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THE ROLE OF DECOMPOSERS AS RECYCLERS IN THE BIOSPHERE

presented by

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has been accepted towards fulfillment  
of the requirements for

Master of Science degree in Biological Science

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Date July 22, 1994

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**THE ROLE OF DECOMPOSERS AS RECYCLERS IN THE BIOSPHERE**

**By**

**Jill Banner Quinley**

**A THESIS**

**Submitted to  
Michigan State University  
in partial fulfillment of the requirements  
for the degree of**

**MASTERS IN BIOLOGICAL SCIENCE**

**College of Natural Science**

**1994**

**Martin Hetherington**

## ABSTRACT

It has been observed in the teaching of biology that while most students are familiar with the concept of recycling most haven't made the connection that nature is the ultimate recycler and that the earth's resources are finite and must be constantly recycled by decomposers. This observation was the premise for the unit of study that focused on special interrelationships, biodegradation, composting, decomposition and biogeochemical cycling.

It was hypothesized that the sequence of material, different laboratory exercises, demonstrations, and projects would make a difference in the student's understanding of the vital role of decomposers in the biosphere.

## ACKNOWLEDGEMENTS

There are many people who have given support, inspiration, and guidance in the development and writing of this thesis. I would foremost like to thank my family for always being there and filling in during my forays to Michigan the past three summers. I wish to thank Dr. Howard Hagerman, Dr. Martin Hetherington, Dr. Merle Heidemann and the Center for Microbial Ecology at Michigan State University for providing the instructional foundation that made this thesis possible. A special thanks to the National Science Foundation and the Towsley Foundation for their funding and special recognition of teachers.

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## **INTRODUCTION**

In recent years, attention has been focused on the mounting garbage crisis, toxic spills, and nutrient overload in rivers, lakes, and the Chesapeake Bay. As these topics receive increased attention, the need for a basic yet unifying understanding of the vital role of decomposers is evident.

It has been observed in the teaching of biology that while most students are familiar with the concept of recycling most haven't made the connection that nature is the ultimate recycler and that the earth's resources are finite and must be constantly recycled by decomposers. This observation was the premise for this thesis and the foundation for the ensuing three week ecology unit that encompassed interrelationships, biodegradation, composting, syntrophy and biogeochemical cycling.

The principal groups of living organisms based on production and utilization of food materials are:

1. producers which possess photosynthetic pigments that in the presence of sunlight, catalyze the chemical reaction between water and carbon dioxide to form sugars.
2. consumers which ingest producers or other consumers.
3. decomposers which reduce the producers and consumers and the products of their metabolism to the original chemicals from which they were formed.

Whenever an organism dies, its remains are attacked and broken down by decomposers which include many microorganisms, fungi, and soil invertebrates. It is this continual breakdown that produces nutrients and minerals required by the photosynthesizers who constitute the broad base of the energy pyramid.

Microorganisms encompass a vast, diverse group of organisms that include producers and consumers but those microorganisms whose role is decomposition were the focal point of this project.. Additional decomposers emphasized in this project include earthworms, termites and fungi.

Earthworms are extremely efficient decomposers and as vermicomposters they are well equipped to feed on dead plant and animal material encountered as they tunnel through the soil. The acceptance of the great importance of earthworms as decomposers though is relatively recent. Charles Darwin's last book, The Formation of Vegetable Mould, published in 1881, was the first methodical study of earthworms. (Conniff 1992)

It has been estimated that an average acre contains 0.5 Ton of earthworms whereas an acre of rich soil contains 12 T. Earthworms consume 50% of their body weight daily and their waste material, casts, are a rich source of nutrients for producers. (Patent 1978)

One of the most interesting groups of decomposers are the bacteria (spirilli, cocci, and bacilli) and protozoa that are mutualistic in the hindgut of the termite, Reticulitermes flavipes. This type of symbiosis permits termites to live by xylophagy. Other xylophagus organisms include cockroaches and aquatic crane fly larvae (Breznak, 1982).

Fungi are heterotrophic, eukaryotic organisms that do not have the

capacity to produce their own food and are totally dependent on preformed organic matter; they exist as either saprophytes or parasites. Fungi have the ability to secrete exoenzymes into their surroundings; these exoenzymes degrade organic matter that is then absorbed into their structures and reorganized to produce new cellular materials.

The end products of decomposition are known both as humus and compost. Since the dawn of cultivation, farmers have been covering their fields with deteriorated food scraps and manure including human waste but the making of compost as a science was not recognized until the late nineteenth century with the work of Albert Howard, a British agricultural scientist. (Gillis, 1992) It has been found that compost forms in much the same way whether in the woods in a home or in a municipal composting facility. In the presence of sufficient carbon, nitrogen, and water, microorganisms go into a feeding frenzy that generates carbon dioxide and heat and reduces the organic source into smaller and smaller bits and pieces which eventually becomes quite fine textured.

The Environmental Protection Agency has estimated that approximately 65% of municipal solid waste is reusable organic material with paper and paper board making up 40% of the total weight; yard wastes and food scraps together constitute another 25%. Presently 80% of all municipal waste is landfilled with only 10% being recycled (including composting) and 10% being incinerated (Narayan, 1992) but a survey conducted within the two honors biology classes who participated in this unit indicated that 66% of the control group said that they did some type of recycling while 57% of the experimental group said that they did some type of recycling. The rationale for including a student recycling survey is included in the discussion section.

**INSTRUCTION:**

The instruction of this unit incorporated two honor's biology classes; the textbook used was BSCS--An Ecological Approach. It was hypothesized that the sequence of material, different laboratory exercises, demonstrations and projects developed for this unit made a difference in the student's understanding of the vital role of decomposers in the biosphere. The control group was taught in the same manner as in previous years using the sequence of topics and chapters that were specified by BSCS. Lesson plans for the control and experimental groups are included in Appendix A

The first two days of the 1993-94 school year required the standard completion of forms, issuing of textbooks, assigning lab and class supplies, and safety contract review; this unit of study actually began the third day of school for both groups but henceforth will be referred to as Day 1, Day 2, etc.

The experimental and control groups were composed of honors level freshmen and sophomore students at Monacan High School in Richmond, Virginia. The students were generally from middle class homes in suburban Richmond.

No specific criterion was used in designating which class would serve as the control or the experimental group. It was decided that first period would be the control group and second period would be the experimental group; each period met for forty-seven minutes.

Each group completed the Student Survey and the Personal Interview on Day 1. The Student Survey was designed to evaluate the student's feelings regarding science whereas the Personal Interview gave the student the opportunity to identify their interests both in and out of school. The pretest was

given to both groups on Day 2 and on Day 3 both groups wrote the "Rotten Apple Essay" using the following scenario:

It is late August, the days are still hot and the first apples of the season have ripened. You love juicy, crisp apples so you have bought the first apples that appeared in your favorite supermarket but when you take the first bite of one of the apples, it is soft and has some brown spots. You try another with the same disappointing results and another until, in disgust, you throw all of the apples under a tree in your yard. For the next three weeks as you come and go to school you notice the apples.

This essay is to be written about your observations of the discarded apples.

You may be as creative as you wish and you may write as much as you feel is necessary to describe what is happening to the apples.

Day 4 was the point of departure for instructional scheduling for the two groups. The control group continued with Unit One: "The World of Life: The Biosphere" and the experimental group began a three week period of instruction that was composed of labs, projects, and a demonstration that focused on the vital role of decomposers in the biosphere. The experimental group **laboratory excercises** included:

- Pop Bottle Landfill
- Composting exercise
- Winogradsky Columns
- Termite observations on the termite hindgut
- Garden of Microorganisms

The **demonstration** was:

Testing for carbon dioxide production in rotting fruit and vegetables

The **projects** included:

- Trash and Garbage diary
- Building and maintaining a school compost pile

## Worm farm

Details for setting up individual labs used by the experimental group are found in Appendix B.

The trash/garbage diary was a project designed to enable the students to appreciate their role in the garbage crisis. Recent surveys indicate that the average person in the United States discards 1,930 pounds of garbage annually and that the United States heads the list of annual discards with 200,000,000 tons. U.S. citizens discard enough trash to fill the Louisiana Superdome every twelve hours. (Seymore and Girardet 1987)

The Trash Diary was kept for two weeks and included the student and one adult family member. The trash diary assignment included cooperative data from an adult member of the family for several reasons:

- \* team effort would improve family communications
- \* team effort would illucidate the need for *individual* recycling
- \* team effort would establish a school to family relationship
- \* determine if amount of discards varied with age

A record was kept of the type of throwaway, its potential for recycling, and an approximate mass. A list of questions targeting the fate of throwaways followed the two week data collection. Closure included discussion, comments, and a question/answer session the day the diary was collected. It was pointed out to the students during the discussion session that 57% of them had indicated three weeks earlier that they were recycling but when their total mass of throwaways was considered, the E.P.A.'s figures of only 10% of solid waste currently being recycled was close to correct for them.

The beginning of the year list of supplies for the experimental group

included three clean pop bottles and an ample supply of vegetable and fruit scraps from home which were used in setting up the pop bottle landfill and the composting lab. **Objectives** for both labs included:

- \* developing an understanding of the meaning of biodegradation nonbiodegradable.
- \* developing an understanding of why safety precautions and usage of microbial technique must be used in these exercises.

Both exercises enabled the students to draw the parallel between decomposition and composting and to understanding that death and decomposition are only part of the cycle that redistributes earth matter and makes it available again for living matter.

Teacher setup time was minimal for these two laboratory exercises but sufficient time was needed for explaining microbial technique and its importance. A review of pathogens and their transmissions was also included as part of the introduction.

The composting exercise gave the students the opportunity to alter abiotic factors that in turn influenced the rate of decomposition. Four different composting situations were set up and included:

- (1) a compost pile that was never turned
- (2) a compost pile made of grass clippings only
- (3) a compost pile made of leaves, grass clippings, and vegetable scraps with just enough water to keep it moist
- (4) a very wet compost pile made of leaves, grass clippings, and vegetable scraps.

Each station was assigned a composting situation; data were collected every three days for two weeks and shared among the stations.

