, directional light. By employing multiple lights, said issues are remedied.

Along with the number of lights, the ability to maneuver lights can greatly affect the potential images. The standard light sources on the microscopes used for the thesis images were stationary sources. The backlights were placed beneath a stage that allowed the light to strike the subject from only one direction and could not be manipulated in any way. The top-light present on the stereomicroscope can be pivoted vertically, however, that is the only range of motion possible. In order to create the

desired lighting solution for a given subject, it was necessary to have a complete range of motion from multiple light sources.

Yet another limitation presented by the standard light sources on the microscopes used for this thesis was the color temperature of the light. Halogen bulbs are employed on both microscopes. The light emitted by these bulbs tends to be yellow, which can result in subjects appearing less pleasing than under other types of light. In addition to the overall unpleasant color of the halogen bulbs, some of the subjects for the images possess properties that only become apparent under certain portions of the light spectrum. To take full advantage of these properties, a solution for how to employ different color light needed to be reached.

Hypothesis

In order to overcome the deficiencies presented by the lighting that is standard on the microscopes used for this thesis, a number of experiments were conducted. To address the issues created by the insufficient number of lights, multiple lights were introduced. The presence of multiple light sources should resolve the harsh light created by a single light source, as well as allow for the photographing of non-transparent subject matter.

Also addressed by the implementation of additional, external light sources was the lack of mobility inherent in the internal microscope lights. Independent light sources allow for each light to be manipulated as desired, similar to the manner in which lights are manipulated for portrait photography. The best suited light for the

requirements is a low wattage lamp with a gooseneck that allows for a complete range of motion.

The final lighting problem anticipated by this thesis was the color spectrum of the light sources. A number of the subjects possess the property of fluorescence and require ultraviolet light to make said property apparent. As with before, it was necessary to acquire multiple lights in order to create the desired lighting solution for a subject. The complete absence of any prior experience with ultraviolet lighting when photographing resulted in a set of unanticipated problems that were dealt with as they arose.

CHAPTER II

HISTORY

Early History

The word microscope is derived from a combination of two Greek words: *mikrós,* meaning small and *skopeîn,* meaning view/see/look (Croft, 2006). Some of the earliest descriptions of experiments with magnification came from the first century A.D. by a man named Senica. Senica observed that objects could be magnified when viewed through a rounded glass container filled with water (Croft, 2006). Approximately 10 centuries later, the first major literary work on optics was written by an Arabian scholar by the name of Alhazan. Alhazan discussed the human eye and how the lens within was able to focus images that it perceived (Croft, 2006). In the year 1280 A.D., the optical principles spoken of by Alhazan would be explored in the city of Florence, Italy, and eyeglasses would become a popular solution to degenerating vision for many people in Florence, and later everywhere (Croft, 2006). Following the invention of the eyeglass, people began experimenting with the magnification properties of the lens. Galileo Galilei is often credited with the invention of the first simple microscope. The next major breakthrough in the microscope came from a father and son working in Holland. In the late 1500s, Hans and Zacharias Jansen created what are believed to be the earliest examples of compound microscopes (those microscopes

having multiple lenses) (Croft, 2006). Unfortunately none of the devices created by the Jansens have survived; but by examining a description of one of their creations, one can gain a fairly good image of what it may have looked like: "The royal instrument consisted of three sliding tubes measuring eighteen inches in length when fully extended and two inches in diameter. It was very ornate and supported by three brass dolphins forming the feet of a tripod" (Croft, 2006, p. 6). The invention of the compound microscope could be considered the birth of modern microscopy since modern microscopes contain multiple lenses. The Jansens' work enabled all subsequent exploration in microscopy.

Edmund J. Spitta

> By photo-micrography is meant the art of photographing a magnified image. (Spitta, 1899, p. 2)

Spitta's (1899) book is one of the earlier works on the subject of photomicrography. How interesting it is that in the first line of his introduction, Spitta chose to define photomicrography as an art as opposed to a science. Given the extremely scientific nature of the book, which is more or less a manual of procedures and equipment, one would think he would have been more inclined to term it as such. Nonetheless, perhaps Spitta was showing a great deal of foresight in defining it as he did.

Immediately following the brief introduction (in which Spitta, 1899, categorized photomicrography into three classes based on magnification), Spitta jumped into the different ways of illuminating subject matter when creating photomicrographs, and which works better in given situations. "Oil, incandescent gas, lime-light, and

electricity have all been pressed into service" (Spitta, 1899, p. 2). Spitta maintained that for situations of low magnification the use of an oil lamp (a simple lamps that consists of a vessel containing oil with a wick protruding that is lit to provide light), and/or an incandescent gas lamp (incandescent light occurs when an object is heated to the point of glowing due to the emitting of radiation, and examples of this are the filament in a light bulb or the mantle in a gas lantern [Incandescence, n.d.]) were well suited. However, once the photomicrographer increased the magnification, they were forced to use either electricity or lime-light. (Limelight is created by heating a piece of calcium oxide, also known as lime, to high temperatures using a gas burner. At high temperatures the lime emits a brilliant white light [University of Leeds, n.d.]). Around the time Spitta's (1899) book was written, electricity was still fairly new and he makes note of its inherent flaws at the time: "One disadvantage, however, putting aside the difficulties of its production, maintenance, let alone its expense, outweighs all the advantages of its use . . . the point of light is *always* shifting" (p. 3).

During the period when Spitta (1899) was working with photomicrography, the most consistent source of light for the illumination of subject matter was limelight. Since it required the use of pressurized gasses at a time when there were few or no regulations regarding the materials used to house the gasses, there were some dangers associated with using this method. Spitta recommended companies whom he had dealt with and found to be reputable, even going so far so to provide an advertisement for their company in the pages preceding his book. Spitta also emphasized that those who attempt to create photomicrographs using limelight exercise extreme caution.

Brief mention is made of the use of sunlight as an illuminant; however, it seems that Spitta (1899) regarded the sun as too inconsistent for such work. The nature of the sun, being in constant motion and susceptible to a variety of atmospheric conditions, created difficulties when trying to create a steady light source. Spitta's book went on describing, in detail, the processes, materials, and equipment necessary for one to engage in the art of photomicrography. Numerous illustrations were presented to aid the readers in understanding of the equipment necessary to begin work.

W. H. Walmsley

> A photo-micrograph is said to be "an enlarged photograph of a microscopic object produced by throwing its image through a suitable combination of microscope and camera." (Walmsley, 1902, p. 3)

Walmsley's (1902) initial approach to the subject of photomicrography differed from that of Spitta (1899). Instead of introducing his book with an explanation of the procedures involved with photomicrography, Walmsley chose to provide the reader with a brief history of the photographic process. Walmsley began by stating that the process of creating photomicrographs predated the work done by Louis Daguerre (inventor of the Daguerreotype process). According to Walmsley, in 1802 two men by the names of Thomas Wedgewood, and Humphry Davy (whom Walmsley indicates was later knighted as a result of the work) created what he considered to be the first photomicrographs by projecting the images of small objects onto chemically treated paper/leather with the aid of a solar microscope. Unfortunately, the images produced by these two men and their methods were not permanent images and quickly faded.

Later work by Wedgewood and Davy did eventually produce permanent images, and Walmsley stated that Daguerre's process was what had made such high quality prints possible. Shortly following Daguerre's announcement of his photographic method, a French man by the name of Donne published a book of anatomy in which photomicrographs were the primary means of illustration. Walmsley believed this book to be the first to use photomicrographs in such a manner.

Walmsley (1902) did not view photomicrography as an artistic endeavor (although, on occasion, he did use the term art to refer to the process of creating photomicrographs), but rather one with endless potential as a tool for teaching. In fact, Walmsley stated that his purpose for writing a book was to provide an entry level guide for students beginning to work with photomicrography.

> The large standard works of Sternberg, Pringle, Spitta, and others are too learned, too scientific for the beginner, and therefore of but little use to him. The smaller publications,—all English in so far as I know—are really of much less use, being merely a compilation of "say so's" without any practical value. I earnestly hope such may not be the case with the present little work. (p. 7)

The subsequent chapters of Walmsley's (1902) book follow much in the same fashion as did Spitta's (1899). Descriptions of equipment necessary were given and so forth with the major difference being that the language used by Walmsley lent itself to the individual who may not have been so educated in the ways of science. As in Spitta's book, Walmsley's book included numerous images of the apparatus he used to perform his work as well as recommendations for companies from which to procure materials. Early historical accounts of photomicrography are somewhat disjointed and

awkward. From one writer to the next, the facts tend to change, most likely due to the fact that numerous individuals were experimenting with it at the same time.

Recent History

Digital Imaging

> Recent developments in digital image recording have brought rapid changes to photography, and in consequence also to photomicrography. (Evennett, 2000, p. 253)

Undoubtedly, one of the most important events in the history of photography has been the advent of digital photography. Few innovations have had such an immediate and revolutionary impact as the digital camera. Digital photography has made it possible for the photographer to immediately view the image that has been created and decide whether it is worth keeping or whether it is necessary to continue photographing. The digital camera has also brought photography to the masses on par with George Eastman's innovation of roll film, and the idea of "you press the button, we do the rest." The field of photomicrography has also seen a great deal of benefits from the invention of the digital camera. Scientists working in the laboratory no longer needed to wait for film to develop in order to see the results of the images they have taken. Both hobbyists and artists have benefitted greatly from being able to use a digital camera with their microscope.

> Last year I saw a demonstration of the Nikon Coolpix 950 digital camera used for photomicrography. I immediately saw that this offered the small laboratory and the lone worker the opportunity to 'go digital'. And in addition could act as a generally useful photographic tool. (Evennett, 2000, p. 253)

Digital photography has made it possible to create images with the microscope in a timely manner. By working digitally, those experimenting with photomicrography

are able to set up their microscope and camera close enough to their computer that once photographing is finished, they can immediately download the images to the computer and begin editing them. The ability to work on photographs in one location without the need for chemicals or a darkroom has proven priceless for many individuals working with photomicrography. Attempts to work with traditional film cameras when practicing photomicrography can prove troublesome when attempting to manipulate images. Something simple like the ability to change the white balance on the digital camera proved highly advantageous when experimenting with different types of lighting. The main benefit presented by digital photography is the ability to edit the content of the photographs quickly and with almost limitless creative potential.

Generally, images taken under the microscope tend to be busy and contain optical noise. (Optical noise is the presence of unwanted subjects in an image that can result in difficulty identifying a focal point or strong subject.) Finding a usable subject matter can present some difficulty; however, with a digital image, it is a simple process to select the main subject of the image, isolate it, and create the desired effect. The series of images (Figures 1, 2, and 3) represent the editing process, from start to finish, for one photograph. Viewing the image's progression from beginning to end, it is easy to see the benefits of the digital process and how film would present certain difficulties not presented by digital. Figure 1 represents the initial image photographed with no editing having been completed. In Figure 2 the subject matter has been chosen and some optical noise has been removed. Figure 3, the final image, is free of all optical noise and a strong subject remains.

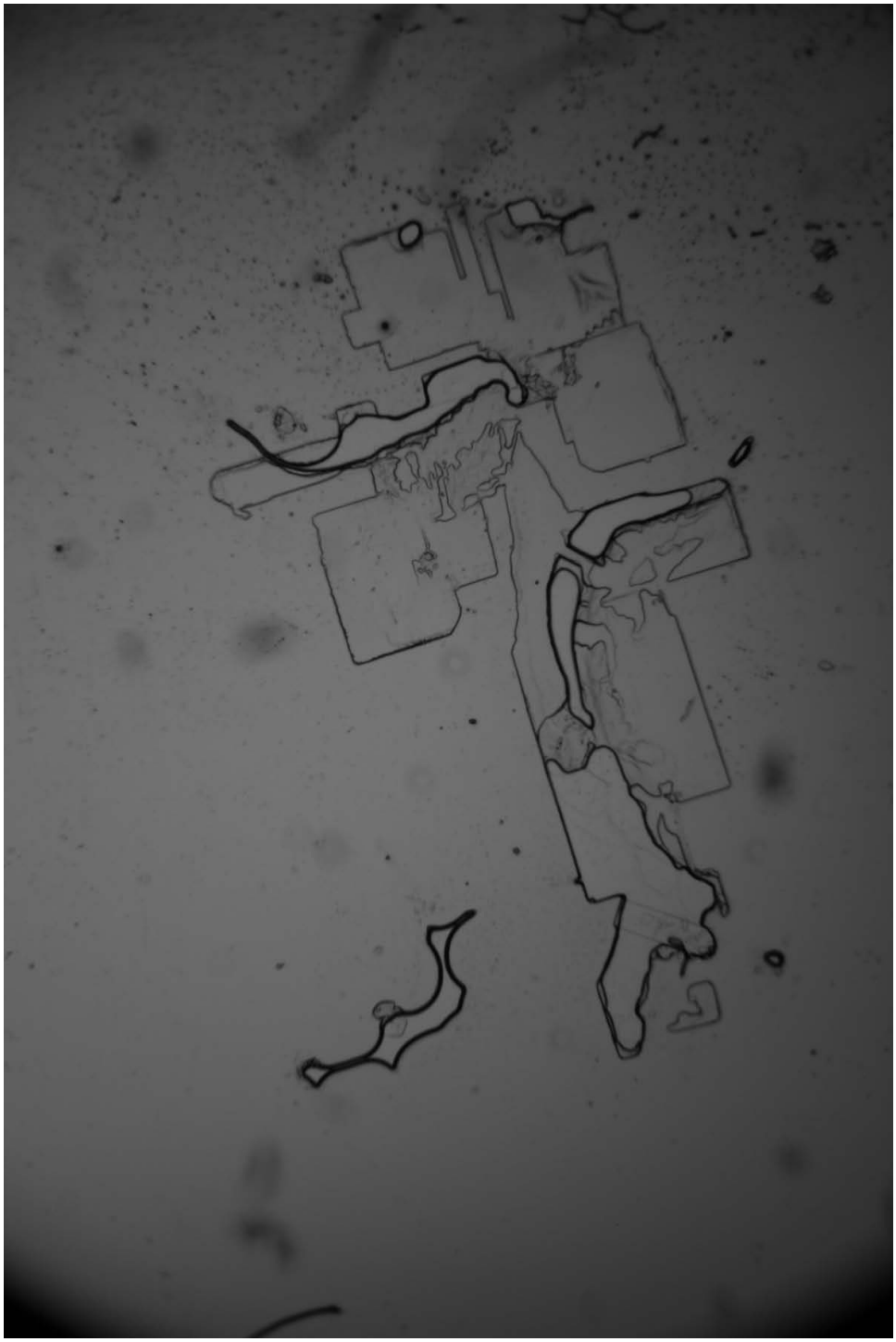

Figure 1. Raw image of “saliva.”

