

BIOLOGY FROM A CHRISTIAN WORLDVIEW

Devotional BIOLOGY

*Learning to Worship the
Creator of Organisms*



KURT P. WISE, PHD

LAB MANUAL

LAB MANUAL

ACCOMPANYING DEVOTIONAL BIOLOGY

Kurt P. Wise, PhD



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MATERIALS NEEDED

The following supplies are needed to complete the lab exercises which are part of the Devotional Biology course. We have partnered with Cornerstone Educational Supply to bundle the less common supplies at a great price. Items preceded by a checkmark below are included in the Lab Materials kit which can be purchased at CompassClassroom.com. Items with an empty circle will need to be supplied by the student.

COMPOUND BIOLOGICAL MICROSCOPE

- ✓ Included in kit. Features include:
 - 40-400X magnification
 - All-metal body construction
 - Monocular head with ergonomic 45° incline, 10X Wide-field ocular lens and 360° rotation
 - Triple-revolving nosepiece featuring achromatic 4X, 10X, and 40X objective lenses
 - Dual-layer mechanical stage and clip for precise slide movements
 - Abbe condenser (0.65 N.A.) for better contrast adjustment
 - Transmitted light from a variable-intensity LED
 - Coaxial coarse and fine adjustment with safety stop
 - Power via plug-in adapter or by 3 AA batteries (not included)

MICROSCOPE SLIDES

- ✓ 2 microscope slides and 2 cover slips
- ✓ boxed set of 12 prepared Microscope Slides
- ✓ letter 'e'
- ✓ colored threads
- ✓ *Paramecium caudatum*
- ✓ *Elodea* leaf
- ✓ *Amoeba proteus*, w.m.
- ✓ *Spirogyra*
- ✓ fish mitosis
- ✓ onion mitosis
- ✓ root hairs
- ✓ corn stem
- ✓ *Privet* leaf
- ✓ *Dicot* leaf epidermis

CHEMICALS

- ✓ 1 gm baking soda

- ✓ 1 gm corn starch
- ✓ 10 mL Methylene Blue
- ✓ 10 mL 2% IKI Indicator (Lugol's Solution)

LABWARE

- ✓ 1 50 mL beaker
- ✓ 1 250 mL beaker
- ✓ 1 10 mL syringe with plunger
- ✓ 1 10 mL graduated cylinder
- ✓ 1 50 mL graduated cylinder
- ✓ 1 glass stir rod
- ✓ 6 glass test tubes
- ✓ 1 test tube rack
- ✓ 1 test tube cleaning brush
- ✓ partial-immersion alcohol thermometer (-10 to 110°C)

OTHER SUPPLIES

- | | |
|---|---|
| ✓ 64 1-cm cubes | ○ pens |
| ✓ DNA Model Kit | ○ poster materials (optional) |
| ✓ magnetic chromosome simulation kit | ○ instrument capable of measuring a meter or a yard |
| ✓ 500 g digital pocket balance with ± 0.1 g sensitivity | ○ straight-edge |
| ✓ 1 single-hole paper punch | ○ camera (optional) |
| ✓ 1 forceps/tweezers | ○ marker capable of drawing on a block |
| ✓ 1 wax marking pencil | ○ calculator |
| ✓ 1 transparent 15 cm vinyl ruler | ○ 2 L distilled water |
| ✓ 2 pre-moistened sheets of lens paper | ○ 18 g white granulated sugar |
| ✓ 3 2"x3" zip-close bags | ○ 1 small cooking pan |
| ✓ 4 1-oz. plastic cups | ○ paper towels |
| ✓ 6 9-oz. short plastic cups | ○ plastic wrap |
| ✓ 3 disposable, plastic, needle-point pipets | ○ coffee cup |
| ○ supply of lined, college ruled paper | ○ refrigerator (for cooling) |
| ○ supply of unruled, white paper | ○ stovetop (for heating) |
| ○ pencils | ○ 2 8-oz. styrofoam cups |
| | ○ 1 raw potato |
| | ○ potato peeler |
| | ○ cutting board |
| | ○ 1 sharp kitchen knife |

- 1 small onion
- 1 toothpick
- 1 cotton ball
- 1 small cup
- 1 sharp kitchen knife
- a visit to a local nursery
- 4 spinach leaves
- 4 drops of liquid dish soap
- 1 stopwatch or timer
- 1 teaspoon
- 1 pair of scissors
- 1 small table
- 1 desk lamp
- 1 60-watt or higher incandescent or 1 13-watt or higher fluorescent light bulb
- 1 small box (enough to cover 4 plastic 9-oz. cups)

INTRODUCTION TO LABS

The lab exercises in this volume have been specifically designed to enhance the learning experience of students using Kurt P. Wise's Devotional Biology as their text.

First, the labs have been designed in a sequence that comes as close as possible to both the order and pacing of the material in the textbook. Specific recommendations about when to take a particular lab is included with each lab, but labs taken in numerical order at regular intervals throughout the course will turn out to parallel the textbook order and pace fairly well.

Secondly, the labs have been designed to facilitate tactile learning of the material offered visually in the text and orally in the videos. Therefore, it is recommended that the labs be completed alongside the corresponding video and text material.

Thirdly, the lab exercises have been tailored for the environment outside the traditional science laboratory. The lab exercises have been designed, for example, to be as non-sight-specific as possible, so that people can do these labs just about wherever they are on the planet.

Also, lab exercises have been created to avoid using chemicals that are not readily available in the average household. This is partly because safety and environmental regulations prevent certain items to be shipped to anything other than certified science laboratories and other items to be in the possession of uncertified personnel. In cases where chemicals are needed they have been designed to utilize chemicals in very small quantities.

MAXIMIZE LEARNING

We would also like you to get the most out of your learning experience. To that end, there are some things that are likely to improve your experience with biology labs. They include the following:

- **Use a Lab Partner.** While all the exercises for this course can be performed individually, it is often fun and useful to have a lab partner to discuss ideas with, help take measurements, and reinforce your learning process. Whether your partner is a parent, spouse, sibling, or friend, you will have to explain what you are doing, and in the process of teaching another, you will better teach yourself. Always review your experiments several days ahead of time so you have time to line up a partner if needed.
- **Read the Exercise Before You Start.** Knowing what you are going to do before you do it will help you organize your work and consider safety issues. Your exercises will be done more quickly, more safely, and you will understand them better.
- **Organize Your Work Space, Equipment, and Materials.** It is hard to organize your thoughts in a disorganized environment. It is also difficult to work through a procedure efficiently if you are continually searching for needed items.