The association between stench and anaerobic decomposers in the wet

The association between stench and anaerobic decomposers in the wet compost pile was quickly made. The aerobic setups were left for the remainder of the year and served as ecocolumns that the students could observe and refer back to during different discussion sessions. Most of the students were surprised at how quickly the leaves and vegetable matter changed in appearance and were no longer recognizable.

The popbottle landfill laboratory exercise examined the abiotic conditions that are found in an actual landfill with those found in a compost pile. The students used deductive reasoning for making inferences about the two different "landfills" and began the reasoning process that explained why decomposition proceeds at different rates. In this exercise, each partner set up one of the two landfills which were examined after one week; the data was shared between the partners.

The Winogradsky columns were used as an inductive laboratory experience by providing the students the opportunity to formulate concepts through first hand experiences before those concepts were taught or discussed in the classroom. The laboratory handout included a materials and procedure section only. A student log was kept and the columns were examined on a weekly basis.

The Winogradsky columns were used to initiate discussion regarding:

- \* biogeochemical cycling
- \* role photosynthetic bacteria play in providing carbon for nonphotosynthetic bacteria
- \* ecological succession
- \* syntrophy

Rich, dark mud was obtained from a local horse farm. Calcium sulfate

was added as a soluble source of sulfate for the sulfur transformation. Rice and pieces of paper were added to supply the organic material needed for the carbon transformation.

Some of the questions asked during the setup were:

Why is light needed?

Are we going to grow plants?

Will the rice grains germinate?

Why do we need special mud?

During the course of observation several different colored regions were seen in the fourteen tubes set up by the experimental group. The bottom of some of the tubes turned black as the fermenting bacteria produced organic acids that were in turn used by the sulfate reducing bacteria. The sulfate reducers further degraded organic acids to produce hydrogen sulfide which reacted with iron forming the black precipitate. Purple areas indicated the presence of the purple sulfur bacteria. The rust colored areas present in some of the tubes were the result of the purple non-sulfur bacteria which preferred lower concentrations of hydrogen sulfide. White deposits of sulfur and pockets of gas were observed in many of the tubes. Throughout the observations, the students could be heard asking each other reasons for the color changes. Seldom were bacteria mentioned in either group and the follow-up questions revealed the same lack of association.

Termites, Reticulitermes flavipes, were found and brought in by students for the termite lab. Preparations were made using a 0.1M potassium phosphate buffer (pH 7) then examined microscopically in order to observe the diversity of protozoa and bacteria that colonize the termite hind gut. The hindguts were withdrawn from the termite using forceps then immediately placed on a slide

containing a drop of the buffer. The paunch region of the hindgut was pierced with a needle to release the bacteria and protozoa. In Reticulitermes it was relatively easy to see three different species of protozoa: Trichonympha agilis which looked like “rapid swimming fish”, Pyrsonympha vertens which looked like a “snake in a bag” and Dinenympha gracilis which looked like a “hairysnake” and was the smallest of the three protozoa.

This laboratory exercise was ideal for teaching mutualism, introducing anaerobic bacteria, and beginning the nitrogen cycle. Studies have shown that nitrogen fixation in termites is mediated by the bacteria living in the hindgut. (Breznak, 1982).

The post lab discussion revealed that while most students are familiar with the potential destructiveness of termites their ecological significance had been largely overlooked. Termites with their intestinal microbiota are important decomposers of plant litter in the biosphere and in temperate climates their effectiveness rivals even the “large decomposer” groups such as earthworms. (Breznak, 1982).

The ecological significance of earthworms was introduced to the experimental group with the reading aloud of an article found in Mother Earth News that recounted the solution to a frequently clogged toilet in a small corporation in southern California. It was hypothesized by the owner that toilet tissue was the culprit in stopping the drain therefore no more tissue would be flushed; instead, it would be placed in a 10-gallon hamper along with a generous supply of earthworms and garden soil. This procedure continued for four years with huge success. (Nyerges 1991)

After a brief discussion and question/answer time, the experimental group was introduced to their new worm bin which had been ordered from Mary

Appelhof in Kalamazoo, Michigan. Newspaper was given to each student with the instructions to shred it into narrow strips; this along with soil would be used as bedding for the two pounds of redworms that would live in the bin. The bin was filled half way with alternating two inch layers of newspaper and soil. Enough water was added to moisten the mixture then the redworms were placed in the bin. The students were asked to bring vegetable scraps from home to feed to the worms. The bin was to be examined on a monthly basis.

This project introduced vermicomposting which is the process of using earthworms and microorganisms to convert organic waste into black, earthy-smelling nutrient humus. It provided hands-on experience that reinforced the concept of decomposition and led to an unexpected and unplanned class project.

The class was so enthusiastic about bringing in vegetable scraps for the worm bin that it became evident after two weeks that there were more scraps and materials than the worms could eat. During class discussion regarding the overabundance of scraps, several students commented that they couldn't just throw the scraps away. One voice said, "Why don't we compost it?" and almost in unison the class replied, "Yes." More discussion ensued and it was decided that one of the students would seek permission from the school administration to set up a compost pile outside the classroom for not only their vegetable scraps but for the vegetable scraps from the school cafeteria. Permission was granted from the principal and a student volunteer began picking up the cafeteria scraps after the last lunch.

The compost pile was maintained for the duration of the school year and was checked periodically. The students were able to compare the rates of decomposition in the winter with the spring and were constantly commenting

about the absence of odor.

The garden of microorganisms lab was designed as an exploratory lab that would enable the student to differentiate between fungal and bacterial growth. Finger bowls of six different food specimens were covered with a glass plate then observed for a week. Included in the specimens were dog food, fruit, home baked bread, and cream cheese. Observations made with the stereoscope soon revealed growth of a slimy material unlike the cottony appearing mold growth. The post lab questions were designed so that the inferences and comparisons would help in identifying the slimy appearing growth on the dog food.

The two day demonstration was done as closure for the decomposition unit. A 500 mL Erlenmeyer flask was half filled with rotting apples and stoppered with a one hole rubber stopper fitted with a U-shaped piece of glass tubing. A beaker of clear saturated calcium oxide solution was positioned on a ring stand so that the other end of the U-tube was submerged. A second beaker containing the clear saturated calcium oxide solution was left open and exposed to air and served as the control. The equipment, an explanation of a closed system and the name of the calcium oxide solution were included for the class and anticipatory questions such as "What might be the purpose of the solution?" and "Why is a closed system needed?" were asked.

The second day, the class was shown the effects of bubbling into a beaker of clear calcium oxide solution which produced a cloudy white precipitate of calcium carbonate. The beaker was set aside until the latter part of the period at which time it was examined and compared with the experimental beaker and the control. The experimental beaker had a layer of white precipitate on the bottom while the control had no layer of precipitate but

did have a few flakes of white scum floating on the top of the solution. The class discussion immediately concluded that the white precipitate formed by bubbling was the result of carbon dioxide and appeared the same as the precipitate in the experimental beaker.

## EVALUATION

Evaluation of this project was determined by using a pretest and posttest, essays, attitude surveys, a personal interview and an exit survey.

The personal interview (Appendix C) gave the student the opportunity to indicate in and out of school interests and the data found in Table 1 below revealed some interesting differences in the two groups.

**Table 1. RESULTS OF PERSONAL INTERVIEW**

|                                            | Groups         |                     |
|--------------------------------------------|----------------|---------------------|
|                                            | <u>CONTROL</u> | <u>EXPERIMENTAL</u> |
| Number of students                         | 22             | 28                  |
| Science given as favorite academic subject | 50%            | 60%                 |
| Read in spare time                         | 13%            | 50%                 |
| Would like to visit a research laboratory  | 77%            | 91%                 |

The Student Survey (Appendix C) was a science attitude survey given to both groups at the beginning and the end of the school year. The survey used bipolar adjectives that were used to develop a scale referred to as a semantic differential instrument. (Collette and Chiappetta 1989). Responses were ranked on a numerical scale of 1 to 7 with 1 being never and 7 being always. The mean score for the pre-control survey was 4.4 and the pre-experimental mean was 4.6 indicating a positive feel about science which did increase during the

year . This increase is reflected in the mean score of 5.4 for the post control survey and the mean of 5.1 for the post experimental survey.

The pretest was given to both groups at the beginning of the school year; the post test was given upon completion of the study of decomposers.

Completion for the experimental group was at end of the first month of the school year and the control group completion was at the end of the first month of the second semester. The pretest was used as a diagnostic tool to determine the level of student knowledge and the means for both groups indicated that they had essentially the same prior knowledge. The pretest and posttest contained the same eighty-two questions pertaining to decomposers, composting, and biogeochemical cycling. A multiple choice and true/false format was used to test cognitive levels of knowledge, comprehension, and application. The student's t statistic was used to determine if the observed differences between the means of the two groups were statistically significant. The research hypothesis states that the sequence of material, different laboratory exercises, demonstrations, and projects would make a difference in the student's understanding of the vital role of decomposers in the biosphere. The null hypothesis states that the sequence of material, different laboratory exercises, demonstrations, and projects would not make a difference in the student's understanding of the vital role of decomposers in the biosphere. The t indicated that there was no significant difference in the performance of the two groups on either the pretest or the posttest. Data for the pretest results are given in Table 2 and posttest results are found in Table 3:

Table 2: RESULTS OF PRETEST

---

|                        | Groups                |                     |
|------------------------|-----------------------|---------------------|
|                        | <u>Control</u>        | <u>Experimental</u> |
| Number of students     | 21                    | 25                  |
| Total number questions | 82                    | 82                  |
| Mean                   | 43.71                 | 45.92               |
| Standard deviation     | 8.0                   | 4.8                 |
| Variance               | 63.71                 | 22.83               |
|                        | $t_{obs} = 1.16$      |                     |
|                        | $t_{.05, 44} = 2.021$ |                     |

The calculated  $t$  of  $1.16 < 2.021$  and is not significant at the 0.05 level therefore there is not a statistical difference in the pretest scores of the control and experimental groups.

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The results of the pretest indicated that there was not a significant difference in the understanding of the two groups.

Table 3: RESULTS OF POSTTEST

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|                        | <u>Control</u> | <u>Experimental</u> |
|------------------------|----------------|---------------------|
| Number of students     | 24             | 28                  |
| Total number questions | 82             | 82                  |
| Mean                   | 53.56          | 56.04               |
| Standard deviation     | 8.0            | 6.8                 |
| Variance               | 64.67          | 46.12               |

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$t_{obs} = 1.17$

$t_{.05, 50} = 2.0$

The calculated  $t$  of  $1.17 < 2.0$  and was not significant at the 0.05 level. Because the calculated value of  $t$  was not significant, the null hypothesis was let stand and the research hypothesis that the experimental group would have higher scores was not supported.