Figure 2. Preliminary editing of “saliva.”

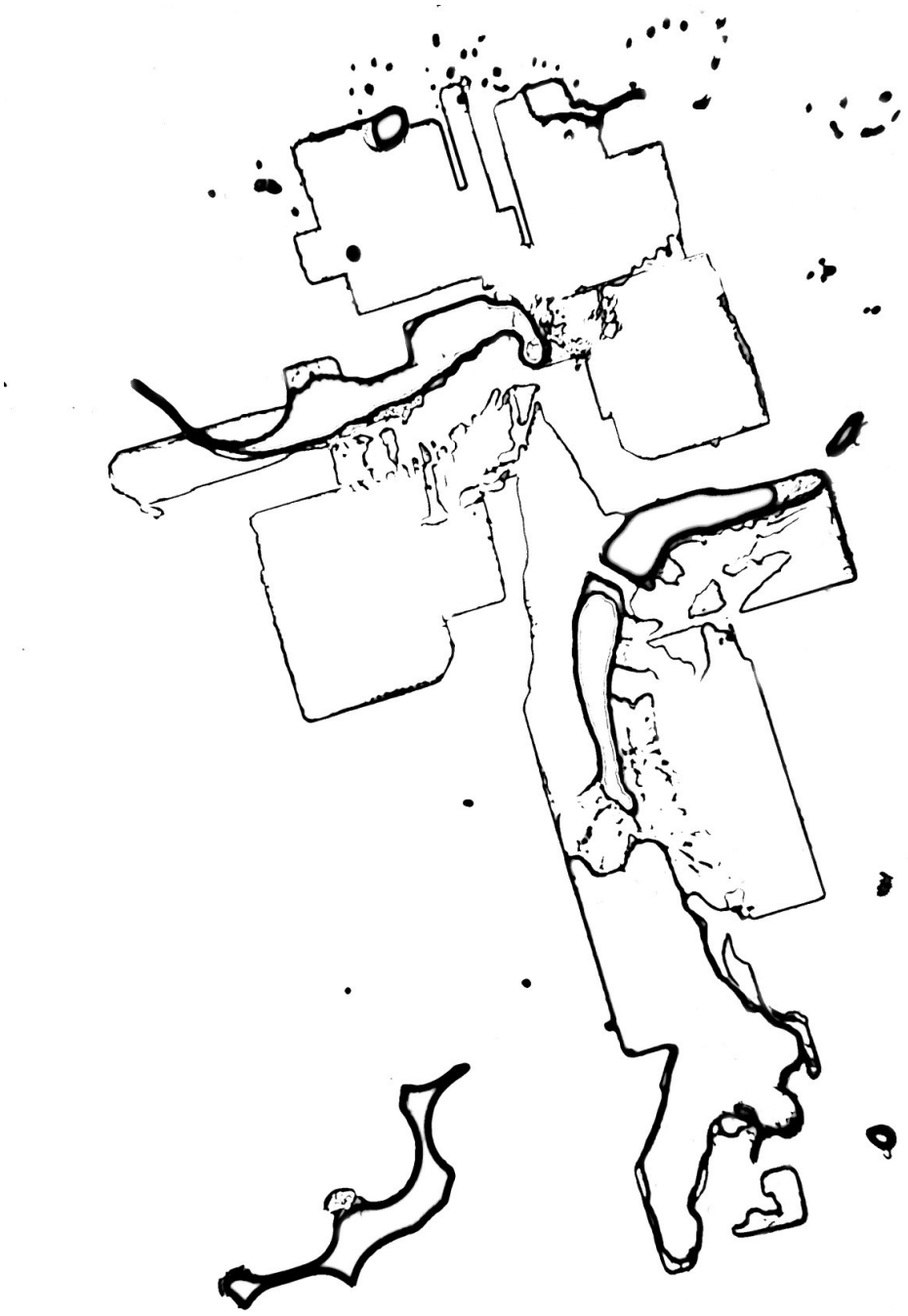

Figure 3. Final version of “saliva.”

In 1984 at the Los Angeles Olympic games, the Japanese-based camera company, Canon, created some of the first images intended for the public using a digital camera, and the images were published in a Japanese newspaper the following day (Mullins, 2004). Unfortunately for Canon, it seemed that the world was not particularly interested in the idea of digital imaging at the time, and few people other than the newspapers, themselves, took much notice. "In 1991 the first tremors of significant change were felt" (Persinger, 2007, pp. 10-11). The first year that Kodak made the first digital camera available to the general public was 1991. Evidently, people finally saw the benefits of the digital camera. Digital camera sales soon exploded, and traditional film cameras and the materials associated with them began to experience decreased popularity.

There are individuals who still cling to the traditional methods of photography, at least partially. Some artists and hobbyists still feel that there is a place for traditional photographic processes. A continuing debate is whether or not the quality of images produced by a digital camera are equal to those of its film-based counterpart. While for the majority of individuals using digital cameras for documenting family gatherings and other significant events, the digital camera may yield high enough quality images; some of those who are using it to create works of art tend to disagree.

> David Brommer, a digital specialist at B&H Photo Video, in New York City, told me. "But how many people print eight-by-tens, even with film? Most people print for their album; for that, as well as for e-mailing photos or uploading to Web pages, a three-hundred-dollar two-megapixel camera is great." (Fisher, 2001, p. 123)

Many artists regularly print images 8 x 10 inches or larger. For that kind of work, some feel that traditional film photography is still preferable. A large part of the argument over whether digital is equal to film photography has to do with film grain versus digital pixels. Images are created on film when grains of silver are exposed to light, resulting in a latent (unseen) image. Through the process of developing the film, the image becomes visible, and prints can then be made from the film. The grains of silver present in the film have a more organic shape than the square pixels of a digital image. In some instances, it can be pleasing to use the film grain to create a certain look for an image; whereas pixels tend not to have the same appealing look due to their square shape. Another factor to consider is the cost of digital equipment compared to film-based equipment. With the cost of a digital medium format camera being significantly higher than that of a film medium format camera, many budding photographers are forced to buy the latter by default. In extreme cases, such as some of the more expensive Hassleblad cameras, which cost upwards of $35,000, a photographer could be forced to decide between buying a camera and buying a vehicle, or placing a down payment on a home. Digital photography does remove the need for an enlarger, a darkroom, chemicals, and other materials associated with film photography, but there are additional costs associated with digital photography beyond just the camera. Computers, software, image storage devices, and other considerations contribute to the cost of digital photography. There are those who, after contemplating both choices, see no reason to continue using film cameras.

> "Students learning photography today should buy digital cameras and never look back," Sprague told me. "By the time they're out of school, no one will

> be shooting film commercially." Richard J. Linke, a professor of art at Skidmore College, went ahead and converted the school's entire photography studio to digital two years ago. "I thought it would be irresponsible not to," he told me recently, "had to decide whether to retire an old fogy or learn the way of the future, and it's been a real, revolutionary thrill." (Fisher, 2001, p. 123)

Nikon's Small World Competition

Since 1974 Nikon has hosted a competition for images created using the various microscopic processes (Nikon Small World, n.d.). Over the years, the Nikon Small World competition has become a venue for the many individuals working with photomicrography to display their finest images and is widely regarded as the leading proponent of photomicrography. Every year prizes are awarded to the winners of this competition, with the first prize winner receiving $3,000 toward Nikon products, and being flown to New York for a presentation ceremony (Nikon Small World, n.d.). Presently at Nikon's website (www.nikonsmallworld.com) is a collection of galleries from 1977 through 2009 displaying the best images from each year. The galleries serve as a virtual timeline showing the progress that has been made technologically, scientifically, and artistically over the life of the competition. Early images captured on film illustrate the difficulties associated with creating micrographs on the less forgiving media, while the images captured using digital cameras show how much the technology has enabled the creativity of photomicrographers. In 2004, Olympus began its own competition for micrographs called BioScapes (Olympus BioScapes International Digital Imaging Competition, n.d.). While the Olympus competition does not have the long history that Nikon does, they are making a strong effort to establish themselves in the world of photomicrography. Osamu Joji, Olympus

America's Vice President as well as General Manager of the Scientific Equipment Group, made the following statement:

> Microscope images forge an extraordinary bond between science and art. . . . We founded this competition to focus on the fascinating stories coming out of today's life science research laboratories. The thousands of images that people have shared with the competition over the years reflect some of the most exciting work going on in research today—work that can help shed light on the living universe and ultimately save lives. We look at BioScapes and these beautiful images as sources of education and inspiration to us and the world. (Olympus BioScapes International Digital Imagining Competition, n.d.)

Micro Art

> When I find something that is visually exciting, I determine which way to capture it. It is almost like creating a painting. (Dabdoub, 2003, p. 7)

Unlike other books on the subject of photomicrography, Dabdoub (2003) approached the subject from the point of view of an artist. Dabdoub spoke of how, as a child in Honduras, he would wander around capturing close up images of driftwood and eroded mud after floods. As an adult, Dabdoub entered into the field of science and began studying chromosomes. Like other scientists, Dabdoub began to appreciate the beauty of the specimen he was viewing and began photographing them. What made Dabdoub different from other scientists, and why his work provides such strong support for this thesis, is because he began approaching the specimen under the microscope with the intent and skills of an artist as opposed to so many others who are scientists, merely trying their hand at an artistic endeavor.

> Isolating and capturing the images on film is time consuming and labor intensive. . . . Photomicrography often requires instruments and techniques not frequently used in traditional photography, and learning how to photograph through a microscope is not an easy task. Many of the procedures, such as lighting, focusing, exposing, and even locating the tiny area to be

> photographed, are much more complex than in ordinary camera work. (Dabdoub, 2003, p. 7)

The added complexity of capturing images through a microscope is less challenging if the individual possesses an understanding of artistic/photographic concepts. The difficulty of selecting a specific area to photograph is less daunting when basic concepts of design have been studied, and there is an understanding of what is visually pleasing to the human eye. Proper exposure is more simple when there is an understanding of how a camera works and what will occur if adjustments are made to the aperture or shutter speed. Most importantly, if lighting techniques have been studied, then the images produced will benefit immensely and be less time consuming to produce. Dabdoub (2003) wisely stated that the mastery of multiple types of lighting is necessary in order to produce photomicrography. "I feel uncomfortable talking about the beauty under the microscope, since I am really trained to find problems, not beauty" (p. 8).

The problem that Dabdoub (2003) faced is the same problem faced by many scientists. Due to the nature of their work, there is a mental barrier in place that prevented them from viewing subjects first and foremost as potential art. While some are able to eventually overcome this barrier, many images produced by scientists still suffer as a result of their preconceptions about subjects. In the case of this thesis, a similar barrier was in place in regard to the coral specimen used as subjects for many of the images. The desire to accurately represent the size, color, texture, etc. of the corals dramatically limited the artistic potential of the pieces. It was only by the application of knowledge gained from studying art and an ongoing discussion with

other artists that those barriers were able to be overcome. "To this day, there is very little scientific explanation for some of the photographs. Nonetheless, the images are intriguingly beautiful" (Dabdoub, 2003, p. 8). This statement by Dabdoub (2003) represents his ability to overcome the need to explain everything in scientific terms and simply appreciate the artistic value of his images.

> I know that when I draw a portrait, or play classical music on my violin, another of my avocations, my imagination is opened. That is the most important thing in any field or any art. People often forget that, despite all the scientific equipment, medicine is an art. (p. 8)

Dabdoub (2003) arrived at a conclusion that an artist approaches everything they do as a means of artistic expression, and every experience as a uniquely beautiful work of art. A true artist has a different mindset than most people, and the ability to attain this mindset is not limited to those individuals working in the fields of fine art. Numerous artistic movements have attempted to express this idea, most notably abstract expressionism.

Robert Irwin, an artist who early in his career worked as an abstract expressionist painter, has evolved into what one could consider one of the definitive proponents of this idea. In the film, *The Beauty of Questions*, Irwin voiced his belief in phenomenology (an area of philosophy), and told how his art had evolved to reflect those ideas. At one point in the film, Irwin traveled to the desert and spoke about the experience of being there. Irwin said that photography may capture the image of a place but it cannot capture the feeling of a breeze, or a rock, or the quality of the light.

> I started spending a lot of time alone, and spending a lot of time in the desert wandering around a little bit sort of trying to think about what I do. We really are constantly pushing towards this thing of the presence of something. I could

> argue that the only real moment is that first moment of actually being there and running your hands intimately over a situation and being in the presence of something that really has impact on you. Every step from there is by degrees an abstraction. (Robert Irwin, as cited in Feinstein, 1997 [motion picture])

Irwin realized that the shadow cast by the painting on the wall was just as real as the subject of the painting itself. The artwork produced closely following this realization played with the idea of how shadows, despite their lack of a physical presence, affect how we perceive the world around us. Irwin's art proceeded to move further away from the traditional definition of what art is towards a style of art intended to emphasize the moments that occur every day that go unnoticed, yet are just as impressive as the art placed in a museum. The pieces Irwin had completed and was working on during the making of the movie were pieces he hoped would enhance the experience of the locations they were in and enhance people's ability to appreciate that experience in any location.

Another scene in *The Beauty of Questions* illustrated Irwin's belief in the idea that people working in completely different fields who have the same state of mind have more in common with each other than peers within their own field with a different mindset. Irwin stated that through his exploration of art, he felt he had stepped beyond the world of art and so he began asking people working within other academic disciplines their thoughts regarding the world (Feinstein, 1997). Irwin met a man he only referred to as Edwards who was working with NASA as a scientist and who had "no interest in art at the time" (Robert Irwin, as cited in Feinstein, 1997 [motion picture]). What Edwards did have was the same state of mind as Irwin. The two men, along with artist James Turrell, began experimenting with phenomenology

and the idea of experience. By manipulating their senses through the use of a deprivation chamber, they discovered they were able to heighten the way they experienced the world; once they returned to it, Irwin applied what he learned experimenting with the other two men to how he made art.

