A Bird in the Hand is Worth Two in the Book: Development and assessment of a teacher- and student-friendly invertebrate learning kit for middle school

by

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A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

Major: Entomology

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Iowa State University

Ames, Iowa

2005

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CHAPTER 1. INTRODUCTION

Throughout history, all celebrated experiments have started with a story. Amazing tales about scientists date all the way back to early days of the earth. Although primitive man's heroic feats were documented using different methods than we employ today, it is widely known that incredible accomplishments were made at this time, such as the invention of the wheel and creating tools out of stone. In modern day, the concept of cavemen being great inventors is often joked upon, even though people during this time were undoubtedly creative. I firmly believe that a spot of creativity is where all great experiments begin.

Scientists' work always stems from creativity. It was this creative type of imagination that helped Thomas Edison discover that running electric current through a piece of carbon would run a light bulb. It was simple inspiration that fueled the exploration of the atom. It required remarkable courage and originality to bring inspirational writers like Thoreau and Muir to the spotlight. Yet a person does not need to be famous in order to be creative in their field. They do not have to be of a certain distinguished age, or highly educated; they do not need to be at the top of their profession, or the "brightest and the best". The first thing a person needs so as to begin creating is an idea and the drive to explore and act on the idea.

As children, we come into the world believing it belongs entirely to us. Children are eager to explore and ready to tackle the unknown, with grasping hands and eyes wide open. The world is a playground. Parents may take their children to the park where they can explore new sensations, such as the beauty of flowers and the smells of the outdoors. To a child experiencing this new atmosphere, life is good. The same child may have the opportunity to visit a zoo where they discover animals along with their exotic displays, loud noises, and their unique ways of living. Life is still good.

Children do not have to travel far to experience nature. Sometimes, all that is required is to simply step out the door into one's own backyard, where a plethora of adventures exist, ready and waiting. The sensation of running through cool grass with bare feet is a feeling one remembers for life. You may recall the delight of picking dandelion bouquets and bringing them home to Mom. Life at times like these felt magical. At night, if you were allowed to be up late, maybe you would stay outside until dark and catch a whole jar full of fireflies that were dancing around in the blackened sky. Life was illuminated until you went back inside, and your mom discovered that the lid on the jar was not on tight enough. Those gross, little, squirmy things were escaping and making their way through the house and this was when you heard those unforgettable words; "Yuck, ick, don't touch that!" Finally, the inevitable would occur - all of the little buggies you thought were remarkable and cute would get squashed. Although few in number, the words leave an everlasting imprint in our lives. Therein, it is not surprising when we look back at times like this, that most of us have been cursed with the belief that anything small, crawly, squirmy or creepy is dirty, bad, and dangerous. The idea of "do not touch" comes back again and again in many similar circumstances, leading us to gain a fear of the unknown.

Over time there have been experts who explored aspects of learning. Throughout the 20th Century and beyond, there has been interest in exploring how individuals learn and which methods of teaching are most successful for a range of individuals. Although there is a multitude of advice on this subject, a few theories on the subject stand out. Among the latter are the CAPSOL style of learning and Kolb's Theory on learning.

Some differences between the styles exist, however both commonly discuss and uncover similar learning patterns. Knowing the preferred learning style can help people develop exercises that enhance the intake of information.

CAP Styles of Learning, CAPSOL, assessments include nine (9) major individual intake preferences (Conrath 1991). **Auditory learners** prefer to listen and respond well to oral direction and noises. A person with a strong desire to do hands-on activities, manipulate, arrange, show and experiment with information, is called a **bodily kinesthetic learner.** Students who are interested in knowing "why" and "where does this fit into my life", and are searching for the bigger part of the whole in problem solving are considered **global learners. Group learners** prefer planning and discussing problems with the support and shared responsibilities of others. In contrast, **individual learners** tend to intake information and compare it to their own experiences, perspectives and opinions. A learner is considered **orally expressive** when they explain their knowledge aloud and verbalize questions, ideas and facts. Timelines, order, charts and diagrams are important for **sequential learners** to see the logic in situations. Images are important to the visual learner who also likes maps, models, charts and demonstrations. **Visual learners** often internalize their understanding of situations, where "seeing is believing". Expression of understanding through words works best for the **written expressive learners.** Word processing, describing conditions and questioning help these learners draw conclusions (Conrath 1991). Students will find that they have a strong tendency toward one, or sometimes more than one, of these styles of learning at the same time.

Kolb's theories on learning were first outlined in 1984 (Hartman 1995). Kolb's theory is based on four (4) major styles of learning.

Here, it is believed that one progresses through each style of learning over time; however, people often concentrate on one style. Being directly involved is the main characteristic for the **concrete experience** style of learning. Someone who fits best in the category of **reflective observation** likes to watch others as well as develop their own opinions and experiences. Creating theories to explain observations is in the style of **abstract conceptualization.** The style of **active experimentation** has students that use theories to solve problems to work through disputed points. In theory, the concrete experience leads one to reflect on the experience, then applying meaning to form a conclusion, and finally to experimenting with similar ideas to start the process all over again (Hartman 1995).

In Kolb's theory there are also combinations of the learning styles that are categorized as follows. **Divergers** are a combination of the concrete and reflective styles. Students who are divergers are motivated by the "why" and use direct facts from which to explore. Detailed information in lectures helps prepare the learner for the use of reference guides during hands-on exploration. A combination of abstract conceptualization and active experimentation explains the **convergers.** With this combination, one wants to explore the "how" of situations. Convergers enjoy interactive instructions and computers to assist in problem solving and exploration. In a third combination, the learners are referred to as **assimilators.** A blend of characteristics from abstract conceptualization and reflective observation describes this group. Assimilators enjoy searching for the "right" answer through accurate, organized information from experts. Lastly, **accommodators** are a mix of concrete experience and active experimentation. The significance of the situation, along with the "what if" and relationships with past explorations are part of the accommodator's characteristics (Blackmore 1996). In one classroom alone there may be several students each preferring a particular style of learning, and therefore, designing lessons appropriate for the entire group may be challenging.

The realization that every student does not learn in the same manner has given organizations ideas on how to improve the educational system. Teachers are often the main focus in research projects as they are the principal force guiding students to understanding and retaining subjects. The aim of some educational systems is to create organized and ready-to-use lessons for the teacher as well as adding interactive components to the classroom. One such organization employing this concept is FOSS (Full Option Science System). FOSS is a continuous research project, first developed over 20 years ago by the Lawrence Hall of Science (De Lucchi and Malone 2003). The core elements to be studied in the classroom are boxed and nearly ready to use units, core-matched for grades K-8. Typical kits arrive at schools as a small cardboard chest of drawers. Each chest holds lesson plans and equipment needed to perform a variety of experiments within the topic purchased.

FOSS provides teachers with most of what is needed to teach one entire unit of subject matter for a particular grade level. Each grade level has several science and math based subject units ranging from weather to balance and motion. The boxes also include assessment tools for students and teachers with support via CD-ROMs, email and the Internet (De Lucchi and Malone 2003). These kits are popular aids for teachers, but problems with them still exist as supplies run out and several components need to be restocked by the user(s). Teachers are sometimes required to share the kits with others in their school to help defuse cost; however, fixing these issues still requires time and money, which cause a negative impact on the usefulness of the kits. A potential way to compensate for these concerns would be for schools to become affiliated with a kit refurbishing service such as ECA Educational Services. This organization provides service to school districts in five (5) Midwestern states and provides a variety of aids. Elements of the business services include replacement of lost or broken equipment, supplement of live animals or plants needed for projects, pick-up and delivery of kits requested, along with technical support before, during and after the use of each unit (Harlan 2005). The use of such services can be helpful, however, they often extend beyond the school's budget.

Another group working toward impacting the educational system, but from a different angle is the NSF (National Science Foundation). This program is entitled the Graduate Teaching Fellows in K-12 Education (GK12). With help from the NSF, graduate students from universities in 10 states throughout the country coordinate with teachers in their local areas to set up innovative and unique projects (Jackson 2002). Starting in 1999, the NSF has provided three-year grants to over three hundred graduate students to develop programs geared toward enhancing the learning process. Ventures include exploration of rocks and fossils, plant and animal life, and statistical problems. These projects not only help build career possibilities for graduate students, but help with the communication and organizational skills needed for their upcoming experiences post graduation (Jackson 2002). Teachers involved in these projects gain extra classroom tools and content as well as motivation and the opportunity to try new agendas with their students. Participating students experience an enriched education and greater understanding in subjects of science, technology, engineering and mathematics. The overall goal is to renovate graduate student education and allow for expansion of professional skills beyond graduation (Ortega 2005). Although the NSF program was noticed after beginning this project, inspiration from other graduate student projects helped fuel new ideas within this research.

The belief that having live-animals as learning tools would help children master information better than children who used less interactive, non-live specimens can be compared to the old saying, a bird in the hand is worth two in the bush. Research in cognitive psychology and student learning in science is unambiguous in the finding that concrete experiences need to precede more formal representations of concepts (Inhelder & Piaget 1969 and Renner & Marek 1990). This is consistent with knowledge generation in science. Scientists do not possess vocabulary words (such as mitosis) before observing the actual phenomenon; such labels and the ideas behind them exist as an attempt to describe a natural phenomenon. Research from the FOSS program verifies that hands-on experience with animals helps give students a better understanding of the natural world (De Lucchi and Malone 2003). Tennessee reporter Dorren Klausnitzer also observed that real animals have a way of captivating children in a way that media and books do not (Klausnitzer 2005). Robert Pierre, author of That's Gross and It's Science and other similar works, is an excellent example of someone providing educational material in an interactive manner. Pierre's basis works off the theory that "kids love gross stuff" (Pierre 2001). Once students are engaged in the learning process they can better relate it to their own experiences.

A concept contributing to the process of developing an invertebrate kit included studying the aspects of inquiry based learning. Teachers that use inquiry-based methods in their classroom give students more freedom to voice questions, form hypotheses, and conduct experiments in a hands-on manner (McComas 2000, Hayden 2005). Teaching in this manner provides an environment conducive to free and creative thought by the students as well as a sense of doing "real" science. Lessons are based off of knowledge that can then be tested by students while using open dialog to explore their thoughts within the subject matter. Inquiry based lessons can also help individuals overcome shyness and improve leadership skills while being involved with group work to perform experiments via an assortment of learning tools (Gonzales Howe 2004). Uniting the concepts of learning styles and inquiry based learning and teaching as well as classroom suitable material to form an innovative and unique kit that teachers would be interested in testing out was the main focus for this project.

Projects like FOSS, GK12, and techniques from inquiry-based activities were a source of interest and encouragement for me as I prepared my own research project. My goal was to use ideas similar to those in the FOSS system, such as, observation of live animals and biological rhythms, awareness of macro- and micro-ecosystems, practice of scientific thinking and experimenting in the form of a congruent, user-friendly kit (De Lucchi and Malone 2003). Although middle school teachers in Iowa already have access to kits like FOSS, this project explored the idea of having all-inclusive kits with hands-on features. The goal was to provide the teachers with all supplies, including the live animals in order to reduce the time and energy that can go into execution other pre-made learning kits. The main focus of this research project was to examine whether kits with live animal components or kits without live animal components would provide the most effective interactive learning tools for students. For the project's investigation, the hypothesis is that middle school students will show marked improvement in understanding when using live-animal lessons, higher marks than the students using the non-live animal lessons. The null hypothesis is that no significant difference exists between treatments.

CHAPTER 2. MATERIALS AND METHODS

Treatment Groups

Four (4) middle school teachers and over two-hundred students between the ages of 12 and 14 agreed to participate in this study. See Table 1 for details of the four (4) Iowa schools. At Ames Middle School in Ames, Iowa, Ron Schuck was the first to agree to test using these lessons. Other teachers involved in this study were Joyce Norton from Bondurant-Farrar Middle School in Bondurant, Angela Tague from Colo-Nesco Middle School in Zearing and Carol Peterson from St. Pius X Middle School in Urbandale.

Table 1. Delineation of the Survey Study

Middle School Teacher	Class Size in Control[a]	Number of Males/ Females	Class Size in Experimental[b]	Number of Males/ Females
Ames Ron Schuck	18	-/-	45	-/-
Bondurant-Farrar Joyce Norton	12	-/-	57	-/-
Colo-Nesco Angela Tague	23	10/13	24	8/16
St. Pius X Carol Peterson	22	8/14	23	10/13

[a] N = 75, [b] N = 149

Test Instruments

A prerequisite for this project was to obtain approval from the Institutional Review Board (IRB). The IRB is a national group that regulates projects that use human subjects as research tools, both in Iowa and across the United States. The organization's primary goal is ensuring only ethical projects are conducted with the public that therein lending to positive and reliable results (Austin Eason 2004).

One requirement of the IRB is that people who are involved as research components must complete a release form consenting to specific aspects of the project. Because this project involved minors, both parent/guardian(s) and the children were required to sign these forms before the students could participate. If for any reason the offer to participate was declined, students were not penalized and their relationship with Iowa State University would not be jeopardized. Those not able to contribute to the results were allowed to study the material with their classmates, but they did not complete the requested survey material. An option for children not wishing to participate or when allergies were contributing factors was for them to study in an alternate science classroom for the duration of the projects.

Open-ended content assessments were developed and used as the primary source of data. Items were written in consultation with a science educator to ensure alignment between kit objectives and each assessment item. Open-ended items were selected because they provide greater insight into students' thinking than more traditional forced-choice items, yet do not require excessive class time to administer. Content assessments were designed to be given as pre- and post-test. To reduce the testing effect, two versions of the assessment were developed and printed on different colored paper (blue and yellow). Each survey included five (5) questions requesting short answers. The questions covered general entomological topics and allowed students an opportunity to voice concerns and personal inquiries. Results were quantified using a three- (3) point system. A score of "3" was given for a complete answer that reflected an accurate understanding of the concept. A "2" was given when the answer was partially correct, showing some accurate yet incomplete ideas. A "1" was given when the answer was incorrect. Copies of survey templates can be found in Appendix A. All student surveys results were graded by myself in one continuous session.

Although the questions on each instrument were similar, each draft was worded differently so as to reduce the possible memorization of questions that sometimes occurs in pre- and post-surveys. For instance, on the blue survey, one question asked students to compare a frog's life cycle to an insect life cycle. The yellow survey asked students to compare the life cycles of a human to that of an insect. Each format required students to compare presumed known concepts to new concepts that were part of their studies.

Lesson Descriptions

To perform a comparison of lessons with live animals versus lessons without live animals, two (2) equivalent programs were developed that differed in the inclusion of live invertebrates. Lesson sets were designed so that they would be completed in equal amounts of time. Titles for experimental groups were designated according to whether or not children worked with live animals. Classrooms participating in lessons without live animals were control groups. Each format used three (3) sets of topics for exploration. Though parallel in subject, the presentation of material for each format was unique. Teachers were asked to introduce control lessons to one science class at random. The remaining science classes learned from experimental, live-animal lessons. In actuality, two of the teachers incorporated only one of each trial. The other pair of teachers taught one control and three (3) experimental classes. Comparisons of these situations are described in the Results section.

Incorporating all aspects of this project presented its own challenges. One aspect of the study's desing was to have each lesson contain an assortment of tasks to accommodate different learning styles. It was also important to create an engaging atmosphere that would incorporate multidisciplinary skills. Dr. Charles Drewes acted as an educational design advisor for the project.

