

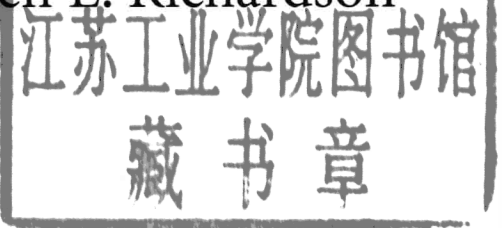
# A LABORATORY GUIDE TO THE NATURAL WORLD



Dennis J. Richardson and Kristen E. Richardson

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Dennis J. Richardson and Kristen E. Richardson



Upper Saddle River, NJ 07458

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*For Katherine, Marjorie, and Emma*  
*Our favorite little varmints*

# Preface

We often hear the argument that non-majors students shouldn't have to learn much about biology because it seems unimportant in the real world. Yet, we humans are animals – linked to all other life on this planet, governed by the same natural laws as everything else. A biology laboratory course gives you a better understanding of yourself and reveals your relationship to all other living organisms. And as we face increasing disease outbreaks, energy crises, and environmental mismanagement, an understanding of biology has never been more important.

And so we present *A Laboratory Guide to the Natural World*. The exercises in this guide are built upon the solid foundation of a traditional approach, while infusing an inquiry-based component that allows you to explore the natural world within the confines of tried-and-true learning experiences. These exercises encompass many levels of biological organization, with a touch of aesthetic and philosophical aspects of natural history. We hope you will walk away with a new understanding of the natural world around you, a world of wonder and beauty. It is our sincere desire that your study of biology will be both pleasant and educational in the truest sense.

## ACKNOWLEDGEMENTS

A sincere thanks to all those who helped us complete this book! Debra Wechsler and Karen Horton at Prentice Hall have been very professional and patient. Dan Holiday assisted in preparation of many of our digital images; Rich Clopton contributed ideas for exercises, as did several reviewers; we owe special thanks to our artists, Susan Jessup and Barbara Nitchke, who toiled to make their line drawings just right. And thanks also to our mentors Wilbur Owen, Brent Nickol, John Janovy, the late Mike Mathis, William Glider, and Neal Buffaloe, who provided us with an insightful view of life while teaching us how to teach.

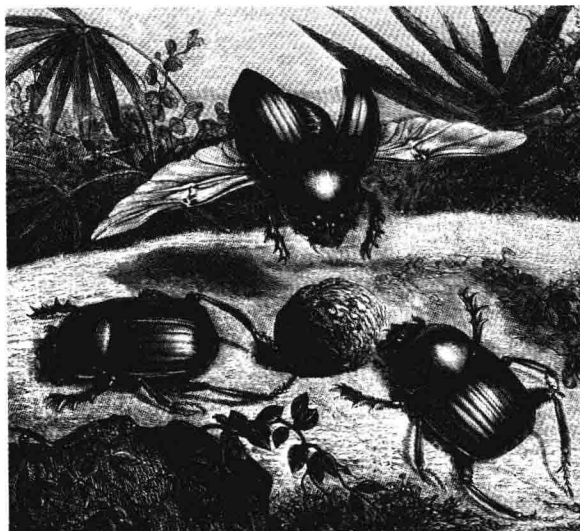
We are especially grateful for our children, who have tolerated us while growing up with this project. And yes, Kate, it will be done by the time you turn 7.

D.J.R. and K.E.R.