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Because there was no statistical difference in the posttest of the two groups overall and it was felt by the researcher that class discussions had indicated a difference in understanding within the groups, the pretest/post questions were carefully scrutinized then divided into specific areas that included composting, decomposition, methanogens and biogeochemical recycling. A  $t$  test was applied to each of the specific areas and it was determined that there was a significant difference in the performance within each of the four areas (Appendix D). Results for the correct responses in these specific areas are given below in Table 4:

**Table 4 RESULTS OF SPECIFIC QUESTIONS RELATING TO COMPOSTING, DECOMPOSITION, METHANOGENS, AND BIOGEOCHEMICAL RECYCLING**

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**Questions 1, 54, 56, 22t/f relating to composting:**

|                    | <u>Control</u> | <u>Experimental</u> |
|--------------------|----------------|---------------------|
| number of students | 20             | 27                  |
| mean               | 13.5           | 21                  |
| standard deviation | 6.2            | 4.5                 |
| variance           | 39             | 20.7                |

**Questions 39,55, 58, and 20, 23 t/f relating to decomposition:**

|                    | <u>Control</u> | <u>Experimental</u> |
|--------------------|----------------|---------------------|
| number of students | 20             | 27                  |
| mean               | 7.8            | 18.4                |
| standard deviation | 6.4            | 6.3                 |
| variance           | 40.7           | 39.3                |

**Questions 27, 29, 4t/f relating to methanogens:**

|                    | <u>Control</u> | <u>Experimental</u> |
|--------------------|----------------|---------------------|
| number of students | 20             | 24                  |
| mean               | 13.5           | 21                  |
| variance           | 39             | 20.7                |
| standard deviation | 6.2            | 4.5                 |

**Questions 34, 42, 13, 16, and 21 relating to biogeochemical recycling:**

|                    | <u>Control</u> | <u>Experimental</u> |
|--------------------|----------------|---------------------|
| number of students | 20             | 27                  |
| mean               | 12             | 17.8                |
| variance           | 18.5           | 15.7                |
| standard deviation | 4.3            | 4.0                 |

The student's t statistic was used to determine if the observed differences between the means of the two groups for each specific group of questions were statistically significant (Appendix D.) and it was determined that there was a

statistical difference in the correct responses when broken down into the specific areas of composting, decomposition, methanogens, and biogeochemical recycling.

The Rotten Apple Essay was evaluated by counting the number of terms used by the students that were indicative of an understanding of decompositions. A complete listing of those terms used in the pre- and post essays are given in Appendix D. The post results from the rotten apple essay indicated a significant difference in the number of relevant terms used by the experimental group. A comparison of the means, variances, and standard deviations for the number of relevant terms used in the post essay are given below in Table 5:

**Table 5: NUMBER OF RELEVANT TERMS USED IN POST ESSAY  
INDICATING UNDERSTANDING OF DECOMPOSITION**

|                    | <u>Control</u>    | <u>Experimental</u> |
|--------------------|-------------------|---------------------|
| Mean               | 4.2               | 6.5                 |
| Standard deviation | 1.7               | 2.1                 |
| Variance           | 2.9               | 5.8                 |
|                    | $t_{obs} = 3.9$   |                     |
|                    | $t_{.05, 49} = 2$ |                     |

The  $t$  indicated that there was a statistical difference in the performance of the two groups.

Exit interviews were given to a select number of students in each group to assess attitudes regarding the course of study. Answers were selected from five different subject areas studied during the year. Those areas included

animals, plants, decomposers, genetics, and cells.

An overview of results relating to decomposition are reported as percentages and are found below in Table 6. A complete listing of the percentage responses for each of the five areas can be found in Appendix D. The individual comments are included in Table 7.

**Table 6: EXIT SURVEY RESULTS**

|                                                                   | <u>Control</u> | <u>Experimental</u> |
|-------------------------------------------------------------------|----------------|---------------------|
| Number of students                                                | 18             | 18                  |
| Learned most in area of decomposition                             | 11%            | 14%                 |
| Ranked decomposition labs as most helpful                         | 5%             | 20%                 |
| Experienced a positive change in attitude regarding decomposition | 77%            | 85%                 |

**Table 7: STUDENT'S COMMENTS REGARDING DECOMPOSITION:**

**Control group:**

I never knew how things decomposed until this year.  
 I understand now how helpful it is to our environment  
 There is more to decomposition than I once thought.  
 Now I recycle because I see how easy it is and understand that  
 decomposition doesn't take very long if you do it right.

**Experimental group:**

I know now how bacteria do it--it is nature's way

I know what's actually happening and I can respect the bacteria more.

My attitude has definitely changed. Before I thought it was disgusting but now I know its a natural recycling thing.

I understand more clearly the natural cycle of nutrients and materials plus the need for decomposers.

I used to think all fungi and bacteria were gross and bad but I have gained a respect for decomposers. I am trying to persuade my friend's mom to have a compost pile in her flower bed.

I still think it looks gross but I do realize the importance and am amazed at nature's built in recycling program.

---

## **DISCUSSION AND CONCLUSION:**

This unit on the role of decomposers in the biosphere was enjoyable to teach and was openly accepted by the students in the experimental group. The laboratory exercises were instrumental in conveying the key concepts regarding decomposition.

The termite laboratory exercise was particularly effective for introducing protozoa and teaching symbiosis. The prodigious number of protozoa observed in this exercise impressed the experimental group much more than the purchased paramecia, euglena, etc. used later in the protist chapter. The post lab discussion tended to be more oriented in identifying the different species but with redirection was effective in teaching interrelationships and introducing the nitrogen cycle.

The carbon dioxide demonstration provided an opportunity for drawing inferences regarding gases released during decomposition. The student response to this demonstration was great enough that this instructor was encouraged to use it in her chemistry classes as well. The Winogradsky columns were also used in the chemistry classes to illustrate redox reactions. These chemical connections are particularly important for both biology and chemistry students and this project provided many opportunities to bridge the gap that unfortunately has formed between those two disciplines.

The worm bin and the compost pile were particularly enjoyed by the students but the worm bin presented an unexpected problem--fruit flies. Initially, the bin was kept in the class room but when the fruit flies became more

numerous than the students, it was moved outside. Going outside to check on the worms or the compost pile were favorite activities of the experimental group and provided numerous observations that led to some outstanding discussion sessions.

Improvements need to be made in the composting laboratory exercise. The pop bottles were insufficiently insulated and should be replaced with styrofoam containers; the students also experienced difficulty in setting up a data table for this exercise. In the pop bottle landfill lab, it was difficult to make adequate observations by just looking through the plastic bottle and in the future, the bottles will be opened and the contents examined using forceps and probes. The pretest/posttest also needs to be reworked. The overall test should be abbreviated, more conceptual questions should be added, and superfluous terminology needs to be removed.

A few of the students indicated on the exit survey that there were too many overlapping observations being made with the composting lab, pop bottle landfill, Winogradsky columns, and garden of microorganisms but the nature of these labs required a prolonged observation time and overlap was inevitable.

One of the difficulties encountered was maintaining controlled classroom conditions for the control group. Both groups met in the same classroom and all of the laboratory exercises conducted by the experimental group required several days of observation therefore the set-ups were always present when the control group met. Both groups were highly motivated and many questions were asked by the control group regarding the lab set-ups and discussion frequently occurred between members of the two classes. There was considerable indignation expressed by the control group because they did not have a compost pile or a worm bin.

The Winogradsky columns were particularly effective for forming hypotheses and interpreting data, however, comments from the exit interviews indicated that a few of the students felt that the columns were not that effective because there were not immediate observable results. It was pointed out to these students that actual research often requires observations to be made over a long period of time. These comments were interpreted as being the result of a “cookbook” approach employed by many laboratory manuals.

Although there was not a significant difference in the overall performance of the two groups on the posttest evaluation, those conceptual areas of decomposition, methanogens, composting and biogeochemical cycling did show a significant difference. All other areas of evaluation showed a significant difference in performance between the control and experimental groups. It is because of the success of this unit that future biology classes will be taught in the same manner as the experimental group.

It is concluded that the research hypothesis stating that the sequence of material, different labs, demos, and projects would make a difference in the student's understanding of the vital role of decomposers is statistically supported by the data generated from this project.

## APPENDIX A

## TIMELINE WITH OBJECTIVES FOR EXPERIMENTAL AND CONTROL GROUPS

| DAY                                                                                                                                | EXPERIMENTAL GROUP                                        | CONTROL GROUP                                                           | OBJECTIVES                                                             |
|------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|-------------------------------------------------------------------------|------------------------------------------------------------------------|
| 1                                                                                                                                  | Survey I and Personal Interview                           | Survey I and Personal Interview                                         | Evaluate feelings toward science                                       |
| 2                                                                                                                                  | Pretest                                                   | Pretest                                                                 | Assess prior knowledge                                                 |
| 3                                                                                                                                  | Rotten Apple Essay                                        | Rotten Apple Essay                                                      | Evaluate prior knowledge of role of decomposers                        |
| <i>Control continued with Unit I and did not study decomposers until second semester. Following schedule was used at that time</i> |                                                           |                                                                         |                                                                        |
| 4                                                                                                                                  | Trash Diary                                               | Water Diary                                                             | Calculate individual's impact on ecosystems                            |
| 5                                                                                                                                  | Compost lab                                               | Video, "Leaf Composting"                                                | Draw parallel between composting and decomposition                     |
| 6                                                                                                                                  | Pop Bottle Landfill lab                                   | Video: "Solid Waste Disposal Alternatives"                              | Identify which types of garbage are biodegradable and nonbiodegradable |
| 7                                                                                                                                  | Termite lab                                               | Introduce archaeobacteria                                               | Hypothesize roles of symbiotic organisms                               |
| 8                                                                                                                                  | Discuss different microbial roles observed in termite lab | Review archaeobacteria                                                  | Determine microbial interrelationships                                 |
| 9                                                                                                                                  | Lab: Winogradsky Columns                                  | Discuss mineral cycles                                                  | Interpret biogeochemical cycling                                       |
| 10                                                                                                                                 | Project: Worm bin                                         | Read article, "On the Lowly Worm We Earthlings Pin Our Loftiest Dreams" | Demonstrate vital role of earthworms as decomposers                    |
| 11                                                                                                                                 | Garden Microorganism lab                                  | Distribution of Microorganisms lab                                      | Utilize and understand the need for microbial technique                |

