EXERCISE 4 Name _____

Cell Structure and Diversity

Objectives

After completing this exercise, you should be able to:

- Calibrate a reticle and use it to measure the size of specimens viewed with the brightfield microscope.
- Identify the basic structural features of a prokaryotic cell when viewed with the brightfield microscope.
- Identify the basic structural features of a eukaryotic cell when viewed with the brightfield microscope.
- Distinguish between prokaryotic and eukaryotic cells when viewed with the brightfield microscope.
- Distinguish between protists, plant cells, and animal cells when viewed with the brightfield microscope.
- Distinguish between unicellular, colonial, and multicellular organisms when viewed with the brightfield microscope

Prelab

Before you come to lab, read this entire exercise. You must also answer all questions and complete all assignments on the first 4 pages of this exercise. Your instructor will give you directions on when and where to turn in your work.

What is a reticle?

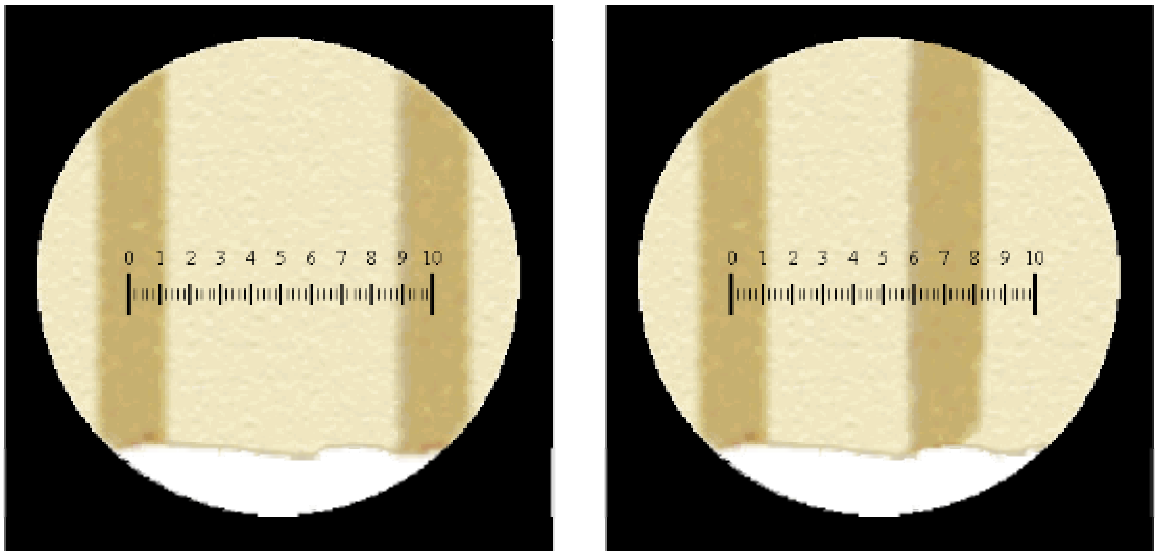
A **reticle** is used to measure objects viewed with the microscope. When you look through the ocular of your microscope, the reticle looks like a small ruler superimposed on the specimen you are viewing. As you increase the magnification of your objective, the image of your specimen increases in size, but the size of the reticle does not change. (Remember, the size of the specimen itself does not change even though it **appears** larger.) Also note that the reticle is on the ocular lens, so if you rotate the ocular lens, the reticle rotates with the lens.

How do I calibrate a reticle?

The cross-lines on a reticle do not represent standard units of measurement, such as millimeters or micrometers. They are simply arbitrary markings superimposed on the specimen. In order to use these "reticle units" to measure a specimen, you must ***calibrate the reticle***. This means you must determine the relationship between a "reticle unit" and a standard unit of measurement. As an analogy, suppose you asked a carpet installer to give you an estimate for carpeting your living room based on the following information: "My living room is 10 tiles wide by 15 tiles long". It would be impossible for the installer to provide an estimate based on this information because a "tile" is not a standard unit of measurement. Are these large Saltillo tiles, medium vinyl tiles, or small ceramic tiles? In other words, the installer doesn't know the size of a "tile" is, although he does know the size of standard units such as inches, feet, or meters. In order for the installer to know how large your room is, you could use a ruler to "calibrate" your tiles, i.e. convert the non-standard unit called a "tile" into standard units such as inches. If the installer knows that each tile is 8 inches long by 8 inches wide, then he can give you an accurate estimate.