Dr. Drewes is an Iowa State University professor in the Ecology, Evolution and Organismal Biology Department. During summers, teachers from across the United States are brought together through a class, Techniques for Biology Teaching, taught at Iowa Lake Side Laboratory. During the week-long course, teachers were introduced to and inundated with projects containing invertebrates that were considered ideal for middle and high school classrooms. Portions of Dr. Drewes' lessons (Drewes 2005) were modified for use in this thesis project.

The first of three lessons for the experimental group introduced classrooms to brine shrimp, (*Artemia franciscana* (Kellogg)). Teachers were encouraged to prepare for treatments by reading the articles students would receive later, reviewing projects outlined in the brine shrimp activity pack, and organizing the hands-on lab materials (see Appendix B). The final step in preparing teachers for administering the treatments was to photocopy printed materials that were to be used for class or homework.

After reading the presented material, teachers were prompted to hold open classroom discussions pertaining to brine shrimp biology. Open talks incorporated information on life cycles, including shrimp growth and reproduction. The biotic and abiotic needs of brine shrimp were also discussed and explored by students.

Readings for this lesson included "The Great Salt Lake" (Appendix C). Activities described in Drewes' "Stuck-on Artemia" lesson were emulated, which allowed students to observe cyst hatching and growth over a one-week time period. Students had the option to explore their own hypotheses about survival rates due to changes in environmental conditions. Suggestions for this experiment were to test survival rates in warm water versus cold water, or survival in continuous light or dark conditions. Variations to these suggestions were open to the students as well. After initial experiments had been completed, all four (4) of the classrooms raised shrimp to adulthood or beyond, and discussed biological subjects that corresponded to survival of the remaining specimens.

The control, "non-live," version of the *Artemia* lesson began with teachers preparing a rubric/grading scale, for a creative poster/paper project in which the students would be participating. Students started this lesson by reading the articles "The Little Things That Run the World," "What Makes Invertebrates Cool?" and "Salt Lakes and Sea Monkeys." Children were then prompted to discus aspects of brine shrimp activity and life that were highlighted in the articles, as well as to view pictures of the different developmental stages of these animals. Additionally, the topics of water quality and human impact were mentioned.

The activity focus for this section was for students to create an old fashioned "wanted" poster that was loosely based on the Drewes' lesson entitled "America's Most Wanted Invertebrates." The fugitive creatures featured on the posters were to be items or organisms that negatively impact water quality. Destructive substances discussed in the lesson included invasive plants, predators, chemicals and/or other human influences. Teachers decided on individual means for student evaluation and performance for this portion of the lesson. Teachers were encouraged to use art within the lesson in hopes that students would utilize a new approach to explain their observations of nature.

Activities in the second set of lessons for the experimental groups with hands-on activities were based on another of Drewes lessons entitled "Leaf Mold." Material from this lesson was introduced during one of the 2004 summer workshops. To prepare for the lesson teachers scouted a location for a short fieldtrip and/or collection site. Then, during the collecting trip, students were able to explore the outdoors, observe the creatures that live in different environments and gather leaf litter. When a suitable location near the school grounds was not available, teachers had the option of either collecting compost material themselves or requesting leaf litter from the researcher.

As a method of gathering invertebrates, modified versions of a Burlese Funnel were crafted by recycling 2-Liter soda bottles and plastic gutter guards that formed sifting trays. A description of this apparatus can be found, along with the lessons, in Appendix B. Leaf litter was placed into the funnel and dried using a low wattage lamp. After an hour of drying time, invertebrates were collected in paper cups as they fell through the screens. Next, students identified the collected animals by using reference books and detailed invertebrate ID pages provided by the teacher. While waiting for the leaf litter to dry, students were urged to discuss dichotomous keys and how to use them. Student journal were used to detail the activities and the animals observed. As an add-on to this lesson, one group created micro-ecosystems for continued classroom observation of animals that emerged from the leaf litter.

The hands-off component (control group) allowed students and teachers to learn about and use dichotomous keys. This type of key is easy to use as well as create. It consists of a series of paired statements, or "couplets," each of which present alternative physical characteristics of a specimen (e.g., "wing red" versus "wing blue").

Users study these statements, choosing the descriptive statement that best fits the specimen they are handling, before proceeding to the next couplet. The end result is a detailed portrayal of the specimen's distinctive characteristics as well as a scientific name.

Both teachers and students created a dichotomous key based on containers of various nuts, bolts and screws (= "specimens"). Teachers completed an initial model for the keys and students worked in groups to create similar versions. Group discussions about the use of keys for identification of other objects, such as geodes, plants and animals reinforced the topic of scientific investigation. It also led to classroom discussions related to jobs and opportunities in the scientific field. Dynamics of micro- and macro- habitats were also topics for discussion in this unit. Students were asked to think about and share experiences with invertebrates in their own lives.

The third and final set of hands-on lessons emphasized insect behavior. Students had the unique opportunity to work with the Madagascar hissing cockroaches (*Gromphadorhina portentosa* (Schaum)), for experimentation. Initial preparation for each classroom began with an introduction and description of the animal to the students. For the duration of this project, teachers and/or students were responsible for the care of their roach colony. Only male cockroaches were used within the classrooms in accommodation with EPA regulations.

Several hands-on activities were available for students during this portion of the project. First, groups of students were presented with two to three roaches in a container. After a briefing on cockroach biology by the teacher and various viewings of the animals, classes talked about different behaviors they wanted to explore further. Students focused on displays of dominance as well as food preference and territorial behaviors.

The next activity was based on more observations. Students noted that Madagascar Hissing cockroaches had a tendency to crawl along the sides of their containers or close to other obstacles in their cage. This prompted some children to design shoebox mazes and, in one classroom, to use stacked books to form larger mazes. Cockroaches were then run through the mazes using different stimuli. Students tried placing food as an incentive for completing the task. A second option was to paint a line down the corridor of the maze to visually stimulate the roaches. Altering the width of the hallways was another experiment that students could create to draw conclusive evidence related to a proposed hypothesis. An add-on to the cockroach activities was for students to keep a journal of experimental results. Open classroom discussions allowed teachers to ask questions multiple times, in different forms. This approach provided a mechanism for shy and unsure students to participate and obtain self-satisfaction in understanding the material as independent learners (Ebrahimi 2005).

In contrast to the live animal activities, the control classrooms did not have extensive contact with roaches. Instead, the lessons were introduced using classroom discussions about life on a micro-scale. For instance, students exchanged ideas about how it would be for them to spend the day shrunken down to be two (2) inches tall. These talks then led to the viewing of <u>Microcosmos</u>, a documentary style video that interprets invertebrate life in a unique fashion (i.e., at their level/scale). Directed by Claude Nuridsany and Marie Pérennou, this film contains few words, but is accompanied by a moving soundtrack. Video clips introduce the audience to the intimate details of invertebrate life, such as feeding, mating and molting. While viewing the film over several days, students took journal notes on insect behaviors they observed. Later, aspects of invertebrate life were compared with aspects of vertebrate life. Teachers were provided with a list of questions that pertained to the film and helped facilitate class discussion. An added assignment was to ask students to write a short story with the theme, "A Day in the Life of an Arthropod." As with their previous activity, the control students were allowed to express knowledge of the topics in a creative manner.

Components from the lessons are shown in more detail in Appendix B. The articles described were drawn from Dr. Drewes' web site or via his summer class. In addition, other articles were created for classroom use during the project (Appendix B). The Microcosmos video was provided to each teacher to use in the final lesson and to be retained for future classes. The video is readily available at most local music/movie stores.

Project Limitations

Due to unexpected logistical constraints, materials were not distributed to teachers all at once. Teachers received paper materials through the mail. One-month later, bulkier supplies such as test tubes, sea salt packets, lamps, pipettes, funnels, invertebrate food and live animals were delivered.

The dependent variable is the use of live animals. Another focus was to emphasize hands-on activities in the experimental group but not in the control groups; however, some interactive elements are evident in the Control lesson plans. Control groups were asked to participate in group discussions as well as activities involving multiple students, but they did not actively participate in the experimentation process.

Statistical Analysis

Multivariate Analysis of Variance (MANOVA) was used to evaluate the results. MANOVA is a computerized statistical program that is often useful for research in education and sociology. This analysis was designed to compare groups and to report significant distinctions between the means of each group, even when multiple variables are being questioned (SPSS Survival Manual 2001). One of the valuable aspects of this anlysis is that it controls or adjusts for the risk of Type 1 error. A side affect of adjustment is a stringent alpha value and a complex set of procedures when setting up the data (SPSS Survival Manual 2001).

CHAPTER 3. RESULTS

The first step of analysis was checking the data for reliability. Compared to other research projects in the education field, the collected sample of over 200 entries was large. Therefore, the amount of skew detected (-1.05) did not detract from the final outcome (Tabachnick and Fibell, 1996, p.73). Kurtosis value of the data was 1.70, indicating a normal distribution around the mean. An expected degree of variance was detected with the pre-test scores, but this was anticipated. Teachers from each school were in different stages in their ecology units when this project began, creating slight differences in pre-test scores. In total, the normal distribution and only slight skew suggests that the data could be examined further with confidence.

In accordance with the initial goal, the data were checked to determine if differences in survey scores existed between the live and non-live experimental groups. Scores were analyzed with an alpha level of 0.05. The pre-test for the experimental (live) group, contained 149 participants and a mean survey score of 11.17 (sd =1.78). The control (non-live) group, had 75 participants and a mean score of 10.76 (sd =1.89). Pre-test results showed no significant difference between groups ($F = 1.60$, $df = 222$, $p = 0.11$). Post-test scores were similar. Results for both live and non-live groups showed improvement, with the average scores of 11.34 and 11.65 respectively (sd =1.48,1.59), and were not significantly different from each other ($F = 1.42$, $df = 222$, $p = 0.16$).

Factors that may have had effects on final results were also examined. An ANOVA was run to determine if the type of form used for the pre-survey affected performance outcomes. No significant difference was found when students started with either blue or yellow forms (Wilks' lambda = 0.96, $F = 2.23$, $p = 0.06$).

Collected data were examined for differences among the four (4) schools. No significant difference was found when comparing pre- and post-test scores; however, separating pre- and post-test scores by schools showed significant differences between the surveys ($F = 19.4$, $df = 3$, $p < 0.001$) and ($F = 3.69$, $df = 3$, $p = 0.01$), respectively. A summary of school survey results is listed in Table 2.

Table 2. Survey scores listed by school and separated by pre- and post-survey means. The highest possible score a student could receive was "15" and the lowest was "5".

	Pre-test Mean	Post-test Mean
School		
Ames [a]	9.9	11.1
Bondurant-Farrar [b]	11.6	11.3
Colo-Nesco [c]	11.9	12.0
St. Pius X [d]	10.3	11.6

[a] N = 63, [b] N = 69, [c] N = 47, [d] N = 45

Ames Middle School had pre-test scores lower than Bondurant-Farrar Middle School and Colo-Nesco Middle School ($p < 0.001$). Students at St. Pius X scored lower than Colo-Nesco Middle School on the pre-test ($p < 0.001$). For the post-test results, Ames Middle School had scores below those of Colo-Nesco ($p=0.002$) and Colo-Nesco outperformed Bondurant-Farrar on the post-test. When comparing scores from teachers that allowed several of their classes to participate versus teachers with just one class per treatment, no trends or patterns in test scores were found.

An analysis to determine the effect that a particular class had on test scores was performed. As anticipated, some classes out-performed others. Speculations as to why this occurred can be found in the Discussion section.

The final variable examined for this project was the effect of gender on survey results. Using MANOVA, pre-test comparisons showed no significant differences overall between male and female scores ($p = 0.47$). However, post-test scores indicated a significant difference between genders ($p=0.01$), as shown in Figure 1. In the experimental groups, lessons that included live animals, males had higher test scores than females. In contrast, when lessons did not use live animal stimuli, females significantly outscored males on the post-tests.

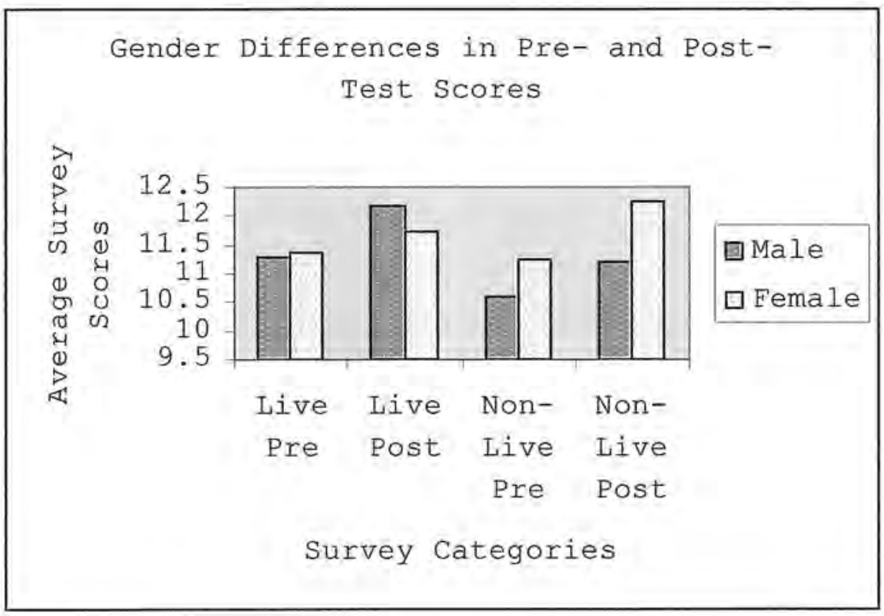

Figure 1. Difference in average survey scores between male and female students participating in activities with or without live animals.
* significant difference is determined at alpha = 0.05

CHAPTER 4. DISCUSSION

During research time spent with the classes, an interaction between a student and teacher at Ames Middle School was observed. While working on the cockroach activities, the teacher, Mr. Schuck asked, "What do you think about working with the cockroaches?" The response was, "it sure beats reading out of a textbook." Simply reading about science from books does not always allow a person to perform, comprehend and realistically experience science (De Lucchi and Malone 2003). The student's response verified that this project was having a positive effect.

The key for students was to take away findings and ideas from physical experiences, introduce science concepts and necessary vocabulary, and then apply what they found. Although significant differences were not detected for the variables that were originally expected (live animals would aid to better learning), some important elements of the project were exposed.

Even with the precautions taken by creating two versions of test forms, not all of the responses reflected students' knowledge of the subjects studied. Several students responded with statements detailing that open-ended assessments were not their favorite way to express themselves. Reactions included loathing and dislike to filling out such forms, however, these complaints did not appear to statistically detract from the results of the project. It was also evident that some students used the tests to communicate amongst themselves, as well as to write letters to their cockroach friends.

The initial goal for this project had been to determine if differences existed when using live-animal, hands-on activities versus non-live, hands-on activities. It was originally anticipated that the use of live animals would increase student understanding and comprehension of the material more than activities that did not include live animals. The data collected were normally distributed around the mean and thus reliable for further interpretation. No significant difference was found between pre- and post-test values for live versus non-live groups, however, meaning that both groups produced similar scores. Within both groups, students had comparable post-test results. The elevated end scores reflected an increase in understanding and the students' ability to interpret information.