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# Contents

<b>PREFACE</b>	<b>xiii</b>
<b>CHAPTER 1      Science as a Way of Learning</b>	<b>1</b>
EXERCISE 1.1      EXPERIMENTAL DESIGN    3	
EXERCISE 1.2      A LIBRARY IN THE SCIENTIFIC METHOD    4	
EXERCISE 1.3      EFFECTS OF NUTRIENTS ON PLANT GROWTH    5	
<i>Extended 5-week exercise</i>	
EXERCISE 1.4      SCIENCE AND TECHNOLOGY    9	
<i>Web exercise</i>	
<b>CHAPTER 2      Natural History</b>	<b>11</b>
EXERCISE 2.1      OBSERVING NATURE    11	
<i>Extended exercise</i>	
EXERCISE 2.2      NATURAL HISTORY IN ART    13	
EXERCISE 2.3      NATURAL HISTORY IN LITERATURE    18	
<b>UNIT 1          ESSENTIAL PARTS</b>	<b>20</b>
<b>CHAPTER 3      Biological Molecules</b>	<b>21</b>
EXERCISE 3.1      THE NATURE OF ORGANIC COMPOUNDS    21	
EXERCISE 3.2      BENEDICT'S TEST FOR SIMPLE SUGARS    22	
EXERCISE 3.3      IODINE TEST FOR STARCH    23	
EXERCISE 3.4      ENZYMATIC DIGESTION OF STARCH    24	
EXERCISE 3.5      SUDAN TEST FOR LIPIDS    25	
EXERCISE 3.6      BIURET TEST FOR PROTEINS    26	
EXERCISE 3.7      COLORIMETRIC ASSAY    27	
EXERCISE 3.8      COMPOSITION OF AN UNKNOWN SUBSTANCE    28	
<i>Continuous with previous exercises</i>	
<b>CHAPTER 4      Microscopy and Basic Cell Structure</b>	<b>31</b>
EXERCISE 4.1      PARTS OF THE MICROSCOPE    32	
EXERCISE 4.2      THE LETTER <i>E</i> 34	
EXERCISE 4.3      CROSSED FIBERS    35	
EXERCISE 4.4      THE DISSECTING MICROSCOPE    36	
EXERCISE 4.5      PLANT CELLS    36	

EXERCISE 4.6	ANIMAL CELLS	39
EXERCISE 4.7	POND WATER	39
<b>CHAPTER 5</b>	<b>Diffusion and Osmosis</b>	<b>41</b>
EXERCISE 5.1	EFFECT OF MOLECULAR WEIGHT ON DIFFUSION	42
EXERCISE 5.2	OSMOSIS IN ANIMAL CELLS	43
EXERCISE 5.3	OSMOSIS IN PLANT CELLS	46
EXERCISE 5.4	THE EFFECTS OF OSMOSIS ON PLANT TISSUES	47
<b>UNIT 2</b>	<b>ENERGY</b>	<b>49</b>
<b>CHAPTER 6</b>	<b>Proteins and Enzymes</b>	<b>51</b>
EXERCISE 6.1a	CHEESE PRODUCTION USING ENZYMES	53
EXERCISE 6.1b	CONVERTING CHEESE TO AMINO ACIDS	53
EXERCISE 6.2	EFFECT OF pH ON ENZYME ACTIVITY	54
EXERCISE 6.3	EFFECT OF TEMPERATURE ON ENZYME ACTIVITY	57
	<i>Continuous with Exercise 6.2</i>	
EXERCISE 6.4	EFFECTS OF ENZYMES ON YOUR DINNER	59
EXERCISE 6.5	ENZYME DEFICIENCIES	59
	<i>Web exercise</i>	
<b>CHAPTER 7</b>	<b>Deriving Energy from Food</b>	<b>61</b>
EXERCISE 7.1	ALCOHOLIC FERMENTATION: CARBON DIOXIDE PRODUCTION BY YEAST	63
EXERCISE 7.2	HEAT PRODUCTION BY LIVING ORGANISMS	65
EXERCISE 7.3	OXYGEN CONSUMPTION DURING CELLULAR RESPIRATION	66
<b>CHAPTER 8</b>	<b>Photosynthesis</b>	<b>69</b>
EXERCISE 8.1	EFFECTS OF CARBON DIOXIDE AND LIGHT ON PHOTOSYNTHESIS	70
EXERCISE 8.2	CARBON DIOXIDE CONSUMPTION BY <i>ELODEA</i>	73
EXERCISE 8.3	PHOTOSYNTHETIC PIGMENTS	74
<b>UNIT 3</b>	<b>GENETICS</b>	<b>77</b>
<b>CHAPTER 9</b>	<b>Cell Division</b>	<b>79</b>
EXERCISE 9.1	MITOSIS SIMULATION	80
EXERCISE 9.2	MEIOSIS SIMULATION	81