- Each lab lists the equipment and supplies needed for that lab, so assemble all required equipment and supplies before you begin working, and lay them out in such a way that they can be accessed easily when needed.
- **Be Ready to Take Notes.** Most of the lab exercises require paper and pencil or pen to take notes as you work through the lab procedures. In some cases, the information is to be recorded in data tables.
- The entire process goes more efficiently if you not only read the lab exercise over to determine what you will need to make the required notes, but also have that paper or those data tables available before you even begin the exercise.
- **Follow Instructions.** Follow all instructions precisely in sequential order. Many of the procedures have been developed over years of experience, maximizing both learning potential, safety, and time efficiency. Being creative might actually compromise one or more of these things.
- **Think.** After you have completed the experimental procedures, and before creating the final write up, stop and give yourself time to reflect on what has happened in your experiment.
- What changes occurred? Why? What do those changes mean? How do they relate to the real world of God's creation? This step can be the most fun and often creates “light bulb” experiences of understanding.
- **Cleanup.** Always clean your laboratory space and laboratory equipment immediately after use. Wipe down all work surfaces that may have been exposed to chemicals. Blot any unused chemicals with a paper towel or flush them down the sink with generous amounts of water. Discard waste in your normal trash. Return cleaned equipment and supplies to the Lab Kit and store the Lab Kit out of reach of younger children and pets.
- **Complete Your Work.** Make all the notes, include all the required sketches, answer the required questions, and prepare your lab report. If you have properly followed all these steps and those above, the conclusion will be easy.

GENERAL LAB SAFETY AND PROCEDURES

GENERAL LAB SAFETY

Safety of our students is a priority. We ask that you please read and take seriously all safety instructions and follow all safety instructions while performing lab exercises. Safety instructions include the following:

- **Be Safety Conscious.** By far the best safety tools that you have are your own brain and your ability to think and plan. Before doing any lab exercises, read through all the safety notes of this section of the lab manual and keep those

principles in mind as you proceed through all lab exercises – even if a particular lab exercise does not include specific safety procedures.

- Then, before each lab exercise, read the procedures for that exercise, noting any safety notes and special procedures required in that exercise. Use that information to choose the best and safest location to perform the lab and to anticipate and avoid any potential hazards you might encounter during that exercise.
- **Choose the Right Place for Your Home Laboratory.** The best place to perform at-home experiments will be determined by the nature of the individual experiments. About half of the lab exercises in this volume are performed with pencil and paper in hand, while being among the organisms of God's creation.
- A couple more require the use of a microscope and are best done in a place with a sturdy table, an electrical power outlet, and no microscope-breaking interference from children or pets. This might be the kitchen or dining room table. A few more involve the use of chemicals. The appropriate location for these experiments would usually be an uncluttered room where a door can be closed to keep out children and pets, a window or door that can be opened for fresh air, ventilation, and fume exhaust, and a counter or tabletop work surface.
- A kitchen usually meets all these requirements. Sometimes the bathroom works too, but it can be cramped and subject to interruptions. Review each experiment before starting any work to help you select the most appropriate work area for that experiment.
- **Safely Store the Lab Kit.** Some of the items in your Lab Kit may be dangerous to children and pets. Although the number of chemicals is minimal and they are shipped to you in only very small quantities, some of the chemicals may cause burns if mishandled, or can cause serious illness and/or death if consumed.
- Some of the lab items may be made of glass and/or have sharp edges that can cause cuts and scratches. There are also small items and materials that could cause choking, injury, or death if eaten or misused by young children. Consequently, between experiments your Lab Kit should always be kept safely stored out of the reach of younger children and pets. And, while the Lab Kit is being used, care should be taken to make sure that children or pets do not have access.
- **Protect Your Body.** When using chemicals, protect your hair by keeping it tied back from your face. Protect your skin by wearing old clothing that fully covers your arms, legs, and feet. Do not wear clothing which hangs loose enough to dip into chemicals.
- **Protect Your Home.** Cover your work surface with plastic or paper towels when appropriate to prevent ruining of furniture, and to aid in cleanup afterwards.

- **Do Not Eat or Smoke.** Since chemicals, dirt, and germs are often involved in laboratory experiments, you should not eat or smoke in your laboratory area.
- **Do Not Goof Around.** A laboratory with potentially dangerous chemicals and equipment is a place for serious work, not for horseplay! Fooling around in the laboratory is an invitation for an accident.
- **Waft, Do Not Smell.** If you are trying to smell something, WAFT the odors to your nose, DO NOT bring your nose to the odor. And this is how you waft: partially fill your lungs with air and, while standing slightly back from (not over) whatever you wish to smell, use your hand to waft (fan) the odors gently toward your nose. Lightly sniff the fumes in a controlled fashion.
- **Never inhale fumes directly!** Treat inhalation problems with fresh air and consult a physician if the problem appears serious.
- **Clean Up Spills Immediately.** There is nothing included in your Lab Kit that is especially caustic, but if anything is spilled, wipe it up with generous amounts of water. If something comes in contact with skin, flush the exposed skin with a gentle flow of water for several minutes at a sink or shower or hose.
- **Have the Poison Hotline Number Available.** Again, there is nothing included in your Lab Kit that should be caustic, but if you or anyone else accidentally consumes or otherwise comes into contact with a substance that could be toxic or cannot be easily washed away, immediately call

