LIGHT OF REASON AND DEAD BUTTERFLIES

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ABSTRACT

Light of Reason and Dead Butterflies is an ongoing research project which attempts to demonstrate the role of analogical interpretation in the choice making processes of scientific investigation. Seeing a given thing as another allows for explanatory simplification - in which the simplicity of explanatory elements is the measure for successful reduction. This idea is based on the understanding that standardized research methods in the natural sciences are ultimately a strategic storytelling device, sustained and promoted through publication and peer review.

This project can be best described as working with a lively and dynamic material, by means of capturing or immobilizing certain aspects of change through adjustment of arbitrary procedures. Although this practice has more freedom to be speculative rather than predictive, it is still bound by countless rules to keep the work completely or partially alive. Meanwhile, many decisions that were made within these rules are highly spontaneous, in which intuitive and imaginative measures are not completely left out.

The photo documentations show an array of performances done at a biology research lab, in which the artist is trained to function as a histologist and imaging technician, producing quantitative data for analysis and publication. The artist and her scientist collaborators have actively worked out a mutual agreement so that the artist is able to freely utilize the lab environment and produced data.

1. INTRODUCTION

Figure 1. 1 *The Borametz : fern-root specimens considered as vegetable lambs*[1]

Shall we then say that the vegetable living filament was originally different from that of each tribe of animals above described? And that the productive living filament of each of those tribes was different originally from the other? Or, as the earth and ocean were probably peopled with vegetable productions long before the existence of animals; and many families of these animals long before other families of them, shall we conjecture that one and the same kind of living filaments is and has been the cause of all organic life?

Zoonomia, vol. I, or, the Organic Laws of Life, Erasmus Darwin[2]

Figure 1. 2 *Motion study : video still*

Every living thing is subject to control. This was also the case for a particular group of butterflies that were raised and killed by the observer, who decided to examine and write about butterfly flight after witnessing a fluttering cabbage white butterfly in open air.

Its wing flap movement was reminiscent of the light-dependent movement of woodsorrel leaves. The transition between the sleeping and waking positions of these leaves takes approximately one hour which is perceivably slower than the average wing beat frequency of cabbage whites which is fifteen times per second. However, the similarity of the motion was meaningful to the eyes of the observer, which lead to further activities in search of possible grounds for this perceived analogy.

Along with brassicas, mints, asters and dandelions, plants in the woodsorrel family are one of the major host plants for adult cabbage white butterflies, establishing a level of interdependence as well as an opportunity to share common

perceived characteristics. Various evolutionary schemas based on parallelistic as well as reticulate thoughts can be considered. Mimicry - the butterfly may have learned to flap its wings from watching the plant leaves open and close. Horizontal gene transfer – the organisms may have been swapping 'genetic information,' that lead to shared traits without common ancestry. Or as it is speculated in this study, the butterfly may have sprung directly out of the plant as an extension into the lifesphere, for the purpose of being fit – a state which is solely demonstrated by our recognition that these traits have in fact survived. Corresponding to this idea is the how 'rhizomes' should form in the minds of the observer, described by Deleuze and Guattari in *A Thousand Plateaus: Capitalism and Schizophrenia*: "Always follow the rhizome by rupture; lengthen, prolong, and relay the line of flight; make it vary, until you have produced the most abstract and tortuous of lines of N dimensions and broken directions[3]."

Sometime after the encounter with the fluttering cabbage white butterfly, the observer was able to catch a wild monarch butterfly to bring home. Without much knowledge of this life form, including how to keep them alive or to kill, the seemingly most relevant step to take was to cut it open and look at the muscles that articulate the wings. The best way to kill a butterfly suggested by a butterfly taxidermy web resource[4] was to pinch its thorax with two fingers. Although the butterfly should die from this action, this will also break the exoskeleton and may damage some muscles.

In order to keep the thorax intact, a killing jar was used, in which the butterfly was placed with a piece of cotton ball soaked with nail polish remover. It took about nine minutes to kill the monarch butterfly, during which time it fluttered around

Figure 1. 3 *The first kill*

frantically in the jar. Two hours after death, the whole butterfly was split down the middle using a paper knife. With the aid of a magnifying glass, some dried out striated structures were visible in the cross section of the thorax.

After obtaining a rough section of this wild monarch butterfly, it became evident that the section needed to be optically or physically magnified to a scale that best suits the capacity of the observer's vision. Also, it was necessary to differentiate the structures in charge of the movement in question from other complicated body structures. This lead to the idea of making finer slices of the whole body part and then taking magnified photographs of each section. These images may be used as maps for understanding the desired anatomical structures, and may also serve as blueprints for building three dimensional models of these structures. The images and

models may be used to compare the body parts of butterflies and woodsorrels, and possibly provide an anatomical evidence for the similarities that were witnessed in their movement.

Pulvinus of *Oxalis regnellii*, a common houseplant in the woodsorrel family and thorax of *Pieris rapae*, the cabbage white butterfly were selected as subjects. In order to secure living samples to repeat the observation with, it was necessary to maintain a consistent stock of these organisms. In addition, a precise and stable technique was essential for physically opening up the samples as they were relatively small in size and also perishable. These objectives were pursued by two distinctive projects that are described in this report - *Part One: Growstand* illustrates the methods and reasons behind a customized environment for maintaining a steady supply of adequate research samples. A growstand was designed to accommodate a combination of conditions that enables the observer to manipulate the samples' environment such as temperature, lighting and nutrients to a desired state. *Part Two: Killing Scheme* discusses the application of histology and micrography techniques used in life sciences for treating these samples. The butterflies that were meticulously kept to emerge as programmed were opened up using standardized life science procedures to achieve a more intimate encounter by the observer.

Both parts aim to contribute to the discussion of controlling and utilizing living things in the name of self interest, regardless of specialized fields defined by the contemporary academies. Despite the adoption of methods that have been standardized, the observer is constantly challenged with the problem of reliability and validity within the moments of life that are crystallized. All treatments done to the living samples for this project are framed as art performances done at a biology

research lab. In this setting, the artist is trained to function as a histologist and biological imaging technician, producing quantitative data for analysis and publication. The artist and her scientist collaborators have worked out a mutual agreement so that the artist is able to freely utilize the lab environment and produced data.

2. PART ONE: GROWSTAND

Figure 2. 1 *Sickroom*

A bottle of flies is not of much use for experimental production in itself, but only as part of an assemblage of material instruments, standard recipes and procedures, and working relationships. We need, therefore, to take as our units of study those systems of material, literary, and social technologies in which working groups make substantial investments and which have the property of expanding and diversifying into many lines of work over a period of time. These are the major systems of material culture that constitute the world of experimental science.