EXERCISE 9.3	PLANT MITOSIS	86
EXERCISE 9.4	ANIMAL MITOSIS	88
<b>CHAPTER 10</b>	<b>Mendelian Genetics</b>	<b>91</b>
EXERCISE 10.1	THE MONOHYBRID CROSS	92
	<i>Extended 5-week exercise</i>	
EXERCISE 10.2	CHI-SQUARE ANALYSIS	95
	<i>Continuous with Exercise 10.1</i>	
EXERCISE 10.3	THE DIHYBRID CROSS AND CHI-SQUARE ANALYSIS	96
<b>CHAPTER 11</b>	<b>Biotechnology</b>	<b>99</b>
EXERCISE 11.1	RESTRICTION ENZYMES AND ELECTROPHORESIS OF DNA	99
EXERCISE 11.2	OUTBREAK! FINGERPRINTING VIRUS DNA	105
EXERCISE 11.3	TRANSFORMATIONS	107
	<i>Extended 2-week exercise</i>	
<b>UNIT 4</b>	<b>EVOLUTION AND CLASSIFICATION</b>	<b>114</b>
<b>CHAPTER 12</b>	<b>Evolution</b>	<b>115</b>
EXERCISE 12.1	NATURAL SELECTION	116
EXERCISE 12.2	GENETIC DRIFT: THE FOUNDER EFFECT	121
EXERCISE 12.3	HUMAN EVOLUTION: QUANTITATIVE SKULL ASSESSMENT	122
EXERCISE 12.4	HUMAN EVOLUTION: QUALITATIVE SKULL ASSESSMENT	127
EXERCISE 12.5	EVOLUTION AND CREATIONISM	129
	<i>Web exercise</i>	
<b>CHAPTER 13</b>	<b>Classification and Taxonomic Keys</b>	<b>131</b>
EXERCISE 13.1	CLASSIFICATION	132
EXERCISE 13.2	A TAXONOMIC KEY	134
<b>UNIT 5</b>	<b>THE DIVERSITY OF LIFE</b>	<b>141</b>
<b>CHAPTER 14</b>	<b>Bacteria</b>	<b>143</b>
EXERCISE 14.1	BACTERIAL TYPES	145
EXERCISE 14.2	GRAM STAINING	146
EXERCISE 14.3	COLIFORM BACTERIA	147
	<i>Extended 2-week exercise</i>	
EXERCISE 14.4	THE PLAGUE	151
	<i>Web exercise</i>	

<b>CHAPTER 15</b>	<b>Protists</b>	<b>153</b>
EXERCISE 15.1	ANIMAL-LIKE PROTISTS	153
EXERCISE 15.2	FUNGUS-LIKE PROTISTS	158
EXERCISE 15.3	PLANT-LIKE PROTISTS	160
EXERCISE 15.4	PROTOZOAN RACES	162
EXERCISE 15.5	HAY INFUSION CULTURES	163
	<i>Extended 2- to 6-week exercise</i>	
EXERCISE 15.6	EMERGING DISEASES	165
	<i>Web exercise</i>	
<b>CHAPTER 16</b>	<b>Fungi</b>	<b>167</b>
EXERCISE 16.1	ZYGOTE-FORMING FUNGI	169
EXERCISE 16.2	SAC FUNGI	169
EXERCISE 16.3	CLUB FUNGI	170
EXERCISE 16.4	LICHENS	172
EXERCISE 16.5	ERGOTISM	173
	<i>Web exercise</i>	
<b>CHAPTER 17</b>	<b>Plant Diversity</b>	<b>175</b>
EXERCISE 17.1	BRYOPHYTES: NONVASCULAR PLANTS	175
EXERCISE 17.2	PTEROPHYTES: SEEDLESS VASCULAR PLANTS	178
EXERCISE 17.3	GYMNOSPERMS: NAKED-SEED PLANTS	180
EXERCISE 17.4	ANGIOSPERMS: FLOWERING PLANTS	183
<b>CHAPTER 18</b>	<b>Flowering Plants: Structure and Function</b>	<b>185</b>
EXERCISE 18.1	ROOT ANATOMY	185
EXERCISE 18.2	HERBACEOUS STEM ANATOMY	187
EXERCISE 18.3	WOODY STEM ANATOMY	189
EXERCISE 18.4	LEAF ANATOMY	190
EXERCISE 18.5	A VISIT FROM DARWIN	191
	<i>Extended 4-week exercise</i>	
EXERCISE 18.6	APPLIED BOTANY AND MYCOLOGY	193
	<i>Web exercise</i>	
<b>CHAPTER 19</b>	<b>Invertebrates</b>	<b>195</b>
EXERCISE 19.1	EMBRYOLOGICAL DEVELOPMENT	195
EXERCISE 19.2	PHYLUM PORIFERA: SPONGES	198