Edwards represents scientists who are passively participating in the fine art world (contributing to a dialogue but not creating artwork themselves). Recent progress in many scientific fields has led to an increase in active participation by many scientists in the art world. "A Scientist's Adventures in Postmodernism" (Markus, 2000) tells of his exploration into the field of fine art after running a number of experiments on the human eye to determine how it responds to low oxygen levels such as those encountered prior to death. Markus discovered that low oxygen levels can cause the eye to react in a manner that sometimes creates the illusion of lights at the end of a tunnel (often described by those who have had near death experiences). By running simulations on a computer that mimicked this response, Markus has created images that extended beyond science into the realm of art. One point of particular interest is Markus' references to phenomenology, which relates to the ideas expressed by Irwin.

Another strong example of the increasing participation of scientists in the visual arts is the fairly recent development of a new school of artistic expression known as bioart. Definitions for what bioart is vary. Some limit it to those working with actual living biological matter such as tissue cultures, while others have extended the term to describe any scientific art endeavor. One of the earliest and most notable

members of this movement is Eduardo Kac who was responsible for Alba, a rabbit that was genetically altered in a manner, which caused it to fluoresce green. Other works of bioart include *Victimless Leather,* a piece in which a living culture of skin was grown into the shape of a seamless jacket (The Tissue Culture and Art Project, n.d.). Bioart has been controversial, and many are opposed to the works of art being produced. Many of the pieces that have been opposed by various groups involve the manipulation of live animals such as Alba.

A scientist and an artist of the same mindset may have more in common with each other than other individuals within their field. That does not mean that they are automatically able to work within each other's fields. Among the scientists who have begun making art, those who have been the most successful are those individuals who possess an understanding of aesthetics. Scientists who fail to educate themselves about such concepts are greatly handicapped. Similarly, artists who try their hand at science without properly educating themselves are handicapped in the same manner. Due to societal preconceptions about art, people are less inclined to study it before calling themselves an artist or what they create art. The presence of images created by scientists who have failed to educate themselves about aesthetics supports the argument for artists to expand into the field of photomicrography.

Magical Display: The Art of Photomicrography

Magical Display: The Art of Photomicrography by Michael W. Davidson (1993) is a book that supports the ideas in this thesis. Where Dabdoub (2003) chose to approach photomicrography from the point of view of an artist, Davidson approached

it as do most individuals practicing photomicrography, as a scientist. *Magical Display* exemplifies the types of images that many scientists tend to produce when working with photomicrography. Davidson's images have been created using polarized light microscopy, a process which results in extremely saturated colors. Many of the subjects were crystal formations of chemicals, which result in a broad spectrum of color due to their prism like attributes. The resulting images are a hodgepodge of colors which are so vibrant that they can easily overwhelm the viewer. While some images show evidence of attention to composition and other artistic ideas, a portion of the images lack attention to such details. Images in which color overrides other design aspects occur due to the fact that many of the scientists creating them have not studied aesthetics.

The mistakes commonly made by scientists are the same mistakes made by any newcomer to photography. Unfortunately, the nature of the subjects in photomicrography can make it easier for scientists to fall into a trap in which they never attempt to improve their photographic technique. Also, since photomicrography is a fairly new art, many people who view these images are so overwhelmed by the appearance and even the idea of an image that they may forget to pay attention to the overall aesthetics of the images as did the scientists when creating them. Compounding this problem is the fact that many forms of microscopy result in images in which color is the predominate aspect of the image due to the dying of subjects as well as the forms of light used. A question that begs to be answered with many scientists' images is, "If the colors were muted or removed completely, would the image still hold the viewer's interest?"

Processes

The variety of microscopes and techniques used in modern science and photomicrography are so broad that an attempt to include them all within this thesis would most likely result in it being too long and too technical. Therefore, a sampling of those techniques that are currently most relevant to work being done in photomicrography, particularly as an art form, are be presented. Figure 4 shows one of the microscope setups used for this thesis. The chosen processes are those most commonly employed by the participants in the Nikon Small World annual competition.

Stereomicroscopy

The term stereomicroscopy refers to the use of a microscope having two eyepieces with identical objectives capable of creating a stereoscopic pair of images which, when viewed simultaneously, create the effect of dimension similar to the way objects are perceived by the human eye. The earliest attempts at stereomicroscopy were made in 1671 by a man named Cherubin d'Orleans. While the microscope d'Orleans used did render the desired effect, it was only able to do so by adding supplemental lenses to the apparatus and, as such, the microscope itself was not a true stereomicroscope, merely a microscope modified to function in the same manner (Nikon MicroscopyU, n.d.b). During the mid 1800s, Francis Herbart Wenham created a microscope able to yield the desired effect without the aid of additional lenses, resulting in the first true stereomicroscope.

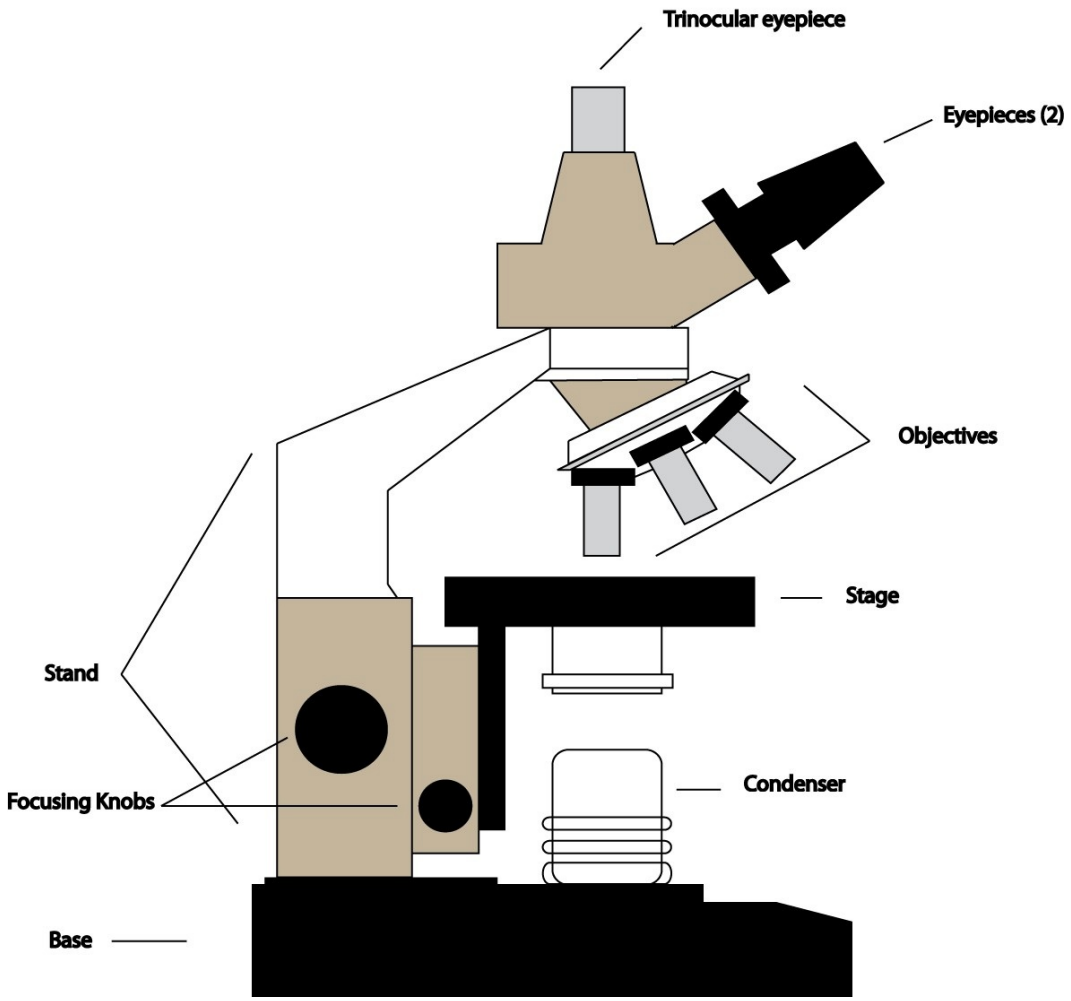

Figure 4. Trinocular compound microscope setup.

The Cycloptic created in 1957 by the American Optical Company was the first microscope built with many of the features that are now standard on microscopes such as the ability to change magnification within the unit itself, an internal source of illumination (opposed to a mirror which relied on the sun or some other form of

external light), as well as a cast aluminum body and stand (Nikon MicroscopyU, n.d.b). Prior to the Cycloptic, microscopes were made of brass, which resulted in their weighing more than those produced with modern methods. Also, early illumination techniques were far less reliable than those used in modern microscopes.

The main advantage of the stereomicroscope is the ability to view subjects without having to press them between a slide and slide cover. Being able to forego the slide process creates a greater number of potential subjects than one has when using a compound microscope. Undergoing a process in which a photographer captures two images of the subject, one from each of the two eyepieces, a stereoscopic effect can be created. This can be done also if the microscope has a single eyepiece by slightly moving the stage side to side between exposures. The two images created in this process are referred to as stereo pairs. Printing the images from the opposing eye-pieces and displaying them aside one another, one can use a stereoscopic viewing apparatus to create the illusion of three-dimensionality. While stereomicroscopy can also be accomplished using a compound microscope, the photographer is confronted by the problem of having a much shallower depth of field (depth of field refers to the amount of an image in sharp focus) than with a stereomicroscope due to the greater magnification levels associated with compound microscopes. Magnification is inversely related to depth of field. The greater the amount of magnification, the less of the image will be in focus. If the photographer wishes for the entire subject to be in focus, then he must take a series of pictures in which the focal point is slightly different in each image. This process is also required for stereomicroscopy; however,

due to the lower magnification levels, less images are required to obtain the desired effect. Once photographing the subject has been completed, the artist must then download the images to a computer, and with the aid of photo-editing software, such as Adobe Photoshop, compile the partially focused portions of the images into one completely in focus image. A simple example of this process is shown in Figure 5. A ladybug had been photographed using a compound microscope and following the previously mentioned process combined into a single image. For this subject, approximately 20 images were taken and then compiled (see Figure 6). In order to create a completely focused and properly exposed image, some artists have taken hundreds of images and spent months compiling them.

Figure 5. A single exposure of a ladybug under 400 times magnification.

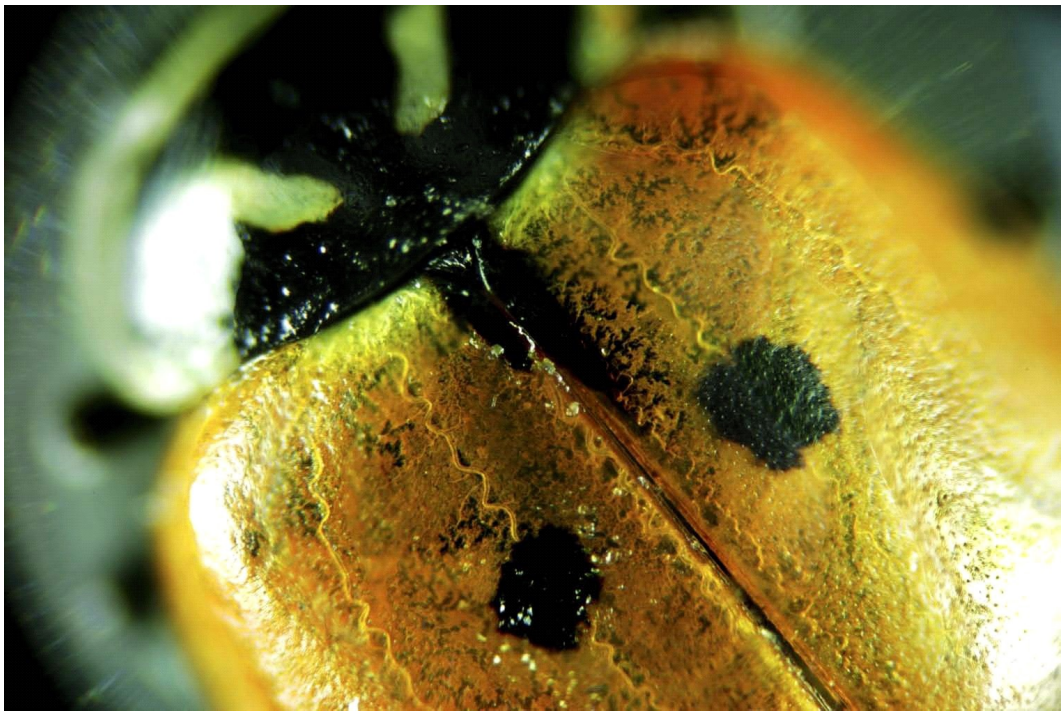

Figure 6. A compilation of 20 exposures of a ladybug under 400 times magnification.

Phase Contrast Microscopy

When photographing under a microscope, certain images can be difficult to observe due to their low contrast nature (low contrast meaning that the anatomy of the subject is highly transparent resulting in difficulty distinguishing characteristics from one another). In 1934 Fritz Zernike, a Dutch scientist, began working with phase contrast microscopy. Zernike realized during his studies that by altering the angle at which a light source struck a subject, it was possible to yield higher definition in the subjects he was observing. Phase contrast microscopy makes it possible to photograph transparent or low contrast subjects by converting small variations in the subject into high contrast variations through the use of various types of optical mechanisms (Nikon

MicroscopyU, n.d.a). What makes this type of microscopy possible is the fact that light striking a subject from different angles will reveal different details of the subject's anatomy. Prior to phase contrast microscopy, highly transparent specimens had to be stained in order to distinguish the minute details that were present. If a subject was alive, then staining usually meant killing said subject. No longer having to stain the specimen allowed the scientist to view living subjects and better observe how they functioned. Prior to the advent of phase contrast microscopy, much of a subject's anatomy was only partially observable under a microscope. Another benefit of phase contrast microscopy is that modifications to some brightfield microscopes can be made in order to render phase contrast unlike some other forms of microscopy that can require purchasing an entirely new microscope. Kits can be purchased for some microscopes that include the objectives and light condenser necessary for phase contrast microscopy.