Lords of the Fly: Drosophila Genetics and the Experimental Life, Robert Kohler[5]

Figure 2. 2 *Growbox*

2. 1 Lifecycle

Observation of the *P. rapae* flight muscle structures required repeated trials to achieve greater accuracy, which was possible by maintaining a certain number of living stocks that were not only of the same species, but were also consistent in their materialistic conditions such as size, age and health at the time of observation. It was assumed that these programmed stocks would be producible through consecutive inbreeding from a single set of preconditioned eggs in a thoroughly controlled environment. A growstand was designed and built to serve this purpose. The growstand was made in form of a shelf with four compartments using PVC pipes

and fittings. This construction allows for easy modification and addition of units to accommodate changes in the development of organisms. The initial stand was 48” H x 52” L x 22” D in dimension. Each compartment could fit a shelf for resting plants or a box (growbox) for keeping butterflies. The shelving and boxes were built with acrylic glass panels, equipped with 0.25mm nylon netting lids. To keep a steady environment less affected by changes in external conditions, the growstand was kept indoors, using 40” natural spectrum shop lights connected to a timer as light source. The temperature was maintained at 18 to 22ºC with an electric oil filled radiator.

Stocks of butterflies not in everyday use were maintained on a forty-day generation cycle. To ensure a steady supply, it was convenient to keep at least two stocks independently on alternating generations, two weeks apart. It may be good practice to keep more than two stocks per generation so that one stock can be used as a backup, should the other fail for any reason.

The first stock of *P. rapae* was produced with eggs purchased online from a science material store[6]. The eggs were placed on napa cabbage leaves for larvae to transfer after hatching. Eggs hatched within one to three days of being laid. Once the young larvae chewed a hole through the top side of the egg and climbed out, some cannibalized adjacent eggs and unhatched larvae. To minimize this chance in later generations, the number of eggs was maintained at thirty per $1cm^2$ by cutting and dispersing the original site of oviposition.

Larvae passed through five instars, the stages of postembryonic growth between molts, in their first eighteen days after hatching. The instars were numbered L1 through L5 respectively. By the end of each instar, the larvae outgrew its exoskeleton needing to molt. Two different species of brassica were used to

Figure 2. 3 *Hatching*

sustain the *P. rapae* life cycle. Store bought napa cabbage (*Brassica campestris*) was effective food source for larvae in later stages of development as they are voracious eaters. Six larvae in stages L3 and L4 went through one full leaf of napa cabbage per day. Wisconsin Fast Plants®, a rapid-cycling *Brassica rapa* bred at University of Wisconsin were grown as oviposition sites. This plant provided fresh young leaves for L1 larvae and nectar from flowers to adult butterflies.

Before adopting brassica plants, a number of gadgets were built into the growbox to serve as artificial sites for oviposition and feeding. A trial ovipositron was prepared by gluing a small piece of napa cabbage leaf to the bottom of empty 35mm film canister and sticking a strip of wax paper along the side. Feeders were made by

Figure 2. 4 *Egg, frass, and feces*

placing a dish with a piece of cotton ball soaked in 10% clover honey and also by hanging pieces of overripe fruits. Although these gadgets were successful at serving their purpose, they were eventually replaced with living plants as they were fresher and more cost effective sources for maintaining the *P. rapae* life cycle. *O. Regnellii* was also placed in the growstand for adult butterflies to rest and feed. As gregarious eaters, the larvae in all stages produced large amounts of feces that needed to be taken out daily to maintain the cleanliness of growboxes. Feces and leftover food sources were collected and mixed into potting soil as fertilizer for growing plants in the growstand unit.

When the larvae have grown to instar L5, they climbed up the sides of the

Figure 2. 5 *Emergence*

growbox to find a pupation site. Once settled, the larva wove a silk carpet to attach their posterior end, and a thin silk belt around its middle. The pupa formed within the exoskeleton of the L5 instar. The pupal stage began by pulling off the L5 exoskeleton, similar to pulling off a sock. The old, tightly condensed L5 exoskeleton was found at the posterior end of some pupae. During the first twenty four hours of the pupal stage, the soft pupation case hardened and became translucent brown. Over the next eight days, the outlines of wings appeared. Wing spots became visible through the pupal case when the pupa was within twenty four hours of emergence.

A pupation stand was built to transfer the pupae into a second growbox, while the first one still accommodated younger larvae. It was convenient to keep the

larvae and adults in separate boxes for the larval box required daily cleaning. The stand was made with acrylic glass panels to which the carefully collected pupae were reattached with non-toxic wood glue. It was observed that many larvae favored corners as pupation site although some settled on open surfaces or underside of napa cabbage leaves. Therefore a removable washboard like structure may be provided to the larval growbox to induce pupation so that less pupa are forcefully removed from its original position for transfer.

Emergence of adult butterfly occurred approximately seven days after the initiation of pupation. The pupal case split, forelegs emerged, rapidly pulling out the adult from the case. Red exuvial fluid was released from the case as the adult came out, leaving drips resembling bloodstains. The adult crawled upward, hanging still for about one to two hours for its wings to expand and harden. The adult remained relatively quiet for a day, neither feeding nor flying. Twenty four hours after emergence, the adult began to fly, actively feeding on nectar and seeking mates. The copulation was tail to tail and persisted for several hours, sometime overnight in which case some couples died of exhaustion. Females lay multiple eggs over a three to seven day period. They were able to discriminate brassicas and other plants, laying eggs only on brassica leaves. Healthy adults died between one to ten days after emergence.

2. 2 Sickroom

The initial stock of P. rapae was produced from quarantined eggs. However, deformation, disease and death in all stages of development were observed, mainly due to inadequate maintenance.

Figure 2. 6 *Wing deformations*

The most common problem was mold growing in the larval food source. Symptoms caused by mold were black, liquefying larvae and pupae. For prevention, growboxes were cleaned on a daily basis by taking out carcasses, leftover food sources and feces. Before introducing a new stock, the growboxes were emptied out completely and wiped with 70% ethanol. Use of mold inhibitors may be necessary if problem should persist.

In one occasion, the butterflies were infected by common fruitflies that normally occur in the open environment. They were mostly interested in the butterflies' food. In rare occasions, the fruitflies were interested in the butterflies themselves, laying eggs in the butterfly larvae. The contaminated stock was discarded without question.

Figure 2. 7 *Immature death*

Saving them was not an issue because the liberal and social attitude characteristic of this home lab should not constrain effective management.