EXERCISE 19.3	PHYLUM CNIDARIA: TISSUE TYPES AND <i>OBELIA</i> LIFE CYCLE	199
EXERCISE 19.4	PHYLUM PLATYHELMINTHES	201
EXERCISE 19.5	PSEUDOCOELOMATES	204
EXERCISE 19.6	PHYLUM MOLLUSCA	206
EXERCISE 19.7	PHYLUM ANNELIDA	208
EXERCISE 19.8	PHYLUM ECHINODERMATA	209
<b>CHAPTER 20</b>	<b>Arthropods</b>	<b>211</b>
EXERCISE 20.1	SUBPHYLUM TRILOBITA: TRILOBITES	212
EXERCISE 20.2	SUBPHYLUM CHELICERATA: HORSESHOE CRABS AND SPIDERS	213
EXERCISE 20.3	SUBPHYLUM CRUSTACEA: CRAYFISH DISSECTION	216
EXERCISE 20.4	SUBPHYLUM UNIRAMIA: THE MILLIPEDE	219
EXERCISE 20.5	SUBPHYLUM UNIRAMIA: INSECT ANATOMY	220
EXERCISE 20.6	INSECT METAMORPHOSIS	222
EXERCISE 20.7	HUMAN-INVERTEBRATE RELATIONSHIPS	224
	<i>Web exercise</i>	
<b>CHAPTER 21</b>	<b>Chordates</b>	<b>225</b>
EXERCISE 21.1	FOUR CHORDATE CHARACTERISTICS	225
EXERCISE 21.2	VERTEBRATE SURVEY	227
EXERCISE 21.3	MAMMALIAN DENTITION	232
EXERCISE 21.4	CONSTRUCTING AN ANIMAL KEY	233
<b>UNIT 6</b>	<b>MAMMALIAN ANATOMY</b>	<b>235</b>
<b>CHAPTER 22</b>	<b>Tissues and the Skeletal System</b>	<b>237</b>
EXERCISE 22.1	EPITHELIAL TISSUE	237
EXERCISE 22.2	CONNECTIVE TISSUE	239
EXERCISE 22.3	MUSCLE TISSUE	242
EXERCISE 22.4	THE SKELETAL SYSTEM	243
<b>CHAPTER 23</b>	<b>The Nervous System and Sensory Perception</b>	<b>247</b>
EXERCISE 23.1	THE NEURON	248
EXERCISE 23.2	REFLEX RESPONSES	248
EXERCISE 23.3	VOLUNTARY RESPONSES	249
EXERCISE 23.4	THE BRAIN	252