Confocal Microscopy

Confocal microscopy is possible due to the property of fluorescence. Fluorescence occurs when one color of light strikes a subject and the color of light reflected back, and subsequently perceived by the eye is a different color than the light being used to illuminate the subject. Researchers working with confocal microscopes utilize fluorescence by dying certain portions of a subject in order to distinguish it from other areas. Due to the fact that the dyes used will fluoresce different colors in response to the light source, it is possible to attach multiple dyes to different areas of a subject and create a highly contrasting image. In the case of confocal microscopes, the light used

to illuminate the subject is a laser. The high frequency of the light emitted by the laser results in more light being reflected back to the collection site (Prasad, Semwogerere, & Weeks, 2007). The reflected light is then collected by the microscope (which functions much the same as a camera) and is processed by a computer. Unfortunately, the collection site is unable to view the entire subject at one time, so it scans the image and then the computer assembles a complete image (Prasad et al., 2007). The advantage to the collection site being small is that stray light rays are eliminated, so only the in focus portion of the subject is seen by the site (Prasad et al., 2007). This aspect of the confocal microscope is similar to the aperture in a camera. When the camera aperture is larger, more light is allowed to hit the film/sensor resulting in a shallower depth of field and less of the subject being in focus. Closing down to a smaller aperture will result in less light being allowed to strike the film/sensor and greater depth of field in the subject. A strong limiting factor with confocal microscopy, as with other advanced forms, is the cost associated with the microscopes. A complete confocal microscope can cost upwards of $10,000. As a result, few if any artists have begun experimenting with this form of microscopy.

Polarized Light Microscopy

Viking sailors, approximately 1,000 years ago realized the polarizing effects of some crystals upon the blue sky and were able to use those crystals to navigate when the sun was not clearly visible (Können, 1985). Polarized light microscopy is another form of microscopy that is built upon the compound microscope. By adding a set of polarizing filters both prior to and following the specimen being examined, an

individual can better control the variations that occur in the light source; as a result, certain characteristics become more prominent (Mozayani & Noziglia, 2006). Polarized light microscopy is widely used in forensic applications as a means of identifying trace evidence found in criminal cases. Soil samples that may have transferred to a suspect from a crime scene can be placed under a microscope; through the properties of polarized light, it can be determined whether the two samples match. A case of particular interest where polarized light microscopy was used involved a chemist named Walter McCrone who was asked to compare two paintings *(Ballet Espagnol* and *Infanta Margarita*), which had been attributed to the painter Eduoard Manet to three known paintings by the artist (Spencer, 2004). Through analysis under the microscope, McCrone was able to discover a unique property present in the known Manet pieces, and then looked for the presence of the same property in the pieces in question (Spencer, 2004). The property was indeed present in the unconfirmed Manet pieces, and definitive attribution was given to Manet for the artworks.

Brightfield Microscopy

Brightfield refers to forms of microscopy in which the subject appears dark when viewed against a field of light (thus, the terming brightfield). The classification brightfield encompasses all lighting situations in which this dark subject/light field occurs, whether the illumination comes from in font or behind the subject (Simon, 1936). Brightfield microscopy is the simplest form of illumination and, as such, is often the first form taught to beginners.

Darkfield Microscopy

Darkfield microscopy varies slightly from basic brightfield microscopy. Many brightfield microscopes can be modified for darkfield by exchanging the light condenser. The darkfield light condenser diverts the path of the light so that instead of striking the subject directly from the bottom, it strikes it from the sides (Darkfield Microscopy.com, n.d.). Viewing subjects under a brightfield microscope, one is confronted with a light background with the subject being the dark portion of the composition. As the name suggests, darkfield microscopy creates a dark background, and the subject becomes the light area of the composition. One of the most common uses of darkfield microscopy is the viewing and grading of gemstones by gemologists (Darkfield Microscopy.com, n.d.). The properties of darkfield make it easier for the gemologist to see flaws, which may be present within the stone. Instead of trying to see a shadow created by a crack in a gemstone, darkfield allows the gemologist to look for a highlight against a dark background, which is much easier to see. Another popular use is the study of transparent live specimen. Viewing live subjects under a darkfield microscope eliminates the need to stain subjects in order to see the detail of their composition; since staining results in the subject's death, greater knowledge of how many organisms function has been gained through the use of darkfield microscopy.

CHAPTER III

EXPERIMENTATION AND OBSERVATIONS

Basic Photomicrography

The purpose of photomicrography is to capture images of specimen that one is viewing through a microscopic apparatus, either for documentary purposes or in the case of this thesis as artistic expressions. Numerous techniques can be employed to a microscope in order to allow the micrographer to capture images. The simplest technique requires the individual to purchase a camera specifically made to fit one of the ocular ports of a microscope. These cameras seem to be generally very limited in regard to their ability to manipulate conditions such as white balance and tend to have lower resolution than a digital single-lens reflex (SLR) camera (at least in the low end models). There are models that have similar resolution to a digital SLR and allow the user to control white balance, exposure, etc.; however, if the individual already has a camera, then it may be possible to fit it to a microscope. Microscope cameras with more controls cost the same as a digital SLR without the ability to use it for any other forms of photography. A lens attachment can be purchased that will connect to the body of a digital SLR camera (and some point and shoot cameras) the same way lenses do, simply by threading onto the equipment. Another method has been to employ a set of bellows of which one side is attached to a camera as normal, and the other end is

extended over the eyepiece of the microscope. Both methods offer the benefit of using a camera with familiar controls. Charles Krebs (2005), a photographer who has worked with photomicrography to create artwork and who has been successful over the past few years when competing in the Nikon Small World competition, lists on his website (krebsmicro.com) how one would go about assembling such an apparatus (see Figure 7).

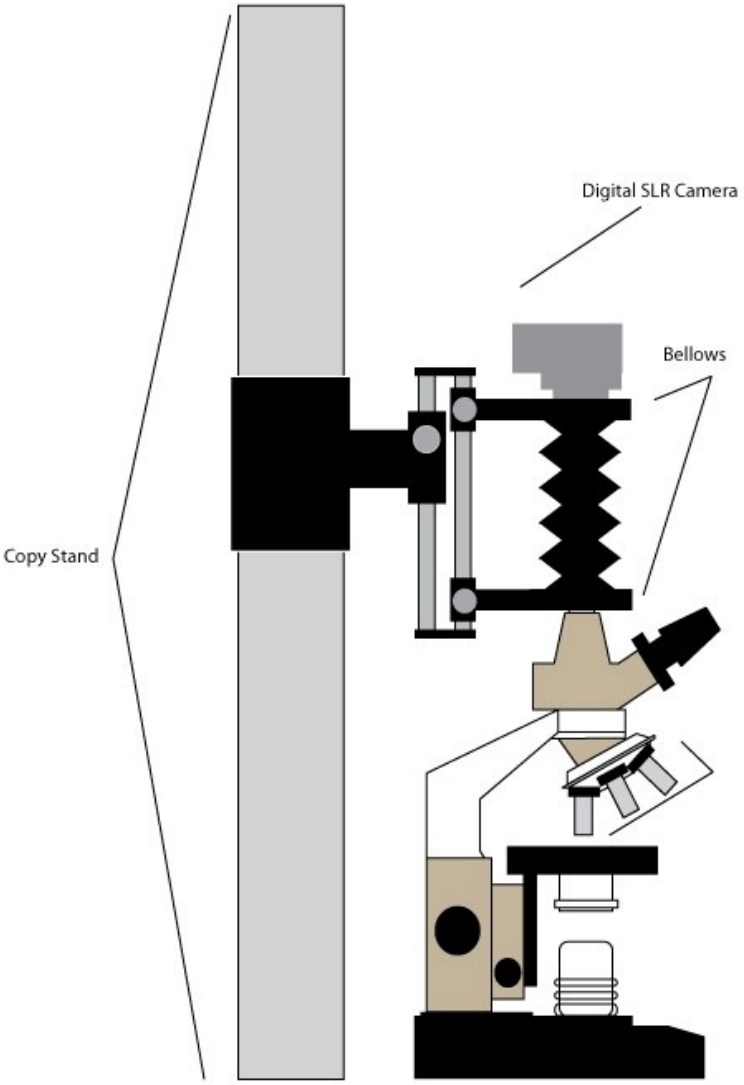

Figure 7. Micrography setup that utilizes a copy stand and bellows.

The obvious first step to creating micrographs is to acquire the necessary equipment. The desired aesthetics of the images to be created determines what kind of microscope should be purchased. Unless prior knowledge of microscopes exists, the best suited types would be either a compound microscope or a stereomicroscope. Both microscopes are relatively simple and inexpensive compared to other forms of microscopy, and modifications can be made to both allow other forms of microscopy than just brightfield. Depending on the desired characteristics of the images to be created, one microscope is better suited to the application than the other.

Aesthetics

Compound Microscope Aesthetics

While it is possible to show three-dimensional subjects using a compound microscope, the design of these types of microscopes lends itself to two-dimensional representations. Images created using a compound microscope tend to have an appearance and character similar to other two-dimensional forms of art. Figures 8, 9, and 10 display such characteristics. All three images have received similar criticism that they had an appearance reminiscent of graphic art. Figures 11, 12, and 13 have all received comments that they possess characteristics similar to those seen in paintings. By recognizing said similarities while capturing images, it affords the opportunity to enhance those aspects in order to create a stronger final image. After receiving feedback from other artists about early photographs, the decision was reached to capture and edit subjects under a compound microscope with the intent of creating photographs that remind the viewer of other two-dimensional art forms.

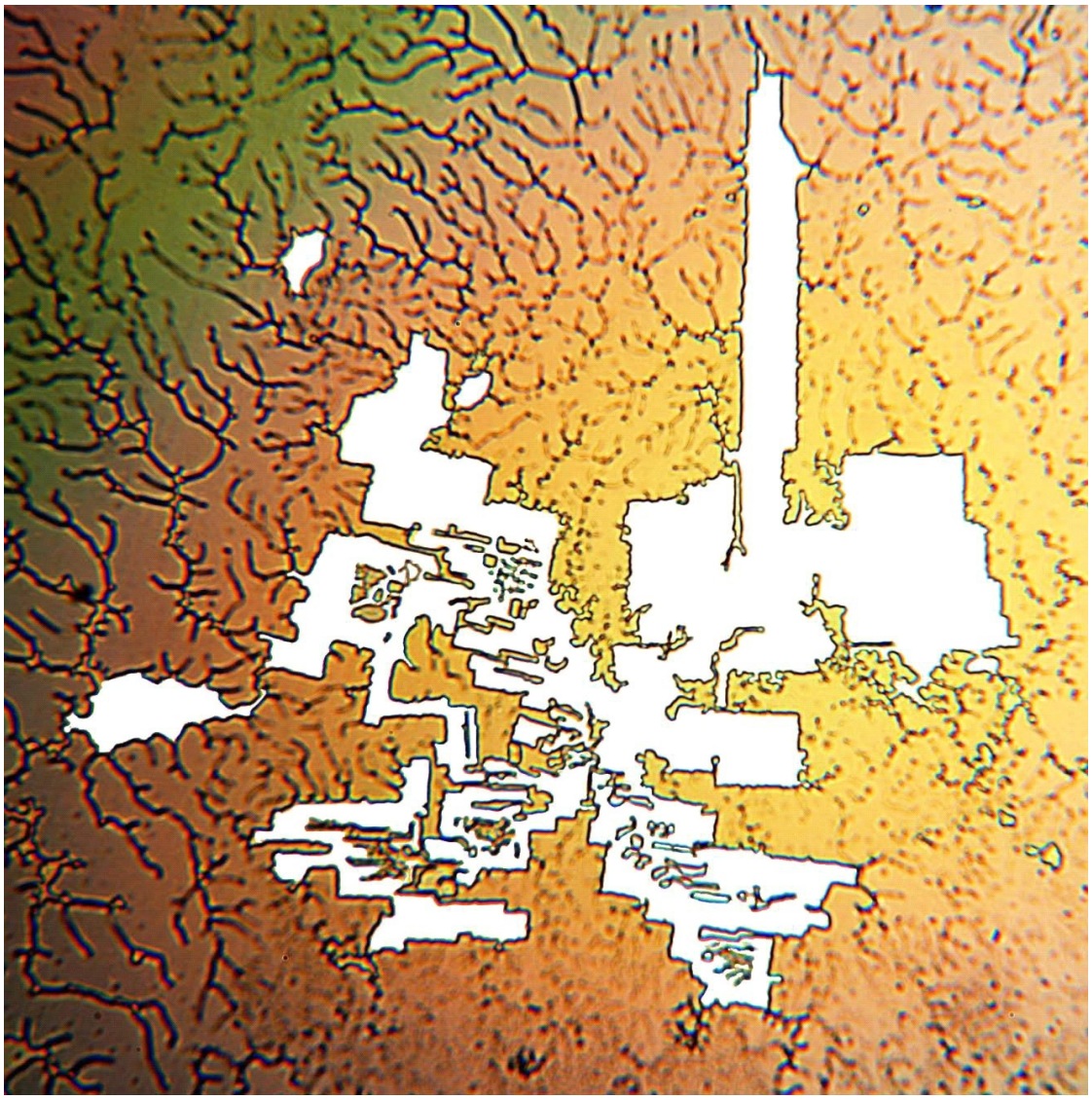

Figure 8. Photomicrograph of crystallized saliva captured with a trinocular compound microscope.

Figure 9. Photomicrograph of nudibranch eggs captured with a trinocular compound microscope.