New stocks were kept segregated from other insects such as flies, cockroaches and ants by replacing the lids of growboxes with a finer mesh. The fruitflies may have come in with the food source purchased at the grocery store. For this reason, it was good practice to self-grow the food source and to be scrupulous about isolating the food source from common pests and pesticides. Infections by mites, bacteria and viruses as well as intoxication by pesticide or other airborne chemicals may have occurred and need further examination. All existing stocks were partially affected by mold. It may be necessary to discard all existing stocks and start a new stock in a

clean and isolated room with regulations for inspection.

P. rapae in pupation were sensitive to physical stimulation, especially during the first twenty four hours of formation when the pupal case is not fully established. Even a slight disturbance caused the pupal case to break and leak green bodily fluid, eventually causing death. Pupae in the final thirty six hours before emergence were also easily influenced by physical stimulation. Disturbances caused adults to emerge prematurely with underdeveloped wings. Although it was relatively safe to touch or move pupae within fourty eight to seventy two hours after formation, overstimulation caused deformation in wings, such as asymmetrical size, shape or various types of wrinkles. The spatial orientation of pupae or the change of orientation from the initial position was not a significant factor in causing deformations. Wing deformation also occurred within one hour after emergence, during which time the wings open up and harden. New adults that fail to hold onto a stable surface to keep wings from touching other objects ended up with partially open wings.

A sickroom was added to the growstand where sickly stocks, or stocks going through a crisis, were kept isolated under special attention. Most adult butterflies in the sickroom were unable to approach the food source by flying, and were force fed by placing them on cotton sheets soaked in 10% clover honey. The reason for using cotton sheets was to prevent butterflies from drowning. The stocks in the sickroom were observed to feed from the honey feeder, but none mated or laid eggs. Stocks in the larval stage were placed on napa cabbage leaves. None made it past stage L4. The purpose of the sickroom is ill defined. The stocks transferred to the sickroom were limited in use as research subjects. Although food and shelter was provided to

Figure 2. 8 *Sick stock*

keep them alive as long as possible, no measures were taken to improve their state of unhealthiness. Sick stocks in various development stages were preserved in formalin and photographed for documentation. Dissection techniques were practiced on some adults. Further consideration is needed for determining the level of intervention for keeping a healthy stock of research subjects. This confusion may be resolved by replacing the sickroom with a morgue to dispose of unwanted stock. A flask with water and dishwashing detergent or rubbing alcohol may be effective as a morgue.

2. 3 The Programmed Butterflies

Seven to ten healthy adults were sampled from each stock for making or testing thorax sections. Adults that are two to five days old after emergence, active at feeding and mating, with fully open wings with wing span over 50mm that show no significant sign of deformation or damages were considered as goodsamples. Samples were selected regardless of sex and history of oviposition, and the possibility of sexual dimorphism was not considered. Others were left to complete their life cycle and produce the next stock. Although the stocks suffered from mold contamination and other problems, the number of butterflies per stock increased from fifteen to seventy six over four generations. As the number of each stock had exceeded the minimum requirement of twenty (ten for experimentation and ten for reproduction), the use of surplus stock needs further consideration. It may be necessary to adjust the grow stand units to accommodate a larger population, or devise a way for keeping the stocks to an optimal size by intervention in one or more of the development stages.

Unlike those in the wild, stocks of *P. rapae* in a closed environment required meticulous maintenance strategies. These strategies were updated and refined by trial and error through interaction with the organism. In addition to serving the purpose of keeping a steady supply of research samples, the growstand itself required constant alteration and reformation, in response to the complex and dynamic needs perceived of the organisms it accommodated.

The needs of each stock were evaluated by signs such as size, shape, color, activity level, and number of population in general. These signs as well as the subjective satisfaction or dissatisfaction of the caretaker were not interpreted as the

level of wellness or happiness of stocks. In other words, providing conditions for life did not involve applying the caretaker's subjective values through empathy. Regardless of well planned and attentive care, different types of 'damages' continuously occurred, decreasing the chance of every egg laid emerging as a good adult fit for experimentation, while increasing the chance of every stock looking and behaving differently from the next. Inevitably, raising and choosing the right work samples to ensure maximum consistency among stocks was a highly intuitive process.

3. PART TWO: KILLING SCHEME

Figure 3. 1 *Dissection plate*

The few pictures that come to terms with the viscera tend to be marginal even in the history of medicine. By rescinding the artificially clear shapes and colors of most medical textbooks, they risk becoming pedagogically useless: an inexperienced viewer, such as a first-year medical student, is apt to search in vain for a recognizable landmark in the chaos of fat and poorly dissected tissues. Such pictures can also seem unpleasantly close to their subject, as if they were the products of pathological fascination, rather than scientific curiosity.

Pictures of the Body: Pain and Metamorphosis, *James Elkins*[7]