In conjunction with the initial investigation, additional tests evaluated other issues commonly associated with social projects (Dr. Joanne Olson, 2004, personal communication). One concern was that the use of different survey formats affects the test result, thus threatening the study's validity. Statistical evaluations showed no significant differences, however. This led to the conclusion that regardless of which test format, blue or yellow, is used the students had an equal chance of understanding the questions and elevating their post-survey scores.

Another analysis investigated the effect that individual schools/teachers may have on the final survey scores of students. Differences exist between schools and amongst the teachers. Educators have varying degrees of effectiveness and unique personalities that affect children in various ways. Teaching methods that engage students and create opportunities to interact often result in elevated grades by the students involved (Murphy 2002). In the current study, some teachers had been instructors longer than others, thus giving them more experience with students. In addition, some teachers had participated in varying levels of professional development. Teachers with more advanced pedagogical- and content knowledge were likely to be more familiar with the concepts and were perhaps more willing to try novel activities. As this study was measuring the impact of science learning through inquiry based instruction, teachers with a better grasp on this style of instruction may have influenced their students' abilities to understand the project (Gonzales Howe 2004). Personal relationships and the attitudes of the teachers and students might have also affected class performance.

This project also allowed the opportunity to analyze how individual classroom performance affected the overall scores from the classes studied. Again, as anticipated, differences were discovered. As elementary school teacher Peggy Carlisle stated, "not every child is going to move at the same rate, but everyone is going to move" (Hayden 2005). Many class schedules are based on the electives that students take. Enrollment in select Math or English classes may cause students with similar learning abilities to take classes together. For example, if an advanced-level class were offered only during first period, then enrolled students would be forced to register for a science class later in the day. This would increase that group of students' probability of being in the same science class together.

It was evident upon reviewing student responses to the survey that being asked to complete the requested follow-up material was an unpopular portion of the research process. Most students, however, did show improvement from the beginning to the conclusion of the study. This improvement is believed to be due to the students' hands-on activities, a feature used in both groups. Students who are active in their educational experiences are more likely to succeed and to find empowerment and ownership of their achievements (Hartman 1995). Altering the surveys to be more topics focused (based on brine shrimp, ecosystems, or cockroaches) could be one way of revealing if differences exist. Students may feel more comfortable expressing themselves orally, with diagrams or by actions and thus were not as able to explain knowledge on the short answer tests. Test formats that allowed students to show their knowledge in ways other than writing may also show greater differences.

Lastly, one striking statistic emerged as the data were analyzed. A significant difference was seen when comparing survey scores of males and females within each treatment. Pre-survey scores showed no significant difference. However, post-survey results indicated that boys outperformed girls on the experimental (live) set of activities and girls outperformed boys on the control (non-live) set of activities. These data led to analyzing the stereotype that boys are better suited to scientific endeavors and whether the data collected from these surveys reflected this perspective. Why did the boys really perform more competently than girls in the live-animals classrooms?

One possible reason for these results is the complex socialization that occurs in formal schooling. Science education researchers have noted that, in laboratory settings, males initially dominate the materials (Carter, Westbrook, & Thompkins 1999). This trend occurred even in laboratory experiences where physical manipulation of the equipment was necessary in order to understand the concepts. Because class periods in Iowa are short (40-45 minutes), sufficient time may not exist for female students to access the live-animals, thus reducing their learning experience in the experimental classrooms. Additionally, female students in middle school are at the age of the onset of puberty, a time when social interactions and gender roles take on increased importance (Gagne 1993). If girls have been socialized not to appear to enjoy things associated with boys (insects, dirt, worms, etc.) the likelihood that they will take initial control of these materials is decreased.

Extensive research exists on gender differences in this study that can account for why males outperformed females in the hands-on classroom. In addition to possibile socialization pressures and gender differences in materials use, teachers' unconscious attitudes may play a role. Research has indicated that male and female students receive differential feedback on schoolwork, regardless of the gender of the teacher. Feedback given to males tends to be more specific to the quality of the work and ways to improve it. Females tend to be rewarded for good behavior or receive comments related to the aesthetic value of their work (such as neatness or handwriting, etc.). However, none of this explains why females significantly outperformed males in the class without live insects. One possibility is that the control groups had more activities that centered on writing, reading, and drawing-tasks in which females typically outperform males at this age (Olson & Cox-Petersen, in press).

By not having the opportunity to study the affects of society on learning, one can only speculate as to why the data displayed such results. Based on personal teaching experiences from the Insect Zoo, it appears that a teacher's attitude can affect students in their classroom. When educators expressed fear or dislike toward the animals used in zoo programs, it their students often would exhibit similar emotions. Similar responses were observed when a well-liked student in the class expressed excitement or distress from a zoo visit. Friends of the popular student had a tendency to react in a corresponding manner. Thus, in relationship to this project, the attitudes displayed within the classroom or within a school may have affected results. Lunchroom chatter among students may have encouraged more males than females to be comfortable around the live animals, and in the opposite manner for the females.

Trying to answer the question of why a difference occurred could spawn a separate independent study. Scientists have been analyzing the brains of men and women for decades, trying to figure out the behavioral differences between the sexes. According to a recent article in Time Magazine, Amanda Ripley states that learning aptitudes of men and women are likely to be similar. Factors such as age, time of day and the attitudes of role models in a person's life can affect their ability to perform well in the scientific field (Hochstein 2005). Findings from this study raise fascinating questions that warrant additional investigation. For instance, to what extent is "hands-on" appropriate for all students? How might science instruction be tailored so it provides equal access to materials for both genders? How might boys' performance be improved when tasks require reading, writing, and drawing? In what ways can students' anxieties about gender-opposite tasks be decreased? Additional research is necessary to explore the possible cause of the gender differences observed in this study, and to determine effective ways to teach both groups.

CHAPTER 5. CONCLUSIONS

Creativity helped fuel this project, however, just as with the invention of early tools and the creation of the light bulb, innovative techniques and continued exploration create an on-going learning experience. This project started as an idea, was tested, compared to knowledge obtained over the years and can now be reformatted into another project to start the process anew. The null hypothesis, that there was no significant difference between the survey results of the live and non-live hands-on activities, however, the project did produce some interesting results. It would be beneficial to further study the topic of gender differences in learning that were exposed in this project. Other aspects of the project such as design and execution could also be reformatted and reexamined for possible improvement. Teacher feedback from the project provided ideas on areas that the Insect Zoo could profit from and use to improve programming.

One area to explore more thoroughly would be differences discovered between males and females during the hands-on and hands-off activities. Originally, the project was designed to keep identities anonymous; however, two of the teachers in the project routinely asked their students to put names on papers that were turned in. This fortunate side effect granted the opportunity to explore differences in the progress between genders. Experts have been investigating brain development and gender differences for decades. As technology has progressed over the years, so have opinions on the differences between males and females (Hochstein 2005). Continued classroom research exploring the differences in how lessons are carried out might show surprising results. The use of microphones or video recorders could expose interactions between students and between teachers and students. Visuals of classrooms could show if boys were taking equipment away from girls. Did girls opt to not participate in projects? Did teachers react to boys and girls differently? Was the teacher's attitude about live-animals affecting student participation? Another change would be to see how test results would change if students were first introduced to materials via films or readings and then permitted to experiment with the live animals. Another study could examine anxiety toward research animals/insects and whether or not this might explain some of gender differences.

The drawn out process of receiving the project materials was not ideal for the teachers. A restructuring of the materials into a clean and organized package would make future use of the lessons more conducive to teacher needs. Providing teachers with one all-inclusive kit would have increase efficiency, but since the project was being conducted from a secondary location rather than the Insect Zoo, future inconveniences such as this are less likely to occur. Teachers appreciate when all of the supplies included are ready to use, therefore organized kits are key (Murphy 2002).

An aspect of lesson design that would improve the usability of the invertebrate kit would be to find or write age appropriate literature that corresponds with the readings. Although the readings presented to students worked for this project, feedback from teachers disclosed that students who were slower readers or who had learning disabilities needed aid to fully comprehend the material. Creating a modified reading or activity for children at various levels of learning would allow students to function as a whole when working on a particular topic.

When evaluating the results as a whole it is clear that lessons had a positive impact on the teachers and children involved. The next step might be to turn favorable portions of these lessons into a permanent addition for the zoo. Developing improved versions of these lessons and new lessons that delve into other subjects could be an ideal addition to an insect kit. Another aspect necessary to create an enduring lending tool for the zoo would be to compile a supply bank. Program animals already reside in a special location at the zoo; however, setting up a place to keep kit items is recommended. Common storage of test tubes, animal cages, food, and other items used solely for school kits would minimize assembly time required (Peters 2004).

Educators from the zoo have traveled to over thirty Iowa counties and have visited many elementary schools. Teachers with younger students already know what the zoo does and what is available for them. However, this project was geared toward teenage students, so the first step in developing a more permanent lending tool would be to advertise to k-12 educators around the state. The Insect Zoo has a link on the ISU Entomology web site thus using the Internet would be an effective method of advertising. Teachers don't always have a lot of time during the day to surf the web for new opportunities, so other methods such as mass emails or mass mailings to school districts would be another method of exposing the zoo to more people.

Inspired by National Science Foundation projects, the projected outcome of this project would be a new outlet for creativity and inspiration for both teachers and graduate students. This project provided four teachers and over 200 middle school students with five weeks of mentally engaging learning activities. It was an opportunity that teachers have a difficult time creating on their own due to restricted budgets and time constraints. Graduate students have opportunities in academia to express their knowledge and expertise when attending professional meetings, publishing in accredited journals and through college class work. Graduate students rarely have the opportunities to apply their skills in a local atmosphere. Teachers and graduate students from all over the state of Iowa would benefit from creating and maintaining bridges of communication in the entomology field.

APPENDIX A. SURVEY TOOLS

Consent Form

Entomology Learning Kits for Middle and High School

"Consent Form" for Students and Parents/Guardians

Investigators: Mary Schuster, Iowa State University

Your son/daughter is invited to be in a research study that looks at how using live insects and arthropods can affect learning.

Your child was selected because they are in the age range that is being studied.

We ask that you read this document and ask any questions you may have before agreeing to be in the study.

Background Information:
The purpose of this study is to examine how live insects and arthropods in the classroom can affect the ability to understand and apply biological concepts. If you agree for your child to be in this study, live critters may be housed in the child's classroom for a few weeks during the semester. Several lessons will be centered around learning about these animals, using hands on activities OR insect and arthropod models. There will be two questionnaires that will each take approximately 15 minutes to complete. Questions will ask students to describe their understanding of basic inset concepts and their feeling toward this area of study.

Procedure:
If you agree for your child to be in this study, they will be asked to be open to new learning experiences using biological models OR live insects and arthropods such as, but not limited to, cockroaches, brine shrimp, and common outdoor invertebrates. Students will also be asked to fill out a questionnaire both before and after the insect unit. These questions will ask the participants to describe insect biology and their experiences in the activities. Each questionnaire will take about 15 minutes to complete.

Risks and Benefits of Being in the Study:
During this study only safe animals and procedures will be carried out. The study does have the following possible risks: One associated risk with the study is a possible allergic reaction to some of the animals. If students have severe allergies to dust, dander or mold they may be asked to refrain from participation. In any case that the student(s) do not feel comfortable with the activities, alternative forms of learning will be provided and/or the study will be ended. Students will be allowed to study in an alternate location using models rather than live animals if allergies or extreme fears arise.

The benefits of participation are that students and teachers can learn to use, handle and appreciate safe insects and arthropods as learning tools. Students may also be able to conquer small fears they have about live animals by participating in hands on activities. Students and teachers alike will also get to have a lot of fun while participating in new series of experiments and leaning methods.

Compensation:
In the event that this research activity results in an injury, treatment will be available, including first-aid emergency treatment and follow-up care as needed. Care for such injuries will be billed in the ordinary manner, to you or your insurance company. The sponsor of the study has some funds available to pay for care for injuries resulting directly from being in the study. If you think that your student has suffered research-related injury and that you may be eligible for reimbursement of some medical care costs, let the researchers know right away.

Confidentiality:

The results of this study will be kept private. In the report of this study names and personal information of students participating will not be recorded or kept on file. Records of the school and the class period the study applies to will be noted, but no further personal information will be needed. If interested, students or parents may request classroom averages on learning growth for up to 6 months after the study has ended by writing to:

Iowa State University
Attn: Dr. Greg Courtney "Classroom Study"
407 Science II
Ames, IA 50011

Voluntary Nature of the Study
No matter what your decision is about the allowing your child to participate in this study, it will not affect your current or future relations with Iowa State University. If you agree to allow your child to participate, he/she may withdraw at any time without concern.

New Information
If during this study any new information or activities come about that might cause a change in the student's willingness for participation, the researchers will inform all those involved immediately.

Contacts and Questions
If you or your child have questions or concerns about this study at any time and you'd like to talk to someone other than the researcher, please contact Dr. Greg Courtney, Iowa State University, 432 Science II, Ames IA 50011; telephone (515) 294-4017.

If you have any questions at a later time, you may contact the primary researcher at: Iowa State University, Attn: Mary Schuster, 407 Science II, Ames IA 50011; telephone (515) 231-2902.

If you have any questions about the rights of research subjects or research-related injury, please contact Ginny Austin Eason, IRB Administrator, (515) 294-4566, austingr@iastate.edu, or Diane Ament, Research Compliance Officer (515) 294-3115, dament@iastate.edu.

You will be given a copy of this form to keep for your records if requested.

Statement of Consent

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. If you would like to receive a copy of the signed and dated written informed consent form, please contact the primary researcher indicated above.

Subject's Name (printed) ____

____ ________________________
(Subjects Signature) (Date)

____ ________________________
(Signature of Parent/Guardian or
Legally Authorized Representative) (Date)

*Please list any known allergies that may affect the student involved:

Blue Survey

Entomology Survey

This is not a test and you will not be graded or judged by your answers. Please fill out the questionnaire to the best of your ability. I f you have questions, please feel free to ask for clarification from the researcher or your teacher.

- There are millions of insects and arthropods that live all over the world. What are at least two reasons why these are such successful groups of animals?

- People often think insects are bad. What are at least two reasons people might think this?

- What benefits do insects provide for people and the environment? List as many as you can.

- How does the life cycle of an insect compare with the life cycle of a frog? What do they have in common? What is different?

- List three things you'd like to know more about insects and arthropods:

    1.
    2.
    3.

** Please turn in your sheets to your teacher when completed. Thank you! **

Yellow Survey

Entomology Survey

This is not a test and you will not be graded or judged by your answers. Please fill out the questionnaire to the best of your ability. I f you have questions, please feel free to ask for clarification from the researcher or your teacher.

- For thousands of years insects and arthropods have lived on earth. List at least two reasons these animals have had such success in survival.

- Insects and arthropods often have a bad reputation. What are some reasons they may be thought of in a negative way?

- On a daily basis insects interact with people and the environment. What are ways that insects are beneficial to your world? List as many as you can.

- How does the life cycle of an insect compare with the life cycle of humans? What do they have in common? What is different?

- List three things you'd like to know more about insects and arthropods:

1.
2.
3.

** Please turn in your sheets to your teacher when completed. Thank you! **

APPENDIX B. LESSONS ONE-THREE

Lesson One Experimental

Live Lesson 1

Teachers:

- Read articles on brine shrimp.
- Become familiar activities outlined in the attached packet. (It may also be helpful to practice some of the activities yourself before students try it out.)
- Prepare and organize materials for activities described.
- Make photocopies of the handouts to be given to the students.