| <b>DAY</b> | <b>EXPERIMENTAL<br/>GROUP</b>                                            | <b>CONTROL<br/>GROUP</b>                                                       | <b>OBJECTIVES</b>                                                              |
|------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 12         | Examine Popbottle<br>Landfill                                            | Read article then write<br>essay on "To Rot or<br>Not"                         | Identify abiotic factors that<br>accelerate or retard<br>decomposition         |
| 13         | Trash Diary due. Discussion<br>on results; tie in with Pop<br>Bottle lab | Discuss landfill<br>construction                                               | Reinforce impact of abiotic<br>factors on decomposition                        |
| 14         | Observations: Garden<br>Microorganisms lab                               | Observations:<br>Distribution of<br>Microorganisms lab                         | Distinguish between microbial<br>and fungal growth                             |
| 15         | Demo: Carbon Dioxide<br>production during<br>decomposition               | Discuss carbon cycle                                                           | Show that carbon dioxide is<br>released during decomposition                   |
| 16         | Project: School compost<br>pile; conclude Garden<br>Microorganisms lab   | Review roles of<br>decomposers;<br>conclude Distribution<br>Microorganisms lab | Compare and contrast myriad<br>roles of microbes                               |
| 17         | Posttest                                                                 | Posttest                                                                       | Evaluate effectiveness of<br>different approaches in teaching<br>same concepts |

**APPENDIX B: EXPERIMENTAL GROUP EXERCISES**

**TERMITE LAB**

**WINOGRADSKY COLUMN**

**TRASH AND GARBAGE DIARY**

**COMPOSTING LAB**

**A GARDEN OF MICROORGANISMS LAB**

**POPBOTTLE LANDFILL LAB**

## TERMITE LAB

Microscopic examination of the hindgut microbiota of termites is a fascinating experience. Motile microorganisms including numerous sizes and shapes of both bacteria (bacilli, cocci, spirilla, and spirochetes) and flagellated protozoa are readily discernible at 400X. The hindgut is an anaerobic environment therefore most of the microorganisms found there are anaerobes. It is this anaerobic environment that requires the use of a specially made phosphate buffer.

### MATERIALS:

Termites--Reticulitermes flavipes  
Ice container  
Light microscope  
Forceps  
Microscope slides  
Coverslips  
Anaerobic buffer  
Distilled water

Dissection of termites: R. flavipes is a cold-blooded animal and the easiest method of inactivating them without harming their microbiota is to place a small container with these insects on ice. Within five minutes the insects will be immobile. Once inactive, the intestinal tract of the insect can be removed by using fine tip forceps, grasping the anterior and posterior end of the termite and pulling. The dissected gut will remain intact until punctured or squashed.

Microscopic observations. Add a drop of buffer to a microscope slide then immediately add the termite gut and coverslip. The coverslip should be depressed slightly to burst the gut tract. Observe first with low power then with high power. Drawings should be made on high power.

**Analysis:**

1. Are all of the microorganisms motile?
2. Give three ways you can distinguish between the different microorganisms.

3. Do you think that the termite could live without these microorganisms.

Substantiate your answer.

4. Using your understanding of symbiosis, which form is exhibited in the termite gut?

Explain why.

5. Why was the buffer solution used?

6. In the space below draw at least four different types of microorganisms observed.

Carefully analyze the data then write a conclusion on the back for this lab.

## **The Winogradsky Column**

### **MATERIALS:**

large test tube  
black mud from an area rich in organic material  
calcium sulfate  
organic material to be decomposed (rice, newspaper, vegetable matter)  
lamp with incandescent bulb but without shade

### **PROCEDURE:**

1. Prepare a slurry consisting of four parts black mud, one part calcium sulfate, and a small amount of dechlorinated water.
2. Add approximately one teaspoon rice and bits of other organic material to the test tube. Avoid trapping air bubbles. Add water to within 1 cm. of top of test tube.
3. Cap test tube loosely with aluminum foil and place about a foot from a 60W incandescent bulb.
4. Incubate at room temperature, checking periodically to see that the water has not evaporated. It usually takes 2-4 weeks for changes to become obvious. Record weekly observations of changes that occur on data sheet.
5. Wash hands and clean lab area.

## TRASH AND GARBAGE DIARY

### Directions:

You and one adult member of your family are to each keep a diary of all your daily discards for two weeks. You are to list each item(s) and then **approximate** the weight for these at the end of each day. Kitchen scales are useful for small items and bathroom scales could be used for the larger items, such as, grass clippings.

Some of the items that you must include are:

- junk mail
- daily newspapers
- discarded notebook paper and pencil shavings
- any type of tissue
- any type of food container
- all kitchen scraps
- any meal leftovers
- yard wastes such as grass trimmings, branches, or leaves
- packaging materials

Obtaining and recording accurate data is a vital part of science. The following sample data may be helpful as you set up your diary:

|        | ITEMS                                                                                                                                                                                                                                                                                                                                                                                                                          | APPROXIMATE WEIGHT |
|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| DAY 1: | 4 tissues<br>small orange juice carton<br>2 small milk cartons<br>lunch bag<br>1 Snickers bar candy wrapper<br>1 newspaper<br>1 unwanted mail order catalogue<br>approximately 1 bushel grass clippings<br>2 cat food cans<br>3 sheets of notebook paper<br>food leftovers from lunch and dinner:<br>about 1/2 slice of bread<br>1 tablespoon of peas<br>fat trimmings from steak<br>several pieces lettuce and onion in salad | 6 pounds           |

*Since an adult member is helping you with this project, it would be*

*helpful for you to show them how you want the data collected and recorded.*

At the end of the two week period, review both sets of data and answer the following questions:

1. Which throwaway(s) produced the greatest weight (mass)?
2. Make a list of all the throwaways that could be recycled.
3. List the throwaways that will go to the landfill.
4. Explain what you think will happen to the throwaways once they are in the landfill.

**Both diaries and questions with answers will be turned in at the end of two week**

## COMPOSTING

**INTRODUCTION:** Composting is a natural biochemical process that converts once living organic material to humus. Living microorganisms like bacteria and fungi feed on material such as food scraps, leaves, grass and twigs thereby breaking it down. This is the biochemical process that results in humus formation. Humus is soil that is rich in soil nutrients and organic matter vital to plants grown in the soil.

An ideal soil contains 45-50% minerals, 25% air, 25% water, and 2-5% organic matter. The production of humus helps to assure that these percentages of materials are maintained in the soil. Furthermore, humus helps control weeds, prevent erosion, prevent rain runoff and decrease evaporation of water from soil thus leaving more water available for plants.

The lab will demonstrate how relatively easy it is to compost as long as a few proper conditions are maintained. Turning the compost every few days provides oxygen for the aerobic conditions needed by most bacteria. Some bacteria, however, prefer no oxygen and are called anaerobes. These are the bacteria responsible for producing the unpleasant smelly odors of hydrogen sulfide and ammonia.

In addition to aerobic or anaerobic conditions, all organisms need a certain amount of moisture. If you have too much water you will have more of the bacteria that produce odors because the water takes the same little spaces that hold oxygen in your compost. If your composting material feels like a damp sponge, you have added the correct amount of water.

Also needed is a proper pH range. pH is an expression of how acidic or alkaline your material is and ranges numerically from 0-14. A pH of 7 is neutral, a pH less than 7 is acidic, and a pH greater than 7 is alkaline. Fresh leaves usually have a pH of 7 but as your materials decompose, more acids are produced and the pH will become lower. If too little oxygen is present, more acids will be present, therefore a low pH may indicate lack of oxygen.

In this lab you will be composting leaves, grass, twigs, soil and vegetable scraps and observing changes in temperature, pH, moisture content, and appearance under different environmental conditions.

**HYPOTHESIS:** From the information above, form a hypothesis for each situation:

1. A compost pile that is never turned.
2. A compost pile composed of grass clippings only.
3. A very wet compost pile.

**MATERIALS:** Insulated coolers or very large styrofoam cups  
pH paper  
thermometers

leaves, grass clippings, twigs, rich garden soil, vegetable scraps  
distilled water  
tweezers  
50 ml. graduated cylinder  
trowels

**CAUTION:** Adding just the right amount of water to groups 1, 2, and 3 is very important. The composting material should feel like a damp sponge with no water standing in the bottom of the container. Should the composting material dry out during the course of the lab, additional distilled water can be added. Do not handle compost with hands.

**PROCEDURE:**

- Group 1:**
1. In large insulated container, place leaves, grass clippings, twigs, soil, and vegetable scraps. Mix.
  2. Add enough distilled water to make it feel moist.
  3. On third day, insert thermometer into middle compost pile and leave approximately five minutes. Take reading then thoroughly mix.
- Group 2:**
1. In second insulated container, place grass clippings only.
  2. Add enough distilled water to make it feel moist.
  3. On third day, insert thermometer into middle of compost pile and leave approximately five minutes. Take reading then thoroughly mix.
- Group 3:**
1. In an insulated container, place leaves, grass clippings, twigs, soil, and vegetable scraps. Mix.
  2. Add enough water to make it feel moist.
  3. On third day, insert thermometer into middle compost pile and leave approximately five minutes. Take reading but do not turn compost.
- Group 4:**
1. In an insulated container, place leaves, grass clippings, twigs, soil, and vegetable scraps. Mix.
  2. Add an excess of water to compost pile so that water fills half of container.
  3. On third day, insert thermometer into middle of compost pile and leave approximately five minutes. Take reading then thoroughly mix.
- All Groups:**
1. Observe the initial volume of contents then note carefully to see if any volume change has occurred each time you examine contents.

2. Record initial temperature of contents, as well as the temperature each time observed.
3. Using pH paper, measure the pH each time the contents are examined.

## DATA

Construct a data table for each of the four groups with heading for pH, temperature, appearance, and other observations. Data is to be collected every three days and shared among the groups.