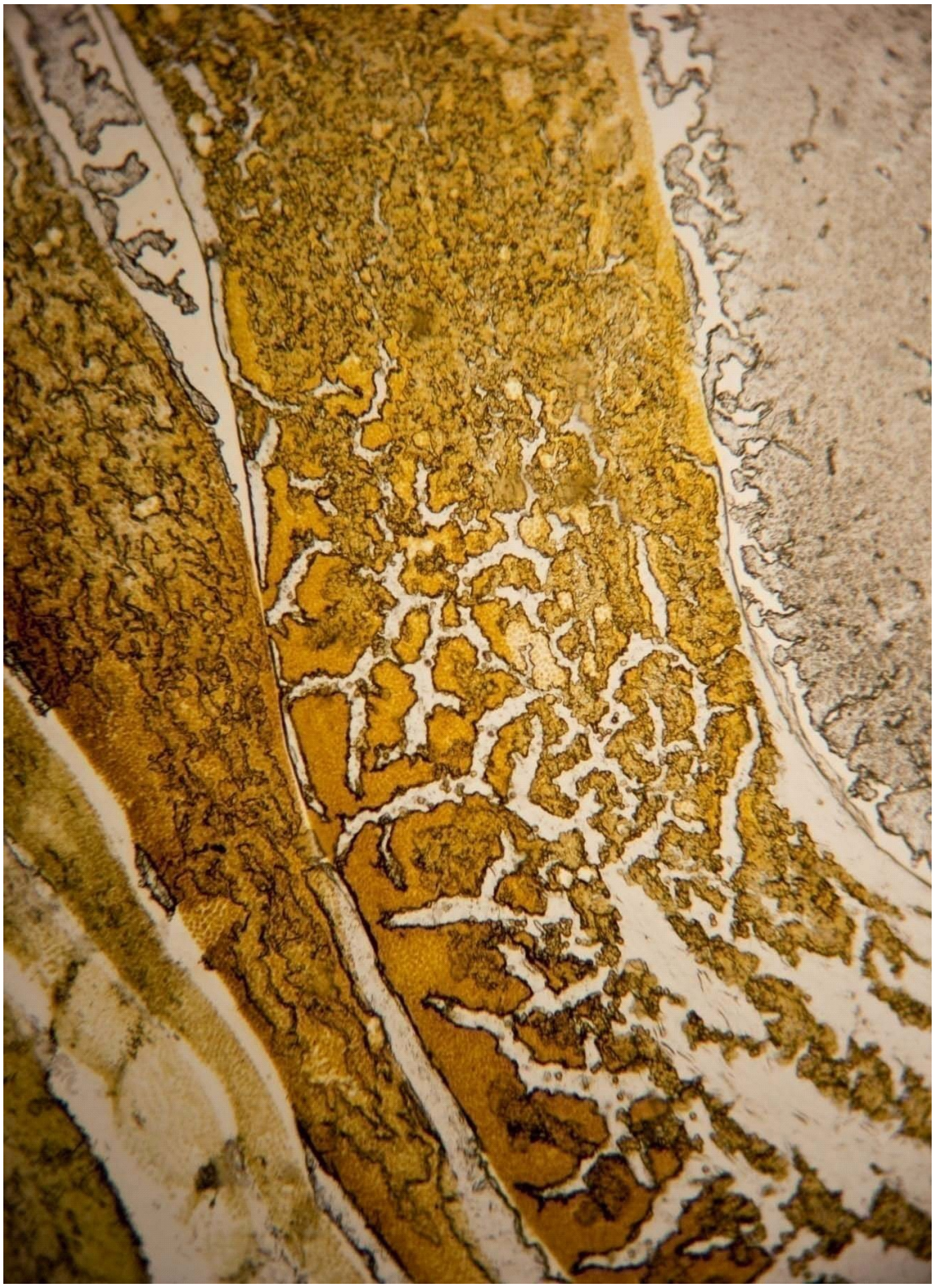

Figure 10. Photomicrograph of an aiptasia anemone captured with a trinocular compound microscope.

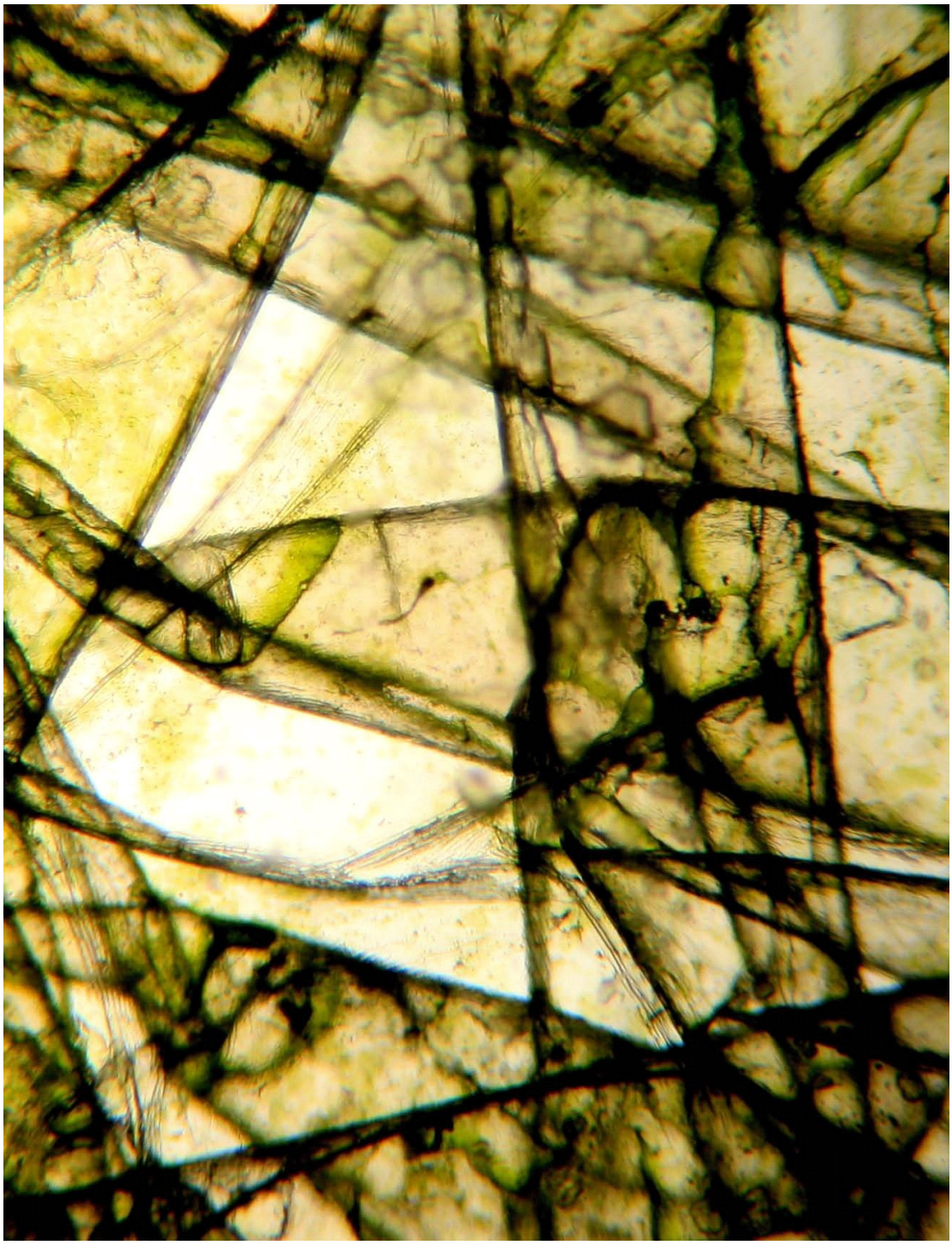

Figure 11. Photomicrograph of bubble algae captured with a trinocular compound microscope.

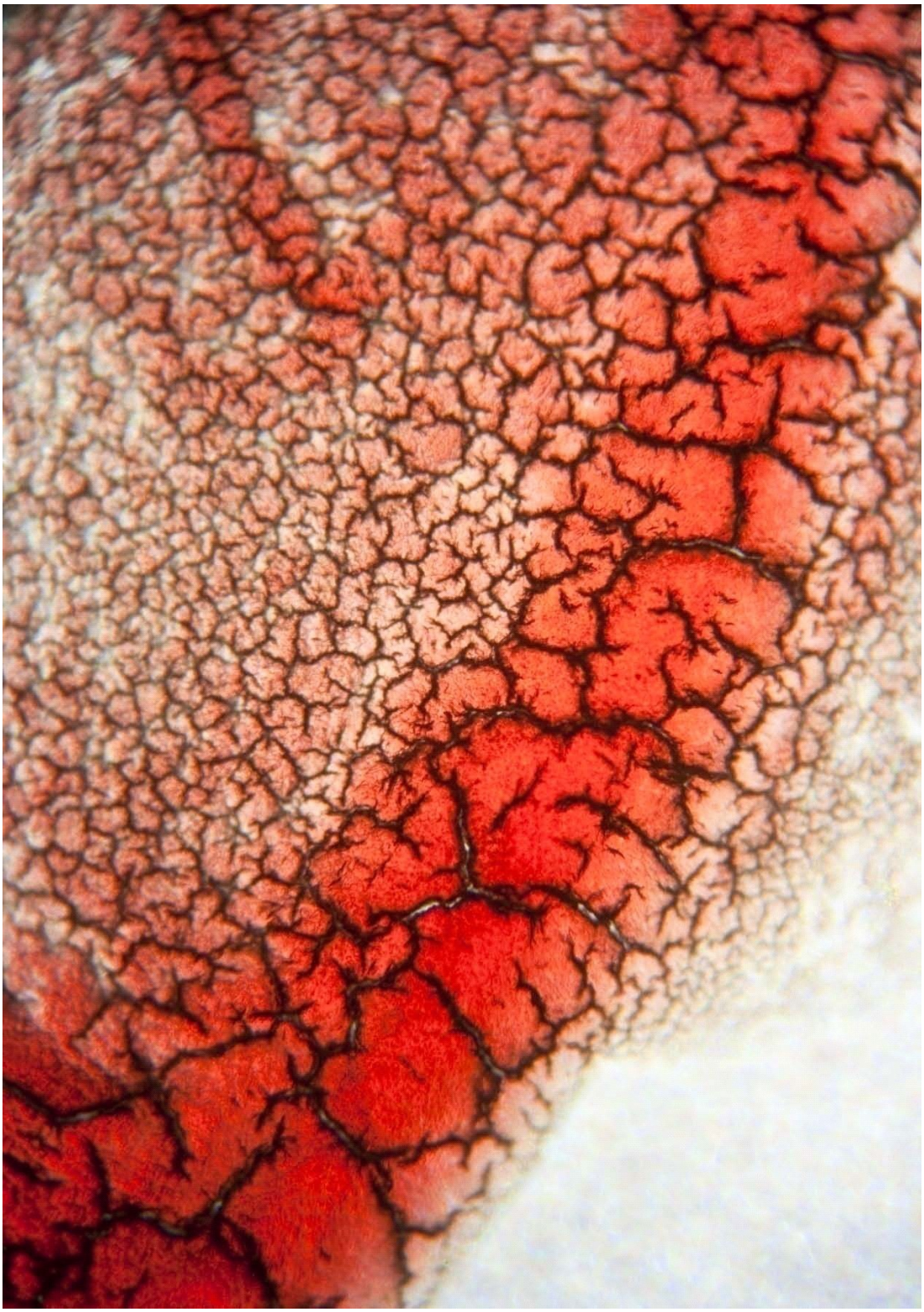

Figure 12. Photomicrograph of blood captured with a trinocular compound microscope.

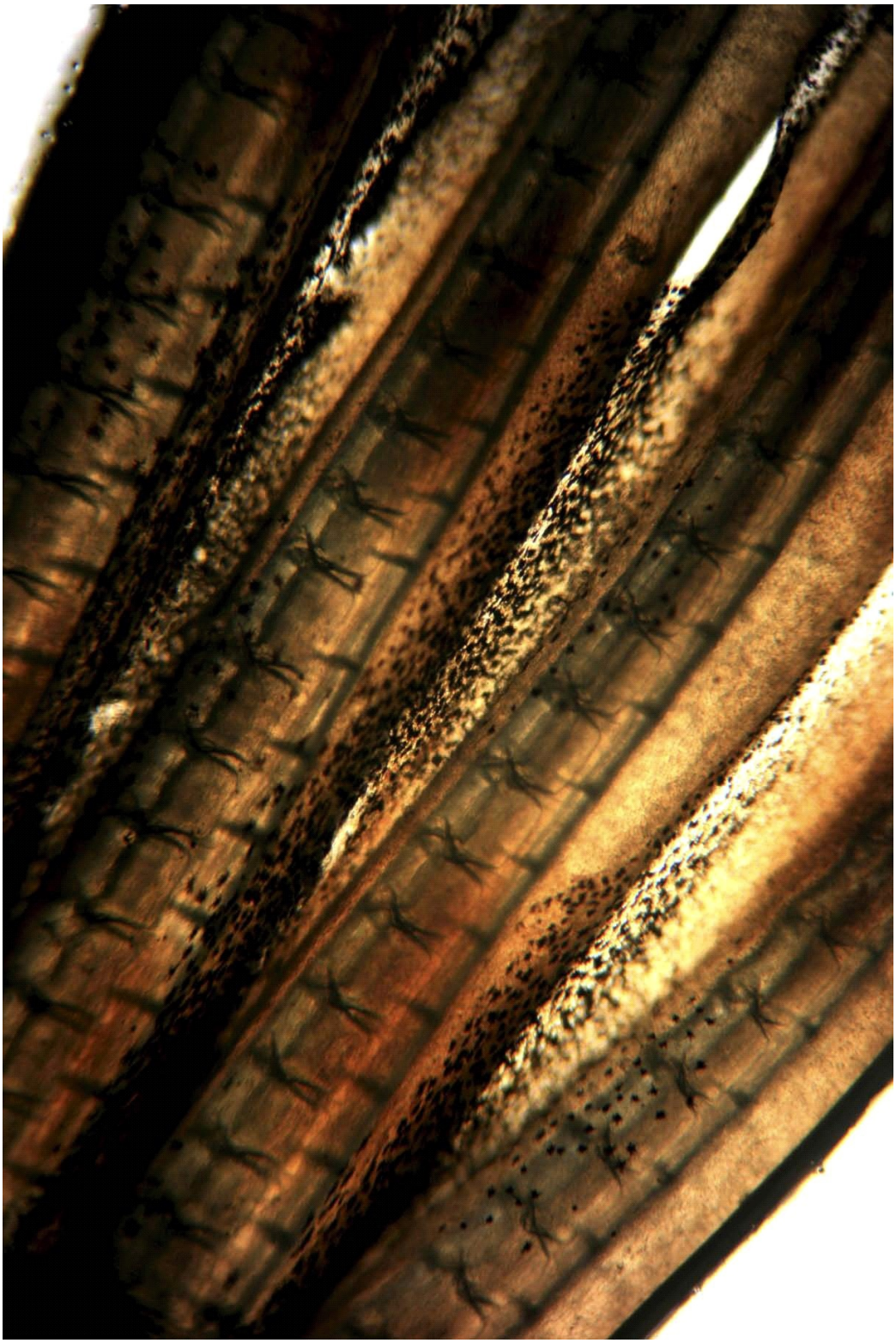

Figure 13. Photomicrograph of a dorsal lionfish fin captured with a trinocular compound microscope.