Discussions:

- Briefly discuss and describe brine shrimp biology. (Allow students to do a lot of the exploring about the animals on their own later as they perform the exercises. Give information to students to get them started and interested in the activity.)
- Explain the tasks at hand and let students explore different experiments they may want to conduct during the learning process. >See page 2 of lesson… (Don't forget to have a couple groups as the control groups!)
- Go over classroom safety procedures and guidelines that would be appropriate to cleanly carry out the exercises.

Activities:

- Read the article "The Great Salt Lake".
- Have students follow the steps described in the "Stuck-on Artemia" lesson.
    - It may help students if teachers are in control of painting on the shrimp cysts. This may ensure that a smaller, but sufficient # are stuck to the tape for the experiment.
- Use the experimental questions provided in the lesson on page 2 to expand the learning opportunities for the students.
- Have students complete and fill out the "Artemia Worksheet".
    - After the initial set up, the monitoring should only take a few minutes at the beginning of each class period.
- Wrap up the activity by combining the surviving shrimp for future classroom enjoyment or dispose of animals in a humane manner.

Discussion of the end results and comparison of the different experimental options that students chose may take some or most of a class period after the 5 day monitoring process. This may be a good time to show pictures or photos of the shrimp life cycle. (Showing them too early in the lesson may inhibit students from learning by seeing.)

Artemia franciscana
C. Drewes (updated, 2002)
http://www.zool.iastate.edu/~c_drewes/
http://www.zool.iastate.edu/~c_drewes/Artemph.jpg

Taxonomy

Phylum: Arthropoda
Subphylum): Crustacea
Class: Branchiopoda (includes fairy shrimp, brine shrimp, daphnia, clam shrimp, tadpole shrimp)
Order: Anostraca (brine shrimp and fairy shrimp)
Genus and species: *Artemia franciscana* (= the North American version of *Artemia salina*)
[Note: The species commonly referred to as "*Artemia salina*" in much research and educational literature appears, in fact, to consist of several closely related species or subspecies. One of these, *Artemia franciscana,* is the main North American species.]

Reproduction

Typically, sexes are separate and adults are sexually dimorphic. Males have large graspers (modified second antennae) which easily distinguish them from females. In some species and populations of *Artemia* (for example, Europe), males may be rare and females reproduce by parthenogenesis. During mating, males deposit sperm in the female ovisac where eggs are fertilized and covered with a shell. Eggs are then deposited and stored in a brood sac near the posterior end of the thorax (Figure 1M). Once fertilized, eggs quickly undergo cleavage and development through the gastrula stage (Figure 1A-E). After one or a few days, eggs are then released by the female (oviposition). Multiple batches of eggs may be released at intervals of every few days by the same female.

Two types of eggs may be laid -- (1) thin-shelled "summer eggs" that continue developing and hatch quickly, or (2) thick-shelled, brown "winter eggs" in which development is arrested at about early gastrula stage. Such "winter eggs," in their dried and encysted form, survive in a metabolically inactive state (termed anabiosis) for up to 10 or more years while still retaining the ability to survive severe environmental conditions. For example, *Artemia* eggs may remain viable after heating to 80 °C for 1 hr, cooling to -190 °C for 24 hrs, or reducing air pressure to 0.000001 mm mercury for 6 months!

Embryology

Cleavage of the developing egg is total and yolk is equally distributed among blastomeres.

While within the female brood sac, egg development proceeds rapidly though cleavage and blastula stages (Figure 1A-C). Eggs are then deposited in the environment where they may remain encysted, with embryonic development arrested at about early gastrula stage (Figure 1D-C). At this time, there are about 4,000 cells in the embryo and these are highly organized, but no organs are discernible.

When encysted eggs are exposed to more favorable conditions (rehydration), the eggs swell and rapid development of the embryo resumes, resulting in completion of the nauplius stage (Figure 1F-G). Hatching occurs in about 1-2 days, depending on temperature. For the first few hours, the nauplius stays within a hatching membrane that hangs beneath the cyst shell. This is also called the "umbrella stage" in which development of the nauplius is completed.

Larval stages and growth

[Note: Larval development of *Artemia* has been described in detail by several authors (see references). Although basic interpretations of development are similar, there are differences between authors regarding the numbering of molts and the naming of various instar stages.]

At hatching, the nauplius larva (= instar #1) emerges as a free-swimming stage (Figure 1H).

This stage is about 0.4-0.5 mm in length and brownish-orange in color, due to the presence of yolk material. In a sense, the body of the nauplius larva consists mainly of a head. It has three pairs of "head" appendages -- a pair of small first antennae (antennules), a pair of well-developed second antennae, and a pair of mandibles. There is a large lip-like structure (labrum) covering a ventral mouth. A nauplius eye is present but it is not easily distinguished at this stage.

The posterior end of the nauplius consists of the future trunk -- it is short, undifferentiated, and unsegmented (Figure 1H). The nauplius larva does not have a complete digestive tract and does not immediately feed. It relies on stored yolk as an energy source. Depending on temperature, it swims weakly for about 12-20 hrs and then molts into the metanauplius larva (= second instar).

The metanauplius larva is translucent in color and about 0.6 mm in length (Figure 1I). Its trunk region is noticeably longer, and this region continues to lengthen and differentiate through the next series of molts. The metanauplius swims vigorously using its second antennae which are now better developed. At this stage, it starts filter-feeding. Its food consists mainly of microalgae, bacteria, and detritus.

The next three stages (each terminated by a molt) are also classified as metanauplius stages.

Examples are shown in Figure J-K. Some developmental trends during these later metanauplius stages include more developed mouthpart appendages (maxillules and maxillae) and a longer thoracic region, with some definition of thoracic segments.

Next, there are seven postnaupliar stages -- one example is shown in Figure 1L. During these stages, the antennae begin to undergo a reduction in size and paired thoracic appendages begin forming. With each stage, these appendages become more numerous, larger, and functional. In addition, the compound eyes become more fully developed, the labrum is reduced in size, and abdominal segments become defined.

Then, there are a series of five postlarval stages (not illustrated) involving further reduction in the antennae, multiplication of ommatidial facets in the compound eyes, lengthening of the eyestalks, and formation of sexual organs. Completion of the 17th molt marks the end of post-embryonic development and the beginning of the final adult stage (Figure 1M). [Note that some authors recognize only 14-15 molts, rather than 17.]

Brine shrimp grow extremely rapidly. The adult stage is reached about three weeks after hatching. At adult size, biomass is about 500 times more than the nauplius biomass. Adults may live up to about 4 months.

Adults

Adult body size is variable, but typically it is about 8 mm in length. The anterior part of the body is not covered by a shield or carapace. The head has a pair of compound eyes at the end of stalks. Head appendages include a short pair of first antennae (also called antennules), a pair of second antennae, mandibles, and paired maxillules and maxillae -- the latter are greatly reduced in size. In males, the second antennae are enlarged and modified as claspers -- in females, they are short and thickened.

The body has 20 trunk segments (some authors say 19). The first 11 trunk segments are classified as thoracic segments and bear paired, paddle-like appendages, also called phyllopods.

Posterior to the thorax, there are 7 abdominal segments that bear no appendages. The last body segment bears a pair of long tail filaments.

Thoracic appendages are used for swimming and the animal swims ventral side up. During swimming, appendages move in a rhythmic and wave-like pattern, at a frequency of about 5-10 waves per second. Although difficult to see with the naked eye, each wave of movement actually starts out in posterior segments and then, rapidly and sequentially, progresses into more anterior segments. During the "power stroke" of each cycle of movement, the paddle-like appendages push water in a rearward direction, thus smoothly propelling the animal forward. Importantly, such water currents also function in food gathering, as well as in respiration, since thoracic appendages also have gills.

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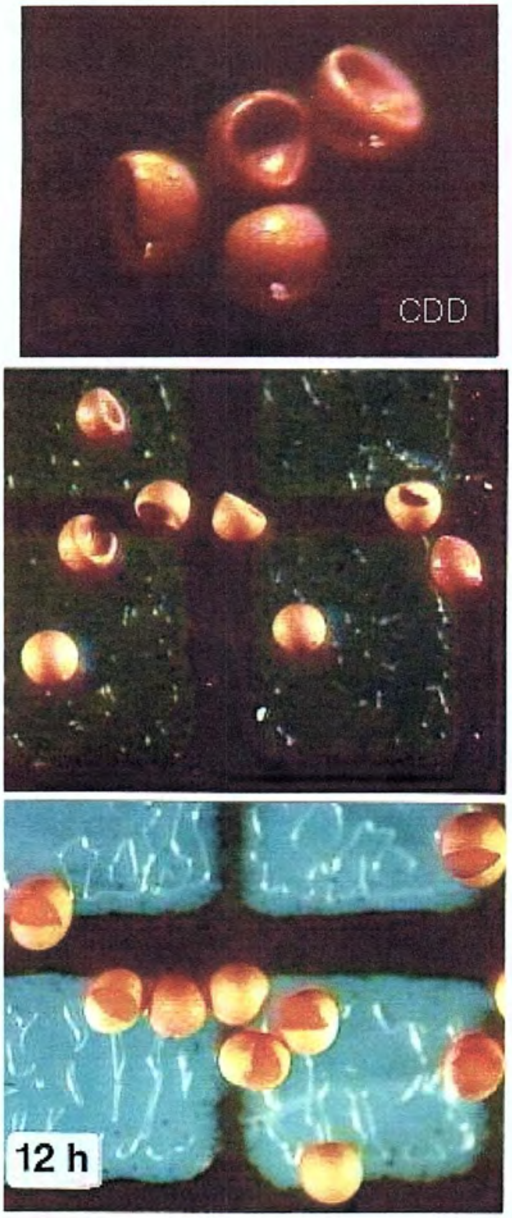
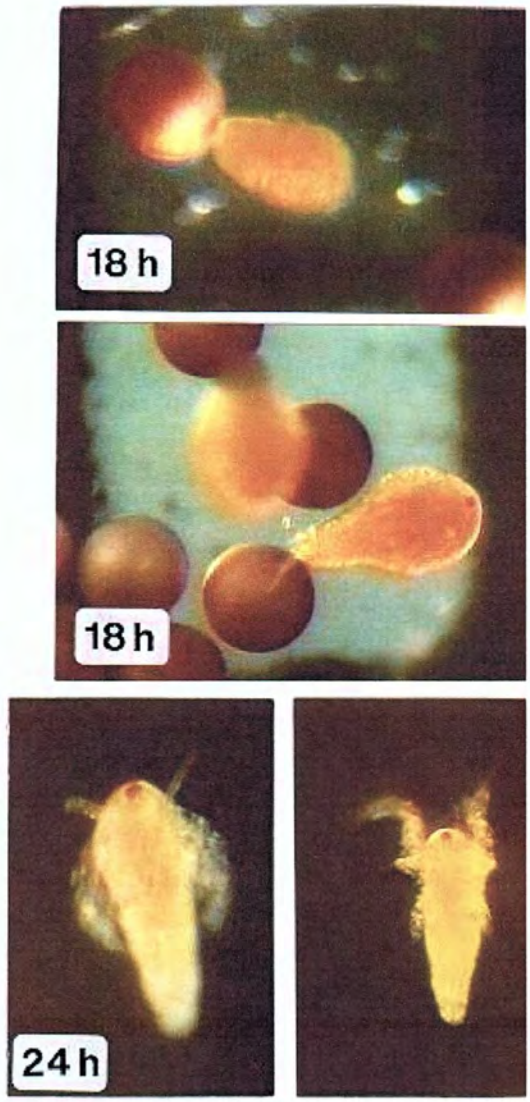
Web Sites for additional background, lab culture methods, and student activities:
http://www.zool.iastate.edu/~c_drewes/ This site provides an new classroom activity entitled: *"Stuck-On Artemia"* [New, simple methods are described for systematically following the developmental fate of individual cysts while quantifying the hatching success of small populations of cysts. The method allows small numbers of cysts to be easily transferred, counted, and kept in the same focal plane for viewing. This technical approach leads to a wide array of open0ended student investigations, as well. Presented by C. Drewes at 1999 NABT]
http://www.zool.iastate.edu/~c_drewes/Artemph.jpg
http://allserv.rug.ac.be/aquaculture/index.htm\
http://www.science.lander.edu/rsfox/artemia.html
http://www.iit.edu/~smile/bi9216.html
http://www.terc.edu/handson/f94/shrimp.html
http://www.terc.edu/handson/f94/spotlight.shrimp.html
Commercial Sources:
Most biological supply companies and tropical fish stores sell small quantities of brine shrimp cysts.
Larger quantities may be purchased from:
http:/www.aqualink.com/marine/z-atemia.html
(sells cysts and *includes suggestions for feeding)*
http:/www.aquaticeco.com
(sells cysts and "Dry Brine Shrimp Feed" that supports growth from nauplius to adult (Cat#: E-16; 1.0 lb/$25).
4
(*Spirulina* powdered algae supports growth from 1-week-old larvae to adult (*Spirulina,* Cat#: SP10; 1 lb/$25).

Brine shrimp cysts hatching
from "Stuck-on Artemia"
by C. Drewes





Lesson One Control

Non-Live Lesson 1

Teachers:

- Read articles:
  - The Little Things That Run the World
  - What Makes Invertebrates Cool?
  - Salt Lakes and Sea Monkeys
- Make copies or articles for students to ready.
- View the brine shrimp video.
- Gather materials (large pieces of paper) for "wanted" student activity.

Discussion:

- Discuss the Great Salt Lake and the unique development of animals that live in that type of extreme environment. Bring up brine shrimp and their unique biology.
- Discuss water quality and how it impacts life.
- Discuss human impact on water quality.

Activities:

- Read articles:
  - The Little Things That Run the World
  - What Makes Invertebrates Cool?
  - Salt Lakes and Sea Monkeys
- View and discuss pictures of brine shrimp through development
- Create a "wanted" poster for items/organisms that can have a negative impact on water quality. This could include invasive plants, predators, or pesticides/chemical pollution.

View brine shrimp video.

America's Most Wanted Invertebrates
Lori Ihrig and Charlie Drewes

Abstract: We present a new "minds-on" activity for the biology classroom that engages students in creative integration of detailed and diverse biological content about invertebrates. The activity results in student-generated written and pictorial profiles that accurately capture the biological features and essence of invertebrates. For each student, the outcome is a "fugitive wanted poster," much like those seen at the post office or on television ("America's Most Wanted").
Program Description: Students "profile and capture the identity of living invertebrates" in this 'minds-on' activity that blends creative writing and illustration.

The amount of class time dedicated to this project can vary depending upon how the project is utilized. If the project is used as an assessment, less time will need to be spent teaching concepts than if the project is used as a basis for the ecology unit. It will be possible for students to do much or all of this activity without using living invertebrates. However, living organisms dramatically increase student interest. Also, the activity need not be limited to invertebrates; any living organism that the instructor has available or familiarity with will work. However, questions may need to be modified to suit other groups of organisms. Students demonstrate an interest in biology, display their creativity, take charge of their learning and have pride in their knowledge.

The Project
Develop and apply your knowledge about ecology and an invertebrate to create a wanted poster. You can use your own creativity and inventiveness to give your organism some "personality" and "preferences," **but specific information about the organism's biology should remain as factual and accurate as possible.** Try to make your poster a coherent collection of information about your wanted invertebrate, rather than a disconnected list of answers to the questions.