The National Poison Control Center: 1-800-222-1222

- **Material Safety Data Sheets (MSDS).** Once again, these labs do not require contact with dangerous chemicals, but an important skill in the safe use of chemicals is the ability to read a Material Safety Data Sheet (MSDS). An MSDS is designed to provide chemical, physical, health, and safety information on chemical reagents and supplies. It provides information about how to handle, store, transport, use, and dispose of chemicals in a safe manner.
- An MSDS also provides workers and emergency personnel with the proper procedures for handling and working with chemical substances. An MSDS provides basic information about physical data, toxicity, health effects, first-aid procedures, chemical reactivity, safe storage, safe disposal, required protective equipment, and spill cleanup procedures. It is important to know how to read and understand an MSDS. An MSDS is generally organized into the following sections:
 - *Section 1:* Product Identification: Chemical name and trade names
 - *Section 2:* Hazardous Ingredients: Components and percentages

- *Section 3: Physical Data:* Boiling point, density, solubility in water, appearance, color, etc.
- *Section 4: Fire and Explosion Data:* Flash point, extinguisher media, special firefighting procedures, and unusual fire and explosion hazards
- *Section 5: Health Hazard Data:* Exposure limits, effects of overexposure, emergency and first-aid procedures
- *Section 6: Reactivity Data:* Stability, conditions to avoid, incompatible materials, etc.
- *Section 7: Spill or Leak Procedures:* Steps to take to control and clean up spills and leaks and waste disposal methods
- *Section 8: Control Measures:* Respiratory protection, ventilation, protection for eyes or skin, or other needed protective equipment
- *Section 9: Special Precautions:* How to handle and store, steps to take in a spill, disposal methods, and other precautions
- You can view MSDS information on any chemical at <https://chemicalsafety.com/sds-search/>. If you ever have a problem or question about the proper handling of any chemical, seek information from this source.

GENERAL LAB PROCEDURES

- **Use Distilled Water.** Tap water frequently contains ions that may interfere with the substances you are studying.
- To avoid such interference, use distilled or deionized water any time water is needed for dilution of concentration or the preparation of experimental solutions. Wash used glassware with soap, rinse with tap water, and rinse again with distilled water.
- **Do Not Return Chemicals.** Once dispensed, do not return chemicals to their storage containers as this could cause contamination. To avoid over-dispensing, dispense only a little at time. Dispense more as needed.
- **Do Not Touch.** To minimize contamination, avoid touching the surfaces of clean items that might later come in contact with test chemicals.
- **Pouring Powders or Crystals.** To obtain samples of a powder or of solid crystals from a container, it is best to pour the approximate amount of powder or crystals onto a small piece of clean, creased paper for easy transport. Pour powders and crystals by tilting the container, gently shaking and rotating the solids up to the container lip, and allowing the solids to slowly fall out.
- If you pour too much, do not put any back in the container. Also, to avoid contamination, never put wooden splints, spatulas, or paper into a container of powder or crystals.

- **Pouring Liquids.** In these labs you usually use only small drops of chemicals. If the chemical is in a pipet with a sealed tip, use scissors to cut off the tip of the pipet perpendicular to the pipet body (cutting at an angle will distort drop sizes). To get drop sizes as uniform as possible, hold the pipet in a vertical position in front of your eyes. This way, as you slowly squeeze the pipet you can carefully observe and count the number of drops dispensed.
- **Resealing a Pipet.** If you wish to reseal a pipet with unused chemicals inside, heat the tip of a metal knife and press the pipet tip onto the hot metal while twirling the bulb. Never simply hold a flame to the tip of the stem!
- **Measuring Mass.** The digital top-loading balance is initially zeroed by pressing the zero button. This button also allows you to exclude the mass of a container: if you will be weighing something on weighing paper or in a beaker, first place that object on the balance without the substance you wish to weigh, then press the zero button. This will produce a zero reading, and the weight of the paper or beaker will be automatically excluded from the weighing process.
- **Measuring Volume.** To obtain accurate measurements from any glass volume measurement container, such as a graduated cylinder, you must identify and correctly read a curved surface known as the meniscus.
- Because water climbs up the sides of glass tubes, the surface of the water is curved, with the water being the highest along the edges of the tube. The standard manner of reading the volume of water is to read the volume at the very bottom of its curve. When using plastic containers, a meniscus will not form.

CLEANUP AT THE END OF EVERY LAB

- **Disposing of Chemicals.** Blot up used and leftover chemicals with paper towels and place in a garbage bin or flush down a drain using copious amounts of water.
- Due to the minute quantities and diluted and/or neutralized chemicals used in these experiments, this disposal method is well within acceptable levels of disposal guidelines defined for the vast majority of local solid and wastewater regulations.
- Since regulations occasionally vary in some communities, you are advised to check with your local area waste authorities to confirm these disposal techniques are in compliance with local regulations and/or if you should seek assistance with disposal.
- **Disposing of Non-Chemicals.** Discard non-chemical experimental items with household garbage but first wrap them in newspaper. Place these items in a securely covered trash container that cannot be accessed by children and animals.

- **Cleaning Plastic Pipets.** To clean a thin-stemmed plastic pipet, squeeze the bulb to draw up and then expel tap water from the bulb several times. Repeat this process with distilled water.
- Dry the pipet by repeatedly squeezing the bulb while tapping the tip on a clean paper towel. Then use gravity to help dry the pipet by forcefully swinging the pipet into a downward arch while squeezing the bulb. Lay the pipet on a clean paper towel or place it in a test tube stand and allow it to air dry.
- **Cleaning Glassware, Plastics, or Equipment.** Use a mild liquid dishwashing detergent mixed with warm water to loosen solids or oils that adhere to experimental glassware, plastics, and equipment and to clean laboratory equipment and the laboratory area after an experiment.
- Use tap water to rinse washed items well and remove all traces of detergent.
- Use a soft cloth or a test tube brush to loosen and clean residue from the surfaces of experimental glassware, plastics, and equipment.
- Use a final rinse of distilled water to clean tap water mineral residue from newly washed items, especially beakers, cylinders, test tubes, and pipets.
- Dry test tubes by placing them upside-down in the test tube rack. Air dry other items by placing them on paper towels, aluminum foil, or a clean dishtowel.
- **Cleanup at the End of the Course.** Since your Lab Kit contains potentially dangerous items, it is important that you perform a final cleanup to properly dispose of any leftover chemicals, specimens, and unused materials.
- Please take a few minutes to protect others from possible harm and yourself from future liability by complying with these final cleanup instructions.
- **Do Not Sell.** While you may wish to sell your used Lab Kit, this is not advisable and would be unfair to a potential purchaser. It is unlikely that a new student trying to utilize a used Lab Kit would have adequate quantities or sufficiently fresh chemicals and supplies to properly perform all the experiments and to have an effective learning experience.
- Further, it is doubtful that adequate safety information would be passed on to a new student in the same way it was presented to you. Instead, you would be responsible for any problems experienced by a new user.
- **Do Not Return.** Please do not return items, as we are unable to resell items or issue any refunds.
- **Disposal of Chemicals.** Due to the minute quantities, low concentrations, and diluted chemicals used in your Lab Kit, it is generally sufficient to wipe up any remaining chemicals with paper towels and dispose of them in a trash bin or flush remaining chemicals down a drain with copious amounts of water. Empty dispensing pipets and bottles can be placed in a normal trash bin.