To further complicate matters when measuring objects with a reticle, if you increase the magnification of your objective, the size of the image you are viewing gets larger but size of the reticle units remains unchanged. This means your reticle must be calibrated for each objective that you use

To calibrate a reticle, switch to the scanning or low-power objective, place a clear plastic millimeter ruler on the stage, and then focus on the mm lines. What you see will resemble the illustrations below. Notice that microscope A is using an objective with a higher magnification than microscope B. Therefore, the mm lines will look farther apart on microscope A compared to microscope B, even though the size of the reticle units on both microscopes looks the same.



Microscope A
(5 X objective lens)

Microscope B
(4 X objective lens)

Figure 4.1 Calibrating a reticle on 2 different microscopes using a ruler with lines 1 mm apart

⇒ Note: Different types of reticles are available, and individual microscopes may vary slightly in their optics and powers of magnification. Therefore, you must calibrate the reticle for each objective and for each particular microscope that you use.

⇒ Careful! Do not be distracted by numbers on the reticle, if present. A reticle unit is the *smallest* unit visible on the reticle. Notice that the reticles of both microscopes shown above have a total of 50 reticle units, not 10.

Observe and record the number of reticle units (r.u.'s) which correspond to 1mm as seen through each microscope in the sample illustrations above.

⇒ **IMPORTANT: You must count the number of reticle units starting from the MIDDLE of one mm line and ending at the MIDDLE of the next mm line.**

r.u.'s per millimeter for microscope A when using the 5X objective _____ r.u./mm

r.u.'s per millimeter for microscope B when using the 4X objective _____ r.u./mm

From this information, calculate the number of µm's per r.u. for microscope A when using the 5X objective and for microscope B when using the 4X objective. To do this, first convert one mm to 1,000 µm, and then calculate the number of µm's equal to one reticle unit.

⇒ **IMPORTANT: Make sure you calculate µm/r.u., not r.u./µm!!!**

µm's per reticle unit when using microscope A with the 5X objective _____ µm/r.u.

µm's per reticle unit when using microscope B with the 4X objective _____ µm/r.u.

Assuming you have correctly determined the number of µm's per reticle unit when using one objective on your microscope, you can calculate the number of µm's per reticle unit for any other objective **on the same microscope** using the following formula:

$$\frac{\mu m}{r.u.}\ \textbf{(using original objective)} \times \frac{\textbf{Magnification of original objective}}{\textbf{Magnification of the new objective}} = \frac{\mu m}{r.u.}\ \textbf{(using new objective)}$$

Example calculation: Using the 4X objective, let's say you determined that for a particular microscope one reticle unit represents 50 µm. If you want to know the number of µm's per r.u. when using the 40X objective on the same microscope, use the formula above:

$$\frac{50\ \mu m}{r.u.}\ \text{(using 4X obj.)} \times \frac{4X}{40X} = \frac{5\ \mu m}{r.u.}\ \text{(using 40X obj.)}$$

In other words, if one r.u. equals 50 µm when using the 4X objective, then one r.u. equals 5 µm when using the 40X objective.

Your turn: Using the general formula above, and the measurements you made for microscopes A and B above, calculate

1. µm's per r.u. when using a 10X objective with Microscope A. Show your calculations below.

2. µm's per r.u. when using a 40X objective with Microscope B. Show your calculations below.

How do I use a calibrated reticle to measure an object viewed with the microscope?

Once you have calibrated your reticle, you can measure objects using the reticle and then convert the arbitrary "reticle units" into standard units of measurement, such as micrometers. To do this, simply multiply the measurement in r.u.'s by the number of µm/r.u. for the particular objective you used.