Questions to consider on your poster
On your poster address the questions listed below. The "**street jargon**" used to embellish the wanted poster is written in **bold and underlined text**. The biological content that you need to research and present on your finished product is written in normal text.

Taxonomy
1. **Name and Relations**- Give the suspect's scientific name. List the suspect's taxonomy as specifically as your instructor desires. State the common names of related organisms.
2. **Aliases, AKA (also known as)**- What are common names for the organism?

Body Plan
3. **Identifying Features**- Provide a detailed description of the suspect's appearance, shape, size, color, texture, symmetry, segmentation (y/n), skeletal features, etc.
4. **Distinguishing Marks**- What distinguishes the suspect from its relatives? (For example, what features would allow you to pick your organism out of a line up of its relatives?) What features are unique, special, or peculiar about the suspect?

Development
5. **Juvenile Record**- Describe the suspect's earlier appearance(s) -- that is, life stages and life cycle. How big will the suspect grow?
6. **Police Sketches**- Create drawings to support information about the organism's life stages and life cycle.

General Ecology
7. **Last Whereabouts**- Describe the suspect's specific microhabitat. (Such as, under a rock, in shallow water near the shoreline, surrounded by plant material.)
8. **Preferred Hangouts**- Describe the suspect's biological community. That is, what populations of plants and animals live around the suspect? What is the suspect's niche?

9. **Rap sheet**- For example, ciliary gliding without a license, carrying a concealed pharynx, construction of a case without a permit.

Locomotion

10. **Suspect Last Seen Heading Towards**- Possible destinations within the suspect's habitat.
11. **Means of Getaway**- Provide a detailed description of the suspect's pattern or means of locomotion.
12. **Caution When Apprehending**- What makes the organism dangerous to its predators and/or prey? Describe the suspect's escape and defense mechanisms.

Use of Resources and Taking Notes:

Use any and all available resources to gather specific information about the organism's ecology, anatomy, behavior, etc. The types of biological information you will need can be determined by reviewing the questions listed above. This information may be obtained from journals, magazine articles, library reference books, textbooks, World Wide Web, resource people, or other references. In addition to biological facts, the information you gather may include copies of photographs, diagrams, etc. You may trace, redraw, or modify these pictures to use on your poster, but **try to maintain accuracy and detail in your pictures. Below each picture, include a legend that describes the picture [for example: "Here the suspect is attached to a..."]**

Create a Visual

Your poster must include visuals that you create. Your visuals can be hand drawn, traced, created on the computer, etc. Your visuals may not be photocopies from print resources (books, magazines, journals, etc.) or printouts from the World Wide Web.

Minimally, you must include a **descriptive** drawing of your invertebrate. This drawing should be large enough to label the distinguishing features without compromising the artistic integrity of the drawing. You may decide to create "profile" drawings of the suspect.

Write Your Speculations About the Suspect

In a journal entry, entitled "SPECULATIONS ABOUT THE SUSPECT", indicate which aspects of the organism's biology you were (a) interested in, (b) unsure of, (c) could find the most information about, (d) could find no information about, and (e) would like to know more about. Your speculations do not need to be written in wanted poster fashion, they can be written in first person from your point of view.

Create Your Poster

Make certain that your poster is not simply lists of answered questions. This is a creative outlet for you to demonstrate your knowledge of the ecology of an invertebrate. Be cautious. Your goal is to produce a unique poster while highlighting accurate biological information. Make sure creativity is not used at the expense of accurate biological information.

Lesson Two Experimental

Live Lesson 2

Teachers:

- Read through the Leaf Mold packet
- Become familiar with the different organisms that are often found in compost material and soil.
- It may also be helpful to do a little personal research or exploring about Burlese Funnels that many scientists use for monitoring wildlife.
- Make copies of the equipment set up and the arthropod "keys" found in the Leaf Mold packet to hand out to students as they work.

Discussions:

- Discuss different classes of invertebrates and how they relate to each other.
- Discuss the use of identification keys used to sort and classify all types of objects.
    - Think about classifying rocks, plants, animals and even the keys people use to sort fabrics, tools, and other man made objects.

Activities:

- Build/assemble the Burlese Funnel by using the materials provided and the diagrams found in the Leaf Mold packet.
    - Note > Keep the compost material loose and fill the funnel only about 1-2 inches thick.
    - Place lamp close to the material, but keep it at least and inch or two away from the material to prevent a risk of fire. Do not leave lamps turned on unattended and avoid leaving lamps on for more than a couple of hours at a time.
- Sort the organisms that are collected in the paper cup using forceps, fingers or small wooden dowels.
    - Take caution not to squash the living organisms that are captured.
    - Also take note, that some organisms may have the ability to pinch or sting. Some organisms may crawl or jump quickly which may startle some of the participants.
- Allow students to journal about the items they find in their collecting jars.
- Ask students to create a new habitat for certain organisms collected either actually or on paper. Ask students to include everything the in the new habitat that the organisms would need to survive.
    - If actual new homes are made for the creatures make sure that their containers are escaper proof or you may have a few new colonies of animals in your classroom.

*** Note: if you do not have access to compost personally, try asking a local green house or nursery for some classroom compost. Other options may be collecting leaf litter from a local park or forested area. If that is still not an option let me know as soon as possible so that I may collect it for you.

Leaf Mold Community

The term "leaf mold" refers to dead, decaying leaves and other vegetable material that accumulates on soil. Leaf mold is eventually decomposed into smaller organic particles that greatly enrich the soil beneath it. The spaces between decayed fallen leaves and other decomposing vegetation provide homes for an incredibly rich diversity of invertebrate organisms. Animals that live in such hidden microhabitats are sometimes referred to as "cryptozoa." Often, hundreds of cryptozoic animals -- including mites, spiders, pseudoscorpions, centipedes, millipedes, and small insects -- may reside within a few handfuls of leaf mold. High humidity, provided by moisture trapped in the small spaces between the leaves and other organic material, is vital to these organisms' survival.

Bacteria, protozoa, and fungi thrive on the decaying material in leaf mold and help break down cellulose. Many of these microorganisms, as well as the decomposing material itself, are eaten by certain types of cryptozoic species (see Table). These organisms, in turn, are preyed upon by carnivorous predator species that also occupy these environments. Thus, complex food webs exist within these leaf mold communities.

A common method used to extract organisms from leaf mold is the Burlese funnel. A small volume of freshly collected leaf mold, along with some of the soil immediately beneath it, are loosely laid on a circular screen within a funnel. A collecting container is placed at the base of the funnel and a lamp is placed above the funnel. The idea is that many of the cryptozoic organisms within the leaf mold will move slowly downward and away from the heat, light, and drying conditions created by the light source. As they move away, they fall into the collecting container below. The animals will remain alive if some damp material, such as a small pad of moistened paper towel, is placed in bottom of the collecting container. For taxonomic studies or population counts, researchers may need to collect and examine dead animals. In this case, a small volume of preserving fluid may be in the collecting jar and organisms will be immediately preserved as they fall into the fluid.

References:

Lavies, B. (1993) *Compost Critters.* E.P. Dutton. [ISBN 0525447636]

Ruppert and Barnes (1994) *Invertebrate Zoology, 6th Ed.* Saunders College Publishing, NY. [ISBN 0-03-026668-8]

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Common Invertebrates in Leaf Mold

Roundworms (nematodes) are light-colored and about 0.1 to 2.0 mm in length. Their worm-like, cylindrical bodies lack appendages and are clearly unsegmented. The ends of the body are tapered and the animal makes side-to-side bending or thrashing movements. They may reach very high population densities in the soil. There may be up to 1 million species world-wide.

Oligochaetes (earthworms and enchytraeids) have bodies that are clearly segmented and lack appendages. The body size and number of segments varies according to species. Large and sexually mature earthworm specimens may have a whitish band, called the clitellum, near the anterior end which is used to produce cocoons that contain developing eggs. Enchytraeid worms (also called potworms) are small, whitish in color, and clearly segmented. Oligochaete worms can crawl by peristaltic contractions of the body involving circular and longitudinal muscle layers. Feeding and burrowing activities of earthworms in the soil are extremely important in soil formation and soil fertility.

Gastropods (slugs and snails) prefer damp places, such as leaf mold or under rocks and logs, especially during the daytime. These soft-bodied animals have tentacles on the head end and a muscular foot with a ciliated surface that propels the animal by slow, gliding movements. Most are nocturnal and, at night, may emerge from their hiding places to feed on surface vegetation. Some may be eaten by larval beetles. Slugs are basically "shell-less" snails. When disturbed, slugs are capable of secreting large amounts of mucous. A breathing hole, the pneumostome, may be visible on the right side of the body.

Daddy longlegs (or harvestmen) are mainly nocturnal hunters, though some eat dead invertebrates. Larger adults are most commonly seen during the autumn. As a defense mechanism they may secrete a nauseous fluid. They are classified as arachnids and have 8 very long legs and a small round body. When disturbed, they may often cast off limbs -- a process called autotomy. The animal cannot regenerate missing limbs, so it is not uncommon to find specimens with fewer than eight legs.

Spiders are predatory arachnids with 8 legs and 6-8 eyes. All spiders can spin silk from silk glands. Some use silken webs to capture prey; others stalk their prey. On the underside of the body there are a pair of fangs located at the ends of appendages called chelicerae. All spiders have poison glands which produce venom that is expelled through openings on the fangs. As spiders grow from small hatchlings to adult, they undergo about 5-10 molts of their exoskeleton. Numerous species of spiders may be found within and atop leaf mold.

Pseudoscorpions are arachnids, usually less than 4 mm in length. They are aggressive predators with eight legs. A very large pair of pincers, located on the paired pedipalps (anterior appendages) are used to catch their prey. Pseudoscorpions sometimes reach high densities in damp leaf mold where they actively hunt small, arthropod prey, such as springtails and mites.

Mites are small arachnids (less than 1.5 mm in length) that are extremely abundant in soil and leaf mold. Some are brightly colored -- red or orange; others are dark brown or black. Though adult mites have eight legs, most mites progress through a six-legged larval stage. Mites have an extremely wide array of feeding habits (see Table).

Pillbugs (also called sowbugs or woodlice) are terrestrial crustaceans with flattened, segmented bodies. They have one pair of legs per segment and a maximum of seven pairs of legs in all. They may be extremely common within leaf mold, and especially under rocks or decaying logs. They feed on dead and decaying vegetable matter and therefore directly contribute to the breakdown of leaf mold. Some species curl up into a motion-less ball when disturbed.

Millipedes are segmented arthropods that consume great quantities of leaf mold and dead wood, and therefore contribute significantly to the breakdown of vegetable matter. They have long bodies with several dozen, or more, body segments. Each segment bears two pairs of legs. When disturbed, some species may coil up into a flattened spiral.

Centipedes are active nocturnal predators that use powerful poison claws to capture prey. Some species have relatively long legs and are fast runners. The number of body segments is variable, but each segment bears a single pair of legs.

Springtails are very small, wing-less insects with paired antennae. Their bodies are less than 3 mm long. They may be extremely abundant in leaf mold, soil, and rotten wood. They are recognized by their ability to jump by means of a spring-like structure called a furcula. The furcula, located on the tail end, is usually held under the animal and folded in a forward-pointing direction. When the animal is disturbed by a potential predator, the spring is released and the animal is catapulted into the air.

Crickets are occasionally found in leaf mold which provides moisture and protection from predators. Paired head appendages (antennae) and tail appendages (cerci) are sensitive to many types of stimuli. Some cricket species use their rear legs for jumping and their wings to make sounds. Mole crickets burrow in the ground.

Flies and fly larvae (maggots) are sometimes associated with leaf mold. Fly larvae (especially crane flies, midges, and fungus gnats) are common in leaf mold where they feed upon decomposing material.

Ants are social insects occasionally found in leaf mold, especially in areas close to a nesting colony of ants. When disturbed, ants may run frantically toward tunnels they have made in the soil. As adults, some ants are predators.

Ground beetles are extremely common in leaf mold, both as adults and larval stages. Most are predatory, especially as larvae. Many are nocturnal scavengers that eat decaying carcasses of other animals, fallen fruit, or fungi.

STEPS FOR MAKING AND USING A BURLESE FUNNEL

MATERIALS LIST:

construction paper or light cardboard
1/8 inch hardware cloth (several sq ft)
metal shears
duct tape
pile
clean 2-liter plastic pop bottle
scissors
gloves
permanent marking pen
dissecting microscope
white paper coffee cup
leaf mold/leaf litter -- from decomposing mulch or compost

40-60 watt bulb and flexible lamp
paper tape
cup holder

PROCEDURES:

1) Make pattern for wire insert. Pattern is made out of heavy construction paper or light cardboard.

2) Lay pattern down upon 1/8 inch hardware cloth. Trace around pattern with heavy permanent marking pen, thus leaving outline on the hardware cloth.

3) Cut hardware cloth around outline using metal shears. Use gloves.

4) Wrap duct tape around flaps, as shown.

5) Cut 2-liter pop bottle into funnel, as shown.

6) Insert wire circle into bottle and fasten all four flaps to inside of bottle with small pieces of tape. This will keep the metal screen from tipping and tilting when leaf mold and soil are added.

7) Place folded pad of wet paper towel in bottom of cup and place cup in a heavy circular holder to keep it from easily tipping over, or tape cup to counter top.

8) Tape pop bottle tightly to cup, as shown.

9) Place leaf mold/soil sample loosely on the screen.

10) Place light source above the screen. Make sure the light source is securely positioned. Periodically check for appearance of living organisms in the collecting container. Some organisms may appear after only 1-2 hours, while others may take longer to appear.

CAUTION:

Do not place the light too close to the screen! This may cause organisms in the leaf mold to be overheated and die before they can escape through the funnel. It may also create the potential for fire!

11) Live organisms in cup may be viewed under a dissecting microscope. To facilitate viewing, use a scissors to trim down the size of the cup. **Note:** Some organisms, such as pseudoscorpions, may be able to easily crawl up the sides of the collecting container. Thus, it may be necessary to immediately transfer these organisms to a more secure container for viewing.

❶ centipede
❷ millipede
❸ pseudoscorpion (about 1-2 mm)
❹ mite (about 1 mm)
❺ springtail (collembola, insect) <1 mm
❻ oligochaete worm
❼ spider
❽ ant
❾ pillbug
❿ other insects (fly, ground beetle, etc.)

Lesson Two Control

Non-Live Lesson 2

Teachers:

- View the example of a dichotomous key and become comfortable with its format.
- Create bags for students to sort and create their own keys for.
    - Try making bags of common objects such as food/candy or items like: nails, bolts, screws and washers. Make bags for each student group the same containing 10-15 objects.

Discussions:

- Discuss micro and macro habitats and the differences between the types of organisms that live there.
    - Discuss the organisms that may live in your own back yard or even on/in other organisms.
- Discuss the uses of dichotomous keys used to sort and classify all types of objects.
    - Uses include sorting and classifying rocks, plants, animals, and even many man made objects like fabric and tools.

Activities:

- Allow students to work in groups to sort out objects in bags and justify their reason for sorting and grouping items as they did.
- Ask students to create a dichotomous key so that others may try sorting objects in a similar manner.
- Have students compare their methods of sorting.
- Have students share and test out their keys.