- These disposal methods are well within acceptable levels of the waste disposal guidelines defined for the vast majority of state and community solid and wastewater regulations. However, since regulations can vary in some communities, if you have any doubts or concerns, you should check with your area authorities to confirm compliance with local regulations and/or if assistance with disposal is desired.
- **Disposal of Non-Chemicals.** Non-chemical supplies can also be discarded with household garbage, but should first be wrapped in newspaper or waste paper. Place such items in a securely covered trash container that will prevent children and animals from accessing the contents.
- **Keep or Discard the Rest.** Many students choose to keep the durable science equipment included with their Lab Kit as most of these items may have future utility or be used for future science exploration.
- However, take care to store any dangerous items, especially breakable glass, out of the reach of children.

LAB REPORT

A lab report is required for each lab. In some cases, a lab report template is included with the lab and student need only fill in the blanks and submit that lab report. In other cases, the student will need to compose his or her own lab report. For lab reports the following is expected:

- Each student is to submit a separate lab report, even if students work on the lab in groups.
- Necessary information required at the top of the first page of the lab report:
 - the student's name and (when applicable) the name of partner(s);
 - the name of the lab and the date the lab was performed; and
 - the date and time that the lab report was submitted.
- When graphs, photographs, and/or sketches are generated in the lab, those are to be included in the lab report document.
- When the lab includes questions, the lab report must not only include the student's answer to each question (in full sentences in the student's own words), but also each question should be included along with the number of the question (as given in the lab manual).
- At the end of the lab report in a section labeled 'Lesson', the student is to summarize what he/she learned (or was supposed to learn) in that particular lab.

An example format is shown on the next page:

LAB REPORT FOR INSECT IDENTIFICATION LAB

Name: Joe Schmough Partners: Mary O. Reelee and Ewe R. Kidding

Lab Date: 1 April 2050 Submission Date: 8 April 2050, 1:00 p.m.

LAB QUESTIONS & ANSWERS

1. How many different fly species, how many different beetle species, and how many different butterfly species did you count?

Answer: I counted 24 fly species, 72 beetle species, and 21 butterfly species.

2. Compare and contrast the wings of the specimens.

Answer: All the specimens had wings, but they differed on the number and type of wings. All the flies had only had one pair of transparent wings; all the beetles had one pair of transparent wings and one pair of hard coverings over them; and all the butterflies had four opaque wings.

3. What are the order designations of the specimens?

Answer: The flies are in the order *Diptera*. The beetles are in the order *Coleoptera*. The butterflies are in the order *Lepidoptera*.

LESSON

The three most diverse insect orders are rather easily identified by the nature of their wings. Insects with two wings are in the order *Diptera* (flies). Insects with four opaque wings are in the order *Lepidoptera* (butterflies and moths). Insects with transparent wings under a hard covering are in the order *Coleoptera* (beetles).

LAB EXERCISE 1: TUNING INTO CREATION

PURPOSE OF THIS EXERCISE

To take time to observe organisms and their environment.

STUDENT LEARNING OUTCOMES

The student will be able to:

- document plants and animals in an environmental plot.

WHEN TO PERFORM THIS EXERCISE

This exercise is designed to be performed before lab exercises 2 and 4, so it is recommended that it be performed while the student is going through the Preface or Chapter 1 in the *Devotional Biology* text.

MATERIALS NEEDED

MATERIALS PROVIDED BY THE STUDENT

meter ruler (or other instrument capable of measuring either a meter or a yard)
unruled white paper
straight-edge
choice for lab report (pencil, pen, or computer)
pencil or camera (for sketching or photographing organisms)

INTRODUCTION

Observation of the physical world is important. First, it's important for scientists because the physical world is science's standard of truth. Second, it *ought* to be important for all people, for humans have been given the responsibility of ruling over the creation. It is hard to rule well over things we don't even notice. Third, God has chosen to illustrate His invisible attributes in it, so we could also learn about God by observing the physical world. This lab exercise is designed to encourage observation of the physical world.

PROCEDURE

- A. Collect the above materials and (optionally) pick a partner.
- B. Find a natural setting and measure out a square plot on the ground one meter (or one yard) on a side. **Note:** If the time of year makes this exercise impractical (*e.g.* If there is 6" of snow on the ground!), choose a location that is simulating a natural

environment (such as a large reef tank in an aquarium or a greenhouse-enclosed tropical forest exhibit at an arboretum or a swamp exhibit at the zoo, *etc.*), and improvise (*e.g.* You may have to ‘imagine’ a meter-sided plot on the surface in front of you because you are not allowed to actually get to it and touch it.).

- C. Draw as large a square as possible on a sheet of unlined paper, and outside the square label its dimensions (meter or yard), indicate where the plot is located (*e.g.* address or GPS coordinates or location on what road in what county in what state in what country), and indicate which way is north [Potentially helpful hint: The sun rises in the east, sets in the west, and (in the northern hemisphere) is always a bit south of the east-to-west midline of the sky.]

Record also time and general weather conditions at the time of observation (*e.g.* approximate temperature, sunny vs. cloudy vs. raining vs. snowing). Inside the square, locate and sketch what you find in the plot (as per the instructions that follow). **Note:** Even if you work with a partner, each student is to sketch the plot and include it in his or her lab report.

- D. Consider the plants in your plot.