Your turn: Assume that you have measured the diameter of six diatoms with microscope A (above) using the 10X objective. The six diatoms measured 2, 2.5, 4, 5, 6, and 6.5 reticle units. What were the diameters of the diatoms in µm's?

If using Microscope A and the 10X objective:

2	r.u. =	_____ µm	5	r.u. =	_____ µm
2.5	r.u. =	_____ µm	6	r.u. =	_____ µm
4	r.u. =	_____ µm	6.5	r.u. =	_____ µm

What are the 2 basic cell types, and how do their characteristics compare?

Biologists recognize 2 basic cell types: **prokaryotic** and **eukaryotic**. The earliest cells on earth were relatively simple prokaryotic cells. Over billions of years, some of these early prokaryotic cells evolved into present-day prokaryotic cells, while others evolved into much larger and more complex eukaryotic cells. Both types of cells have genetic material in the form of **DNA**; a thin, flexible, **plasma membrane** which surrounds the semi-fluid contents of the cell called the **cytoplasm**; and specialized structures within the cytoplasm called **organelles**. In addition, both types of cells may have a thick, rigid **cell wall** surrounding the plasma membrane.

On the other hand, eukaryotic cells are much larger and more complex than prokaryotic cells. On average, a typical eukaryotic cell is about 1,000 X larger in volume than a typical prokaryotic cell. Because of their much larger size, eukaryotic cells generally have much more DNA than prokaryotic cells, and there is a much greater degree of compartmentalization and division of labor within a eukaryotic cell. The interior of eukaryotic cells is generally divided into many specialized compartments by **internal membranes** (membranes separate from the plasma membrane) and **membrane-bound organelles** (organelles completely surrounded by membranes). Usually, prokaryotic cells lack internal membranes and membrane-bound organelles. In addition, the DNA of eukaryotic cells is enclosed within a membrane-bound **nucleus,** while the DNA of prokaryotic cells is located in the cytoplasm.

During this lab, you will use the brightfield microscope to examine and compare the features of several types of prokaryotic cells, and several types of eukaryotic cells.

What types of organisms are composed of prokaryotic cells?

Although generally not visible to the naked eye, organisms composed of prokaryotic cells still dominate the earth. Their collective mass is at least 10 times greater than the mass of all eukaryotes combined. Organisms composed of prokaryotic cells are classified into 2 main groups: **archaea** and **bacteria**. Archaea most closely resemble the first primitive cells on our planet. They are often adapted to extreme environments (such as high temperature, high salt concentration, and no O_2) which were common on the primitive earth. Bacteria, on the other hand, are a more recent group that includes most of the prokaryotes known today.

Prokaryotic organisms are usually unicellular, but a few form simple colonies. **Unicellular** means an organism is composed of a single cell. **Colonial** means an organism is composed of many attached cells, but the cells are all similar in structure and function. If separated from the colony, each cell can usually survive on its own and grow into a new colony. Almost all prokaryotic cells have a rigid cell wall external to the plasma membrane, and about half can actively move themselves through their environment, usually with the use of flagella.

In spite of their relatively simple structure, prokaryotic cells have much greater metabolic diversity than eukaryotic cells. Although most prokaryotes are heterotrophs, some are autotrophs. **Autotrophs** can manufacture their own food (organic molecules) from inorganic substances, while **heterotrophs** cannot. Most autotrophic bacteria are **photosynthetic** (they use light energy to manufacture organic molecules) but some are **chemosynthetic** (they use energy from inorganic chemicals to manufacture organic molecules.)

What types of organisms are composed of eukaryotic cells?

Organisms composed of eukaryotic cells are divided into 4 main groups:

1. **Protists** are mostly unicellular or colonial eukaryotes. They may be either photosynthetic autotrophs or heterotrophs.

2. **Plants** are mostly multicellular, photosynthetic autotrophs. Like colonial organisms, **multicellular** organisms are composed of many cells. However, in a multicellular organism there is considerable specialization and division of labor among the cells.