The first step taken was to create the greatest depth of field possible given the equipment being used. Subjects were pressed in microscope slides, and the lowest level of magnification was selected in order to produce the largest subject area in sharp focus. Figures 8, 9, and 10 were allowed to sit for approximately one day before being photographed. This period allowed for any water content present in the subjects to evaporate, which further flattened their appearance and created sharp edges to the lines. The sharp edges led viewers to relate the images to graphic works of art. Figures 11, 12, and 13 were photographed immediately after being pressed between the slides. Foregoing the delay meant that water content remained in the subjects, which resulted in a layered appearance, as well as the presence of both hard and soft edges to the lines. The appearance of layers and the variety of line quality in the images was what caused viewers to describe them as having an appearance similar to paintings.

It is important to be able to recognize and exploit the advantages that one piece of equipment may have over another in producing a particular look for a photograph. Photographers have long known that a particular camera or lens will enhance a certain feeling or atmosphere they may be striving for in their photography. Working with microscopes, it becomes quickly evident that the same situations exist and that a high amount of experimentation may be required to produce the desired look. Traditional photography and equipment has been explored to the extent that finding information as to which camera or lens will produce a desired effect is readily available. How the equipment used for photomicrography will affect an image has been explored by far

fewer people and, as a result, finding information presents more of a challenge. One of the few resources for those looking to begin working with photomicrography is a website run by an artist named Charles Krebs (krebsmicro.com), who provides information as to how an individual might go about creating a photomicrography setup as well as various articles discussing topics pertinent to the subject.

Stereomicroscope Aesthetics

In contrast to the two-dimensional aesthetics produced by compound microscopes, stereomicroscopes create more three-dimensional images. The lens attachment used to create the images for this thesis lacked an aperture; therefore, any adjustment of the depth of field was controlled by the magnification chosen on the microscope. The lower magnification levels standard on stereomicroscopes allowed for a greater portion of the subject to be in focus for any given exposure in comparison to a compound microscope. To create a depth of field in which a large portion of the subject is in focus while a small amount remains out of focus can take only one exposure under a stereomicroscope as opposed to the multiple exposures necessary with a compound microscope. A good example of this is shown in Figure 6 in which a series of exposures on a compound microscope were necessary in order to have a large portion of the subject in focus. Had the same image been taken under a stereomicroscope, it may have only required a single exposure for the same amount of focus. The drawback of using a stereomicroscope would be that the image would most likely require a greater amount of cropping and may show less of the minute details due to the lower magnification. To have an entire subject in sharp focus would still take

multiple exposures and then layering the images together using photo editing software. The major difference between such a process on a compound microscope and a stereomicroscope is the number of images required to achieve the desired result. Figure 6 required approximately 20 exposures be layered together using Adobe Photoshop, whereas a similar effect could be achieved with half the work using a stereomicroscope. Another advantage of the stereomicroscope is the greater distance between the stage/subject and objective, which makes using supplemental light sources easier than with the compound scope.

Figures 14, 15, and 16 were all photographed using a stereomicroscope. The appearance of said images was similar to what most people have come to expect photographs to look like. Early feedback on these images did not contain any comparisons to other forms of art as did images created with compound microscopes. Emphasis for these images was placed upon showing depth.

Stereoscopic Pair Aesthetics

Any microscope with two eyepieces presents the opportunity to easily create a set of images that when viewed side by side creates a three-dimensional effect. Capturing an image from the perspective of each eyepiece without any additional adjustment produces the proper distance between images to render said effect. The presentation of such images was intended to create the feeling that one is actually peering through the microscope's eyepieces in order to view a specimen and seeing the subject as the photographer saw it when capturing the images. After seeing the response to the images presented, it is apparent that in order to convey the feeling of

looking through the microscope, one cannot simply present the images hung on a wall. A more successful approach to creating the desired atmosphere might have been to either create a viewing device that mimics the look of microscope eyepieces only larger in size or, more obviously, to have had the viewer actually peer through a microscope to view the images. Either of these two methods would have required that the viewer crouch over a device as did the photographer creating the most realistic experience. The drawback to such a method would be that it would also recreate the discomfort of having to lean over the apparatus, which quickly becomes off-putting. An alternative solution to the issue might be to create prints large enough that when viewed, the individual is overwhelmed and loses sight of any objects in their peripheral vision.

Figures 17 and 18 are both sets of stereoscopic pairs. One of the major differences when working with pairs of images is that it greatly effects the composition. What may have looked better were it a single image can have a negative impact on the stereoscopic effect. Figure 17 is a good example of this. As an individual image, a closer crop, which eliminates some of the distraction in the background, would result in a stronger composition. In the case of Figure 17, the closer crop, resulted in a reduced stereoscopic effect. Figure 18 was given a wider crop slightly beyond the edges of the subjects. As a result, this image appeared more three-dimensional when viewed stereoscopically.

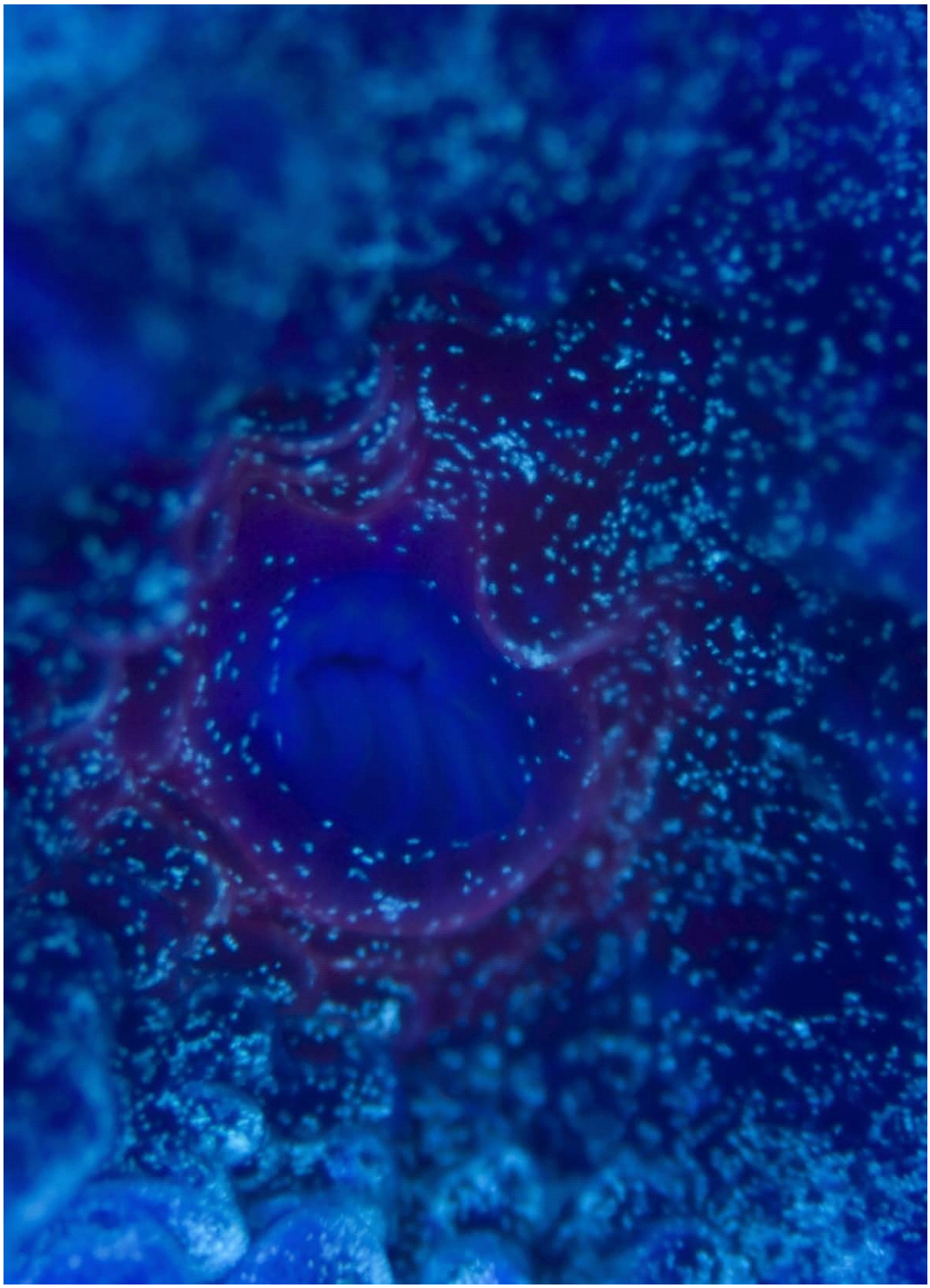

Figure 14. Photomicrograph of a favia coral captured with a stereomicroscoe illuminated with ultraviolet light.

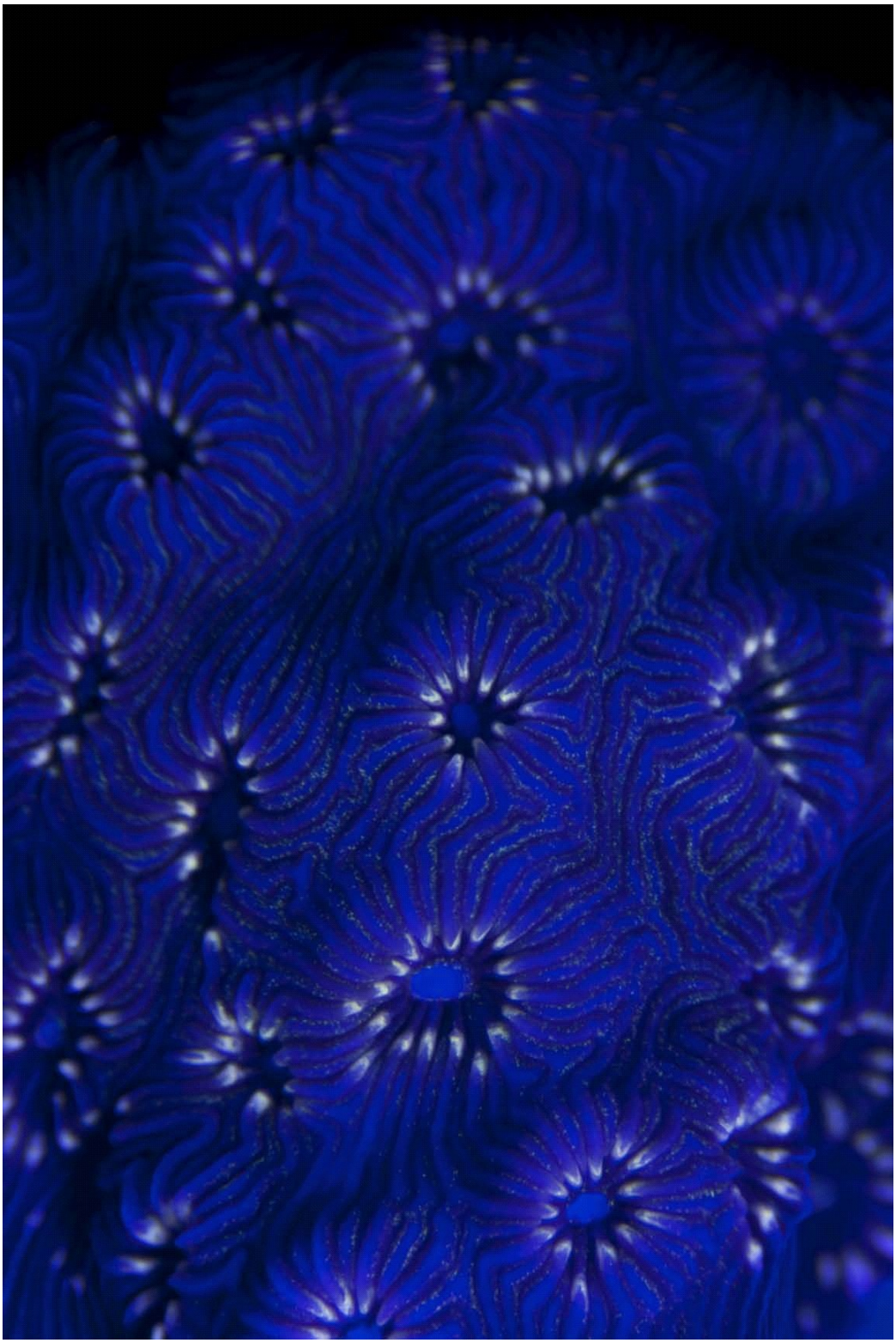

Figure 15. Photomicrograph of a pavona maldivensis coral captured with a stereomicroscope illuminated with ultraviolet light.

Figure 16. Photomicrograph of a pavona maldivensis (same as Figure 15) under daylight spectrum light.

Figure 17. Stereoscopic pair of a starfish.

Figure 18. Stereoscopic pair of a zoanthid.