1. On your lab report list the different types of plants found in your plot. For each plant species give the name of the species if you know it, otherwise ‘name’ it with a brief description.
2. [**Note:** If you are considering an environment that lacks plants (such as a coral reef) consider the organisms that are creating the motionless structures of the environment and the food for the other organisms (*e.g.* the corals in a coral reef).]
3. Using distinguishing alphabet letters for each plant species, indicate on your sketch of your plot where each plant species is located.
4. Somewhere outside of your plot square, sketch (or photograph) at least two different plant species that are found in your plot. **Note:** If you photograph the plant species, the photograph(s) must be embedded in the final lab report.
5. Carefully examine the plants and determine if there is any evidence that they are being eaten by animals. Include these observations on your sketch.

- E. Consider the animals in your plot. Look around, in, and under things to see what animals you can find in your plot.

1. On your lab report list the different types of animals you find in your plot. For each animal species give the name of the species if you know it, otherwise ‘name’ it with a brief description.
2. Using distinguishing numbers for each animal species, indicate on your plot sketch where each animal species was found.

3. Somewhere outside of your plot sketch, sketch (or photograph) at least two different animal species that are found in your plot. **Note:** If you photograph the animal species, the photograph(s) must be embedded in the final lab report.
- F. Science is usually done to answer questions about the physical world that intrigue the scientist. As you consider your plot, include in your lab report at least three such questions that come to mind about the plot and its organisms.
- G. Compose and submit a lab report that includes your environmental plot, any sketches or photographs you created, and answers to the following questions, and summary of what you have learned.

QUESTIONS FOR THE LAB REPORT

1. Considering the organisms you found in your plot, list 10 things in the environment that must be available for those organisms to live there. (Be specific.)
2. Do you think the environment of your plot would be acceptable to every species of plant in the world? Why or why not?
3. Is there anything about your plot that points to God or reminds you of God?

LAB EXERCISE 3: BIOLOGICAL BEAUTY

PURPOSE OF THIS EXERCISE

To observe, capture, and share the significance of biological beauty.

STUDENT LEARNING OUTCOMES

The student will be able to:

- recognize examples of biological beauty and what that indicates about God, and
- share biological beauty so that another person is brought into praise to God.

WHEN TO PERFORM THIS EXERCISE

It is recommended that the student perform this lab experience while or just after going through the material of Chapter 3 in the *Devotional Biology* text.

MATERIALS NEEDED

MATERIALS PROVIDED BY THE STUDENT

choice (whatever is needed to capture and share beauty)

INTRODUCTION

There is considerable beauty in the biological world. In fact, it is likely that every person on this planet finds at least some beauty in at least some part of the biological world. Whether in flowers or butterflies or fields of crops or wilderness landscapes, *etc.*, beauty is all about us.

That beauty is a dim physical illustration of the awesome glory of the Creator of organisms. Such a God could not help but create things in the beginning with incredible beauty (He called everything ‘very good’). He cannot help but make every beautiful in time – even those things not now beautiful (Eccl. 3:11). He could do nothing else than make heaven awesomely beautiful (*e.g.* heaven’s description in Revelation 22).

It is the primary purpose of humans to bring glory to God. We can do this by testifying of His awesome acts. One of the ways we can do this is by bringing attention to something God has done and bringing others into praise to God for it. We can and ought to do this for all those things which reflect on the nature of God – including biological beauty.

When we recognize the beauty in the creation and acknowledge where it comes from, we bring glory to Him. If the beauty impresses us enough, it can even cause us to worship Him. And, if we share that beauty with others, we may be able to minister

to others. Christians might have opportunity to share the gospel with unbelievers and bring fellow believers into worship with us. This exercise is designed to encourage you to observe creation's beauty, recognize what it means about God, and share that beauty with others.

PROCEDURE

- A. Choose some aspect of biological beauty (*e.g.* a flower, a bird's song, a biological landscape, feeding of offspring, a butterfly's flight...) [25% of possible points of lab].

Note: It is beauty of biology that is to be captured here, so the Andromeda Galaxy or a sunset over the ocean might be beautiful, but it is not biological, so make sure that which you are capturing the beauty of is both beautiful and biological.

- B. Choose some medium through which you will represent that beauty (*e.g.* via high quality photograph, or recording, or poem, or song, or drawing, or painting, or sculpture...) [25% of possible points of lab].
- C. Design and construct a context for that presentation (*e.g.* webpage, or wall-hanging, or desk ornament, or tract, or pdf, or sound file...). Make sure that when a person experiences what you have done, you have done something that encourages them to bring praise to God for that beauty. [20% of possible lab points for attractiveness of presentation; 20% for message of God's praise; 10% point for creativity].
- D. Compose a lab report that includes all the components of your presentation, as well as a summary of what you learned in this lab.

Note: Students may work in groups (to, for example, share a photographer or sound technician, etc.), but if so, each student is still to hand in a separate and different lab report.

LAB EXERCISE 5: SURFACE AREA/VOLUME RELATIONSHIPS

PURPOSE OF THIS EXERCISE

To understand how surface area and volume increase with size and what consequences this has for organisms.

STUDENT LEARNING OUTCOMES

The student will be able to:

- describe how surface area and volume increases with size,
- explain why within bird and mammal families the largest species tend to live in cold environments and the smallest species tend to live in warm environments,
- explain why small people tend to freeze to death before large people,
- explain why flatworms are so flat, and
- explain why bacteria have no organelles.

WHEN TO PERFORM THIS EXERCISE

This lab exercise introduces a principle that is helpful in understanding a wide range of biological observations. The principle explains how mycorrhizal fungi help plants bring in water (Chapters 5 and 8 of *Devotional Biology*), why *Devotional Biology* refers to single-celled organisms without organelles as ‘bacteria’ and not ‘prokaryotes’ (Chapter 11) and how root hairs help plants bring in water (Chapter 12).

It is most useful if this lab exercise is performed before the student tackles Chapter 11. If done while the student is studying Chapter 6, the overall lab pace is kept more or less constant.