3. **Fungi** are mostly multicellular heterotrophs that secrete digestive enzymes and digest their food outside the body before absorbing it through the body surface.

4. **Animals** are mostly multicellular heterotrophs that digest their food inside an internal digestive tract.

Lab Procedures

I. Calibrate your reticle

1. Rotate the scanning (4X) objective into viewing position and place a transparent plastic ruler on the stage. Focus the microscope and align the ruler until the millimeter lines come into clear focus in the field of view.

2. Define the distance between 2 of the lines closest together on the reticle as one reticle unit (r.u.).

   ⇒ **Careful! Do not be distracted by numbers on the reticle, if present. A reticle unit is the *smallest* unit visible on the reticle.**

3. Rotate the ocular and move the ruler until the reticle is aligned across 2 adjacent millimeter marks. Determine the number of reticle units (r.u.'s) which correspond to 1mm as seen through the microscope. Make sure you count the number of r.u.'s from the middle of one mm line to the middle of the next mm line.

   Reticle units per millimeter for your microscope using the 4X objective: _____.

   Using this information, calculate the number of µm per r.u.

   With this microscope, using the 4X objective, one reticle unit corresponds to _____ µm

4. Rotate the nosepiece to bring the 10X objective into aligned position. Note that the reticle appears the same size, with its marks the same distance apart as when the 4X objective was in position. However, the millimeter lines on your ruler appear to be spaced much further apart at higher magnification.

   Determine the µm's per r.u. when using the 10X objective. If the reticle in your microscope is not be long enough to reach between 2 adjacent millimeter marks at this magnification, use the following formula to calculate µm's per r.u.

$$\frac{\mu m}{r.u.}\ (\text{using 4X obj.}) \times \frac{4X}{\text{Mag of the new obj.}} = \frac{\mu m}{r.u.}\ (\text{ using new obj.})$$

   With this microscope, using the 10X objective, one reticle unit corresponds to _____µm .

   Also determine the µm's per r.u. when using the 40X objective, using the formula above.

   With this microscope, using the 40X objective, one reticle unit corresponds to _____µm .

II. Examining Prokaryotic Cells

1. **Bacterial shapes -** Because bacterial cells are very small, not much more than their basic shape will be visible under the light microscopes available in lab. Usually, bacteria exhibit one of 3 shapes: **bacilli** (rods), **cocci** (spheres), or **spirilli** (spirals).

   a. Place the prepared slide labeled "bacterial types" on a white background and examine it with your naked eyes. You should see 3 distinct pinkish or purplish spots under the coverslip. Each spot contains bacteria exhibiting one of the 3 shapes listed above.

   b. Place the slide on the stage of your microscope and examine each of the 3 colored spots. Focus with low power first and then switch to high power. The cells you observe should be stained pink or purple. They will be much smaller than the eukaryotic cells you observed last week. Note that in some cases the cells may be attached to form clusters or chains. Be sure you locate and can recognize all 3 bacterial shapes. For assistance, check photographs that may be available in lab or in your textbook.

c. In your lab notebook, draw diagrams of the 3 bacterial shapes observed on your slide and label each shape with its name.

d. Use the reticle to measure the size of a few bacterial cells with each shape. Record the results in your lab notebook in reticle units, then convert the measurements to micrometers. Make sure you mark down the objective you used when making your measurements.

e. When you are finished, return the slide to its original location.