## QUESTIONS

**Note:** Data from all four groups will be needed before answering the questions.

1. Did each compost pile increase or decrease in size? Give an explanation.
2. Did the temperature increase or decrease in each compost pile during the course of the lab? Give an explanation.
3. Identify the pH range as alkaline or acid for each compost pile and describe any changes that occur.
4. What were the effects of limiting the material to grass clippings?
5. What were the effects of NOT turning the compost over?
6. What were the effects of adding too much water?
7. Where do the bacteria and fungi observed in this lab come from?
8. What conditions are necessary for successful aerobic composting?

## CONCLUSION

Carefully analyze the data collected. Accept or reject your chosen hypothesis on the basis of the class data. Be sure to explain acceptance or rejection of the hypotheses on the basis of observable and tabulated data.

### **A Garden of Microorganisms**

The purpose of this lab is to observe different types of microorganisms growing on different media. Each of the culture dishes are covered and are to remain so during the course of the observations. Each station has a culture dish and stereoscope and can be observed in any order.

Five observations will be made on every other day. Be specific with your observations.

| General Appearance | Color | Size | Appearance<br>with stereoscope | Additional<br>comments |
|--------------------|-------|------|--------------------------------|------------------------|
| 1.                 |       |      |                                |                        |
| 2.                 |       |      |                                |                        |
| 3.                 |       |      |                                |                        |
| 4.                 |       |      |                                |                        |
| 5.                 |       |      |                                |                        |
| 6.                 |       |      |                                |                        |

#### **QUESTIONS:**

1. Do all of the organisms have the same general appearance?
2. Which type of growth, according to general appearance, was most often observed?
3. Did all of the organisms appear the same color.?
4. Which color was most often recorded?
5. Do all the bowls have only one type of growth?
6. If not, identify the bowls and the different types of growth.

7. Which bowl had the greatest variety of growth?
8. Was the general appearance always the same when described macroscopically as when described with the use of the stereomicroscope?
9. Support your answer in #8 with specific examples.
10. Did you record any characteristics other than general appearance, color, and size?
11. List those additional characteristics.
12. What was the food source for the organisms in this lab?
13. What effect did the growing organisms have on the media?
14. In review of this lab, list five ways in which microorganisms observed may differ from one another.
15. Name two substance released through decomposition.
16. How did the growth on the dog food differ from the growth on the orange?

**CONCLUSION:**

## **POPBOTTLE LANDFILL**

**TO THE STUDENT** One of the purposes of this laboratory exercise is to develop an understanding of the scientific method and an appreciation of its practical applications to everyday problem solving.

**INTRODUCTION** Solid waste disposal is reaching crisis proportions in many communities. Our throw away mentality, as well as our increased use of nonbiodegradable plastics and other synthetics, has substantially increased our solid waste output. It has been estimated that the average American produces four to six pounds of garbage per day. This volume, coupled with the increasing toxicity of the garbage, makes landfilling more technically challenging than ever before.

Siting of landfills has become a volatile issue and the acronym NIMBY (not in my backyard) reflects the feelings of most U.S. citizens. Public concern is focused on esthetics, odors, ground water contamination and pestilence. New methods of disposal are needed to address our current and future waste streams which are composed by biodegradable and nonbiodegradable materials.

Biodegradable materials can be broken down into simpler substances by bacteria and other decomposers but in modern landfills this can take decades. Nonbiodegradable materials are not broken down by biological organisms and include plastics, aluminum, and many chemicals used in industry and agriculture.

Scientists must address the effects on the environment, as well as, the economic impact of handling our wastes. In this investigation, the student will study some of the characteristics of their waste stream and the problems associated with its disposal.

Two simulated landfills will be constructed: one using garden soil and the other using sand. Both landfills will contain discarded food samples and discarded food packaging samples and they both will be left at room temperature.

**HYPOTHESIS** Write three hypotheses for this lab.

**MATERIALS**

2 - 2 liter pop bottles  
garden soil  
scissors  
tweezers  
distilled water  
graduated cylinder  
wax-pencil or permanent marker  
metric ruler  
trowel  
discarded food samples, i.e., vegetables and fruits but **ABSOLUTELY NO MEAT!!**  
discarded food packaging samples  
shallow pan  
sand

**CAUTIONS**

1. Hands should be washed before and after this lab with soap and water.
2. **ABSOLUTELY NO FOOD OR DRINK IN THE LAB AT ANY TIME DURING THE COURSE OF THIS LAB.**
3. Lab area should be wiped with a 10% bleach solution before and after setting up the lab and before and after examining contents.
4. Use a wafting technique for detecting odors.
5. Lab area should be uncluttered with **NO** books, pens, etc.
6. Special care should be used when cutting the pop bottles. Plastic, as well as scissors can cause cuts.
7. At the completion of the lab, dispose of all materials as directed by your teacher.

## PROCEDURE

1. Obtain two 2-L plastic pop bottles and remove the labels leaving only a clear bottle. Using a marker, label the bottles with your name, date, and I or II.
2. Using scissors, cut the discarded food samples into small pieces, approximately 3 square centimeters in size, keeping all samples uniform in size. Repeat this procedure for the pieces of discarded packaging.
3. With scissors, cut each pop bottle in half.
4. Using a trowel, fill the base of bottle's I and II with approximately 6 cm. of garden soil or sand. Add garden soil to Bottle I and sand to Bottle II.
5. Record the size, color, texture, odor and any other important characteristic features of each sample in your data table. Include a prediction as to how each sample will look after a weeks time.
6. Using a pair of tweezers, place an assortment of food and packaging samples on the soil in Bottles I and II. Cover the samples completely with approximately 3 cm garden soil if setting up Bottle I and 3 cm. sand if setting up Bottle II
7. Add enough water to the soil to moisten it. Contents should not be soggy but should feel like a damp sponge. **Add no water** to the sand in Bottle II.
8. Place the top half of the bottle over the bottom half. Patience and repeated attempts are needed at this point, making sure that top half is pushed down far enough for a tight fit.
9. After one week, examine Bottles I and II by carefully removing the top layer of soil or sand into a shallow pan then remove food and packaging material with tweezers. Measurements can be made but be very careful not to touch the specimens.
10. Replace samples and soil in respective bottle and reseal. Observe the bottles at weekly intervals for the next three weeks but **DO NOT REOPEN THE BOTTLES**. Observations can be made by rotating the bottle on its side and viewing through the plastic. Record observations in data table.

11. Follow your teacher's instructions for proper disposal of all materials.
12. Answer questions 1-6.

## DATA

Make a data table for all observations and measurements made for each of the samples at one week intervals. Include changes in size, appearance and other observations; use an "X" if no change occurs.

## QUESTIONS

1. Rank samples in order of fastest to slowest rates of degradation. Give an explanations for different rates of degradation or decomposition.
2. Based on your data, classify each specimen used in this lab as biodegradable or nonbiodegradable.
3. What conditions proved to be most favorable for decomposition?
4. Devise a plan for lowering the amount of garbage going into the landfills in your community.
5. Are there any specimens or materials in this landfill simulation that could be recycled or re-used?
6. Account for the condensation that collected on the inside of the bottle.

## CONCLUSION

Carefully analyze the data collected. Accept or reject your chosen hypothesis on the basis of the class data. Be sure to explain acceptance or rejection of the hypotheses on the basis of observable and tabulated data.

Using prior knowledge suggest possible reasons for the changes or lack of changes observed.

**APPENDIX C:**

**STUDENT SURVEY**

**PERSONAL INTERVIEW**

**EXIT INTERVIEW QUESTIONS**

## **STUDENT SURVEY**

**Rank the following questions:**

- 1. Never**
- 2. Almost never**
- 3. Seldom**
- 4. Occasionally**
- 5. Frequently**
- 6. Almost all the time**
- 7. Always**

- 1. I use science to help explain how things work.**
- 2. Only smart people understand science.**
- 3. I am reminded of science daily.**
- 4. Understanding science is rewarding.**
- 5. I use science to solve problems.**
- 6. I understand science labs.**
- 7. Science means learning useful facts.**
- 8. I am thinking of pursuing science as a career.**
- 9. Science is too complex for me.**
- 10. Science classes are challenging.**
- 11. Realizing that I understand a new science concept makes me feel good about myself.**
- 12. Science classes are a struggle and not meaningful to me.**
- 13. Science is fun.**

**PERSONAL INTERVIEW**

**ANSWER EACH OF THE FOLLOWING QUESTIONS AS HONESTLY AS POSSIBLE.**

1. What subjects do you like most?
2. What do you do in your spare time?
3. What hobbies do you have?
4. Do you like to visit museums?
5. Would you like to visit a research laboratory?
6. Have you made a career choice?
7. If you have a career choice, identify it.
8. If you have not made a career choice, identify career areas that are of most interest to you now.
9. Would you like to meet a scientist?
10. What do you think he/she will be like?
11. What do you like about science?
12. What do you dislike about science?
13. Has anything in your science class(es) been useful in your everyday living?
14. Identify those things that you did find useful.