MATERIALS NEEDED

MATERIALS PROVIDED BY THE STUDENT

marker capable of drawing on a block
calculator
choice for lab report (pencil, pen, or computer)

MATERIALS FROM THE LAB KIT

at least 64 blocks

INTRODUCTION

Why is a flatworm flat? Within a family of mammals and birds why do the larger species tend to live in cold environments? Why do bacteria lack organelles? How can earthworms live without lungs? Why were the thin people the first to freeze to death in the Donner party? Why does an organism change shape as it grows up? Why is it that even though the upper leg bones of humans and cows are of equal lengths, the cow's bone is much thicker? Why is the interior of our intestines so much rougher than the interior of frog intestines?

The answer to these questions and many others are the consequence of a simple mathematical relationship between area and volume – a relationship we will examine in this lab.

PROCEDURE A: SURFACE AREAS AND VOLUMES OF CUBES

BACKGROUND INFORMATION

Assume that each of the blocks is a perfect cube – in other words that the length of each side is exactly the same. For this lab we will create a measuring system based upon these blocks. We will say that each side of each block has a *length* of one **bim** (*i.e.* the unit of length is a 'bim'). The plural form of bim will be '**bims**', and bim will be abbreviated as **b**.

We will further say that each side of each block has a *surface area* of one **square bim** (plural form: 'square bims'; written as b^2), and each block has a *volume* of one **cubic bim** (plural form: 'cubic bims'; written as b^3). Since we usually refer to the 'size' of a cube by the length of one of its sides, we will do the same with our cubes. For example, a 'two-foot cube' would refer to a cube where each side of the cube is two feet long. Consequently, each block you have is a 'one bim cube'.

- A. Consider one block. Noting the background information given above, and counting blocks (to determine volume) and exposed sides (to determine surface area), *record in the appropriate rows of the 'by counting' column of Table A of your lab report* the volume and total surface area of this 1 bim cube (in square bims and cubic bims). Note The block's *total* surface area is the sum of the surface areas of all sides of the block.
- B. By stacking blocks, create a '2 bim cube' [After doing so, check to make sure it's 2 bims wide, 2 bims long, and 2 bims high.]. By counting blocks (to determine volume) and exposed sides (to determine surface area), determine the volume and total surface area of a 2 bim cube, and *record in the appropriate rows of the 'by counting' column of Table A of your lab report*.
- C. Repeat B for a '3 bim cube'.
- D. Repeat B for a '4 bim cube'.

- E. The mathematical formula for the area of any rectangle is ‘length times width’ ($L \times W$). Since the sides of a cube are all the same length, the area of any side of a cube is ‘length times length’ ($L \times L$, or L^2), and since there are six sides on a cube, the total surface area of a cube is ‘6 times length times length’ ($6 \times L \times L$, or $6L^2$).

Using the $6L^2$ formula, *calculate* the surface area of the 1, 2, 3, and 4 bim cubes and *record in the appropriate rows of the ‘by calculating’ column of Table A of your lab report.*

[**Note:** It may be helpful to note that units can be multiplied like numbers. So, for example, 5 bims times 5 bims equals 25 square bims.] *Note also in the right-most column of Table A of your lab report* whether or not you got the same surface areas by counting (steps A1 through A4) that you got by calculating (step A5).

- F. The mathematical formula for the volume of any rectangular cube is ‘length times width times height’ ($L \times W \times H$). Since the length, width, and height of a cube are all equal, the volume of a cube is ‘length times length times length’ ($L \times L \times L$ or L^3).

Using the L^3 formula, *calculate* the volume of the 1, 2, 3, and 4 bim cubes and *record in the appropriate rows of the ‘by calculating’ column of Table A of your lab report.* [**Note:** Since units can be multiplied like numbers 5 bims times 5 bims times 5 bims equals 125 cubic bims.] *Note also in the right-most column in Table A of your lab report* whether or not you got the same volumes by counting (steps A1 through A4) that you got by calculating (step A6).

PROCEDURE B: SURFACE AREA TO VOLUME RATIOS

- A. Using the formulae for surface area ($6L^2$) and volume (L^3) that you (hopefully) proved to yourself in Procedure A, calculate the area and volume for cubes with side lengths of 0 bims, 25 bims, 50 bims, 75 bims, and 100 bims and *record in Table B of your lab report.*
- B. Prepare the graph paper of your lab report to plot both surface area and volume against (or versus) cube size. This is done as follows:
1. Place the label “Cube Size” in the margin below the graph. This means that the bottom (or horizontal or X) axis will represent cube size.
 2. Since you have cube sizes from 0 to 100 bims, the bottom axis must represent at least 100 bims. Since there are 40 boxes across the page, each box width will represent $100/40 = 2.5$ bims. Thus, the lower left corner can be labeled “0 bim”, and each 10 boxes to the left can be labeled “25 bims”, “50 bims”, “75 bims”, and “100 bims”. This should use the whole width of the paper for the X-axis.
 3. Place the label “Area and Volume” sideways up the margin to the left of the graph. This means that the left (or vertical or Y) axis will represent cube area and volume.

4. Since you have cube area and volume numbers that range from 0 to 1,000,000, the left axis must represent at least 1,000,000 bim^2 or bim^3 . Since you have 50 boxes up the page, each box height will represent $1,000,000/50 = 20,000$. Thus, the lower left corner is 0 and top of the uppermost box can be labeled "1,000,000". Half-way down can be labeled "500,000". Mark also "100,000" and the first 3 boxes ("20,000", "40,000", and "60,000").
- C. On your graph, for each cube (0, 25, 50, 75, and 100 bim cubes) plot the surface area with small circles at the proper position above the side length. Sketch a smooth curve through the small circles, and label that curve "Surface Area".
- D. On the same graph, for each cube (0, 25, 50, 75, and 100 bim cubes) plot the volume of each cube with small x's at the proper position above the side length. Sketch a smooth curve through the small x's, and label that curve "Volume".
- E. Based on the graph, *answer questions 1 and 2 on your lab report*. We conclude that *if the shape of something does not change*, then as that object increases in size its volume increases faster than its surface area (which is the same as saying that the volume to surface area ratio *increases* with size and the surface area to volume ratio *decreases* with size).

In order to keep the surface area to volume ratio constant, the shape of that object would have to change. This is the main reason that an organism changes shape as it grows.