2. Cyanobacteria - Cyanobacteria are a fairly common group of bacteria that carry out a type of photosynthesis that produces O_2. (Note: Some bacteria carry out alternative types of photosynthesis that do not produce O_2.) Scientists believe cyanobacteria were largely responsible for converting the early earth's atmosphere from a reducing atmosphere into an oxidizing atmosphere. Cyanobacteria use a pigment called **chlorophyll a** to absorb light energy for photosynthesis. This type of chlorophyll is also found in photosynthetic eukaryotes. However, in cyanobacteria the chlorophyll molecules are not located in chloroplasts, as they are in eukaryotes. Instead, they are found on the surface of **photosynthetic lamellae** located throughout the cytoplasm.

a. Prepare a wet mount of *Anabaena*, making sure you get some of the green filaments from the culture onto your slide. Examine *Anabaena* using low power first and then high power. On high power you should be able to distinguish the individual cells that make up each filament. For assistance, check photographs that may be available in lab or in your textbook.

b. In your notebook, draw a filament of *Anabaena* which clearly shows the shape of the individual cells. Do all the cells look identical? Note any differences on your diagram.

c. Use the reticle to measure the size of a few *Anabaena* cells. Record the results in your lab notebook in reticle units, then convert the measurements to micrometers. Make sure you mark down the objective you used when making your measurements.

d. When you are finished, remove the coverslip and place it in the discard container provided. Wash the slide, dry it, and return it to its original location.

III. Examining Eukaryotic Cells

1. Mixed Protozoans (non-photosynthetic protists) - "Protozoans" is a general term for a variety of mostly unicellular, non-photosynthetic protists.

a. Prepare a wet mount of the Mixed Protozoans culture.

⇒ Note: Protozoans are relatively large and tend to settle to the bottom of the culture jar. You will get the best results if you leave the water in the jar undisturbed, and take your sample from the bottom. Squeeze some air out of a dropper BEFORE you place it into the jar, and then slowly suck in some of the water and debris from the BOTTOM of the jar. Do NOT disperse the cells by stirring up the water in the jar or by squeezing air out of the dropper into the water.

b. Examine the slide with your microscope. Using the keys and diagrams provided, identify at least 2 different protozoans on your slide.

⇒ Careful: The protozoan culture may be contaminated with small animals called rotifers or other organisms. If you are not sure the organism you are viewing is a protozoan, check with your instructor

c. In your lab notebook, draw diagrams of 2 different protozoans and label each with its name. Next, record the length and width of each organism in reticle units, and then convert the measurements into micrometers. Finally, indicate whether each organism is unicellular or colonial.

d. When you are finished, discard the coverslip in the container provided. Clean and dry the slide and return it to its original location.

2. ***Paramecium* (non-photosynthetic protist) -** *Paramecium* is a common protozoan that uses **cilia** for locomotion and feeding. It feeds mainly on bacteria and has a long oral groove lined with cilia that beat food into an oral cavity. At the end of the oral groove, the food is engulfed by **phagocytosis** and becomes enclosed in **food vacuoles** which fuse with enzyme-filled **lysosomes** to be digested. Undigested food is eliminated through an **anal pore**. Like *Euglena*, which you viewed last week, *Paramecium* lives in freshwater lakes and ponds, and depends on contractile vacuoles to remove excess water from its cytoplasm.

   a. View a prepared slide of *Paramecium* with your microscope using low power first and then high power.

   b. In your lab notebook, draw a diagram of *Paramecium*. Make the diagram at least 10cm long. With the help of photographs, diagrams, or models, LABEL the structures listed below:

      plasma membrane
      cytoplasm
      nucleus
      nucleolus
      nucleoplasm
      nuclear membrane
      contractile vacuole
      oral groove
      food vacuole

   c. Next, you will be measuring the length and width of 6 different paramecia in reticle units. After you are finished, you will convert your measurements into micrometers. Prepare a table in your lab notebook to record your data. Give the table a descriptive title.

   d. Using whichever magnification is most appropriate, measure and record the length and width of 6 different paramecia in reticle units. For proper measurement, the length of one *Paramecium* should appear no longer than the total length of the reticle, but its width should appear at least as wide as one reticle unit. Also record the magnification at which the measurements were made.

   e. Convert all measurements to micrometers, and record the results in you table.

   f. When you are finished, remove the slide from your microscope and return it to its original location.