**EXIT INTERVIEW QUESTIONS:**

THE FOLLOWING QUESTIONS PERTAIN TO THE DIFFERENT SUBJECT AREAS WE HAVE STUDIED IN BIOLOGY THIS YEAR. THOSE AREAS INCLUDE:

**ANIMALS   PLANTS   DECOMPOSERS   GENETICS   CELLS**

1. Which subject area do you feel you learned the most?
  
2. Think back to the labs for each area and in which area were the labs particularly helpful? (Choose only one.)
  
3. Which area do you feel the labs were least helpful?
  
4. We did not follow the sequence of topics in the book. Did this bother you??  
 Circle your response from:
  - a. Not at all
  - b. Somewhat but it did not affect my academic performance
  - c. Yes, it bothered me but did not affect my academic performance
  - d. Yes, it bothered me and affected my academic performance
  
5. Has your attitude regarding decomposition changed?
  
6. Briefly state how.

## **APPENDIX D: DATA ANALYSIS**

## PRETEST SCORES

Total number of questions in pretest = 82

|          | Control Group of 21 students<br>total correct responses | Experimental Group of 25 students<br>total correct responses |
|----------|---------------------------------------------------------|--------------------------------------------------------------|
|          | 49                                                      | 41                                                           |
|          | 47                                                      | 54                                                           |
|          | 52                                                      | 42                                                           |
|          | 45                                                      | 47                                                           |
|          | 33                                                      | 52                                                           |
|          | 45                                                      | 42                                                           |
|          | 41                                                      | 41                                                           |
|          | 36                                                      | 52                                                           |
|          | 41                                                      | 51                                                           |
|          | 59                                                      | 47                                                           |
|          | 52                                                      | 56                                                           |
|          | 42                                                      | 43                                                           |
|          | 46                                                      | 37                                                           |
|          | 49                                                      | 41                                                           |
|          | 38                                                      | 41                                                           |
|          | 39                                                      | 49                                                           |
|          | 43                                                      | 46                                                           |
|          | 46                                                      | 45                                                           |
|          | 24                                                      | 51                                                           |
|          | 55                                                      | 45                                                           |
|          | 36                                                      | 46                                                           |
| mean     | 43.71                                                   | 46                                                           |
| stdev    | 8.00                                                    | 41                                                           |
| variance | 63.71                                                   | 45                                                           |
|          |                                                         | 47                                                           |
|          | mean                                                    | 45.92                                                        |
|          | stdev                                                   | 4.80                                                         |
|          | variance                                                | 22.83                                                        |
| t calc   | 1.16                                                    |                                                              |
| df       | 44                                                      |                                                              |
| alpha    | 0.05                                                    |                                                              |
| t        | 2.021                                                   |                                                              |

Calculated t of 1.16 < 2.021 and is not significant at the 0.05 level.  
 Because the calculated value of t is not significant, the null hypothesis is not rejected and the research hypothesis that the experimental group would have higher scores is not supported.

48  
POSTTEST

Total number of questions in posttest=82

| Control group of 25 students      |       | Experimental group of 26 students |       |
|-----------------------------------|-------|-----------------------------------|-------|
| total number of correct responses |       | total number of correct responses |       |
|                                   | 54    |                                   | 59    |
|                                   | 52    |                                   | 51    |
|                                   | 50    |                                   | 46    |
|                                   | 58    |                                   | 41    |
|                                   | 52    |                                   | 54    |
|                                   | 54    |                                   | 54    |
|                                   | 61    |                                   | 61    |
|                                   | 53    |                                   | 50    |
|                                   | 61    |                                   | 57    |
|                                   | 61    |                                   | 52    |
|                                   | 59    |                                   | 50    |
|                                   | 38    |                                   | 62    |
|                                   | 54    |                                   | 62    |
|                                   | 57    |                                   | 46    |
|                                   | 59    |                                   | 60    |
|                                   | 51    |                                   | 60    |
|                                   | 61    |                                   | 70    |
|                                   | 51    |                                   | 52    |
|                                   | 26    |                                   | 65    |
|                                   | 58    |                                   | 65    |
|                                   | 49    |                                   | 63    |
|                                   | 52    |                                   | 58    |
|                                   | 57    |                                   | 52    |
|                                   | 47    |                                   | 52    |
|                                   | 64    |                                   | 59    |
| mean                              | 53.56 |                                   | 56    |
| stdev                             | 8.00  | mean                              | 56.04 |
| variance                          | 64.67 | stdev                             | 6.80  |
|                                   |       | variance                          | 46.12 |

t calc    1.17  
df        50  
alpha    0.05  
t         2

Calculated t of 1.17 < 2.0 is not significant at 0.05 level. Because the calculated value of t is not significant, the null hypothesis is not rejected and the research hypothesis that the experimental group would have higher scores is not supported.

## PRE- ROTTEN APPLE ESSAY

|              |               |             |             |                    |
|--------------|---------------|-------------|-------------|--------------------|
| <b>WORDS</b> | mushrooms     | methane     | life cycle  | decay              |
| <b>USED:</b> | fermenting    | fungi       | evaporation | biodegrade         |
|              | nutrients     | decompose   | mold        | chemical structure |
|              | deteriorate   | bacteria    | gas         | disintegrate       |
|              | worm          | larva       | fertilize   | pH change          |
|              | rotting       | evaporation | maggots     | microorganisms     |
|              | small insects | fertilizer  |             |                    |

Control group of 22 students  
total number relevant terms used

1  
2  
2  
1  
2  
1  
4  
1  
2  
2  
3  
5  
1  
2  
2  
2  
1  
2  
0  
1  
5  
4

mean = 2.16  
stdev = 1.42  
variance = 2.03

Experimental group of 24 students  
total number relevant terms used

2  
1  
1  
0  
3  
1  
2  
1  
4  
2  
2  
1  
0  
0  
3  
2  
1  
1  
4  
1  
1  
1  
6  
1  
0

mean = 1.64  
stdev = 1.44  
variance = 2.07

**POST ROTTEN APPLE ESSAY**

|                                    |             |                |               |                |               |
|------------------------------------|-------------|----------------|---------------|----------------|---------------|
| <b>WORDS FROM PRETEST</b>          | mushrooms   | methane        | life cycle    | decay          | fertilizer    |
|                                    | fermenting  | fungi          | evaporation   | biodegrade     | small insects |
|                                    | nutrients   | decompose      | mold          | microorganism  | maggots       |
|                                    | deteriorate | bacteria       | gas           | disintegrate   | rotting       |
|                                    | worm        | larva          | fertilize     | pH change      |               |
| <b>NEW WORDS FOUND IN POSTTEST</b> | methanogens | recycle        | temperature   | food web       | humus         |
|                                    | anaerobic   | denitrifying   | methane       | ammonia        | spores        |
|                                    | rhizoids    | nitrifying     | ammonia       | nitrogen cycle | surface area  |
|                                    | hyphae      | nitrate        | enriched soil | organic        |               |
|                                    | food chain  | carbon dioxide | evaporation   | protist        |               |

Relevant terms chosen by  
control group of 24 students

mean 4.2  
stdev 1.7  
variance 2.9

Relevant terms chosen by  
experimental group of 25 students

mean 6.5  
stdev 2.1  
variance 5.8

t calc 3.9  
df 49  
alpha 0.05  
t 2

Calculated t of 3.9 > 2.0 and is significant at the 0.05 level therefore the null hypothesis is rejected and the research hypothesis that the experimental group would have higher scores is supported

**SELECTED PRETEST QUESTIONS**  
**qsts. 1, 54, 56, 22t/f regarding composting**

| <b>CONTROL GROUP</b> |                             | <b>EXPERIMENTAL GROUP</b> |                              |
|----------------------|-----------------------------|---------------------------|------------------------------|
|                      | <b>#Correct/21 students</b> |                           | <b># Correct/27 students</b> |
|                      | 3                           |                           | 3                            |
|                      | 12                          |                           | 20                           |
|                      | 19                          |                           | 24                           |
|                      | 16                          |                           | 21                           |
| <b>mean</b>          | 12.5                        | <b>mean</b>               | 17                           |
| <b>variance</b>      | 48.3                        | <b>variance</b>           | 48.3                         |
| <b>std dev</b>       | 6.9                         | <b>std dev</b>            | 9.8                          |

**SELECTED PRETEST QUESTIONS**  
**qsts. 39, 55, 58 and 20, 23 t/f regarding decomposition**

| <b>CONTROL GROUP</b> |                             | <b>EXPERIMENTAL GROUP</b> |                             |
|----------------------|-----------------------------|---------------------------|-----------------------------|
|                      | <b>#Correct/21 students</b> |                           | <b>#Correct/27 students</b> |
|                      | 15                          |                           | 8                           |
|                      | 19                          |                           | 22                          |
|                      | 10                          |                           | 13                          |
|                      | 8                           |                           | 14                          |
|                      | 15                          |                           | 19                          |
| <b>mean</b>          | 13.4                        | <b>mean</b>               | 15.2                        |
| <b>variance</b>      | 19.3                        | <b>variance</b>           | 29.7                        |
| <b>std dev</b>       | 4.4                         | <b>std dev</b>            | 5.4                         |

## SELECTED PRETEST QUESTIONS

qsts.27,29, 4tf regarding methanogens

| CONTROL GROUP |                       | EXPERIMENTAL GROUP |                      |
|---------------|-----------------------|--------------------|----------------------|
|               | # Correct/21 students |                    | # Correct/27students |
|               | 16                    |                    | 18                   |
|               | 9                     |                    | 14                   |
|               | 8                     |                    | 16                   |
| mean          | 11                    | mean               | 16                   |
| variance      | 19                    | variance           | 4                    |
| std dev       | 4.4                   | std dev            | 2                    |

## SELECTED PRETEST QUESTIONS

qsts. 34, 42, 13, 16 and 21  
regarding biogeochemical recycling

| CONTROL GROUP |                       | EXPERIMENTAL GROUP |                      |
|---------------|-----------------------|--------------------|----------------------|
|               | # correct/21 students |                    | #correct/27 students |
|               | 11                    |                    | 17                   |
|               | 15                    |                    | 25                   |
|               | 13                    |                    | 15                   |
|               | 15                    |                    | 23                   |
|               | 5                     |                    | 8                    |
| mean          | 12                    | mean               | 17.6                 |
| variance      | 17.2                  | variance           | 45.8                 |
| std dev       | 4.1                   | std dev            | 6.8                  |

**SELECTED POSTTEST QUESTIONS**  
**qsts.27,29, 4tf regarding methanogens**

| <b>CONTROL GROUP</b> |                              | <b>EXPERIMENTAL GROUP</b> |                              |
|----------------------|------------------------------|---------------------------|------------------------------|
|                      | <b># Correct/20 students</b> |                           | <b># Correct/27 students</b> |
|                      | 20                           |                           | 24                           |
|                      | 13                           |                           | 25                           |
|                      | 14                           |                           | 20                           |
| <b>mean</b>          | 15.6                         | <b>mean</b>               | 23                           |
| <b>variance</b>      | 14.3                         | <b>variance</b>           | 14.3                         |
| <b>std dev</b>       | 3.8                          | <b>std dev</b>            | 2.6                          |
| <b>t cal = 3.9</b>   |                              |                           |                              |
| <b>df = 47</b>       |                              |                           |                              |
| <b>alpha = 0.05</b>  |                              |                           |                              |
| <b>t = 2</b>         |                              |                           |                              |

Calculated t of 3.9 > 2.0 is significant at the 0.05 level therefore the null hypothesis is rejected and the research hypothesis that the experimental group would have higher scores is supported.