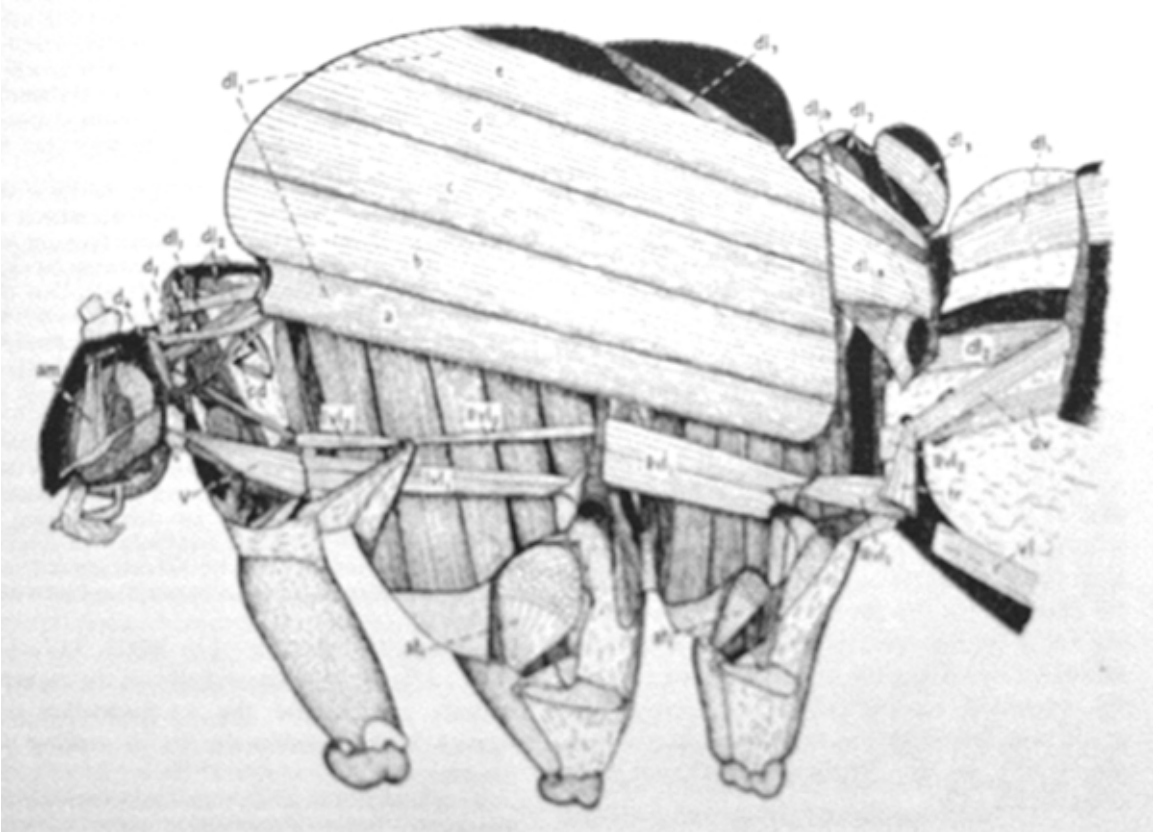

Figure 3. 2 *Diagram of Lepidopteran thoracic section after Nuesch*[8]

3. 1 Sectioning

As the Growstand was successful at accommodating a continuous supply of programmed samples, the stocks were used in four additional experiments in attempt to accomplish more observable sections of the *P. rapae* thorax. The sectioning of *P. rapae* thorax was planned in order to access the inner structures that were hidden underneath the exoskeleton. The speculation of the ideal sections was based upon a scientific drawing of Lepidopteran thorax section published in a scientific journal (Fig. 3.2).

The carefully maintained organisms were systematically killed, as moral

Figure 3. 3 CO_2 Gun

economies of the sacrifice suggested hopes for intimate and truth-to-nature observation. In order to make this process more efficient so that the amount of inoperative kills were minimized, conventional tools and techniques from the well establish field of histology were used. Most of the workspace, equipment, materials, resources and practice regulations were provided by an on campus biology research laboratory. This lab specializes in muscle physiology and has adopted Drosophila thoracic muscles as their main work subject. Innumerable protocols were available for making tissue sections. Therefore, choosing and combining the method that best suited the *P. rapae* thorax through research, experimentation as well as communication with specialists was the most important aspect of the process. In

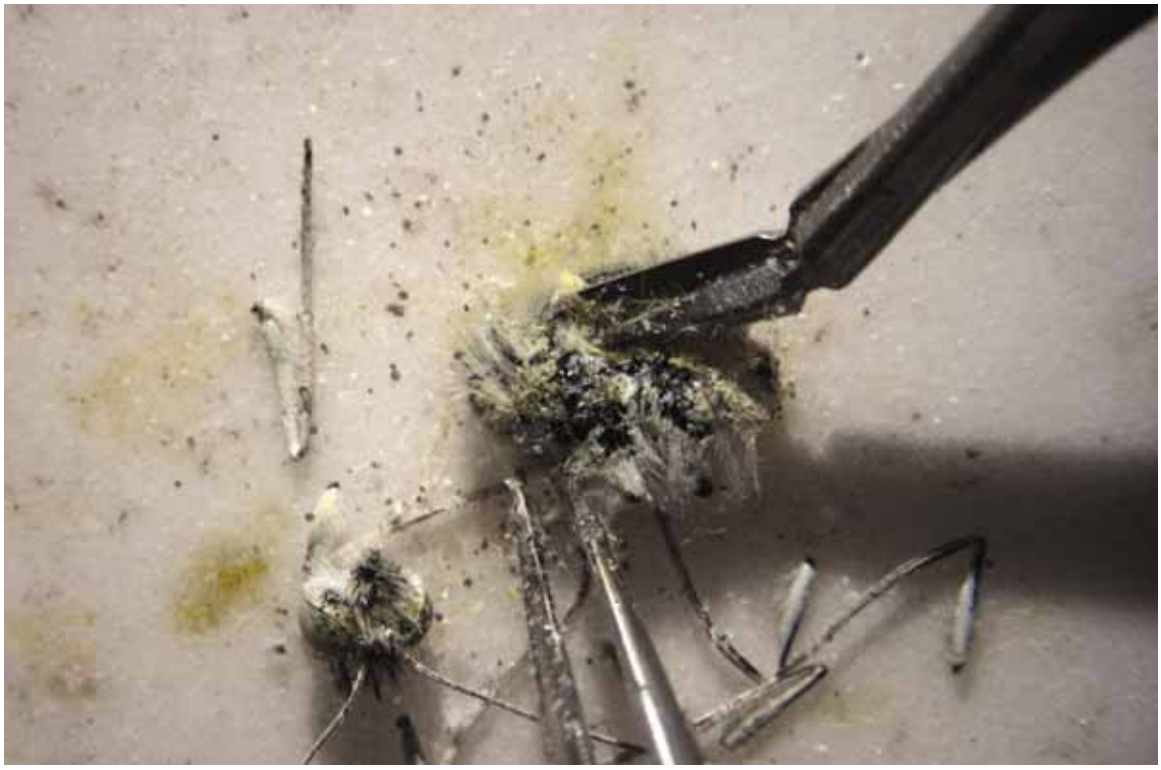

Figure 3. 4 *Dissection*

practice, acquisition and testing of necessary materials and equipment as a non-specialist also required significant time and effort.

The first experiment was successful as a practice for making reliably fresh thorax specimens. The butterfly was knocked out with a CO_2 gun. It took less than two minutes to immobilize the butterfly, while keeping it alive to ensure freshness at the time of dissection. Cuts were made at a dissection station equipped with a stereo microscope, dissection plate and fiber lights, using microdissection tools such as forceps and scissors. The thorax specimen was prepared in the following order.

1. Choose the right sized tools and clean them with ultrasonic cleaner. Choice of

tools may vary with individual work style.

2. Wipe dissection plate with kimwipes. Use alcohol if necessary.

3. Place knocked out butterfly on the dissection plate, then adjust magnification, focus and lights of microscope.

4. Hold wing tip with forceps and cut off all four wings with scissors at the base. It is better to leave a little wing base than to cut into the thorax.

5. Lightly hold head with forceps and remove abdomen with scissors.

6. Hold the thorax with scissors at the neck and quickly pull the head out with forceps. Forelegs may come off with the head.

7. Lightly hold thorax with scissors and pull off middle and hind legs with forceps.

8. Discard undesired body parts and clean dissection plate and tools.

This trial did not produce thin slices of the entire thorax, but a simple split across the middle showing fresh muscle tissues. Individual muscle cells which appeared as cylindrical strips of translucent mass were separated from this section. All cuts were made in dissection fluid on a cold plate to ensure freshness. The section was documented through one of the microscope eyepieces with a consumer grade digital camera.