3. **Green Protist Survey Mixture (photosynthetic protists) -** "Green Protists" is a general term for a variety of unicellular and colonial, photosynthetic protists.

   a. Prepare a wet mount of the Green Protist Survey Mixture. Make sure you get some of the green material at the bottom of the culture jar on your slide.

   b. Examine the slide with your microscope. Using the keys and diagrams provided, identify at least 2 different green protists on your slide.

   ⇒ Careful: The green protist culture may be contaminated with *Anabaena* or other organisms. If you are not sure the organism you are viewing is a green protist, check with your instructor

      What gives these organisms their green color? _____

      What does this tell you about their method for obtaining organic compounds? _____

      _____

   c. In your lab notebook, draw diagrams of 2 different green protists and label each with its name. Next, record the length and width of each organism in reticle units, and then convert the measurements into micrometers. Finally, indicate whether each organism is unicellular or colonial.

   d. When you are finished, discard the coverslip in the container provided. Clean and dry the slide and return it to its original location.

4. ***Euglena* (photosynthetic protist) -** *Euglena* is a common green protist that uses a flagellum for locomotion. Last week, you viewed a wet mount and a prepared slide of *Euglena*.

   a. View a prepared slide of *Euglena* with your microscope using low power first and then high power.

   c. You will be measuring the length and width of 6 different *Euglena* in reticle units. After you are finished, you will convert your measurements into micrometers. Prepare a table in your lab notebook to record your data. Give the table a descriptive title.

   c. Using whichever magnification is most appropriate, measure and record the length and width of 6 different *Euglena* in reticle units. For proper measurement, the length of the *Euglena* should appear no longer than the total length of the reticle, but its width should appear at least as wide as one reticle unit. Also record the magnification at which the measurements were made.

   d. Convert all measurements to micrometers, and record the results in you table.

   e. When you are finished, remove the slide from your microscope and return it to its original location.

5. **Onion Bulb Cells (non-photosynthetic plant cells) –** These plant cells live underground and, unlike most plant cells, are not photosynthetic.

   a. Place a drop of Lugol's solution on a CLEAN microscope slide.

   b. Use forceps to peel the very thin and transparent "skin" from the inner (concave) surface of the onion bulb. Carefully spread the onion skin in the Lugol's solution on the slide so that it lies flat and in a single smooth layer. Cover it with a coverslip.

   c. Examine your slide with both low and high power. The onion cells should resemble the photographs provided in lab. The "lines" that form the box-like grid are nonliving **cell walls** composed chiefly of **cellulose**. The cell wall surrounds the **plasma membrane**, which encloses the **cytoplasm**. The central part of the cell is filled with a large membranous sac called the **central vacuole,** which is filled with water and salts. The vacuole squeezes most of the cytoplasm, organelles, and the nucleus into a thin layer around the edge of the cell. This is difficult to observe under the light microscope, but can easily be seen in the plant cell models, photos, and diagrams available in lab. It is also difficult to observe any membranes in this preparation, but you should be able to determine where they are with the help of photographs, diagrams, or models.

   d. As you examine each cell, locate the **nucleus**, which will appear as a bright yellow, round structure.

      Why does the nucleus appear yellow? _____

      Inside each nucleus there will be one or more tiny circles called **nucleoli** (singular is **nucleolus**). Note that in some cells the nucleus appears to be located near the center of the cell (where the vacuole is supposed to be) rather than squeezed along the side of the cell. Explain this apparent discrepancy.

      _____

      _____

   e. In your lab notebook, draw ONE onion cell. Make the diagram at least 10cm long. With the help of photographs, diagrams, or models, LABEL the structures listed below:

      cell wall
      plasma membrane
      cytoplasm
      central vacuole
      nucleus
      nucleolus
      nucleoplasm
      nuclear membrane

f. Measure the length and width of an onion cell using the reticle. Convert the measurements to micrometers and record the result next to your diagram.

g. When you are finished, discard the coverslip in the container provided. Clean and dry the slide and return it to its original location.