PROCEDURE C: THERMAL INERTIA

- A. Recalculate the surface areas and volumes of 1 bim , 2 bim , 3 bim , and 4 bim cubes and *record in the second and third columns of Table C on your lab report*.
- B. Imagine that each of your blocks were hollow and that the sides were made of a very fine mesh that allows water in or out of the block at a uniform rate (in other words, the cubes have a permeable outer surface). If your block submerged in water takes 20 seconds to fill with water, calculate the flow rate through the sides and *record the flow rate in the Flow Rate column of Table C on your lab report*.

Your answer will be in cubic bims per square bim per second (i.e. so many cubic bims of water pass through every square bim of cube surface area every second). [Divide the volume of the one bim cube by the total surface area of the one bim cube, and divide that in turn by 20 seconds.].

- C. Let us now assume that the 1 bim , 2 bim , 3 bim , and 4 bim cubes were also hollow and made of the same mesh with the same flow rate as the block you were considering in C2. For each cube size, calculate how long it should take to fill the cube if it were quickly submerged in water.

[For each cube, divide the volume of the cube by the surface area of the cube and divide that in turn by the flow rate that you calculated in C2. **Note:** If you did this

properly, the Fill Time of a 1 bim cube will be 20 seconds.] *Record your answers in the appropriate rows in the Thermal Inertia Column of Table C on your lab report.*

- D. Based on Table C, *answer questions 3 through 9 on your lab report.* It is because of the relationship of surface area to volume that within a family of mammals or birds, larger species tend to live in colder environments and smaller species tend to live in warmer environments. It is for the same reason that the thin people in the Donner party froze to death first.

PROCEDURE D: CHANGING SHAPE

As we have seen so far in this lab, as an organism grows, *if its shape does not change* its surface area will not increase as rapidly as volume. However, many things that an organism must do, are done through surfaces (*e.g.* an organism takes in nutrients, expels wastes, and cools off through body surfaces).

Thus, for a larger organism to survive, it must find ways of increasing its surface area. One way to do this is to change its external shape. In this procedure we will examine the affect that changing external shape has on surface area.

- A. Rebuild a 2 bim cube, count the sides again to re-convince yourself of its surface area, and *record the surface area of an $8 b^3$ cube in Table D.*
- B. Take the four cubes off the second row of your 2 bim cube and arrange the 8 cubes in something as close as possible to a square. Note that the resultant shape ('square' rather than a cube) has the same volume as the 2 bim cube. Count sides and *record the surface area of an $8 b^3$ 'square' in Table D.*
- C. Arrange the 8 cubes in such a shape that it has the maximum possible surface area (while still holding together as an 'organism' – in other words each cube is attached by at least one side to another cube). Note that the resultant shape has the same volume as the 2 bim cube. Count sides, *describe the shape you came up with, and record its surface area in Table D.*
- D. Rebuild a 3 bim cube, count the sides again to re-convince yourself of its surface area, and *record the surface area of a $27 b^3$ cube in Table D.*
- E. Take the top row of cubes off your 3 bim cube and arrange the 27 cubes in something as close as possible to a 2-bim high square. Note that the resultant shape (a 2-bim high 'square' rather than a cube) has the same volume as the 3 bim cube. Count sides and *record the surface area of a $27 b^3$ 2-bim-high 'square' in Table D.*
- F. Take the second row of cubes off your 2-bim-high 'square' cube and arrange the 27 cubes in something as close as possible to a 1-bim high square. Note that the resultant shape (a 1-bim high 'square' rather than a cube) has the same volume as the 3 bim cube. Count sides and *record the surface area of a $27 b^3$ 1-bim-high 'square' in Table D.*

- G. Arrange your 27 cubes in such a shape that it has the maximum possible surface area (while still holding together as an 'organism' – in other words each cube is attached by at least one side to another cube). Note that the resultant shape has the same volume as the 3 bim cube. Count sides, *describe the shape you came up with, and record its surface area in Table D.*
- H. It is to keep a constant surface area to volume ratio that many organisms change their external shape as they grow. Based upon your entries in Table D, *answer questions 10 and 11 on your lab report.*
- I. Complete your lab report with a summary of what you learned in this lab.

LAB REPORT FOR SURFACE AREA / VOLUME RELATIONSHIP LAB

Name: _____

(Partner: _____)