**SELECTED POSTTEST QUESTIONS**  
**qsts. 34, 42, 13, 16, and 21**  
**regarding biogeochemical recycling**

| <b>CONTROL GROUP</b> |                              | <b>EXPERIMENTAL GROUP</b> |                             |
|----------------------|------------------------------|---------------------------|-----------------------------|
|                      | <b># correct/20 students</b> |                           | <b>#correct/27 students</b> |
|                      | 8                            |                           | 15                          |
|                      | 17                           |                           | 23                          |
|                      | 11                           |                           | 14                          |
|                      | 16                           |                           | 21                          |
|                      | 8                            |                           | 16                          |
| <b>mean</b>          | 12                           | <b>mean</b>               | 17.8                        |
| <b>variance</b>      | 18.5                         | <b>variance</b>           | 15.7                        |
| <b>std dev</b>       | 4.3                          | <b>std dev</b>            | 4                           |
| <b>t cal = 5.2</b>   |                              |                           |                             |
| <b>df = 49</b>       |                              |                           |                             |
| <b>alpha = 0.05</b>  |                              |                           |                             |
| <b>t = 5.2</b>       |                              |                           |                             |

Calculated t of 5.2 > 2.0 is significant at the 0.05 level therefore the null hypothesis research hypotl is rejected and the research hypothesis that the experimental group would have higher scores is supported.

**SELECTED POSTTEST QUESTIONS**  
**qsts. 1, 54, 56, 22t/f regarding composting**

| <b>CONTROL GROUP</b>        |      | <b>EXPERIMENTAL GROUP</b>    |      |
|-----------------------------|------|------------------------------|------|
| <b>#Correct/20 students</b> |      | <b># Correct/27 students</b> |      |
|                             | 5    |                              | 15   |
|                             | 20   |                              | 26   |
|                             | 14   |                              | 22   |
|                             | 15   |                              | 21   |
| mean                        | 13.5 | mean                         | 21   |
| variance                    | 39   | variance                     | 20.7 |
| std dev                     | 6.2  | std dev                      | 4.5  |
| t calc =                    |      | 6.1                          |      |
| df =                        |      | 47                           |      |
| alpha =                     |      | 0.05                         |      |
| t =                         |      | 2                            |      |

Calculated t of 6.1 > 2.0 and is significant at the 0.05 level therefore the null hypothesis is rejected and the research hypothesis that the experimental group would have higher scores is supported.

**SELECTED POSTTEST QUESTIONS**  
**qsts. 39, 55, 58 and 20, 23 t/f regarding decomposition**

| <b>CONTROL GROUP</b> |      | <b>EXPERIMENTAL GROUP</b>   |      |
|----------------------|------|-----------------------------|------|
|                      |      | <b>#Correct/27 students</b> |      |
|                      | 4    |                             | 22   |
|                      | 4    |                             | 18   |
|                      | 19   |                             | 27   |
|                      | 5    |                             | 12   |
| mean                 | 7    |                             | 13   |
| variance             | 7.8  | mean                        | 18.4 |
| std dev              | 40.7 | variance                    | 39.3 |
|                      | 6.4  | std dev                     | 6.3  |
| t calc =             |      | 5.9                         |      |
| df =                 |      | 47                          |      |
| alpha =              |      | 0.05                        |      |
| t =                  |      | 2                           |      |

Calculated t of 5.9 > 2.0 and is significant at the 0.05 level therefore the null hypothesis is rejected and the research hypothesis that the experimental group would have higher scores is supported.

## EXIT SURVEY

### CONTROL GROUP

18 students surveyed and results reported as per centages

|                                                                      | Animals | Plants | Decomposers | Genetics | Cells |
|----------------------------------------------------------------------|---------|--------|-------------|----------|-------|
| 1. Which area feel you learned the most                              |         |        |             |          |       |
|                                                                      | 0.33    | 0.11   | 0.11        | 0.33     | 0.12  |
| 2. Areas in which labs were helpful                                  |         |        |             |          |       |
|                                                                      | 0.39    | 0.17   | 0.05        | 0.11     | 0.28  |
| 3. Labs that were least helpful                                      |         |        |             |          |       |
|                                                                      | 0.17    | 0.17   | 0.17        | 0.44     | 0.05  |
| 4. How you were affected by not following sequence of book           |         |        |             |          |       |
| a. Not at all                                                        |         |        |             | 0.61     |       |
| b. somewhat but it did not affect my academic performance            |         |        |             | 0.17     |       |
| c. yes, it bothered me but it did not affect my academic performance |         |        |             | 0.17     |       |
| d. yes, it bothered me and it affected my academic performance       |         |        |             | 0.05     |       |
| 5. Has attitude regarding decomposition changed?                     |         |        |             |          |       |
| a. yes                                                               |         |        |             | 0.77     |       |
| b. no                                                                |         |        |             | 0.23     |       |

Some comments regarding the student's attitude change.

I understand how helpful it is to our environment.

There is more to decomposition than I once thought.

Decomposition happened before, it happens now, and it will always happen.

I never knew how things decomposed until this year.

I didn't know much about decomposition before this class but now I know more about it.

Now I recycle because I see how easy it is and understand that decomposition doesn't take long if you do it right.

## EXIT SURVEY

## EXPERIMENTAL GROUP

18 students surveyed and results reported as per centages

|                                                                      | Animals | Plants | Decomposers | Genetics | Cells |
|----------------------------------------------------------------------|---------|--------|-------------|----------|-------|
| 1. Which area you feel that you learned the most                     |         |        |             |          |       |
|                                                                      | 0.18    | 0.07   | 0.14        | 0.39     | 0.22  |
| 2. Areas in which labs were helpful                                  |         |        |             |          |       |
|                                                                      | 0.44    | 0.11   | 0.2         | 0        | 0.25  |
| 3. Labs that were least helpful                                      |         |        |             |          |       |
|                                                                      | 0.03    | 0.26   | 0.18        | 0.26     | 0.07  |
| 4. How you were affected by not following sequence of book           |         |        |             |          |       |
| a. not at all                                                        |         |        | 0.61        |          |       |
| b. somewhat but it did not affect my academic performance            |         |        | 0.17        |          |       |
| c. yes, it bothered me but it did not affect my academic performance |         |        | 0.17        |          |       |
| d. yes, it bothered me and it affected my academic performance       |         |        | 0.05        |          |       |
| 5. Has your attitude regarding decomposition changed?                |         |        |             |          |       |
| a. yes                                                               |         |        | 0.77        |          |       |
| b. no                                                                |         |        | 0.23        |          |       |

Some comments regarding the student's attitude change:

I know now how bacteria do it—it is nature's way.

I understand now how it plays an extremely important role in the environment.

I know what's actually happening and I can respect the bacteria more.

My attitude has definitely changed. Before I thought it was disgusting but now I know it's a natural recycling thing.

I understand more clearly the natural cycle of nutrients and materials plus the need for decomposers

I still think it looks gross but I do realize the importance and am amazed at nature's built in recycling program.

I used to think compost piles would smell and but now I know differently.

## STUDENT SURVEY

## Ranking of questions:

1. never      2. almost never      3. seldom      4. occasionally      5. frequently  
 6. almost all the time      7. always

|                                                                                       | Pre-Control<br>Average | Experimental<br>Pre Average | Post Control<br>Average | Experimental<br>Post Average |
|---------------------------------------------------------------------------------------|------------------------|-----------------------------|-------------------------|------------------------------|
| 1. I use science to explain how things work                                           | 3.7                    | 3.7                         | 5.4                     | 4.5                          |
| 2. Only smart people understand science                                               | 3                      | 3.1                         | 3.6                     | 2.7                          |
| 3. I am reminded of science daily                                                     | 4.7                    | 4.2                         | 6.4                     | 6.6                          |
| 4. Understanding science is rewarding                                                 | 4.6                    | 5.3                         | 6.1                     | 5.9                          |
| 5. I use science to solve problems.                                                   | 3.3                    | 3.8                         | 4.3                     | 4.6                          |
| 6. I understand science labs                                                          | 5.8                    | 5.6                         | 6.5                     | 5.8                          |
| 7. Science means learning useful facts.                                               | 5.4                    | 4.8                         | 6.1                     | 4.9                          |
| 8. I am thinking of pursuing science as a career                                      | 3.6                    | 3.9                         | 4.6                     | 4.9                          |
| 9. Science classes are challenging                                                    | 4.7                    | 4.6                         | 5.6                     | 5.5                          |
| 10. Realizing that I understand a new science concept makes me feel good about myself | 4.4                    | 5.6                         | 5.7                     | 5.8                          |
| 11. Science is fun.                                                                   | 5.5                    | 5.9                         | 5.5                     | 5.3                          |

**APPENDIX E**  
**TEST MATERIALS**

**APPENDIX E****PRETEST:**

Choose the BEST answer for the following questions:

1. Everything the organisms of an ecosystem use is recycled except:
  - a. air
  - b. energy
  - c. food wastes
  - d. water
2. Obligate anaerobes:
  - a. require oxygen for their life processes
  - b. require an absence of oxygen for their life processes
  - c. can live in oxygen or an absence of oxygen
  - d. under special conditions all of the above are true statements
3. Facultative anaerobes:
  - a. require oxygen for their life processes
  - b. require an absence of oxygen for their life processes
  - c. can live in oxygen or an absence of oxygen
  - d. under special conditions all of the above are true statements
4. A fungus such as *Rhizopus* gets its food by:
  - a. secreting enzymes to digest starch into soluble compounds
  - b. absorbing food from cells of its host
  - c. producing it from raw materials of the soil
  - d. chemical reactions similar to photosynthesis
5. Why are fungi important to us?
  - a. all of the following
  - b. many are decomposers
  - c. many cause diseases, especially in plants
  - d. some are used to make chemical and food products
6. Fungi are classified mainly on differences in:
  - a. composition of cell walls
  - b. pigments in their cells
  - c. sexual reproductive structures
  - d. size and shape of vegetative structures