Lesson Three Experimental

Live Lesson 3

Teachers:

- Prepare a space for the cockroaches and review the care/rearing procedures.
- Prepare an experimental space.
    - Items needed may include: cardboard, or wooden blocks, critter keepers with tight fitting lids (clear boxes of any kind, but leave some breathing holes), small wooden dowels (for disturbing the roaches) and data sheets for making observations (notebook paper is good).
- Create a grading rubric for the creative essay.

*** Note: Have experiments come first with discussion and questions to follow.
Also, these lessons may be done similarly with isopods (pillbugs) in place of roaches.

Discussion:

- Discuss biology and behavior of the animals.
- Discuss aspects of life on a micro scale.
- Discuss procedures, precautions and any classroom rules that go along with using live animals.

Activities:

- Perform various experiments with the live cockroaches as outlined below.
    - Students may come up with their own inquiries they wish to carry out. Let the imagination go and allow for free experimentation as long as it fits into the time available.
- Based on the observations made about insect interactions, ask students to create an environment that might be suitable for the cockroaches. How many cockroaches would work well for a small space? How much food and water should be added? What kind of ground cover and extras would make the cage feel more like an insect home?
- Have students write a creative essay comparing cockroach behaviors to human behaviors. Ask them to think about what it is like to be in a crowded space, with limited food. Would a large group of boys act the same way as a large group of girls? How would a large group of just one gender compare to a group of boys and girls? What would it feel like to live as a little animal in a big world?

<u>Live Activities:</u>

I. Place several males into a small container with a tight fitting lid. Make observations on hissing and aggressive behaviors of the males. What happens if you add or remove a stump of wood/sitting spot? What happens if you add or remove food? Try altering the number of males?

*** Note: if female roaches are wanted to perform extra experiments, please let me know as soon as possible. These are permitted species and will need to be handled carefully.

II. Create cockroach mazes. Using wooden blocks or strips of cardboard create two similar mazes, one with a narrow row width and one with a much wider row width. Time some cockroaches as they race through the mazes. (You may need to help them along the way through the maze if they choose to stop for a prolonged period of time.) Do you notice a significant time difference between the two mazes? Does having a food reward at the end vs. no food cause a difference in race times within the same maze? Add a black stripe down the middle of the wide maze. Did this affect the race time of the cockroach? How?

*** Note: Many cockroaches tend to feel more comfortable and move quicker in small areas and along lines/edges. Test to see if this theory holds true for your roaches…

Rearing:
Cockroaches should be held in an aquarium with a tight fitting lid. Often times a sheet of plexi-glass cut to size and secured on all sides with electrical tape will help keep roaches in and invaders out. Bedding for the cockroaches should be either slightly dampened peat moss or chemical free aspen chips (mouse bedding). Both of these materials tend work well, but should be replaced and the tank cleaned at least once a month or as needed. Hissing cockroaches tend to be territorial so a piece of bark or a small log should be placed in the tank for climbing. Roaches are not able to drink from a dish of water easily, so water should be provided by placing a piece of cotton in a test tube of water or via a sponge in a small dish of water. Dry dog food/puppy chow works well for feeding the cockroaches. Simply place a handful of pellets in a shallow dish and let them eat. Food should be replaced at least once a week. The roaches will also really appreciate a slice of apple or a hunk of banana every once in awhile. Don't worry if the fruit looks kind of soft or brown; they like decaying things, but watch for mold!

Common Name: Madagascar Hissing Cockroach

Kingdom	Animal
Phylum	Arthropod
Class	Insect
Order	Blattaria
Family	Blattidae
Genus	*Gromphadorhina*
Species	*portentosa*

Incomplete lifecycle / stages of development: Egg → Nymph → Adult

Gromphadorhina portentosa is a large wingless cockroach that naturally lives on the island of Madagascar, located just off the eastern coast of southern Africa. Their long lives, 2-5 years, are mostly spent on the moist forest floor acting as good natural recyclers. Madagascar hissing cockroaches eat decaying plant matter and help put the nutrients back into the environment. Recently, these interesting insects have received a lot of publicity from zoos and the general public. Shows like Fear Factor and Survivor have created a lot of buzz about these wild animals.

Both male and female cockroaches have heavily sclerotized or hardened, three segmented bodies. A thick, dark plate, called a pronotum, covers and protects the cockroach's head. Males have two large bumps or horns on their pronotum. Females have much smaller bumps on their pronotum, which provides us as well as the cockroaches a way to tell the genders apart. Other sexually dimorphic traits include the hairs found on the antennae and the aggressiveness of the animal. Males tend to have more hairy antennae and display much more forceful behaviors.

As hinted at in their names, these cockroaches are able to produce a hissing noise. When disturbed, during mating or defensive displays the cockroach will depress its abdomen forcing air out of small breathing holes. These breathing holes are called spiracles, and these roaches have a special modified pair located toward the rear of the insect. When air is forced out it causes a hissing noise. Males are particularly loud hissers, especially when engaging in aggressive acts. Females and nymphs rarely hiss but if disturbed or handled are known to produce noise.

Mating occurs year round, provided the temperatures and humidity are good. These cockroaches cannot tolerate cold. The whole process is initiated by the smells or pheromones produced by the female. Males may compete via pushing and shoving each other using the tough pronotum on top of their heads. The larger and louder males usually win competitions. Females may be able to distinguish the winner by the type and loudness of the hissing. The hissing also helps the cockroaches distinguish between family and friends. If everything checks out, the male and female get together end to end and the mating process begins.

This cockroach is often described as being ovoviviparous, meaning that it has live birth. In the females lifetime it may have up to 30 birthing experiences. Once mating has occurred the female may hold her developing young in her body for about 60 days before the roaches emerge as 1st instar nymphs. Females can produce 15-60 young from one mating experience. Development to the adult stage takes about 7 months and in their lifetime the cockroaches will molt or shed their skin about 6 times. Although hundreds of little cockroaches can come from just one adult, Madagascar Hissing Cockroaches are not considered problematic. There are over 3500 species of cockroach in the world, but less than 30 of them are actually considered pests.

Lesson Three Control

Non-Live Lesson 3

Teachers:

- View video of Microcosmos.
  - Video will need to be watched over 2-3 days so try and decide on stopping points that work for your class time.
  - View teacher annotations of the video, think about places to stop and allot for student questions or areas where you'd like to pose questions to the students.
- Create a rubric for the short story students will be asked to create.

Discussions:

- Discuss life on a micro scale. Get students thinking about challenges and benefits of being small in a big space, or the other way around depending on how you look at it…
- Discuss how small things play big roles in the environment.
- Discuss different invertebrate behaviors that are witnessed in the video.
- Discuss comparable vertebrate behaviors.

Activities:

- View Microcosmos video.
- Have students create a comparative sheet.
  - Ask students to split a paper in half and label one half vertebrates, the other invertebrates.
  - Students can then fill out different invertebrate behaviors witnessed in the film.
  - After viewing, have students make notes of ways that other animals (vertebrates) may handle similar situations. List similarities & differences.
- Discuss aspects of the video as they watch.
- Ask students to create a short story about a moment of time as an invertebrate in the world.
  - Include a description of the animal, its environment, and behaviors.
  - Ask students to include at least 3 ways that small things play an important role in the larger world/environment.

*** Note: This last activity may be altered to fit into a classroom activity for small groups. Have students make a list of 3 important insect roles and details as to why they think so.

Here are some possible questions for discussion, let the students lead the questioning…

1. Insects may spend up to half of their day grooming. Imagine what it would be like to have dirt stuck to you the size of a beach ball. How much time a day do you think you spend grooming?
2. What does the caterpillar do right after hatching from its egg? Why do you think it does this?
3. What is the large dark beetle rolling and what is it going to do with it? Ancient Egyptians used to think dung beetles were mystical. They go underground and then seemed to be re-born as a new insect. The beetle brings a ball of dung underground and lays an egg in it. As the larva matures it will eat the poop. When it reaches the adult beetle stage it will come back out of the ground. Magic! What are some things that parents (humans and other animals) do to make sure their young will be taken care of even after they are gone?
4. Something keeps tapping the bee on its back as it drinks nectar, why is this? What role does pollination play in our lives? What would happen if bees were eliminated?
5. The rhino beetle uses its horn for many tasks. What does it use its horns for in the film? Compare human behavior for finding a mate & defending a home/territory to that of the beetle.

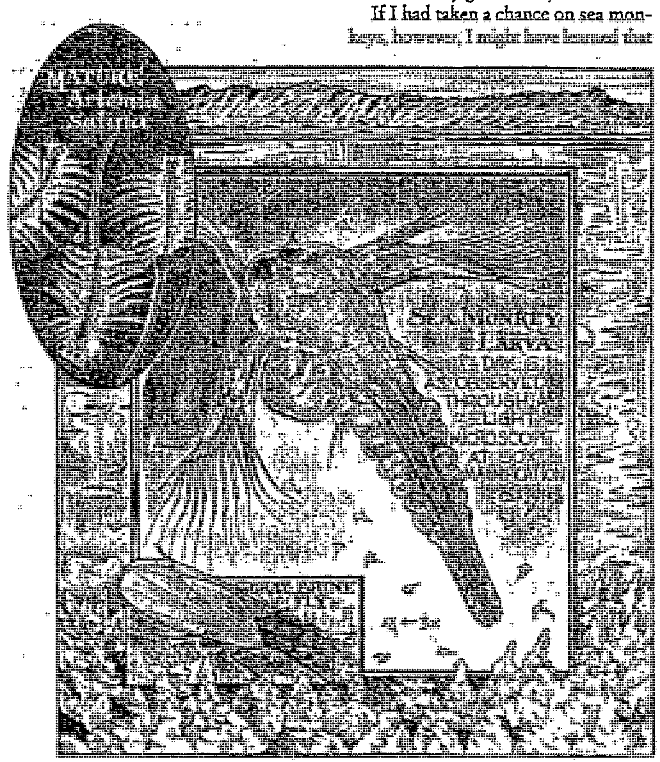
NATURAL ENQUIRER

By Jerry Dennis • Illustrations by Glenn Wolff

Salt Lakes and Sea Monkeys

SUPERMAN AND WONDERWOMAN CAN'T HOLD A CANDLE TO SEA monkeys. That's clear to me now, but when I was 12 and studying comic-book advertisements for pet chameleons, flesh-eating plants, pen-size spy telescopes, and secret Eastern techniques for transforming my bare hands into lethal weapons, I was skeptical. The ads for sea monkeys claimed that for one dollar I could receive a packet of mysterious eggs that would hatch into creatures guaranteed to fill my life with wonder and enchantment. But I was a shrewd kid, not easily duped. I spent my money instead on hypnotism discs and x-ray glasses.

If I had taken a chance on sea monkeys, however, I might have learned that they were not some bizarre species of aquatic primate, but brine shrimp, half-inch-long crustaceans native to certain saline lakes, the most famous being Utah's Great Salt Lake. If I had been less of a skeptic, my fishbowl might have been home to some of the world's toughest survivors.



The Great Salt Lake is only one of countless such bodies of water around the world, many of them with habitats so harsh even most bacteria find them impossible to live in. Although there is much variation among the lakes, all share a single characteristic: They have no outlets. Because they are located below sea level or in basins surrounded by hills, the water entering them by rain, river, or runoff stays put. Rather, the solvent material in the water stays. The water itself evaporates, leaving behind a gradually increasing accumulation of chemicals and minerals.

Those chemicals and minerals vary according to the composition of soils and rocks in the drainage system feeding the lake. Each lake is distinct, a chemical fingerprint of the land around it. The salinity in Great Salt Lake is derived primarily from sodium chloride and sodium sulfate. The bitter lakes high in the arid valleys between the Rockies and the Sierra Nevadas have high concentrations of sulfates. The soda lakes of East Africa's Rift Valley contain dissolved carbonates. The Dead Sea, the greatest salt lake of all, contains almost nothing but chlorides.

Great Salt Lake is no pond—it stretches across 2,000 square miles of sunbaked desert in northwest Utah—but it is a remnant of a much larger body of water known as Lake Bonneville. Fifteen thousand years ago Lake Bonneville covered 20,000 square miles of Utah, Nevada, and Idaho and drained north to the Pacific through what are now the Snake and Columbia rivers. As the level of the ancient lake declined, salt accumulated. Some of it was deposited on its former bed, part of which is now known as the Bonneville Salt Flats, and a lot of it ended up in the Great Salt Lake.

It is remarkable that anything can live there. The shores of the lake are rimmed and the bottom coated with cementlike layers of crystallized salt. The water itself is so dense with salts that it is virtually impossible to swim under the surface. The deepest portions of the lake (nowhere more than 50 feet, with an average of only about 13 feet) are so salty they contain no oxygen. Even the less salty surface water holds little oxy-en because of warm temperatures and high altitude. In the summer, the shore of the highly saline north arm of the lake is often fringed with a reddish-colored scum of bacteria and algae trapped beneath layers of crystallized salt. The algae receive enough sunlight to photosynthesize, producing oxygen that accumulates beneath the salt. But even that bounty of oxygen is unavailable to organisms in the lake. The gas rises in small domes of salt, which open at the surface and release bursts of pure oxygen into the air. Very little dissolves in the water.

Yet organisms have colonized this inhospitable habitat, evolving into a simple aquatic food chain with bacteria and algae at the bottom and one species of brine shrimp and the larvae of the gray brine fly at the top. Other inhabitants, including a protozoan, a fungus, and a few viruses, live in the less salty regions near the mouths of tributary rivers, but in the main body of the lake -e are only bacteria, algae, shrimp, brine flies.

Though this exclusive community is simple, it is astonishingly crowded. A rule of thumb in salt lakes (as in many extreme environments) is that the number of species is low and the number of individuals is high. When the population of brine shrimp is at its peak, the numbers are too vast for comprehension. In 1965 more than 77 tons of eggs were harvested from the lake. Likewise, brine flies hatch from the water in such quantities that they sometimes cover it with a seething black quilt of insects. Such abundance does not go unnoticed: The shrimp and flies of Great Salt Lake attract hundreds of thousands of shorebirds and waterfowl.

Brine shrimp belong to an order of crustaceans sometimes referred to as the fairy shrimps. The group is noted for its ability to survive extreme conditions, thriving in salt lakes, in temporary desert puddles, and in lakes that are frozen most of the year. Relatives of Great Salt Lake's *Artemia salina* live in salt lakes all over the world. Typically, they feed by swimming on their backs and filtering algae and bacteria from the water. They are sometimes pink in color, due to hemoglobin, which assists them in extracting oxygen from oxygen-poor waters.

When it comes to reproduction, brine shrimp hedge their bets, producing two kinds of eggs: a thin-skinned variety that clump together in egg sacs in the water and hatch after five or six days, and thick-skinned eggs encased in hard shells, which sink to the bottom and enter a state of rest called diapause. Washed up on shore or left stranded as the lake evaporates, the hard-shelled eggs dry out and become tougher than the toughest superhero, able to survive temperatures as low as minus 310 de-

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NOTEBOOK
Death of a Salt Lake

SOME ENVIRONMENTALISTS CONSIDER WHAT HAS HAPPENED TO RUSSIA'S Aral Sea the greatest ecological disaster of the twentieth century. That large saline lake was once larger than all the Great Lakes except Superior. The Aral Sea is located in a warm, arid region, which in the days of the Soviet Union supplied more than a third of the nation's fruits, vegetables, and rice and almost the entire cotton harvest of a country that led the world in cotton production.