6. *Elodea* Cells (photosynthetic plant cells)

a. Place a drop of water on a CLEAN microscope slide.

b. Use a pair of forceps to remove a leaf from the *Elodea* plant, place the leaf in the drop of water, and cover it with a coverslip.

c. Examine the leaf under low power and high power. The *Elodea* cells should resemble the photographs provided in lab. The small, green, circular objects are **chloroplasts**. Why do some of the chloroplasts appear to be in the center of the cell where the central vacuole is supposed to be?

_____

_____

_____

The nucleus in these cells is much more difficult to see than it was in the onion cells. Explain why:

_____

d. Cells are 3-dimensional; therefore, they have depth as well as width and length. Choose an individual cell and adjust the fine focus up and down (never use the coarse adjustment on high power). Notice the location of the various cell structures as you focus on the upper, middle, and lower part of the cell.

e. Continue to focus carefully up and down through the *Elodea* leaf. Notice the overlapping cells. How many cell layers comprise the leaf's thickness?

_____

f. You may see the chloroplasts in some cells moving in a circular fashion around the edge of the cell, just INSIDE the plasma membrane. [Note: You can often stimulate this motion by increasing the diameter of the diaphragm.] It is actually the movement of the cytoplasm that carries the chloroplasts around the cell. This phenomenon is called **cyclosis** or **cytoplasmic streaming**. Is the direction of movement the same in all the cells? Explain:

_____

_____

_____

g. In your lab notebook, draw ONE *Elodea* cell. Make the diagram at least 10cm long. With the help of photographs, diagrams, or models, LABEL the structures listed below. If you observed cytoplasmic streaming, draw arrows to show the direction of streaming.

cell wall
plasma membrane
cytoplasm
chloroplasts
central vacuole
nucleus
nucleolus
nucleoplasm
nuclear membrane

h. Measure the length and width of an *Elodea* cell using the reticle. Convert the measurements to micrometers and record the result next to your diagram.

i. When you are finished, discard the coverslip in the container provided. Clean and dry the slide and return it to its original location.

7. Human Cheek Cells (animal cells)

a. Place a drop of Lugol's solution on a CLEAN microscope slide.

b. Remove a CLEAN toothpick from its package and use it to gently, but firmly, scrape the inside of your cheek. Be careful not to gouge your cheek. Some cheek cells will be in the saliva which sticks to the toothpick.

⇒ **CAUTION – HUMAN BODY FLUIDS MAY TRANSMIT DISEASE. USE ONLY A TOOTHPICK WHICH YOU HAVE PERSONALLY REMOVED FROM AN UNOPENED PACKAGE. DO NOT GIVE YOUR TOOTHPICK TO ANOTHER STUDENT. DISCARD THE TOOTHPICK IN THE DESIGNATED CONTAINER AS SOON AS YOU HAVE PREPARED YOUR SLIDE. DO NOT HANDLE A CHEEK CELL SLIDE THAT WAS PREPARED BY ANOTHER STUDENT!**

c. Stir the scrapings into the drop of Lugol's solution on the slide, and then discard the toothpick in the container provided.

d. Cover the drop of Lugol's solution with a coverslip and examine it using low power on your microscope. The cells will look yellow (why?) and should resemble the photographs of cheek cells available in lab. Note that groups of cheek cells may be clumped together.

e. Move your slide so that one particularly clear cell is in the middle of the field of view. Now switch to high power and examine the cell more closely. Compare the cheek cell with the previous cells you have viewed. Note that animal cells lack a cell wall, chloroplasts, and the large central vacuole characteristic of plant cells.

f. In your lab notebook, draw ONE human cheek cell. Make the diagram at least 10cm long. With the help of photographs, diagrams, or models, LABEL the structures listed below.

plasma membrane
cytoplasm
vacuole
nucleus
nucleolus
nucleoplasm
nuclear membrane

g. Measure the length and width of a human cheek cell using the reticle. Convert the measurements to micrometers and record the result next to your diagram.

h. When you are finished, place your slide in the container of disinfectant provided.