EXERCISE 23.5	THE EYE	254
EXERCISE 23.6	THE EAR	256
<b>CHAPTER 24</b>	<b>The Cardiovascular System</b>	<b>259</b>
EXERCISE 24.1	THE HEART	259
EXERCISE 24.2	PULSE RATE AND BLOOD PRESSURE	263
<b>CHAPTER 25</b>	<b>Rat Dissection</b>	<b>267</b>
EXERCISE 25.1	EXTERNAL ANATOMY	267
EXERCISE 25.2	INTERNAL ANATOMY	268
	<i>Continuous with Exercise 25.1</i>	
EXERCISE 25.3	THE DIGESTIVE SYSTEM	270
	<i>Continuous with Exercise 25.1</i>	
EXERCISE 25.4	THE EXCRETORY SYSTEM	272
	<i>Continuous with Exercise 25.1</i>	
EXERCISE 25.5	25.5 THE REPRODUCTIVE SYSTEMS	274
	<i>Continuous with Exercise 25.1</i>	
<b>UNIT 7</b>	<b>ECOLOGY</b>	<b>276</b>
<b>CHAPTER 26</b>	<b>Population Ecology</b>	<b>277</b>
EXERCISE 26.1	DYNAMICS OF AN ANIMAL POPULATION	278
	<i>Extended 5- to 11-week exercise</i>	
EXERCISE 26.2	DYNAMICS OF A PLANT POPULATION	282
	<i>Extended 5- to 15-week exercise</i>	
EXERCISE 26.3	LIFE TABLE FOR A HUMAN POPULATION	284
	<i>Extended 2-week exercise OR only 1 week if data is already available</i>	
EXERCISE 26.4	HUMAN POPULATION PATTERNS	294
	<i>Web exercise</i>	
<b>CHAPTER 27</b>	<b>Community and Environmental Ecology</b>	<b>297</b>
EXERCISE 27.1	AQUATIC COMMUNITY TROPHIC STRUCTURE	298
	<i>Extended 2-week exercise</i>	
EXERCISE 27.2	INVERTEBRATES AS WATER QUALITY INDICATORS	301
	<i>Continuous with Exercise 27.1</i>	
EXERCISE 27.3	EFFECTS OF ACID RAIN	304
	<i>Extended 4- to 26-week exercise</i>	
	<i>Continuous with Exercise 27.1</i>	
EXERCISE 27.4	SPECIES DIVERSITY	307
	<i>Continuous with Exercise 27.1</i>	

EXERCISE 27.5	DIVERSITY OF INSTITUTIONS	312
EXERCISE 27.6	ECOSYSTEMS	314
<i>Web exercise</i>		
<b>CHAPTER 28</b>	<b>Predation</b>	<b>317</b>
EXERCISE 28.1	PREDATOR-PREY INTERACTIONS AND POPULATION DYNAMICS	317
<i>Extended 2- to 3-week exercise</i>		
EXERCISE 28.2	OWL PELLETS	318
<b>CHAPTER 29</b>	<b>Symbiosis</b>	<b>325</b>
EXERCISE 29.1	HUMAN MITES	325
EXERCISE 29.2	TERMITES AND PROTOZOANS	327
EXERCISE 29.3	HUMAN HELMINTHS	328
EXERCISE 29.4	JAR OF WORMS	336
EXERCISE 29.5	WATER	337
<i>Web exercise</i>		
<b>CHAPTER 30</b>	<b>Animal Behavior</b>	<b>339</b>
EXERCISE 30.1	TERRESTRIAL TAXIS	339
EXERCISE 30.2	AQUATIC TAXIS	342
EXERCISE 30.3	SOCIAL BEHAVIOR OF BETTA FISH	344
<b>APPENDIX</b>	<b><i>Darwin: The Power of Movement in Plants</i></b>	<b>347</b>
<b>REFERENCES AND SUGGESTED READINGS</b>		<b>351</b>
<b>ART SOURCES</b>		<b>365</b>
<b>CREDITS</b>		<b>367</b>

# 1

## *Science as a Way of Learning*

*We start off confused and end up confused on a higher level.*

*A. F. Chalmers, 1976*

Here you are, in a biology course that you've put off as long as possible. Does the word *science* give you an uneasy feeling? Science can be overwhelmingly complex, but learning about it doesn't have to be. A famous scientist once said that science is "nothing but trained and organized common sense" (*Huxley, 1854*). Take it one step at a time, and you will see how the pieces fit together.

