**Instructors Guide**

**“Sizes, Scales, and Specialization:**

**An activity highlighting the diversity in cell types”**

This activity can be conducted in a typical 50-minute class period. Students can be put into groups for the activity to help facilitate conversation.

## Overview

The activity will contain a pre-assessment to gauge student understanding of the material and provide an opportunity for students to predict the number of various cell types, as well as the mass of various cell types, in the human body. This prediction activity will be followed with a guided approach to calculating these values. After guiding the students in this activity, students will then have a chance to practice the activity on a new set of cell data provided.

## Authorship & Origin of Module

Developed by Heather Seitz, Jillian Miller, Kristen Jenkins, and Joseph Esquibel. [Quantitative Biology at Community Colleges (QB@CC)](https://qubeshub.org/community/groups/qbcc/) is a National Science Foundation (NSF) supported project that received funding in 2019. The long-term goal of QB@CC is to drive the disciplinary expectation that all biology courses should significantly enhance student's quantitative skills. QB@CC does this by providing educational materials and professional development for faculty. The network will generate a large collection of Open Education Resources (OERs) that may be used by anyone, and professional development programming will be designed to address many of the challenges in teaching quantitative skills. Although this network focuses on community college faculty, most of the materials generated will be appropriate for lower level biology courses in four-year institutions.

## Learning Outcomes

* Compare and contrast the structureand function of different cell types.
	+ List the largest and the smallest cells in the body based on number.
	+ List the largest and the smallest cells in the body based on mass.
* Describe the advantages of specialization in eukaryotic cells.
	+ Give examples of how specialization in cell types affects cell size (volume) and shape.
* Perform measurements and conversions using the metric system.
	+ Measure the scale of cell size variation in the human body
	+ Calculate the relative proportions of cell types in the human body by mass and frequency

## Materials Needed for this activity

* Calculators (per student or student group)
* *Note about index cards for student sorting- The index cards are color coded to allow for instructors to easily scan student progress. In addition, the cards have a superscript “A” or “B” to help you sort them into the bags at the end of the lesson. It is also helpful to simply use colored index card and notch one set as A and leave another set unnotched.*
* Bag A (one bag per group) - 1 set of index cards with cell names written on them
* Erythrocytes (red blood cells)
* Adipocytes (fat cells)
* Epidermal cells (skin cells)
* Muscle cells
* Neurons (brain cells responsible for cognition)
* Hepatocytes (liver cells)
* Vascular endothelial cells (blood vessel cells)
* Bag B (one bag per group) - 1 set of index cards with same cell names written on them, same as in Bag A.

## Pre-assessment (5 minutes)

* Pass out pre-assessment questions to students and have them work individually. You may choose to collect these answers or use an automated response system such as clickers to collect this data.

## Activity-Part 1 (5 minutes work time, 5 minutes discussion)

Upon completing the multiple-choice questions, have students break into groups and provide each group with Bag A containing the cards with cell types listed. Ask the students to sort the cards on their desk or table from the cell type they feel is most prevalent to the cell type that is least prevalent in the human body. Remind students to leave the rankings on their desk/table if possible.

* Discuss the card sorting with these prompts:
	+ 1. Share with a neighboring group what you found, how are they similar or different?

a. What made you put the most prevalent cells at the top? What was your thinking?

b. Why (scientific explanation) do you think the least prevalent cells are at the bottom?

## Activity-Part 2 (5 minutes discussion, 5 minutes work time)

* Prepare students for the next step in the activity by having them answer the following prompts:
	1. Given a list of cellular measurements, what information would you need to use to determine a cell’s mass? Cellular measurements: length, width, height, density, surface area, volume, average circumference.
	2. Using the cellular measurements you chose in question 1, how might these values be arranged mathematically to calculate mass?
* In student groups, use the provided cards in Bag B to have students take a guess on the total mass of these cell types and make a new ranking of the cells in order from highest mass to lowest. Remind students to leave the rankings on their desk/table if possible.

Reveal the data to the students. Bar graphs of the data are found in “SSS Data Slides” powerpoint slides. The first slide shows the bar graph with the percentage of total human cells by cell type. In this graph, it’s important to point out to students that the data is difficult to fully visualize because Erythrocytes make up 84% of all cells in the body. To better visualize the rest of the cells, the second slide shows the data without Erythrocytes included. Compare these results to the students’ results and discuss the cells students find most surprising. Also look at the data visualization for the sizes of the cells. Compare visualization techniques and ask students for which they prefer.

## Activity-Part 3 (10 minutes of explanation, 10 minutes of work time)

* Handout a copy of the Part 3 Data Table Worksheet to students.
* Explain the different values on the table.
* Depending on the comfort level of your students, it may be useful to facilitate the discussion on formulas/literal equations at the top of Part 3. (See Background Information file.)
* As an instructor, walk through a few of the first calculations to determine the mass of the cell type.
* Have students work in groups to finish the remaining calculations.
* Instructor can then reveal the data. A pie chart of the data can be found in “SSS Data Slides” powerpoint slides. The sixth slide shows the pie chart of total mass from each cell type. An alternative visualization, total cellular mass, displayed as a bar graph, can be found on slide twelve. Slide seven displays the true scale of cellular volume from different cell types, which explains why the most numerous cell types account for a small amount of mass.
* Compare these results to the students’ results and discuss the cells students find most surprising. (Part 1 Answers)

## Activity-Part 4 (10 minutes of work time/could also be used as homework for students)

* Provide students or groups with Bag C containing some new cell types.
* Ask them to predict how the cell types in Bag C will fit with their existing sorting from Bag A and Bag B.
* Hand out the Part 4 Data Table Worksheet.
* Have students calculate missing values in the data table for the new cell types.
	+ To ensure all students can do these calculations, the remaining questions on this sheet can be conducted individually, outside of student groups.
	+ After the ranking is completed, students can complete the rest of the sheet out of class, if desired.
* Instructor can reveal and discuss answers with provided graph of total human cells by cell type (Part 1 Answers). Slide ten in “SSS Discussion and Data Slides” powerpoint slides lists both the total cellular number and mass from all cell types analyzed in this activity.