7. The threadlike structures of fungi that anchor them and absorb food products are called:
  - a. hyphae
  - b. rhizoids
  - c. shoots
  - d. stalks
8. In the carbon cycle, carbon dioxide is released to the atmosphere by:
  - a. all organisms
  - b. consumers only
  - c. consumers and decomposers only
  - d. producers and decomposers only
9. Spores are:
  - a. pollen grains produced by plant like structures
  - b. small openings in many fungi that permit circulation of air
  - c. asexual reproductive cell capable of developing into an adult organism
  - d. thread-like structures found in many fungi that enhance absorption
10. Why is it advantageous for fungi to produce large numbers of spores?
  - a. spores live a very short time
  - b. very few spores have a chance for fertilization
  - c. very few spores find a suitable environment for growth
  - d. mutation rates of fungi are low
11. Autotrophic means:
  - a. an organism that is unable to make its own food therefore must rely on other organisms for its food source
  - b. an organism that makes its own food by photosynthesis
  - c. an organism that produces spores
  - d. a type of bacterial that survives at extremely high temperatures

12. Which of the following groups of organisms includes producers, consumers, decomposers, parasites, predators, and prey?
  - a. animals
  - b. bacteria
  - c. fungi
  - d. protists
13. The nitrogen cycle is vital because animals and most green plants cannot use:
  - a. gaseous nitrogen
  - b. nitrates
  - c. nitrogen in any form
  - d. organic nitrogen compounds
14. Animals get their nitrogen from:
  - a. animal and plant foods
  - b. atmospheric ammonia
  - c. atmospheric nitrogen gas
  - d. nitrates in water or soil

The next 5 items refer to the nitrogen cycle. Select the letter of the term from the key that best matches each numbered item.

KEY: a. ammonia ( $\text{NH}_3$ ) or ammonium ( $\text{NH}_4$ )  
b. atmospheric nitrogen ( $\text{N}_2$ )  
c. soil nitrates ( $\text{NO}_3$ )

15. The most abundant nitrogen supply
16. The kind of nitrogen compound produced by nitrogen-fixing bacteria
17. The nitrogen supply used by most producers
18. The source of nitrogen in nitrogen-fixation by bacteria
19. The kind of nitrogen compound produced by nitrifying bacteria
20. In the nitrogen cycle, the organisms that take nitrogen from the air and fix it in compounds plants can use are:
  - a. algae
  - b. bacteria
  - c. fungi
  - d. legumes

The next four items use the following groups of bacteria as responses. Any one group may be used more than once or not at all. There is only one response for each item.

KEY: a. decomposing bacteria  
b. denitrifying bacteria  
c. nitrifying bacteria  
d. nitrogen-fixing bacteria

21. Convert atmospheric nitrogen to ammonia
22. Change ammonium ion to nitrates
23. Break down nitrogen containing compounds and release ammonium ions.
24. Change nitrates to nitrogen gas
25. Which of these plants are hosts to organisms that put nitrogen compounds into the soil?
  - a. carrots and corn
  - b. onions and potatoes
  - c. peas and soybeans
  - d. weeds and wild flowers
26. Which best describes archaebacteria?
  - a. appeared on earth only recently
  - b. are fundamentally different from all other organisms
  - c. are very similar to algae
  - d. have DNA and RNA similar to all other organisms
27. Which is true of methanogens?
  - a. all of the following
  - b. they are found in sewage treatment plants
  - c. they are killed by oxygen
  - d. they produce methane
28. Which of the following groups of prokaryotes are considered to be archaebacteria?
  - a. all of the following
  - b. the extreme halophiles
  - c. the methanogens
  - d. the thermoacidophiles

29. Which group of microorganisms could play an important role in solving our garbage, sewage and agricultural waste problem?
- a. cyanobacteria
  - b. halophiles
  - c. methanogens
  - d. thermoacidophiles
30. How do prokaryotes differ from eukaryotes? Eukaryotes:
- a. have DNA, prokaryotes do not
  - b. have membrane-bounded nuclei, prokaryotes do not
  - c. lack mitochondria and lysosomes which prokaryotes have
  - d. lack mitotic nuclear divisions which prokaryotes have
31. In the 5-kingdom classification system, prokaryotes are grouped in the kingdom(s):
- a. Monera
  - b. Plantae
  - c. Protista
  - d. Animalia
32. In the 5-kingdom classification system, fungi are separated from other eukaryotes mainly by:
- a. cell wall structure and development from spores
  - b. ability to make their own food
  - c. sized
  - d. color
33. Which best describes prokaryotes?
- a. most are beneficial
  - b. most are harmful
  - c. they are complex structurally and functionally
  - d. they are evolutionarily recent and quite delicate
34. Which organisms are essential to the carbon cycle?
- a. consumers and decomposers
  - b. first-and second-order consumers
  - c. producers and consumers
  - d. producers and decomposers

35. Which organisms are decomposers or include many species that are decomposers?
- a. amoebas, centipedes, nematodes
  - b. bacteria, earthworms, fungi
  - c. centipedes, earthworms, insects
  - d. insects, nematodes, plants
36. Which organisms include species that have mutualistic relationships with plant roots?
- a. bacteria and fungi
  - b. centipedes
  - c. earthworms and nematodes
  - d. insects
37. The death of a organism is advantageous to a:
- a. decomposer
  - b. herbivore
  - c. parasite
  - d. producer
38. The relationship between an alfalfa plant and the nitrogen-fixing bacteria in nodules on its roots is one of:
- a. commensalism
  - b. competition
  - c. mutualism
  - d. parasitism
39. Some of the things bacteria can breakdown are:
- a. metal ores
  - b. oil
  - c. dead material
  - d. all of these
40. For each 1 gram of compost material, the microorganism population is approximately:
- a. 10
  - b. 1,000
  - c. 100,000
  - d. 10,000,000
41. Nematodes are vital to composting they are:
- a. bacteria
  - b. fungi
  - c. microscopic roundworms
  - d. algae

42. Which of the following are examples of carbon cycling made possible by microorganisms?
- a. fermentation
  - b. photosynthesis
  - c. methane or smelly "swamp gas" formation
  - d. all of these
43. Nitrogen is vital to the production of which of the following biomolecules:
- a. carbohydrates
  - b. nucleic acids
  - c. proteins
  - d. fats
  - e. both b + c
44. Prokaryotes are organisms that
- a. have no organized nucleus
  - b. always are anaerobic
  - c. always photosynthesize
  - d. have recently evolved but are vital to carbon cycling
45. The weight of leaves formed in a single season by a hardwood tree such as an oak or elm is:
- a. 40 pounds
  - b. 400 pounds
  - c. 40 tons
  - d. 400 tons
46. The average American throws away \_\_\_\_\_ of garbage a year:
- a. 150 lbs.
  - b. 1500 lbs.
  - c. 15 tons
  - d. 5000 lbs.
47. Earthworms are moist because:
- a. they can slip easily through soil
  - b. moisture is needed for oxygen and carbon dioxide exchange.
  - c. they contain a glass-like material similar to sand which makes them slippery
  - d. all of the above.

The next six questions refer to the information given below:

Four glass covered bowls were set up as follows:

Bowl A: stale moistened bread

Bowl B: warm, 10-day old beef soup

Bowl C: pond water

Bowl D: crushed grapes in water

48. In which bowl would you find the fewest decomposers?
49. In which bowl would you find the most bacteria?
50. In which bowl would you find the most algae?
51. In which bowl would you find the most mold?
52. In which bowl would you find the most yeast?
53. In which bowl would you find the most producers and consumers
54. Composting is:
  - a. recycling by nature
  - b. important because it saves landfill space
  - c. a natural way to make enriched soil
  - d. all of the above
55. Decomposition proceeds best in:
  - a. dry conditions
  - b. moist conditions
  - c. sunlight
  - d. cold temperatures
56. Humus is:
  - a. a funny story
  - b. a bone in your upper arm
  - c. decomposed organic matter
  - d. a radioactive material produced in nuclear power plants
57. Bioremediation is:
  - a. study of very slow growing organisms
  - b. breaking down of hazardous waste by microorganisms
  - c. study of life
  - d. none of the above
58. Gases are released when decomposition occurs. Identify those gases.:
  - a. carbon dioxide
  - b. methane
  - c. oxygen
  - d. all of the above
  - e. only a + b

59. Identify the gas needed by aerobic organisms.
- carbon dioxide
  - methane
  - oxygen
  - nitrogen
  - hydrogen
  - all of the above
60. Which of the following is nonbiodegradable?
- grass clippings
  - lettuce leaves
  - plastic
  - dead animals

**TRUE OR FALSE:**

- Plants aren't the only producers. Some bacteria contain chlorophyll and can photosynthesize.
- Methanogens are methane producing bacteria and are responsible for releasing most of the methane found in the atmosphere.
- Bacteria are the most numerous living organisms on earth.
- Methanogens are anaerobic bacteria that chemically convert carbon dioxide and hydrogen into methane and water.
- The cell walls of fungi are made up of cellulose.
- Earthworms remove their nitrogenous wastes with specialized structures called nephridia.
- Our atmosphere consists of about 70% nitrogen but we are unable to use nitrogen and must rely on other organisms, e.g., bacteria to put it in a usable form for us.
- Methane and carbon dioxide are both greenhouse gases responsible for global warming.
- We depend on microorganisms, e.g., bacteria for fermentation to produce alcohol and many organic acids, e.g., acetic acid.

10. Large particles that can be broken into smaller particles greatly increase surface area which enables decomposition to proceed at a much faster rate.
11. Some bacteria can cause oxidation of copper ores therefore making recovery of copper from low-grade ore easier.
12. Bioremediation is the process of using bacteria and fungi to biodegrade waste material.
13. Decomposition is complete when organic compounds are returned to the environment in their inorganic form as carbon dioxide.
14. Decomposition returns nitrogen containing compounds to the environment in the form of ammonia.
15. Worms can eat one half their weight daily.
16. There is a finite amount of materials available for the construction of all living organisms and life would cease if these materials were not released by decomposition.
17. Antibiotics are "warfare chemicals" made by fungi and bacteria for the purpose of eliminating their competitors.
18. Fast food packaging, styrofoam and disposable diapers are main constituents of American garbage.
19. America is running out of places to build landfills
20. A lot of biodegradation takes place in modern landfills.
21. Paper takes up much more landfill space than plastic.
22. A compost pile produces almost no odor.

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