Start by observing something about the living world around you. You may notice a vine-like morning glory climbing on a fence, for example (Figure 1.1). Then ask a question. Why do the flowers of a morning glory bloom (open) only for a few hours each day? By asking a question, you are already on your way to understanding biology. You may not realize how many steps you take just to ask a question: you look at the plant on several occasions, and you observe how the flowers are open in the morning, but closed later in the day.

Why do they bloom only for a few hours? The steps you take to answer the question will flow in a logical manner. You think of some factors that may affect blooming. Do the flowers open only on sunny days? Does blooming depend on the temperature? Does humidity play a part in blooming? You decide to answer your question by investigat-



FIGURE 1.1 Morning Glory.

ing one of the possibilities. If blooming is temperature-dependent, then the flowers should open as the temperature climbs, and close as higher temperature approaches.

After observing the flowers for a few days, you may see a pattern that is consistent with the temperature-dependent approach. Or you may see a pattern that isn't. In either case, you could start the investigation over to learn additional information. If the flowers bloom in a temperature-dependent manner, then you can investigate why they might do so. Or if temperature doesn't seem to have an effect on blooming, then you can eliminate that possibility and investigate another.

In this manner, we do indeed start off confused (with a question) and end up confused (with another question) on a higher level! Much of biology is discovered with this approach, called the **scientific method** [Krogh section 1.3]. As you can see, it is only organized common sense, but it can lead to fascinating knowledge.

## THE SCIENTIFIC METHOD

The example just presented fits into the steps of the scientific method.

1. **Observation** You observe that *morning glory blooms only during certain hours of the day*. In many experiments, this step includes personal observation as well as reading what is already published. Such pieces of information are sometimes referred to as *facts*. In science, *fact* refers to a piece of information; this is unlike the vernacular (every day) use, where *fact* refers to a statement of truth, or something that is undeniable.
2. **Question** The question that follows is *Why do the blooms close at midday?*
3. **Hypothesis** A hypothesis is a tentative, general statement based on specific observations. You have several hypotheses: *Sunlight affects blooming. Temperature affects blooming. Humidity affects blooming.*
4. **Prediction** Predictions are logical conclusions to be expected in view of the hypothesis. They may be phrased in the form of an if-then statement: If the hypothesis is correct, then a certain outcome is expected. Predictions provide opportunities to find independent pieces of evidence supporting a

hypothesis, as well as opportunities to reject a faulty hypothesis. Based on the temperature hypothesis, this prediction follows: *If blooming is temperature dependent, then the flowers should open as the temperature climbs and close as higher temperature approaches.*

5. **Experiments** Predictions are tested by observation and/or experimentation. If you conduct your experiment over a few days, you may find that *blooming is temperature dependent*. Or you may not.
6. **Conclusion** New data is the product of observation and experimentation. *The new data will either support or fail to support the hypothesis.* *Datum* is singular, and *data* is plural.

**A hypothesis can never be proven.** To claim that you have proven a hypothesis is to claim that you have a hold on absolute truth. Within the conceptual boundaries of science, absolute truth is unattainable. This is not to say that absolute truth does not exist, just that it can never be known in regard to science. It is most appropriate for a scientist to use terms like *data* rather than *facts* and *principles* rather than *truths*. It is better for a scientist to say that data *suggest* than to say that data *prove* something.

Why is a scientific discovery not “absolute truth”? There are several reasons. One is because hypotheses are based on observations and data from a particular point in time. We are continuously learning more about the world around us, and sometimes new information pushes old conclusions aside. You may say “Eureka! I have proven that blooming in morning glories is temperature dependent!” But you’ll be scratching your head if someone else finds that the flowers bloom even in colder (yet very sunny) weather next week. And so, you’ll have to show your objectivity, step aside, and consider their findings.

Once a hypothesis has amassed a great amount of supporting evidence, it may be afforded the status of theory. A **theory** is a general set of principles that explain some aspect of nature. Note that a theory is *not* a hypothesis that has been proven. It is a hypothesis with a tremendous amount of supporting evidence.

In scientific use, a *theory* is a widely accepted paradigm, or model, that is supported by a tremendous amount of evidence. In vernacular use, *theory* refers to an idea, often with no more validity than a guess.