Three additional sectioning experiments produced serial slices thin enough to capture details of the muscle structure as well as allow light to be transmitted for microscopic observation. The specimen first needed to be processed to prevent cell damage, and embedded in a harder material suitable for making even sections with a microtome, which is an instrument for cutting thin slices of various materials for microscopic examination. Although many plastics were available for embedding,

Figure 3. 5 *Fixation*

paraffin wax was chosen as the least expensive and non-toxic material that is relatively simple to handle and allows for slices as thin as five microns.

As cells begin to decompose immediately after the death of an organism, the thorax needed to be fixed to prevent changes in structure. 10% neutral buffered formalin was used as fixative. For full infiltration of all solutions including the formalin fixative, the exoskeleton of *P. rapae* thorax had to be punctured. Additional cuts were made to the transparent membrane in between middle and hind legs during the time of thorax preparation. As formalin is known as a cause for allergy reaction and maybe a carcinogen, it was handled in a fume hood with gloves and disposable tools. All waste was disposed of separately from regular waste. Fixation

was performed in the following order.

1. Fill 3ml disposable plastic test tube with 10% neutral buffered formalin.

2. Drop prepared thorax specimen into test tube.

3. Place tube in vacuum flask for thirty minutes to facilitate infiltration. A completely soaked thorax should sink to the tube bottom when vacuum suction is turned off.

4. Take tube out and incubate specimen at room temperature for twelve hours or more, but less than twenty four hours.

5. After incubation, wash specimen by ten successive changes of water to prevent formalin from reacting with later procedures.

6. A disposable polyethylene pipette can be used for transferring or handling specimen. The pipette hole may be cut into a spoon shape for easy scooping.

7. After washing, specimen not in immediate use may be stored at 4ºC in neutral phosphate buffer.

After the thorax is fixed, all traces of water had to be removed for paraffin does not mix with water. The specimen was not air dried, but dehydrated by substituting water in the tissue with alcohol. This process was accomplished by passing the specimen through a series of increasing alcohol concentrations to let alcohol slowly replace water (sudden change of water to 100% alcohol may destroy the cells). Dehydration was performed in the following order.

1. Prepare 3ml of 30%, 50%, 70%, 80%, 90%, 95% and absolute ethanol in separate test tubes.

2. Place washed specimen in 30% ethanol and incubate in room temperature for 2 hours.

3. Sequentially transfer specimen into next higher concentration of ethanol for two hours each.

After dehydration, the thorax did not change in size or shape, but the initially fuzzy exoskeleton lost most of its hair and looked shiny and black. The dehydrated specimen was then cleared with xylene which is an intermediate fluid that is miscible with ethanol and paraffin. Clearing was performed by placing the dehydrated thorax into two changes of pure xylene for one hour each. As xylene is toxic, it was replaced with a citrus based solvent for later samples.

Specimens for the second, third and fourth sectioning trials were all prepared according to the procedures described above, but were embedded and sectioned differently.

For the second trial, the thoraxes were embedded in pure paraffin purchased at an art material store and sectioned using a student hand microtome. The paraffin had not fully infiltrated, leaving bubbles in the section. The hand microtome was not appropriate for making sections thinner than 1mm, while the single edge razor blade used for cutting ripped the tissues instead of slicing. The cuts were made in a room that was not temperature controlled, which was later found to be crucial for making good sections. Henceforth, the thoraxes were embedded in Paraplast® Plus, which is a pellet-style paraffin containing dimethyl sulphoxide to facilitate penetration. Quality of infiltration was significantly improved by using this medium. Embedding was performed in the following order (as prepared by the methods derived from the USCF

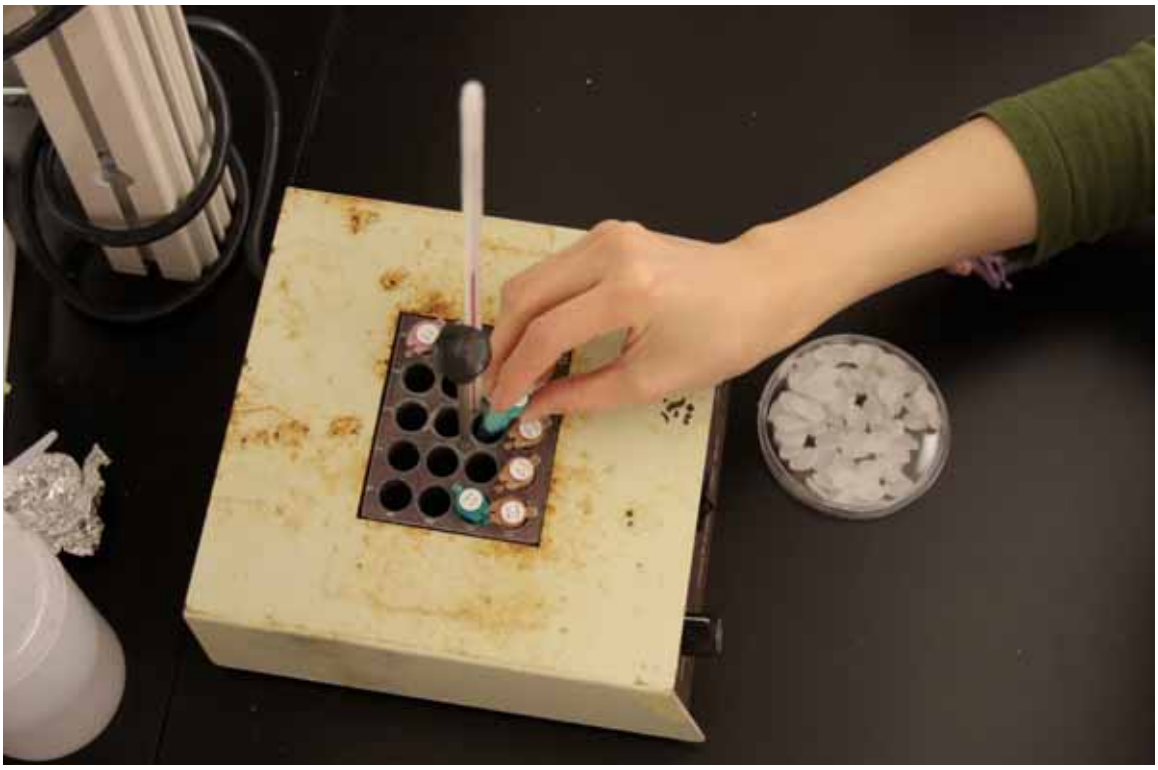

Figure 3. 6 *Paraffin embedding*

Chuang Lab Protocol[9].)