Lab Date: _____

Submission Date: _____

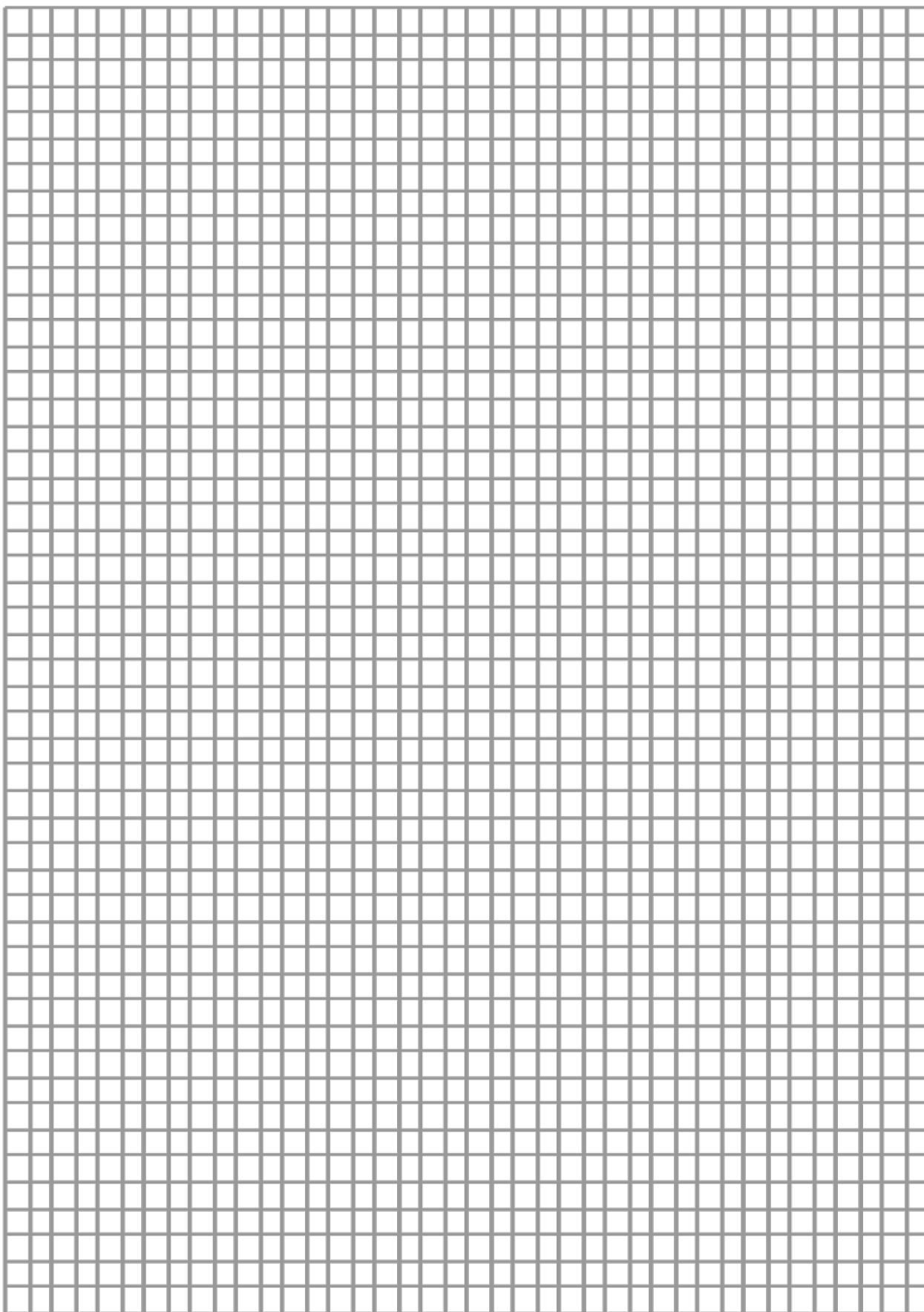
Submission Time: _____

PROCEDURE A: SURFACE AREAS AND VOLUMES OF CUBES

Table A		by counting	by calculating	Did you get the same answer counting & calculating? (Yes or No)
1 bim cube	Surface Area		$6L^2$:	
	Volume		L^3 :	
2 bim cube	Surface Area		$6L^2$:	
	Volume		L^3 :	
3 bim cube	Surface Area		$6L^2$:	
	Volume		L^3 :	
4 bim cube	Surface Area		$6L^2$:	
	Volume		L^3 :	

PROCEDURE B: SURFACE AREA TO VOLUME RATIOS.

Table B		
Side Length	Surface Area	Volume
0 b	b^2	b^3
25 b	b^2	b^3
50 b	b^2	b^3
75 b	b^2	b^3
100 b	b^2	b^3



QUESTIONS

1. Based upon the graph, as the side length of a cube increases...
 - a. does the surface area also increase?
 - b. does the volume also increase?
 - c. does the volume change slower, faster, or at the same rate as the surface area increases?

2. Generalizing from cubes to ANY shape... If an object increases in size *but does not change shape*,
 - a. its surface area/volume increases faster than its surface area/volume. [circle the appropriate answers]
 - b. the *ratio* of surface area/volume to surface area/volume decreases. [circle the appropriate answers]
 - c. the *ratio* of surface area/volume to surface area/volume increases. [circle the appropriate answers]

Table C				
Cube Size	Volume	Surface Area	Flow Rate	Fill Time
1b	b^3	b^2	$b^3/b^2/\text{sec}$	s
2b	b^3	b^2		s
3b	b^3	b^2		s
4b	b^3	b^2		s

Table D		
Volume	Shape	Surface Area
$8b^3$	cube	b^2
$8b^3$	'square'	b^2
$8b^3$		b^2
$27b^3$	cube	b^2
$27b^3$	2-hi 'square'	b^2
$27b^3$	1-hi 'square'	b^2
$27b^3$		b^2

(**Note:** On questions from #3 on, please answer in complete sentences)

3. According to Table C, as the size of a cube increases, does it take longer, or shorter, or the same amount of time to fill with water through a permeable outer surface?
4. Imagine heat doing the same thing as the water did in these cubes. In other words, heat flows in or out through the walls of the cube at a certain rate and warms or cools the cubes in a similar way as water fills or empties a cube with a permeable surface.
 - a. What size cube would cool off the fastest and what size cube would cool off the slowest?
 - b. What size cube would heat up the fastest and what size cube would heat up the slowest?
5. Based on your answer to question #4, in winter survival situations why would younger people and lighter people freeze to death before older and heavier people?
[**Note:** Assume that there is exactly the same percentage body fat in all these people]
6. Based on your answer to question #5, if a child and an adult both fell through the ice, who would you save first and why?
7. Based on your answer to question #4,
 - a. would a larger species of a given type of animal be more comfortable living in warmer situations or colder situations?
 - b. would a smaller species of a given type of animal be more comfortable living in warmer situations or colder situations?

8. The penguin that lives in the coldest environment is the emperor penguin, whereas the penguin that lives in the warmest environment is the Galapagos penguin. Based upon what you have learned in this lab, what would you expect the relative sizes of emperor and Galapagos penguins to be, and is your expectation correct?
9. What are the largest and smallest species of deer in the world, at what latitudes are each species found, and why do they live in those locations?
10. According to your results in Table D, what happens to surface area as something...
 - a. gets 'flatter'?
 - b. gets thinner and longer (like a string)?
11. Based on your answer to Question 10,
 - a. why are flatworms flat? [**Note:** Flatworms breathe and take in nutrients through their skin]
 - b. why do tapeworms get longer (and not thicker or wider) as they grow? [**Note:** Tapeworms are a type of flatworm that are called 'tape' worms because they are shaped like tape (flat and narrow).]
 - c. [assuming African and Asian elephants live in the same climate – in other words at the same temperatures] why are African elephant ears so much larger than Asian elephant ears? And is your hypothesis correct? [**Note:** Elephants cool their blood – and thus their body – by passing the blood through blood vessels in their ears.]

LESSON