Projecting Image Aesthetics

One of the more appealing aspects of backlit subjects is the vibrancy of the colors. Light passing through the object imparts a glow that is difficult to reproduce in a print. Projecting an image maintains the look one sees when peering through a microscope far more accurately than a print. Knowing that, it seemed only natural to include a number of projected images when displaying a gallery of micrographs. Figure 11 is one of three images that were projected by means of a small, digital projector. The projector was hidden inside a podium, and the image was projected out of a hole in the top of the podium onto a mirror, which redirected the projection horizontally onto the back of a sheet of glass. The glass was cut with the same height-to-width ratio as a scientific slide, and a portion was etched to provide a suitable surface for the image to be viewed upon. A stand was crafted to hold the sheet of glass approximately five feet above the floor. Both the stand and podium were crafted from oak wood due to the fact that the room in which the images were to be displayed was made of oak. The mirror that redirected the image from the projector to the sheet of glass was framed in brass with the intent that it would be reminiscent of the mirrors used as sources of illumination on old microscopes, which were constructed from brass (See figure 19). Unfortunately, due to the placement of the mirror directly behind the sheet of glass, it seemed to go largely unseen by many who viewed the images. Also, the size of the mirror used may have been too small for many viewers to make the connection with a microscope. A larger mirror, as well as a new stand for the glass, would most likely result in the desired response to the piece. Also, placing

the mirror beneath the glass so that it reflects upward like the mirror on a microscope would strengthen the connection (see Figure 20).

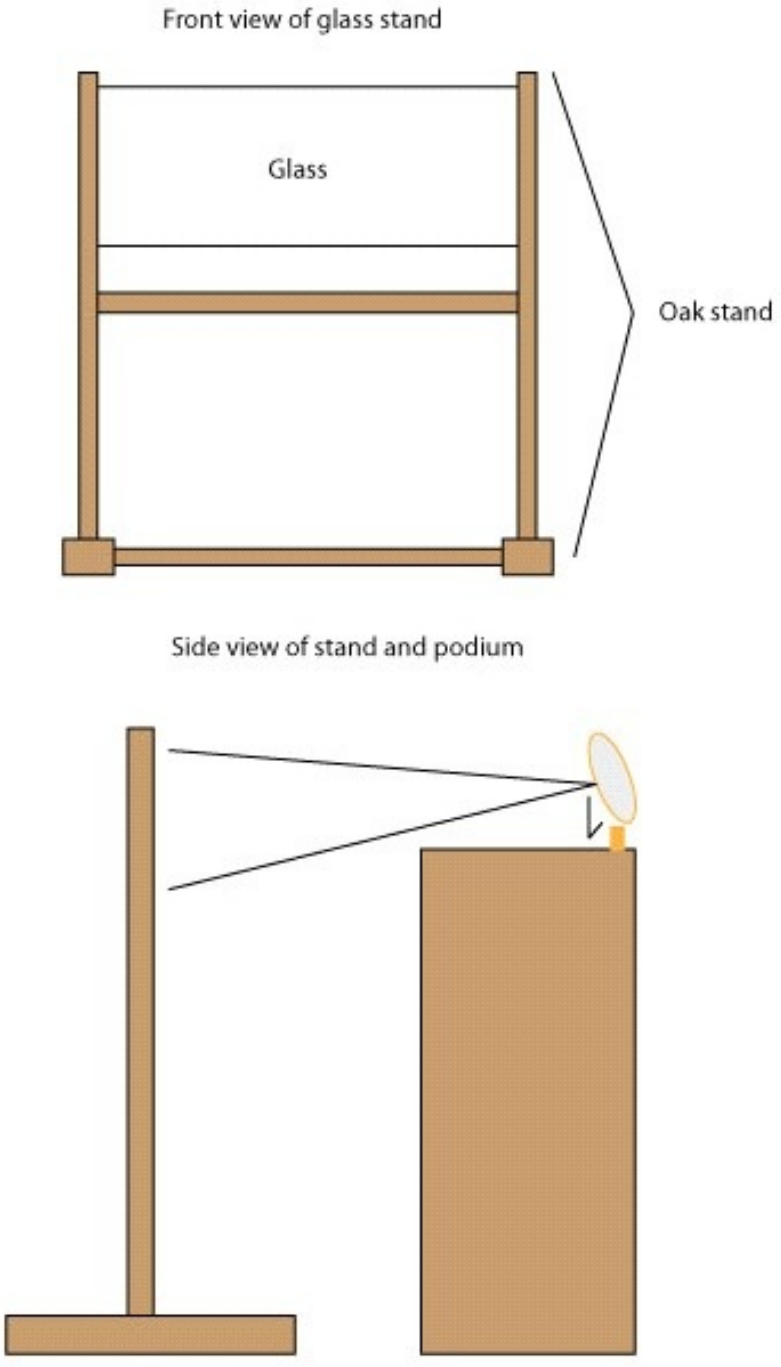

Figure 19. Projection setup for displaying digital images.

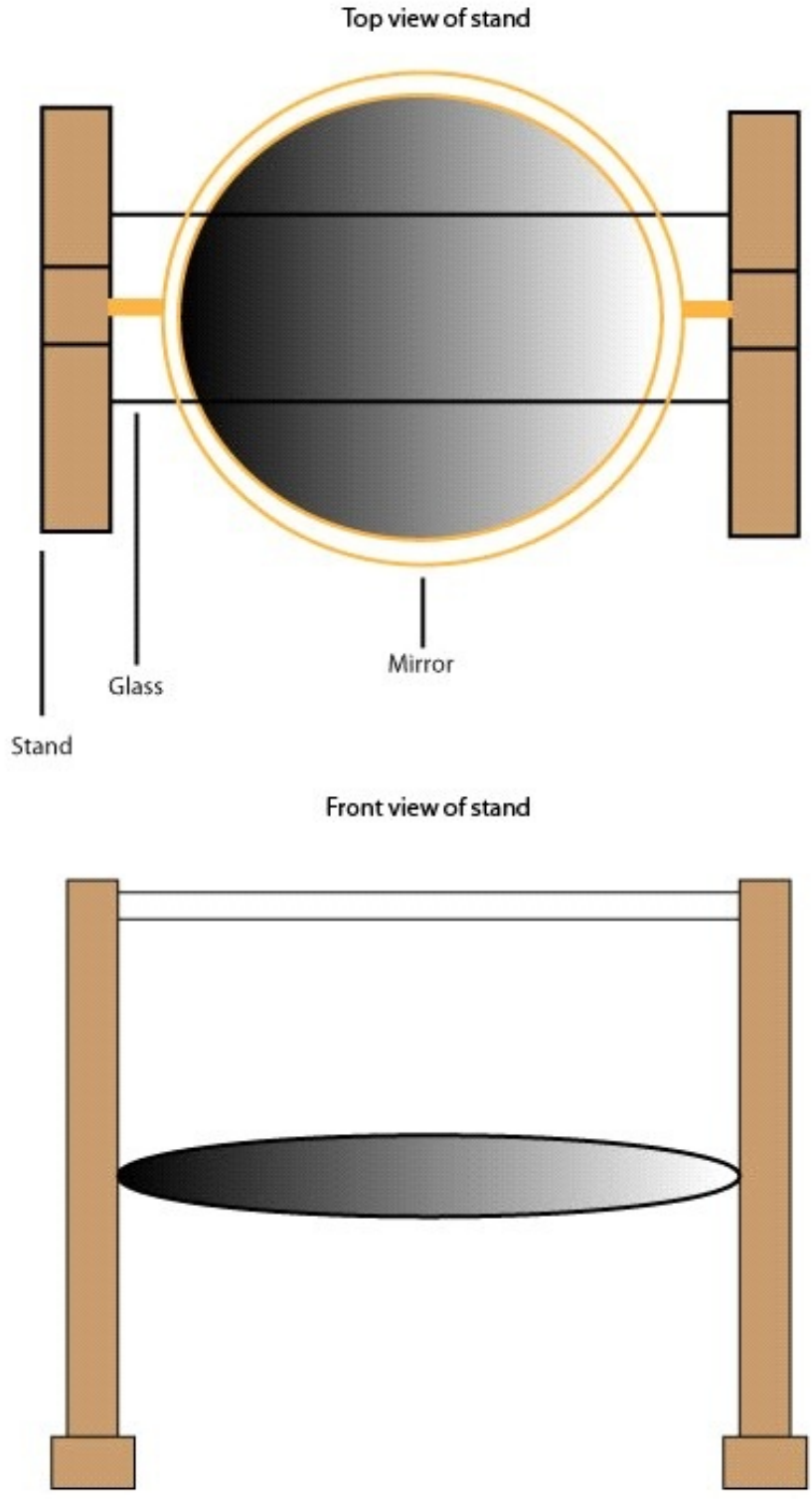

Figure 20. Alternative projection setup for displaying digital images.

Lighting

Photography has been described as painting with light. That description illustrates well the importance of adequate knowledge of lighting techniques when creating photographs. Why then should photomicrography be any different than any other form of photography when it comes to lighting? More than any other aspect of photography, lighting has the potential to enhance or detract from an image. If the lighting is too flat, the image will lack depth; if too strong, it may result in a loss of detail in the subject. One must be able to determine the correct exposure for an image or lose vital information in highlights or shadows. Without the proper knowledge of lighting, a photographer is greatly handicapped.

Backlight

Working with alternative means of illuminating subjects, it is easy to forget about the simple solution of backlight when capturing images using a microscope. The common compound microscope used by so many throughout their education can become irrelevant or childish to those who work with more complicated microscopes. Looking through the galleries of the Nikon Small World competition, there is an overwhelming lack of images created using the simple microscopes many first used. Artists just beginning to explore microscopy should take the time to appreciate the simple beauty possible using only backlight. Figures 1 through 3 are examples of an image created using backlight and shot in black and white. After editing, the image becomes a study of line and takes on a very formal quality. The simple appreciation of line as an aspect of design capable of standing alone to create a strong composition is

absent in images being created by many scientists. Figures 8 through 13 were also created using only backlight to illuminate the subject. The fact that some scientists fail to appreciate simplicity in their images is one of the strongest arguments supporting the need for artists to begin experimenting with photomicrography.

Portrait Lighting

Compound microscopes generally are equipped with a system that only provides backlight as a means to illuminate subjects. While backlight worked well for transparent or semi-transparent subject matter, opaque subjects required alternative illumination solutions. Many stereomicroscopes offer the ability to light subjects with both backlight as well as a single light located above the subject for non-transparent objects. Other microscopes offer other forms of lighting; however, more advanced microscopes can cost considerably more than basic microscopes. Some companies have made advancements in providing external lighting solutions for microscopy work, but these commercially available lights tend to be expensive. A company named Volpi provides led, as well as fiber optic lighting solutions, but the fixtures cost hundreds of dollars. The availability of small inexpensive led lights that can be easily modified to suit the needs of the situation means that these more expensive solutions can be hard to justify. For a situation with limited funding and the limited lighting provided by the microscope, the best thing to do is experiment. Given the small size of subjects viewed in photomicrography, it is unnecessary to purchase large expensive lighting systems in order to create the desired effect. A small 20 or 40 watt halogen desk lamp provides ample light for subjects, is easily affordable, and most importantly,

is small enough to maneuver into the necessary position (the lamps with flexible goosenecks offer the best range of motion). If working with a stereomicroscope that already has a top mounted light, then generally only one additional light is necessary to provide a simple lighting solution for the subject. If working with a compound microscope or any other that only provides a backlight at least two external lamps will be needed. Using two lamps, employ one lamp as the main light and the other as the fill light (on stereomicroscopes, the lamp attached to the microscope works well as the fill light). A third light, or group of lights, can also prove useful when filling in dark areas that cannot be reached by the main or fill light. A small directional light works best for this, such as a single led with a gooseneck. The use of multiple types of light, that is, halogen and led light may result in the need to create a custom white balance for the situation (a strong argument for the use of a digital SLR camera). Figure 21 shows a solution used while creating the images for this thesis. A small stand purchased from a local hardware store for around $4 that was equipped with two alligator clamps made an effective base to attach the two small gooseneck lights. The lights, also purchased at the hardware store, were around $3 each, making the total cost for the lighting solution around $10. The alligator clips make it possible to exchange the lights to suit the needs of the situation; for example, a second set of lights was used for ultraviolet photographing.

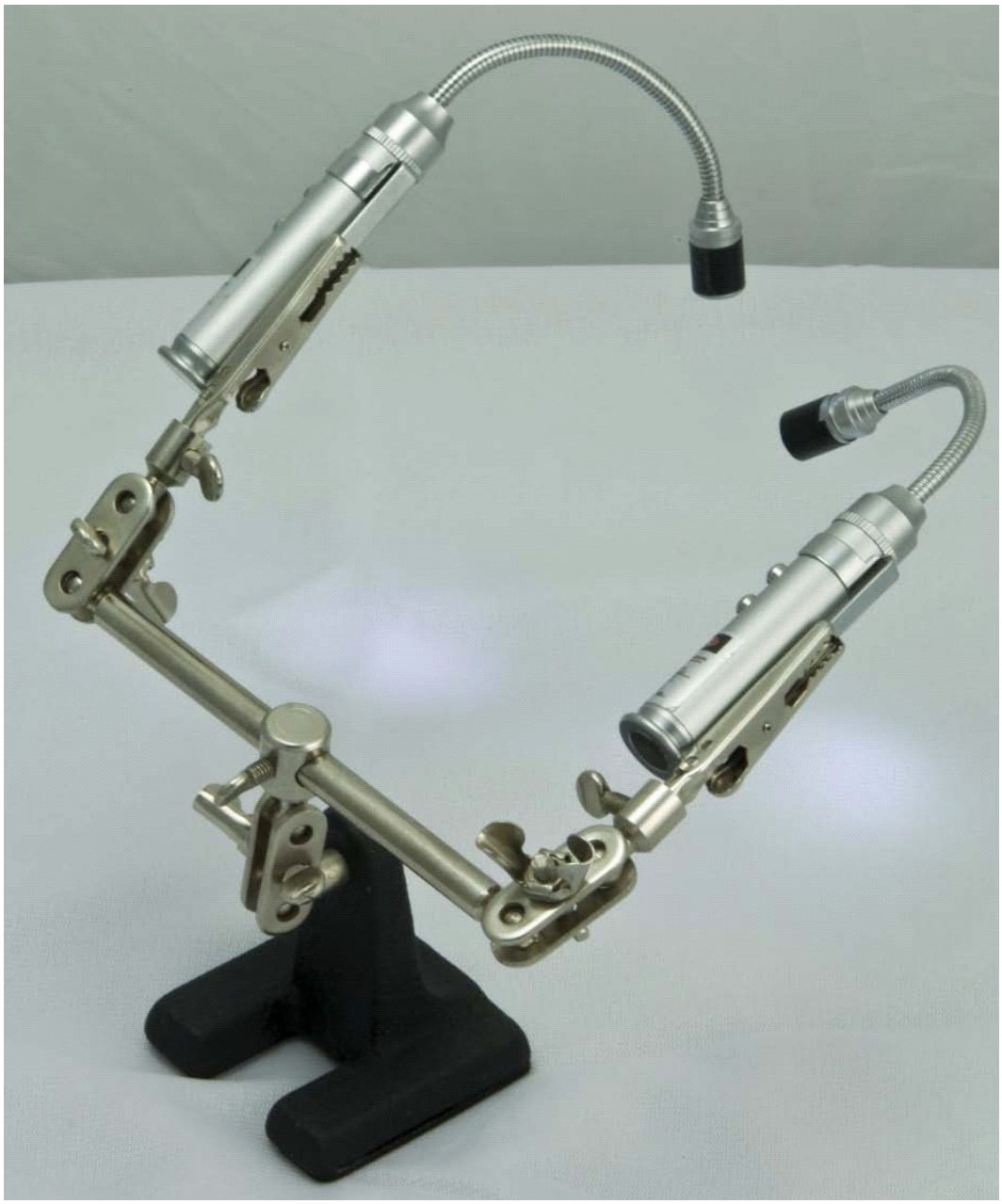

Figure 21. Lighting setup for illuminating microscopic subjects.