1. Set dry heat bath to 56ºC.

2. Four changes of Paraplast are required. Place three Paraplast pellets in one microtube and six pellets each in three microtubes. Six pellets are approximately 1ml when melted.

3. When melted, add 0.5ml of xylene to the microtube with three pellets.

4. Place cleared thorax in 50% Paraplast - 50% xylene solution and infiltrate for twelve hours in 56ºC dry heat bath.

5. Transfer thorax into 100% Paraplast melt and infiltrate for twelve hours in 56ºC

dry heat bath.

6. Perform two more changes of Paraplast every twelve hours. During the final infiltration, melt Paraplast for embedding. Less than 1ml is needed if 7 x 7 x 5mm base mold is used.

7. Place disposable base mold on heat bath, transfer infiltrated thorax in mold and fill mold with melted Paraplast.

8. Remove mold from heat bath and let Paraplast to harden at room temperature. When surface hardens, flip over mold to allow thorax to sink into middle of block. Mold may be gently shaken to orient thorax. Timing is crucial for this step.

9. In a well embedded block, one side of thorax is parallel to bottom of base mold, while thorax is set at the middle of block without any surfaces being exposed.

10. Let Paraplast solidify at room temperature for one hour and then at 4ºC to harden overnight.

11. After hardening, detach mold from the Paraplast block. The block should be marked and stored in plastic bag at 4ºC.

The third sectioning was made with a microtome at -40ºC with handmade glass blades. The temperature was too low, causing the wax and tissues to crumble. The blade was not large enough for the specimen. The final two trials were performed done at a cryostat (Microm HM 505E10) with disposable metal blades at 31ºC. This method produced twenty-micron sections that were mounted on frosted microslides. Sectioning and mounting of specimen was performed in the following order.

1. Preheat water bath at 37ºC.

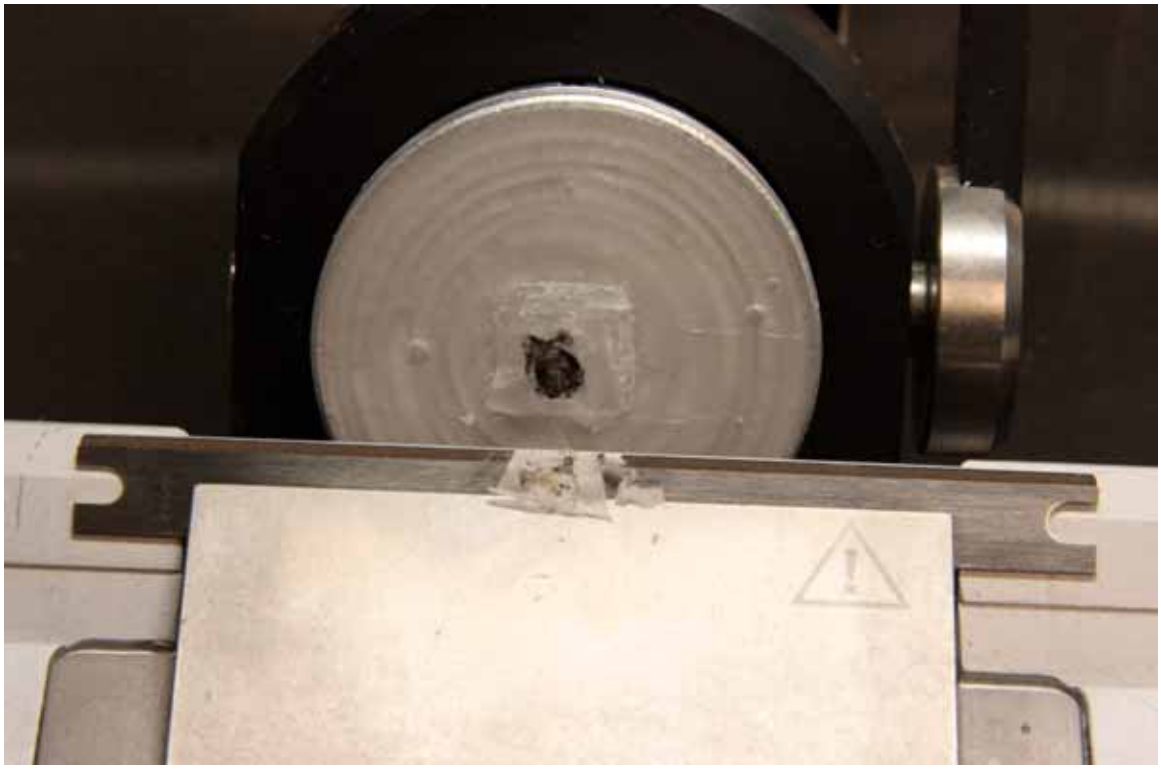

Figure 3. 7 *Microtome sectioning*

2. Set dry heat bath at 56ºC.

3. Turn on cryostat. Do not use the cooling system and perform sectioning at room temperature.

4. Mount embedded mold on specimen holder. Warm specimen holder on preheated heat bath and melt ten pellets of Paraplast directly on the holder. Remove the holder from heat bath and gently press embedded mold onto the melted Paraplast at the center of the holder. Let it harden at room temperature for one hour.

5. Carve mold surrounding the specimen into a trapezoid using a razor blade.

6. Line petri dish with wax paper for transferring sections from the cryostat to heat bath. The purpose of wax paper is to prevent slices from sticking to the dish.

7. Mount specimen holder to cryostat and make sections. Orient mold so the longer base of trapezoid touches blade first. Blade angle, position of anti-roll plate and slicing speed should be carefully adjusted depending on the specimen. Do not remove or change position of mold or blade during slicing to keep the angle and thickness of slices even.

8. Place slices on petri dish lined with wax paper using a fine brush.

9. The brush may be slightly dipped in clearing solution for better adhesion and also for blade cleaning.

10. After sectioning is completed, unmount specimen holder and blade, clean out crumbles of wax or specimen if any, and switch off cryostat.

11. Briefly float sections in 37ºC water bath to loosen any wrinkles, curls or folds. Carefully pick up sections with frosted microslides. Sections should be picked up in a similar manner each time, such that all slides have sections with a consistent orientation. The sections should be picked up in sequential order.