But such productivity was purchased at a steep price. Vast collective farms were laid out across hundreds of miles of near-desert terrain and could keep up with state-mandated production quotas only with constant irrigation. The sole dependable sources of water in the region were two rivers, the Amu Darya and the Syr Darya, primary tributaries of the Aral Sea. Irrigation claimed so much of the rivers' water that for more than 20 years not a drop of the Syr Darya reached the Aral Sea and only a trickle from the other river reached it. The lake was strangled. In 30 years the area of the lake was cut in half and it fell nearly 50 feet. A once-productive fishery was destroyed. Fishing villages previously located along the shore are now stranded 20 to 50 miles from it. Water that supported varied and abundant marine life, including 24 species of native fish, became too saline to support any fish at all. The mudflats left behind

as the water receded are so encrusted with salts and the residues of massive amounts of fertilizers, pesticides, and herbicides dumped on adjacent fields that the wind picks them up in swirling clouds of toxic dust and scatters them across the surrounding region. The chemicals have found their way as well into the groundwater, poisoning the area's last reserves of drinking water.

J.D.

NATURAL ENQUIRER

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grees Fahrenheit and as high as 212 degrees. Even after many years of desiccation, if the eggs are submerged in water, they will soon hatch.

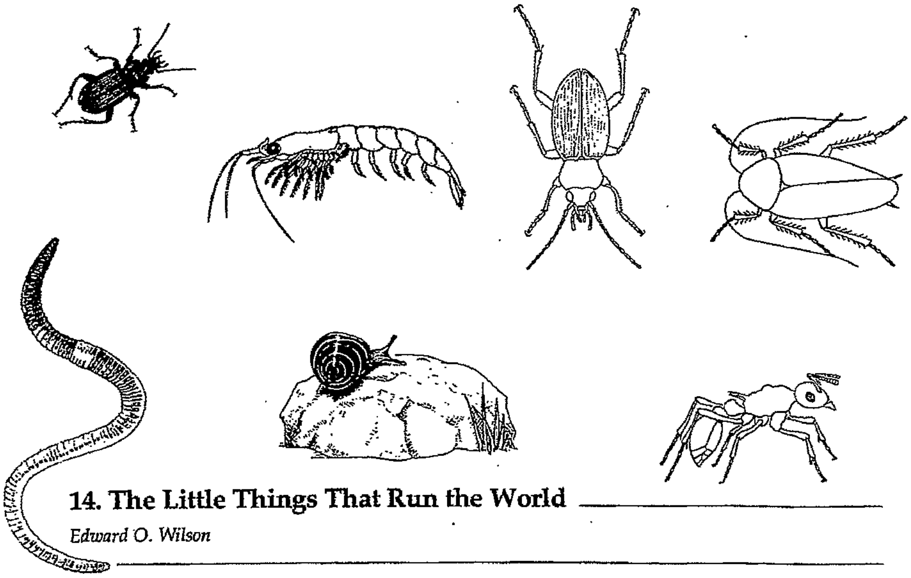
Not long ago, Glenn Wolff and I received two packages of brine shrimp eggs in the mail and emptied them into jars of specially prepared saline solution. Our Sea-Monkeys arrived in luridly and brightly illustrated packages designed for novelty stores. The front of each package depicts a family of cartoon characters sporting buck teeth, knobby heads, and mermaid tails, all grinning like mad and frolicking in front of a submerged castle. "Illustration is fanciful," warns the fine print at the bottom.

Two days later, we could see minute, pale dots lurching through the water. After four days, they had grown large enough to be clearly identified as brine shrimp. At six days Glenn and I got together in his basement studio, picked up one of the larvae with an eyedropper, deposited it onto a slide, and placed it under a microscope. Magnified 150 times, the shrimp filled the lens and we could see its parts in vivid detail: a feathery and gently pulsating leg, a translucent egg sac, a digestive system flowing with bubbling fluids.

Of course, there was nothing simian about the shrimp. Whoever thought of calling it a sea monkey was a marketer not a naturalist. But the old comic-book promises weren't completely empty. Glenn and I took turns looking through the microscope at the brine shrimp, amazed that such a small animal could have such a powerful will to live. Glenn examined it longer than I did. For nearly 15 minutes he sat staring into the microscope. When he finally looked up, his eyes were shining and he was grinning the kind of grin you often see on a 12-year-old boy.

◆

Jerry and Glenn regret to report that Glenn's wife recently threw out his Incredibly Growing Brain (it was grow- ;). Be sure to look for this writer/artist :m's latest collaborative project, The .rd in the Waterfall, *by HarperCollins, which is scheduled to appear in bookstores this summer.*



14. The Little Things That Run the World

Edward O. Wilson

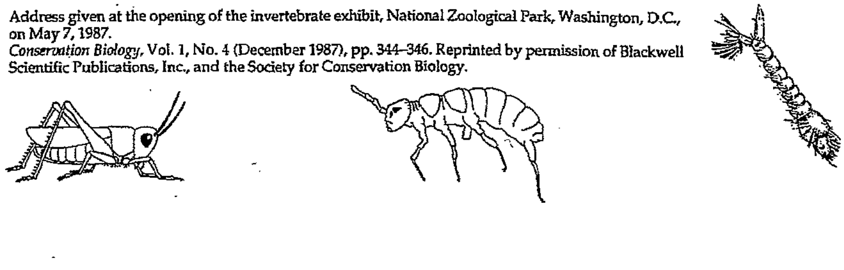
On the occasion of the opening of the remarkable new invertebrate exhibit of the National Zoological Park, let me say a word on behalf of these little things that run the world. To start, there are vastly more kinds of invertebrates than of vertebrates. At the have just completed (from the literature and with the help of specialists), I estimate that a total of 42,580 vertebrate species have been described, of which 6,300 are reptiles, 9,040 are birds, and 4,000 are mammals. In contrast, 990,000 species of invertebrates have been described, of which 290,000 alone are beetles—seven times the number of all the vertebrates together. Recent estimates have placed the number of invertebrates on the earth as high as 30 million, again mostly beetles—although many other taxonomically comparable groups of insects and other invertebrates also greatly outnumber vertebrates.

We don't know with certainty why invertebrates are so diverse, but a commonly held opinion is that the key trait is their small size. Their niches are correspondingly small, and they can therefore divide up the environment into many more little domains where specialists can coexist. One of my favorite examples of such specialists living in microniches are the mites that live on the bodies of army ants: one kind is found only on the mandibles of the soldier caste, where it sits and feeds from the mouth of its host; another kind is found only on the hind foot of the soldier caste, where it sucks blood for a living; and so on through various bizarre configurations.

Another possible cause of invertebrate diversity is the greater antiquity of these little animals, giving them more time to explore and fill the environment. The first invertebrates appeared well back into Precambrian times, at least 600 million years ago. Most invertebrate phyla were flourishing before the vertebrates arrived on the scene, some 500 million years ago.

Invertebrates also rule the earth by virtue of sheer body mass. For example, in tropical rain forest near Manaus, in the Brazilian Amazon, each hectare (or 2.5 acres) contains a few dozen birds and mammals but well over one billion invertebrates, of which the vast majority are not beetles this time but mites and springtails. There are about 200 kilograms dry weight of animal tissue in a hectare, of which 93 percent consists of invertebrates. The ants and termites alone compose one-third of this biomass. So when you walk through a tropical forest, or most other terrestrial habitats for that matter, or snorkel

Address given at the opening of the invertebrate exhibit, National Zoological Park, Washington, D.C., on May 7, 1987.
Conservation Biology, Vol. 1, No. 4 (December 1987), pp. 344–346. Reprinted by permission of Blackwell Scientific Publications, Inc., and the Society for Conservation Biology.



above a coral reef or some other marine or aquatic environment, vertebrates may catch your eye most of the time—biologists would say that your search image is for large animals—but you are visiting a primarily invertebrate world.

It is a common misconception that vertebrates are the movers and shakers of the world, tearing the vegetation down, cutting paths through the forest, and consuming most of the energy. That may be true in a few ecosystems such as the grasslands of Africa with their great herds of herbivorous mammals. It has certainly become true in the last few centuries in the case of our own species, which now appropriates in one form or other as much as 50 percent of the solar energy captured by plants. That circumstance is what makes us so dangerous to the fragile environment of the world. But it is otherwise more nearly true in most parts of the world of the invertebrates rather than the nonhuman vertebrates. The leafcutter ants, for example, rather than deer, or rodents, or birds, are the principal consumers of vegetation in Central and South America. A single colony contains over two million workers. It sends out columns of foragers a hundred meters or more in all directions to cut forest leaves, flower parts, and succulent stems. Each day a typical mature colony collects about 50 kilograms of this fresh vegetation, more than the average cow. Inside the nest, the ants shape the material into intricate sponge-like bodies on which they grow a symbiotic fungus. The fungus thrives as it breaks down and consumes the cellulose, while the ants thrive by eating the fungus.

The leafcutting ants excavate vertical galleries and living chambers as deep as 5 meters into the soil. They and other kinds of ants, as well as bacteria, fungi, termites, and mites, process most of the dead vegetation and return its nutrients to the plants to keep the great tropical forests alive.

Much the same situation exists in other parts of the world. The coral reefs are built out of the bodies of coelenterates. The most abundant animals of the open sea are copepods, tiny crustaceans forming part of the plankton. The mud of the deep sea is home to a vast array of mollusks, crustaceans, and other small creatures that subsist on the fragments of wood and dead animals that drift down from the lighted areas above, and on each other.

The truth is that we need invertebrates but they don't need us. If human beings were to disappear tomorrow, the world would go on with little change. Gaia, the totality of life on earth, would set about healing itself and return to the rich environmental states of a few thousand years ago. But if invertebrates were to disappear, I doubt that the human species could last more than a few months. Most of the fishes, amphibians, birds, and mammals would crash to extinction about the same time. Next would go the bulk of the flowering plants and with them the physical structure of the majority of the forests and other terrestrial habitats of the world. The earth would rot. As dead vegetation piled up and dried out, narrowing and closing the channels of the nutrient cycles, other complex forms of vegetation would die off, and with them the last remnants of the vertebrates. The remaining fungi, after enjoying a population explosion of stupendous proportions, would also perish. Within a few decades the world would return to the state of a billion years ago, composed primarily of bacteria, algae, and a few other very simple multicellular plants.

If humanity depends so completely on these little creatures that run the earth, they also provide us with an endless source of scientific exploration and naturalistic wonder. When you scoop up a double handful of earth almost anywhere except the most barren deserts, you will find thousands of invertebrate animals, ranging in size from clearly visible to microscopic, from ants and springtails to tardigrades and rotifers. The biology of most of the species you hold is unknown: we have only the vaguest idea of what they eat, what eats them, and the details of their life cycle, and probably nothing at all about their biochemistry and genetics. Some of the species might even lack scientific names. We have little concept of how important any of them are to our existence. Their study would certainly teach us new principles of science to the benefit of humanity. Each one is fascinating in its own right. If human beings were not so impressed by size alone, they would consider an ant more wonderful than a rhinoceros.

New emphasis should be placed on the conservation of invertebrates. Their staggering abundance and diversity should not lead us to think that they are indestructible. On the contrary, their species are just as subject to extinction due to human interference as are those of birds and mammals. When a valley in Peru or an island in the Pacific is stripped of the last of its native vegetation, the result is likely to be the extinction of several kinds of birds and some dozen of plant species. Of that tragedy we are painfully aware, but what is not perceived is that hundreds of invertebrate species will also vanish.

The conservation movement is at last beginning to take recognition of the potential loss of invertebrate diversity. The International Union for the Conservation of Nature has an ongoing invertebrate program that has already published a Red Data Book of threatened and endangered species— although this catalog is obviously still woefully incomplete. The Xerces Society, named after an extinct California butterfly, was created in 1971 to further the protection of butterflies and other invertebrates. These two programs are designed to complement the much larger organized efforts of other organizations on behalf of vertebrates and plants. They will help to expand programs to encompass entire ecosystems instead of just selected star species. The new invertebrate exhibition of the National Zoological Park is one of the most promising means for raising public appreciation of invertebrates, and I hope such exhibits will come routinely to include rare and endangered species identified prominently as such.

Several themes can be profitably pursued in the new field of invertebrate conservation:

- It needs to be repeatedly stressed that invertebrates as a whole are even more important in the maintenance of ecosystems than are vertebrates.
- Reserves for invertebrate conservation are practicable and relatively inexpensive. Many species can be maintained in large, breeding populations in areas too small to sustain viable populations of vertebrates. A 10-ha plot is likely to be enough to sustain a butterfly or crustacean species indefinitely. The same is true for at least some plant species. Consequently, even if just a tiny remnant of natural habitat exists, and its native vertebrates have vanished, it is still worth setting aside for the plants and invertebrates it will save.
- The *ex situ* preservation of invertebrate species is also very cost-effective. A single pair of rare mammals typically costs hundreds or thousands of dollars yearly to maintain in a zoo (and worth every penny!). At the same time, large numbers of beautiful tree snails, butterflies, and other endangered invertebrates can be cultured in the laboratory, often in conjunction with public exhibits and educational programs, for the same price.
- It will be useful to concentrate biological research and public education on star species when these are available in threatened habitats, in the manner that has proved so successful in vertebrate conservation. Examples of such species include the tree snails of Moorea, Hawaii, and the Florida Keys; the Prairie sphinx moth of the Central States; the birdwing butterflies of New Guinea; and the metallic blue and golden ants of Cuba.
- We need to launch a major effort to measure biodiversity, to create a complete inventory of all the species of organisms on Earth, and to assess their importance for the environment and humanity. Our museums, zoological parks, and arboreta deserve far more support than they are getting—for the future of our children.

A hundred years ago few people thought of saving any kind of animal or plant. The circle of concern has expanded steadily since, and it is just now beginning to encompass the invertebrates. For reasons that have to do with almost every facet of human welfare, we should welcome this new development.

"Mysterious and little-known organisms live within reach of where you sit. Splendor awaits in minute proportions..."
E.O. Wilson [see: www.xerces.org]

The Great Salt Lake is an inland sea, with a diversity of bird and wild life, shore lines unique to itself, mysterious islands, wide open spaces filled with salt air, sunshine, and of course, the salt water that is the natural environment which supports the life cycle of brine shrimp.

The species of Brine Shrimp that live in the Great Salt Lake, in Utah is *Artemia franciscana*. Aquatic Lifeline, Inc. is in the business of harvesting *Artemia* cysts, commonly known as brine shrimp eggs. The harvest is a seasonal occurrence that usually begins in the month of October each year and lasts until the regulated quota has been harvested. The harvest quantities are closely monitored by the Aquatic Division of the Utah Wildlife Recources. The Brine Shrimp that inhabit the waters of the Great Salt Lake are a mystery, in and of themselves. In some past years, the season has lasted 4-5 months, and has been as short as 27 days.

Brine shrimp are interesting and well adapted to varied environment conditions. Scientists say they can survive in both cold (38 degrees) and hot (106 degrees) water temperatures. The brine shrimp in the Great Salt Lake must tolerate the changing salinity levels (from 7% to 12% or even lower and higher) which are influenced and regulated by the results of high or low water year levels which occur naturally with the weather conditions.