### Exercise 1.1 EXPERIMENTAL DESIGN

In designing an experiment several variables are defined:

The **independent variable** is the variable that is manipulated. *You manipulate the temperature of the plant's atmosphere.*

The **dependent variable** is the variable that will be measured. *You measure plant blooming, noticing the temperature at which the plant blooms.*

**Controlled variables** are kept constant throughout the experiment. *The soil type, amount of water applied, and amount of light are kept constant.*

The **experimental group** contains plants that are subjected to manipulation. *Morning glory plants in this group will be subjected to rising temperature.*

The **control group** contains standard conditions, in which the independent variable is not manipulated. The control group usually approximates "normal" conditions. However, these plants should be grown in the lab, to eliminate effects of humidity and plant growth, variables we do not want in this experiment. *Morning glory plants in this group will be exposed to constant temperature.*

Read this very carefully: When comparing the experimental group to the control group, the effects of the independent variable can be determined by measuring the dependent variable in both groups. *You compare blooming in the experimental group to blooming in the control group. Does temperature appear to have an effect on blooming? If yes, then the data support the hypothesis. If not, then the hypothesis is rejected.*

When scientists compare experimental to control groups, they do so using statistical analysis, which are mathematical tests to determine whether observed differences in the two groups are "real" or are a result of "pure chance." When a scientist claims that something is significantly different from something else, she is implying that the differences are real according to statistical analysis.

After reading the following example, identify the components of its experimental design.

Farmer Hen read an article in *Sodbuster* magazine that some researchers "down at the U" had developed a new fertilizer called *Big Red*

*Fertilizer*. The product was supposed to be nothing short of an agricultural miracle. It produced corn plants that had more ears per plant. The article even claimed that kids who ate the corn grown with *Big Red Fertilizer* would turn into star athletes.

Based on what he read and what he had heard, Farmer Hen generated the hypothesis that *Big Red Fertilizer enhances corn production better than regular fertilizer*. From this hypothesis, Farmer Hen predicted that *if Big Red Fertilizer enhances corn production better than regular fertilizer, then corn plants raised on Big Red Fertilizer will have more ears of corn per plant than corn raised on regular fertilizer*. He designed an experiment to test the prediction as follows: Corn was planted at the same time in two adjacent fields. One field was fertilized with *Big Red Fertilizer* and the other received regular fertilizer. The fields were plowed on the same days and were irrigated, receiving equal amounts of water on the same days.

At the end of the season, Farmer Hen observed the corn plants and found that plants maintained on *Big Red Fertilizer* indeed had more ears than those that had received regular fertilizer. Thus his prediction was found to be correct, and the hypothesis that *Big Red Fertilizer enhances corn production better than regular fertilizer* was supported. Note that although the hypothesis was supported, it was not *proven* to be correct!

### Questions

1. What is the hypothesis?

2. What is the prediction?



**3. Which plants are included in the experimental group?**

**have more ears of corn per plant than plants from the experimental field?**

**4. Which plants are included in the control group?**

**9. What conclusion would be drawn if the corn plants in the control field were found to be taller than plants from the experimental field?**

**5. Identify the independent variable.**

**10. What other prediction(s) might be generated from the hypothesis in the preceding example?**

**6. Identify the dependent variable.**

### **Exercise 1.2 A LIBRARY EXERCISE IN THE SCIENTIFIC METHOD**

**7. Identify the controlled variables.**

Another step in the scientific method is publication of the findings. Findings are of no value unless they are communicated throughout the scientific community! Results of scientific investigation are sometimes reported in journals maintained by professional scientific societies. Examples of these include *Journal of Protozoology*, *American Journal of Botany*, and *American Midland Naturalist*. Table 1.1 gives the common parts of a scientific paper and describes the purpose for each section.

**8. What conclusion would be drawn if the corn plants in the control field were found to**

The vast majority of good experiments follow the scientific method, even if the hypothesis and prediction(s) are not explicitly stated. You will be assigned a scientific paper from a professional