12. Place slides upright against a clean support on clean kimwipes for a few minutes for water to drain.

13. Air dry slides in hood overnight.

14. Label and store slides in a slide box.

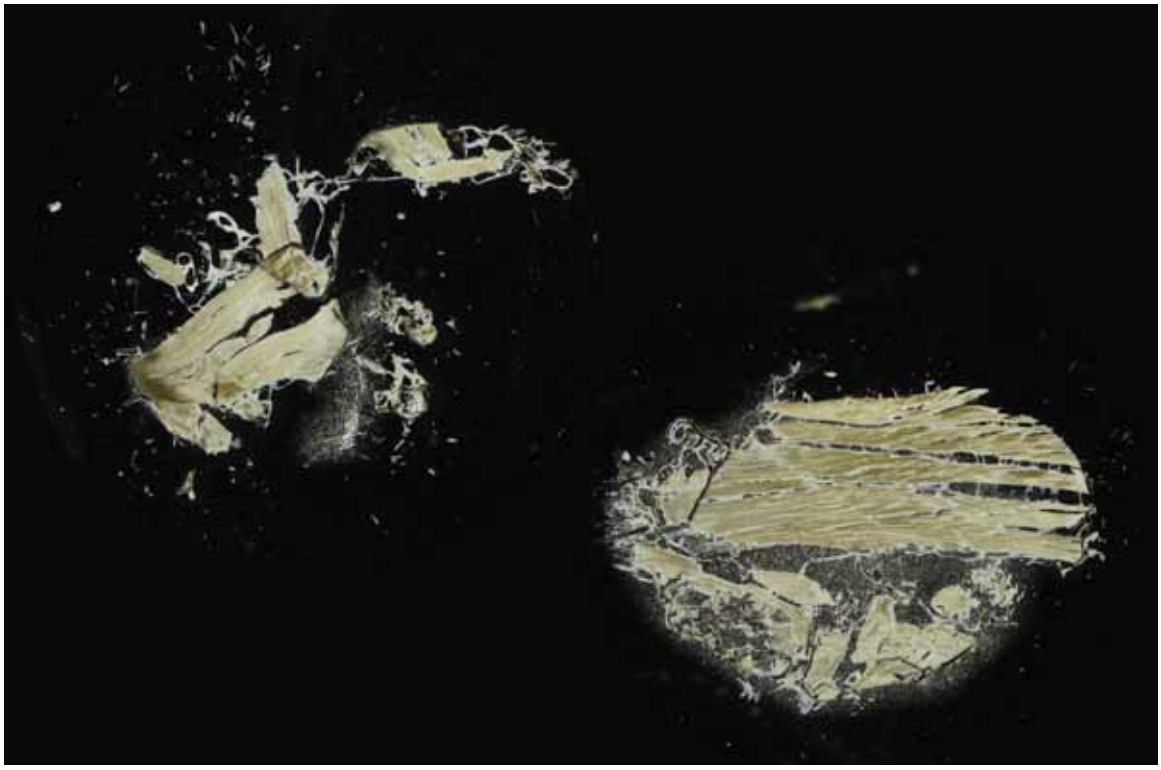

Figure 3. 8 *Thoracic sections*

3. 2 The Ideal Section

After numerous trials, one thorax was sectioned in complete sequence, producing sixty two slices. Among these, only a few came out relatively undamaged after clearing the embedding medium (Fig. 3.8). Data represented in the Nuesch diagram (Fig. 3.2) were identifiable in some of the sections, although it became clear that this illustration is an interpretation of the object that emphasizes structures considered important by the person or persons who produced the drawing. It was hard to determine the accuracy of this schematic diagram, although it was clearly useful in identifying some structures that were visible in the sections.

All procedures from dissection to mounting as described in this report were

performed in the interest of producing the ideal section, which should be perfectly intact, with no wrinkles, no artificial spaces, no streaks, and no missing parts of the thorax. In reality, every time something was done to the specimen, it caused changes, some perceivable and likely, some not. Most of these changes were undesirable, unintended or unexpected ones that were not helpful in studying the thoracic anatomy. However, they provided good information for fine tuning the treatment procedures to mitigate these changes. Inevitably, no matter how careful and meticulous, the resulting sections were technical interpretations of a *P. rapae* thorax. The issue of what constitutes the representational value of these interpretations was constantly raised during the production and judgment of sections. As summarized by Lorraine Datson et al., “the problem of variability in right depiction … haunted scientific atlas makers who pursued truth-to-nature as much as it did their successors dedicated to objectivity[10].”

A brief relief to this difficulty, perhaps by design, is expounded in Helen Longino's thoughts on “transformative criticism[11]” by developing an account of objectivity that incorporates such dilemma of subjective choice making. Her argument is that science is primarily practiced not by scientists as individuals, but rather by scientists as members of social groups, and it is the social character of scientific inquiry that allows us to treat the results as objective knowledge. An individual scientist’s products are subjected to a process of critical evaluation and modification by the rest of the scientific community. Before a scientist’s work becomes an accepted part of knowledge, it has to undergo this process of critical scrutiny and emendation by the larger community. It is this social character of scientific inquiry that allows us to treat the results as objective knowledge. This

characteristic is considered as being “anarchistic[12]” by Paul Feyerabend, who elaborates by stating “the consistency condition which demands that new hypotheses agree with accepted *theories* is unreasonable because it preserves the older theory, and not the better theory. Hypotheses contradicting well-confirmed theories give us evidence that cannot be obtained in any other way. Proliferation of theories is beneficial for science, while uniformity impairs its critical power. Uniformity also endangers the free development of the individual[13].”

These assessments of scientific speculation are in agreement in that the observer as an individual has the freedom to get her hands dirty in whichever way that leads to the heart of the matter. In other words, the ideal section is not a state that demands achievement. The ideal section can only be assumed by intimately and persistently engaging with the opened body of the dead butterfly itself. This perspective allows for the reorganization of facts in two different ways: first, by unveiling the processes to show how messy and contingent it really is, and second, by analogy making. As a result of this hands-on analogical interpretation, the observer would perceive a relationship, without having to consider an object in the real or physical sense.