The approach for lighting photomicrography subjects was the same as the approach for lighting a portrait model. The lighting was manipulated until it properly captured the character of the subject being photographed, highlighting the strong points and disguising the weak points. While photographing coral, there were certain circumstances that revealed more interesting aspects or habits of the animal than others. One of the more simple circumstances to create was the occurrence of a feeding coral. Many corals have mouths, which when feeding, will open to allow food particles to be consumed. Some species of coral simply intake water, which has particles floating in it, while others will use tentacles to grab particles from the water column and place them in their mouth. Coaxing a coral into opening its mouth to create a more interesting image is similar in idea to coaxing a family into smiling for a portrait. A photographer who understands the nature of his subject will always be able to create the images others cannot.

Other aspects of corals can make capturing an image much more difficult than with other subjects. Coral species such as Zoanthids, Palythoa, and many other soft corals (corals that lack a solid skeletal structure) have a defensive response when confronted with abrupt changes in their environment. These corals will retract their polyps as a means of defending themselves from any possible predators. The problem with this behavior when attempting to photograph corals, particularly under a micro-scope, was that the slightest change resulted in the polyp (often the colorful and interesting part of the coral) retracting. Photographing a coral under a microscope required that the specimen be placed inside a container filled with saltwater. Moving

the coral into this container caused the coral to withdraw its polyps as did any vibration in the water, and any changes made to the lighting. It was fairly common in the instance of this thesis for a coral to sit for hours under a microscope and never fully open, which made capturing a usable image a difficult and time consuming process. Another factor in this process was the temperature of the water. The longer the water sat, the colder it became ,and the less likely the coral was to open. The end result of all these issues was that there was a brief window of time in which to manipulate the subject into a suitable composition. Knowing the behavior of the subject, as well as how to manipulate it quickly and concisely to achieve the desired results, was essential to successfully capturing images.

Figures 22 and 23 illustrate the difference manipulating a subject can have on an image. Figure 22 shows a coral that was not manipulated in any way to attempt to create a stronger image. Figure 23 shows the same coral a few minutes after a supplement designed to encourage growth and overall health was added to the water. As a result of the presence of the supplement, the coral opened the mouth located at the center of the polyp, thus, exposing the contrasting green flesh that is normally hidden except for when feeding. Also, a secondary circular shape has emerged inside the ring that was present in Figure 22, creating repetition within the image and strengthening the overall composition. Within the smaller, inner ring present in Figure 23, one can see a series of yellowish circles that once again create repetition.

Figure 22. Coral, not manipulated.

Figure 23. Coral (same as Figure 22), post manipulation.

Ultraviolet Lighting

Types of algae, which live inside corals, known as zooxanthellae, are responsible for the impressive pigmentation displayed by the coral. These algae provide food for their host animal by utilizing sunlight and carbon dioxide to photosynthesize sugars just as any other plant. Aquarium keepers have realized that different colors of light can effect these algae in different ways. While light that falls in the yellow part of the light spectrum can cause these algae to produce more sugar, it also causes the color of the algae to become less attractive. Light, which falls in the blue portion of the light spectrum, can result in the algae producing less sugar, but the algae tend to become far more attractive when kept or viewed under this type of lighting. One of the ongoing discussions in coral husbandry is what type of lighting is most beneficial to coral growth and color. An interesting experiment for many aquarium hobbyists has been to use an ultraviolet light to view their corals at night to maximize the vibrancy of the algae. The most interesting corals to view under ultraviolet light are those that fluoresce. It was only natural that in the case of the images created for this thesis, some of them capture the fluorescence that occurs in coral specimen (see Figure 24).

As with other types of lighting, the availability in recent years of inexpensive led lights has made it possible to experiment without having to spend large amounts of money (although the single bulb gooseneck lights were more difficult to find). The same portrait lighting approach used for normal conditions was applied when utilizing ultraviolet light. Unfortunately, it quickly became evident that ultraviolet light makes focusing much more difficult. Compound microscopes are less affected by this

problem since subjects are generally flattened between microscope slides. Stereo-microscopes have presented the most difficulty with focusing under ultraviolet light due to their lower magnification and greater ability to show depth. As of yet, the most successful process for focusing under ultraviolet light has been to utilize three or more lights. Attaching single bulb gooseneck lights to a stand provided fill light for areas of the subject while still having hands free to perform other tasks (see Figure 21). Once the desired lighting situation had been attained, the simplest way to focus the camera was to use a much brighter light source to brighten the subject enough that details could be seen. This focusing light was also ultraviolet so that when it was removed the subject remained in focus. Attempting to use a light source that fell under a different portion of the spectrum to focus resulted in improper focus when said source was removed and only ultraviolet light remained. Capturing an image using only the single bulb lights tended to create a long exposure time. The simplest way to shorten the exposure was to apply the focusing light to paint-in more light. An important factor to note was that the in-camera meter did not provide a proper reading for ultraviolet light situations. Proper exposures tended to be close to two stops longer than the camera metered. Also, prolonged shooting under ultraviolet conditions may have had a negative effect on the in-camera light meter causing it to read improperly when returning to photographing under normal lighting conditions. Fortunately, after a period of shooting under normal lighting conditions and resetting the camera, the meter did return to normal operations.

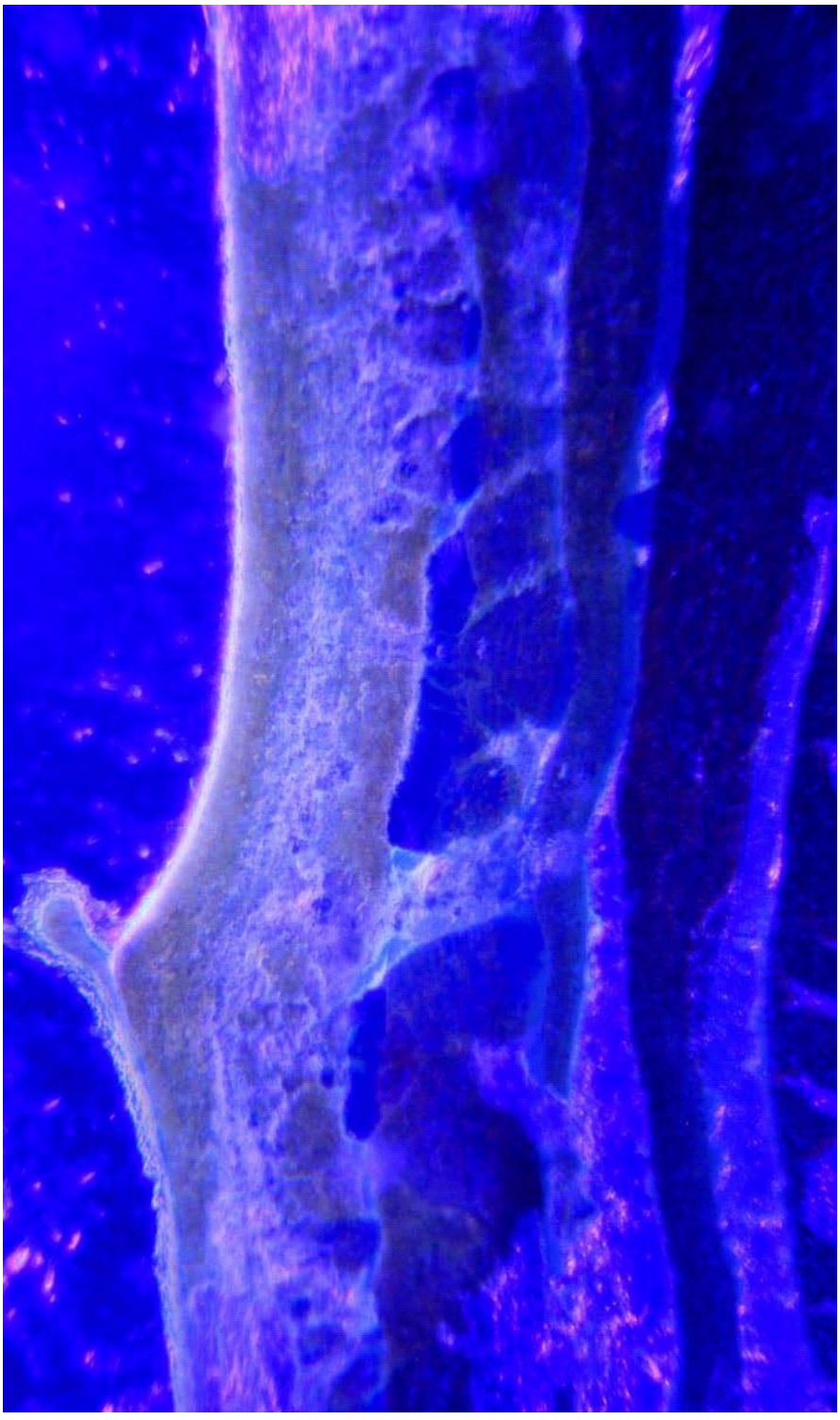

Figure 24. Photomicrograph of an aiptasia anemone captured with a trinocular compound microscope illuminated with ultraviolet light.

CHAPTER IV

CONCLUSION

The artwork for this thesis was created as an attempt to educate artists as to the potential of photomicrography. By expanding the number of lights used from a simple, single-light solution intended to enhance scientific knowledge of a subject to a multiple-light system, the artistic potential of photomicrography is greatened. Nikon Small World (n.d.) offers arguably the most comprehensive collection of micrographs for public viewing on their website (www.nikonsmallworld.com). One could easily argue that with such a wealth of images already presented by Nikon, what was the use of creating a much smaller body of images to be seen by a much smaller portion of the public. These images are intended to stand in contrast to those images created by scientists that lack proper attention to aesthetics. Each subject was carefully lit, manipulated, and composed through a camera.

The method used for lighting subjects has been an area that allowed a great deal of artistic exploration and offers much room for innovation to those wishing to experiment with photomicrography. The use of ultraviolet light in creating images was restricted to a small portion of subjects, all of which were forms of marine life. Ultraviolet light could easily be expanded from lighting marine creatures to whatever subjects also possess the property of fluorescence. Also considered while capturing

images under ultraviolet light for this thesis was the idea of combining daylight spectrum light with ultraviolet light in a single image. In the case of corals, certain portions of their tissue appear more colorful under daylight, while other parts fluoresce under ultraviolet light. Lighting the overall image with daylight and using small directional lights to show the fluorescence where it occurs could produce a more attractive image than either type of light on its own.

A style of lighting was used for capturing subjects while working with the stereomicroscope that was based on the techniques used in portrait photography. Multiple lights were employed and treated as one does the lights for a portrait; one acting as the main light, another the fill light, but for this thesis none were used beyond those two. The reason no other lights were used was that due to the small size and relatively uniform surface of the subjects, two lights provided sufficient illumination. Subjects larger in size or with greatly varying surfaces may require additional lights to achieve the desired effect.

In his experimentations with lighting, Charles Krebs has also employed a style that is based on portrait lighting. Using the backlight standard on his microscope, Krebs modified his scope to accommodate an external flash unit. This modification allowed Krebs to use the backlight of his microscope as a modeling lamp and the flash to create the actual exposure. Images of Krebs' setup can be seen at www.krebsmicro.com under the articles section, "My Initial DSLR Photomicrography Setup" (Krebs, 2005). Flash photography is another possible area of exploration for photomicrographers.

Regarding the images captured using a compound microscope for this thesis beyond using ultraviolet light in some instances, no other experimentation took place. Since subjects viewed under compound microscopes are generally pressed between sheets of glass, virtually no variation was present in the surface. The images of backlit subjects that were shown, all received comments that they were similar to two-dimensional forms of art such as painting or graphic design. An attempt to use different styles of lighting when photographing with a compound microscope could potentially weaken the two-dimensional feel of the images, which is one of the stronger aspects of such photographs. Instead of attempting to use a multiple light system when photographing with a compound microscope, one would most likely experience more success by changing the spectrum of light used as was done with the ultraviolet light. Another option would be to simply explore the other forms of backlit microscopy employed by scientists such as darkfield microscopy.

There are many other forms of microscopy that were not used in creating the images for this thesis. The most limiting factor of working with photomicrography has been cost. Both styles of microscope used for this thesis were relatively inexpensive and can be easily attained. Other forms of microscope such as scanning electron microscopes would be most likely difficult to afford for most individuals and difficult to operate for anyone not trained on the equipment. As stated earlier, there is much to appreciate in the more simple microscopes.

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