In years past there have been experiments done with different species of Artemia (brine shrimp) that come from different environments throughout the world. They found, that if you take an Artemia egg from, say for the purpose of this writing, Saudi Arabia, and introduce it to the same conditions in which brine shrimp live here in the Great Salt Lake, that this species will take on the same physical characteristics as the species that lives here....or visa versa. So this factor would have us assume that it is possible that the environment in which they live (including different salinities and mineral dissolutions) cause different physical characteristics and account for different species classifications. This is not a proven fact, but food for thought nonetheless.

Ideal conditions: Water temperature = **80° F: Salinity level 12%** or specific gravity 1.022 (aprox. 30 ppt). They eat blue-green algae which grows in the lake naturally.

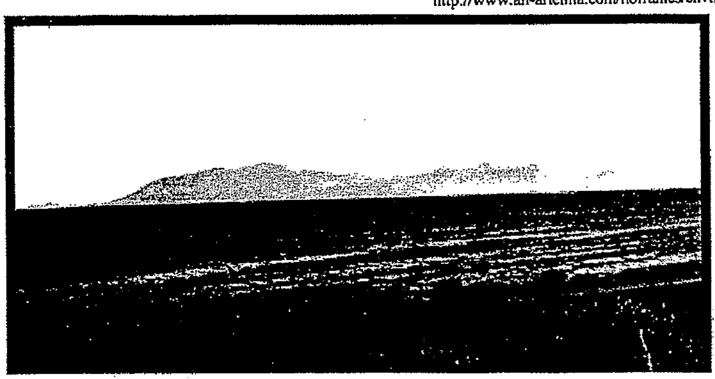
The brine shrimp life cycle is dependent on the naturally occurring and varied environment conditions. They can reach adulthood in as little as 21 days, and begin the reproduction cycle, producing eggs or cysts. Adults may survive and reproduce for several months. The salinity level in the lake changes with the amounts of water received during the spring run off from the mountain snow pack of the year. If Utah receives unusual amounts of heavy snow in the winter, the run-off from the snow melt will drop the salinity level to around 7%, which is the salinity level in the Great Salt Lake this year. If we have a drought year with little or no snow pack, the salinity levels will become higher, 12% or more. If the environment conditions are ideal, the eggs will begin to hatch within 18-24 hrs.

When winter approaches, and the weather temperature drops the lake water temperature to 45 degrees or below, the adults begin to produce eggs rapidly, laying in a natural reserve for the next spring hatches. Then, as the water temperature drops to freezing, the adults die off and the eggs float in the lake waiting for the warmer temperatures of spring to begin the life cycle again.

Freezing temperatures do not harm the eggs. They go into a suspended life form (diapause), and can survive freezing temperatures for long periods of time. We have brine shrimp eggs that have been in our freezing unit for over 15 years that we test occasionally for hatching rate changes and they have maintained the same hatch rate quality during all this time (this is an ongoing and long term experiment for our lab). We have a culture of Artemia in an aquarium in our laboratory that has survived and reproduced itself naturally for a term of 3 years now. So, it is possible to hatch the eggs in a home or school environment and culture them artificially.

Early Morning View of Antelope Island from the South Shore of the Great Salt Lake

http://www.ali-artemia.com/noframes/env.htm



What makes invertebrates cool?

WHY SHOULD WE CARE ABOUT AND CONSERVE INVERTEBRATES?

Invertebrates have intrinsic importance to local & global ecosystems

- More than 95% of all animal species are invertebrates. Invertebrates play key roles in maintaining the integrity, resiliency, and stability of terrestrial and aquatic ecosystems in the natural world. Examples of their ecological roles include involvement in food webs, energy and nutrient transfer, pollination, and decomposition processes. Invertebrates play major roles in ecological interactions such as herbivory, predation, parasitism, competition, and mutualism. Ecosystems are not sustainable without continuing presence of a wide diversity of invertebrates.

Invertebrates have utilitarian value to humans & human activity

- Soil invertebrates enhance soil fertility and, thus, benefit crop production.
- Many invertebrates have many uses and values in commercial markets, such as medicine, pharmaceuticals, agricultural pest management, forestry, household products, jewelry, silk, fish bait, aquaculture, animal food, and human food.
- Many invertebrates have great aesthetic, artistic, and cultural appeal and value to humans because of their unique and pleasing shape, color, symmetry, design, and movement.
- Invertebrates are greatly valued and extensively used as experimental models for many types of basic and applied scientific research, in areas such as physiology, toxicology, and biotechnology.
- Invertebrates have outstanding potential to stimulate student curiosity, involvement, and learning in natural science and biology classrooms.

prepared by C. Drewes
http://www.zool.iastate.edu/~c_drewes/

What on earth is biodiversity?

HERE'S WHAT'S HAPPENING TO BIODIVERSITY *

Today, many species are dying out, or becoming extinct, at top speed!

Why? Mainly because of the "HIPPO dilemma."

Habitat loss
When people cut down forests, dig mines, build cities, or make roads, they destroy habitats - the places where plants and animals live.

Introduced species
Seeds catch on people's clothes. Mice, rats, and birds hitchhike on ships. Snakes stowaway on airplanes. When these species land in new places, they often crowd out the species already there.

Pollution
Acid rain destroys forests. Oil spills kill coastal plants and animals. Poisons wash into waterways. Plastic trash entangles wildlife. It's easy to see how pollution is a big problem for biodiversity.

Population growth
Nearly 6 billion people live on Earth. Each year, we add 90 million more! All these people use resources for food, water, medicine, clothes, shelter, and fuel. This leaves fewer resources for Earth's species and habitats.

Over-consumption
Some people use more resources than others. For instance, one American uses as much energy as 422 people in Ethiopia! People everywhere must learn to reduce, reuse, and recycle Earth's resources.

Adapted with permission from the "The HIPPO dilemma" from WOW! A Biodiversity Primer Educator's Guide published by World Wildlife Fund, ©1994.

Remember the HIPPO!

* Reliable estimates indicate that species are currently becoming extinct at a rate that is about one thousand times faster than the extinction rate has been at any previous time in the history of the world.

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ACKNOWLEDGEMENTS

The following is a tale of my own experiences and explains where they have led me. My story maybe unique to my own self, however, it has a similar pattern to many other people's experiences. I guess the first thing that I want you to know is that I believe my parents to be magnificent people. My father is a horticulturist and holds a true love for the outdoors. My mother is also a brave adventurer, serving our community as a high school math teacher. Together, as young parents, they vacationed every summer when I was growing up. They brought with them, my brother, two sisters and me, as they ventured all over the country. We traveled by van, with my father driving us to cities all over the United States - from Washington to Florida, and just about everywhere in between. Being a large family, we tried to save money by camping, rather than staying in hotels, and at night, we slept in tents or sometimes even in the van.

Thanks to these experiences, I was no stranger to ants, moths, or spiders; however, I cannot say that they were considered friends of mine at the time either. Yuck! So how did I change my opinion from "Gross!" to "Great!"? Well one wonderful thing that my family helped me figure out early on is that the best way to overcome your fears is to face them. And so, as my life progressed and college loomed in my future years I decided to opt for a major in Biology.

Four years at Iowa State University (ISU) was spent not only having fun, but also studying and developing my love for nature and the environment. My courses of research ranged from ecology to evolution, biology to genetics and were spiced with some writing, math and art classes as well. In my senior year, during what I thought would be the final round of my college education, on a whim I decided to enroll in a

class called Insect Biology, taught by Dr. Elwood "Woody" Hart. This was my first "re-introduction" to the world of those taboo creatures that I had sworn off so long ago, and I loved it. Dr. Hart was a true inspiration to me and helped guide me into exploring my newly found excitement through enrolling in more Entomology courses. In spring of 2001 I followed through with three more courses, each focusing on different aspects of insect life. Every professor brought their own unique enthusiasm to the lectures and it had an impact on me. I could see change was on the horizon.

It takes inspiring and distinctive people in our lives to adjust our method of thought and to re-teach us that "life is good" again. Educators are often talented at giving people new perspectives on life. Teachers are not the only ones who are able to open our minds to change, but for myself, two professors (Dr. Elwood Hart and Dr. Thomas Baker) in particular helped me to grow, open up my mind, and to modify my fears.

After obtaining my bachelor's degree, I continued to work at Iowa State University with a job on campus as a lab technician in a butterfly rearing facility. The lab, run by the USDA, allowed me my first opportunity to work with and experiment with insects. I spent nearly a year and a half rearing monarch butterflies for research. It was hard not to fall in love with the little caterpillars and the beautiful orange and black butterflies. Though the summer-time work was exhausting and difficult at times, I also found it to be very interesting. This job also allowed me to keep in touch with activities and faculty in the Entomology Department.

Even with all of my newly found knowledge and interest in the field of Entomology, I realized that I was still holding onto many of my old, and not necessarily accurate, thoughts and terminology. I had learned that not all "insects" are "bugs" but that all "bugs" are "insects". At the time however, this did not matter to me. Back then I called everything a bug and sometimes I still do. Working with the monarchs was an amazing and educational experience, but that did not stop me from smashing a mosquito that landed on my arm or screaming whenever a bee buzzed near my ear. Even with my evolution, some fears stayed with me. I decided to try and pursue more knowledge, more awareness, and more compassion for Entomology.

My next adventure began in 2002 when I was granted the opportunity to work as an intern at the ISU Insect Zoo. Working at the Insect Zoo was a special time, and I was able to truly immerse myself in the life of "bugs." The zoo is a campus/departmental organization that puts together and delivers educational programs regarding Entomology. As an intern I had the opportunity to present programs to schoolchildren, as well as to participate in some of the rearing programs that the zoo had available. Nanette Heginger, a charismatic and ambitious woman, was the coordinator of the zoo when I first began working there. Nanette's responsibilities included managing the inner workings of the zoo, such as the rearing room, in addition to organizing the educational programs that the zoo offered. Not long after beginning work at the zoo, Nanette became a sort of mentor to me and guided my efforts and projects relating to the zoo.

As an intern I was given specific duties. My first task was to create a semester project that would be both useful and enjoyable, and would be put into practice as one of the educational tools the zoo would employ. For this project, I chose to use some of the knowledge I had obtained from Dr. Baker's Insect Behavior class to create a giant insect eye using an umbrella base and polarized lenses. The lenses were inserted to form a specific pattern similar to that of an ant or bee eye. My creation was a success, at least by my standards, and it was displayed during VEISHEA (a campus event held every spring). The second task I was to fulfill as an intern was to perform public programs. This duty was a bit more involved and allowed me to not only travel around Iowa visiting schools all over the state, but it forced me to begin interacting more with the animals in the rearing room.

The rearing room is a home for the zoo insects and arthropods when they are not being used for programs. The first time I set foot in the small, 12 x 12 foot room was a memorable experience for me. As I entered the double quarantined doors, the first thing I noticed was the intense heat. The warmth is important for the insects, as invertebrates are cold blooded and thrive best in an environment that is about 80 degrees Fahrenheit, with high humidity. There was also a lot of activity in the small room. During my initial introduction to the rearing room, four people, each running around and chattering back and forth, greeted me. Then I realized what all of the people were actually doing. They were holding, cleaning and/or feeding big, wiggling, live BUGS! One person had several giant millipedes walking up and down her arms. A worker was holding a rose-hair tarantula, speaking to it in a silly, flirty voice. Another person was peering into a large container, writhing with hundreds of crickets as his friend watched over and caught any of the escapees trying to jump to their freedom. It was intimidating to see all of this activity, but I managed a smile, waved hello, and then quickly moved on to another room, contemplating what I was actually doing at the Insect Zoo.

After a few more visits to the rearing room and a little coaxing and encouragement from the other zoo workers, I began to feel more comfortable handling the live animals. For programs that required travel to a school, I needed to prepare an assortment of animals to go with me. The collection usually consisted of six "child-friendly" arthropods that did not mind being passed around and handled. When I packed my program boxes of arthropods, they usually would include a set of tobacco hornworm caterpillars, super mealworms, bessbugs, Madagascar hissing cockroaches, giant millipedes and Chilean rose hair tarantulas. Each of these animals has a scientific name for reference, but when one is talking with a group of seven to eight year old children who do not speak Latin, it was more practical to use common names. It did not take very long before I felt at ease with the animals, just like the workers I met on my first visit to the zoo.

Over several months of work I really began to enjoy the Insect Zoo. The people were pleasant to work with, the arthropods were terrific fun, and I loved being able to share in the learning process with youth all over Iowa. Typical weeks included visits to at least three schools throughout the region and around ten or fifteen one-hour sessions with students. Traveling to each school meant a lot of time was spent in the car, but it was fantastic to see the state and its wonderful flora and fauna. During my travels I had time to reflect on life and to think about where I wanted to go with my education.

My semester-long internship was quickly drawing to an end however, and I needed to decide on the next step in my educational process soon. It was brought to my attention that the director of the zoo, Dr. Greg Courtney, had an opening for a graduate student to work with him. Dr. Courtney is a dedicated taxonomist who typically does research on species identification. Graduate students working with Dr. Courtney usually collect specimens from locations spanning the globe and then share their findings with the entomological community. At the time though, this idea did not appeal to me, and I began to consider other options. At first, I thought maybe I could explore some of the rearing aspects of the zoo, or possibly try rearing some original invertebrates to use for programming. Instead, Dr. Courtney and I held a meeting and decided to try something new - a fresh opportunity that no one in the department had explored with a masters student yet. We proposed the idea of having the Insect Zoo as the major inspiration for my research and it was well received. I applied for graduate study and was accepted, with my official program of study being Entomology and my research focus on Entomology Education.

The transition between intern and graduate student was easy for me. I continued to work in the zoo, leading school programs, and helping with the rearing of insects. During the fall of 2002 I began to get more involved as I took on additional programs in combination with my class work. I had the opportunity to help design and run new events in hopes to increase awareness and revenue for the Insect Zoo. One of these events was the Fall Hike. This is an annual event held each October at a local park. Children attending are encouraged to dress-up in costumes for a fun (and sometimes spooky) hike on a wooded trail as they listen to an insect themed children's story. Eventually, I also became a collaborator on other projects such as the spring and summer bug camps for local children.

Projects with the Insect Zoo began to take priority in my life and it was fabulous. All of the experiences brought me in contact with teachers as well as other professionals who were seeking more hands-on opportunities in their work. A typical school program consisted of one presenter, Nanette or myself, hosting one-hour "hands-on" sessions with the invertebrates we would bring to show the students. At each of these sessions, children were put into small groups, and then gathered around special mats we brought along with us. Each animal we brought was introduced, as we would discuss its life cycle, trivia facts, and proper handling techniques. As we gave our lectures, children would sit in their groups and be given the opportunity to observe, touch and learn about invertebrate. Teachers would usually be present in the classroom during our visits and would walk from group to group helping when needed. Many post-visit comments showed that teachers gained as much knowledge and had as much fun as the students in their classes.

All of the amazing and fulfilling experiences in the classrooms across Iowa inspired me attempt to do more for teachers. This is where most of the inspiration for my project derived. I never would have been able to even attempt a project of this magnitude, however, without a little help along the way. I have to say thank you to the extraordinary people that deserve a extra appreciation now and every day. Thank you Dr. Baker, Dr. Courtney, Dr. Drewes, Dr. Hart, Dr. Jurenka, Dr. Olson, Abby, Karen, Karmin, Matthew, Molly, Nanette, Rebecca, Mom, Dad, and most of all Nick.