4. DISCUSSION

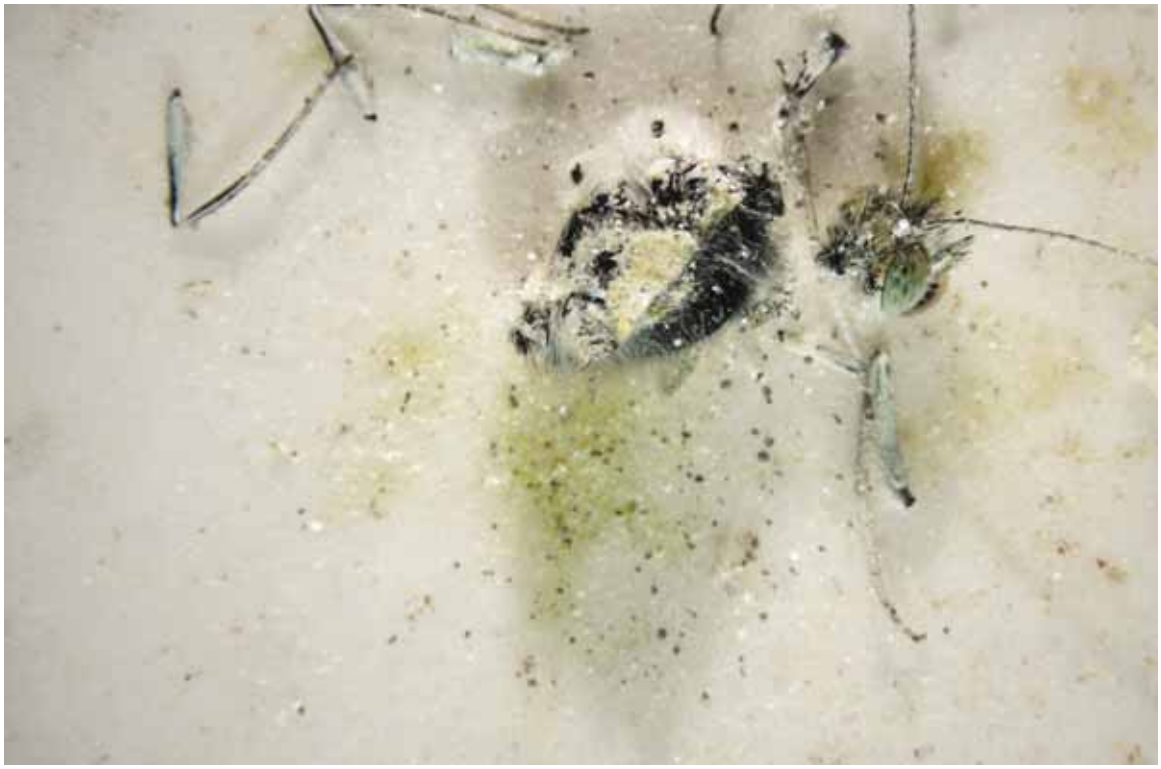

Figure 4. 1 *Opened body*

I'm an inch away from her, I thought. I could touch her with my hand.

Tales of Ordinary Madness, Charles Bukowski[14]

This project can be best described as working with a lively and dynamic material, by means of capturing or immobilizing certain aspects of change through adjustment of arbitrary procedures. The anticipated goal of producing an interpretation that might be conclusive or monumental lost its meaning during the process, as the practice consisted mainly of responding to divergence. This divergence was unimaginable - or rather nonexistent - until the actual manipulation of material began. Although this project had more freedom to be speculative rather than predictive, it was still bound by countless rules to keep the work completely or partially alive. Meanwhile, many decisions that were made within these rules were highly spontaneous, in which intuitive and imaginative measures were not completely left out.

Conceivably, most processes adopted in this project followed the convention of standardized methodology, which has also become crucial to the practices of today's artists - even though they are perceived as being more accepting of enigmas. As for many of us today, this approach appears a more valid way of explaining our sense of reality than does say, religion or myth. However, it is also true that such reality is also an inventive reality layering probable events within a framework of the bodies of knowledge we inherited. Parenthetically, both art and science attempt to give imaginative credence to improbable events, starting from a completely arbitrary cause and effect relationship.

The aim of this project was not to demonstrate, teach, or produce knowledge in life sciences or make statements that may be considered misleading or fraudulent. Rather, it was a personal activity designed strictly for first-hand experience of a

particular storytelling strategy. This project clearly benefited from crossing with the academic tribe of life science, where examples of arbitrary departmentalization were already diverse and openly available for exploration.

The pursuit of the goal to make analogical inferences on the development of butterfly wing flap movement is ongoing. Along with an open conclusion, the following questions are yet to be explored. If similar body construction can be used as a criterion for grouping of living things, then how do we decide upon the similarities? To what extent can we trust our senses and reason to conclude certain similarities are worthy of belief? Based on the experiences described in this report, the grounds for this study will continue to be hands-on, analogical observation. Evaluating the method and techniques, negotiating between different styles of evasions or even engaging in the ethical jam that follows processes such as these are of secondary interest.

Seeing a given thing as another allows for explanatory simplification, in which the simplicity of explanatory elements is the measure for successful reduction. To be clear, reduction is by all means, linked with the essentialist goal of explaining things to an extent that is neither in need of or capable of further explanation. In dealing with ambiguity, allowing more flexibility to react to more information will not necessarily enhance the quality of interpretation. Reduction should not be expected to have direct consequences with the world as a whole. Instead, it is a process of selecting units of analogical stories that form within the limits of our perception and reason.

This is how a summary or classification of all living things, about one million animal species, and about one-half million plant species seems not only appropriate

but possible. Existing life forms are being differentiated and categorized through a schematic matching of information that is ultimately registered through our senses. Therefore, in practicing analogy making, it is important to keep in mind that the physical state is not causally closed, but open to the world of mental states and events. Moreover, intuitive advances in such thinking are catalyzed by an intimate knowledge of the organisms in question - a knowledge acquired only by keeping them close at hand while applying means to magnify the perception of them.

5. EPILOGUE : LIGHT OF REASON AND DEAD BUTTERFLIES

As it has been observed, modern science loves to torture matter. I-as-a-scientist caught a butterfly with a straw hat, killed it with poison, then separated its organs with tiny tools, and to my delight, discovered that this butterfly belongs to an unknown species. Given the circumstances this particular specimen might well have been the very last of its kind.

Later my delight acquires a learned form known as scientific text usually made up of those amazing yet illiterate expressions that now constitute scientific language - a language so lively and picturesque in former times.

If I have the capacity to write, I will certainly describe how to become a butterfly in terms that best fit that state of a personally-lived-through scientific text. I-as-a-scientist may have an additional gift for capturing those things we see as dancing in a ring around the butterfly, my only living hero and art device. Of course, if I try to dissect this character with a pair of microsurgical scissors, I would find all the necessary organs inside, and even some reddish liquid circulating in the imperceptible drains.

My device and I are linked by the fluorescent shop lighting on the stage. I might name it the Light of Reason, what is also frequently mentioned in the naturalist novels of the past. Under this light, my mind with all its inclinations toward analysis and atomization, eagerly plunges into activity, in order to make sense of the analogical formation of my butterfly's wing flaps. Now my rationality has taken on

the role of the main lighting appliance.

Through this process I have come to realize, one who follows the path of sacred science does not poison and dissect a butterfly. I would watch it, think about it, and then, stopping all discourses, allow its essence fill my vessel. Then, sensing pairs of sails behind my back, in that very instant I will understand exactly how a cabbage white butterfly of the twenty first century has come to flap its wings.

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APPENDIX A

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