Clean up

Turn off your microscope, unplug it, wrap the power cord around the base, rotate the scanning objective into viewing position, and return the microscope to the microscope cabinet.

All disposable glassware goes into the special glass disposal receptacle.

Wipe off your work space with a damp paper towel. Leave your work area in the same order that you found it in. Make sure everything that you have used is clean, put away, or discarded. Ask your instructor to check your work area before you leave.

Postlab

1. Prepare a **table** that shows the number of µm per r.u. when using the 4X, 10X, and 40X objectives on your microscope.

2. Use the Internet or other reference to look up the size of the following bacterial types: coccus, bacillus, spirillum. Indicate where you found your information, and then compare your average value for the size of each bacterial type with the value found in your reference.

3. Do the following calculations using standard units (e.g. µm), and make sure your final answers have the correct number of significant digits and appropriate units:

   a. Calculate the mean and standard deviation for the length of the 6 *Paramecium* cells that you measured.

   b. Calculate the mean and standard deviation for the width of the 6 *Paramecium* cells that you measured.

   c. Calculate the mean and standard deviation for the length of the 6 *Euglena* cells that you measured.

   d. Calculate the mean and standard deviation for the width of the 6 *Euglena* cells that you measured.

4. Do a t-test (using a spreadsheet program such as Excel) to test the null hypothesis that there is no significant difference in the length of *Paramecium* and *Euglena* cells. Be sure to show your p value and explain your conclusion.

5. Look up the lengths of *Paramecium* and *Euglena* using the Internet or another reference source (be sure to indicate where you found your information.) Compare your average value for the length of each organism with the value found in the reference.

6. Based on the 6 *Euglena* cells you measured:

   a. Calculate the approximate volume (V) of an "average" *Euglena* cell. For this calculation, use the volume of a cylinder ($\pi r^2 h$) to approximate the volume of a *Euglena* cell (where the radius is approximated by one-half the average width, and the height is approximated by the average length of the cells.) Make sure your answer has the correct number of significant digits and appropriate units.

   b. Calculate the approximate surface area (S) of an "average" *Euglena* cell. For this calculation, use the surface area of a cylinder ($2\pi r h + 2\pi r^2$) to approximate the surface area of a *Euglena* cell. Make sure your answer has the correct number of significant digits and appropriate units.

   c. Calculate the surface-to-volume ratio (S/V) of an average *Euglena* cell. Make sure your answer has the correct number of significant digits and appropriate units.

7. Based on the 6 *Paramecium* cells you measured, calculate the approximate volume (V), surface area (S), and surface-to-volume ratio (S/V) of an "average" *Paramecium* cell. Use a cylinder to approximate the shape of the cell. Make sure your final answers have the correct number of significant digits and appropriate units.

8. Based on your calculations for *Euglena* and *Paramecium*, as a cell gets larger, while its shape remains constant, what happens to its volume (V)? What happens to its surface area (S)? What happens to its surface-to-volume ratio (S/V)?

9. Based on your answer to question 6, explain how the surface-to-volume ratio might act to limit the size of cells.

10. Using your textbook or other references, briefly describe the function of the following cell structures:

    cell wall
    cell membrane
    cytoplasm
    nucleus
    nucleolus
    nuclear membrane
    DNA
    vacuoles and vesicles
    ribosomes
    endoplasmic reticulum
    Golgi apparatus
    lysosomes
    mitochondria
    chloroplasts

11. In this lab, you examined 7 cell types under the microscope: bacteria, *Anabaena*, protozoans, green protists, onion bulb, *Elodea*, and human cheek. Prepare a table with 7 columns and 14 rows. At the top of each column, write the name of one of the cell types you viewed. On the left side of each row, write the name of one of the cell structures listed in the previous question. In each cell of the table, place a check if the cell structure listed at the left of the row is usually or always present in the cell type listed at the top of the column. Leave the cell empty if the structure is usually or always absent.

12. Briefly describe the main similarities and differences between prokaryotic and eukaryotic cells.

13. Briefly describe the main similarities and differences between plant and animal cells.