Activity-Part 5 Closing Discussion (10 minutes)

* Prompts for student discussion:
1. What did you learn about cell types in the human body?
2. How would this research be done?
3. What about a person with cancer? How would this impact the number and mass of cells? Feel free to give an example.
4. What about different ages throughout your life?
5. Why do you think the density of the cells are all very similar?

# Answer Key for Sizes, Scales, and Specialization

## Pre-Assessment Answers

**Answer Key (Answers to multiple choice are bold)**

1. Do you think all cells:

a) Have roughly the same size and same shape

b) Have roughly the same size but different shapes

c) Have different sizes but similar shapes

**d) Have different sizes and different shapes**

2. Consider what you think the smallest and largest cells in the human body are. How many of the smallest cell could fit inside the largest cell?

a) Between 1 to 100 of the smallest cells could fit in the largest

b) Between 100 to 10,000 of the smallest cells could fit in the largest

c) Between 10,000 to 1,000,000 of the smallest cells could fit in the largest

**d) Between 1,000,000 to 10,000,000 of the smallest cells could fit in the largest**

3. Consider all the different cell types that exist in the human body (for example, lung cells, muscle cells, skin cells, etc.). Which statement best describes how the total amount of cells for these different cell types varies?

a) All the different cell types have almost exactly the same total number of cells

b) Some different cell types are more common than others but the numbers only vary a small amount (1-10 times)

c) Some different cell types are more common than others with some cell types having 10-100 times more cell numbers than other cell types

d) Some different cell types are more common than others with some cell types having 100-10,000 times more cell numbers than other cell types

**e) Some different cell types are more common than others with some cell types having 10,000-1,000,000 times more cell numbers than other cell types**

4. Convert 2.50 x 105 to standard notation.

a) 25,000,000

b) 2,500,000

**c) 250,000**

d) 0.000025

e) 0.0000025

5. Perform the operation: (7.80 x 10-5)(2.5 x 108) and provide your answer in scientific notation.

a) 19,500

b) 195 x 102

c) 19.5 x 103

**d) 1.95 x 104**

e) 1.95 x 10-3

6. The density of an object represents:

**a) the mass that an object has in some specified volume**

b) the volume that an object has in some specified amount of mass

c) the same concept as its weight

d) the same concept as the size of the object

7. If two objects have the same mass but different volumes, then

**a) The one with the larger volume has the lower density**

b) They must have the same density

c) The one with the larger volume has the higher density

## Part 1 and 2 Answers:

Remove the cards from **Bag A** and work to sort the cards on your desk or table based which cell types you think are most prevalent to least prevalent in the human body. Put the cell type you think is MOST prevalent at the top and the LEAST prevalent at the bottom.

|  |  |
| --- | --- |
| **Bag A** Sorted by Prevalence | **Bag B** Sorted by Weight |
| **Erythrocytes** | **Muscle fibers** |
| **Endothelial cells** | **Adipocytes** |
| **Epidermal cells** | **Erythrocytes** |
| **Neurons** | **Epidermal cells** |
| **Adipocytes** | **Neurons** |
| **Muscle Fibers** | **Endothelial cells** |

After completing the table above, answer the following questions:

1. Given a list of cellular measurements, what values would you need to determine a cell’s weight? Cellular measurements - density, surface area, volume, length, average circumference, width.
2. Using the cellular measurements you chose in question 1, how might these values be arranged mathematically to calculate weight?

## Part 3 Answers:

Work to fill out the following table showing data about the size and prevalence of various cell types.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Cell type** | **Number of cells in the human body** | **Average volume of one cell (mL)** | **Average density for one cell (g/mL)** | **Average mass of one cell (g)** | **Total weight from cell type in human body (g)** |
| **Muscle fibers** | 2.50\*108 | 7.09\*10-5 | 1.10 | 7.80\*10-5 | **1.95\*104** |
| **Adipocytes** | 5.00\*1010 | 2.93\*10-7 | 0.92 | 2.70\*10-7 | **1.35\*104** |
| **Neurons** | 1.00\*1011 | 2.40\*10-9 | 1.10 | **2.64\*10-9** | 2.64\*102 |
| **Epidermal cells**  | **1.50\*1011** | 9.60\*10-9 | 0.9 | 8.6\*10-9 | 1.29\*103 |
| **Erythrocytes** | 2.5\*1013 | 9.70\*10-11 | **1.01** | 9.8\*10-11 | 2.46\*103 |
| **Endothelial cells** | 5.73\*1011 | 3.00\*10-10 | **1.10** | 3.30\*10-10 | 1.89\*102 |

## What are the formulas for each of the calculations:

Average volume of one cell

$$volume (mL)=\frac{mass (g)}{density (g/mL)}$$

Average density for one cell

$$density (g/ml)=\frac{mass (g)}{volume (mL}$$

Average mass of one cell

$$mass (g)=density (g/ml)×volume (mL)$$

Total mass from cell type in human body

$$total mass=mass of one cell (g)×number of cells$$

## Part 4 Answers

|  |  |  |  |
| --- | --- | --- | --- |
| **Bag A** Sorted by Prevalence | **Where do the new cells fit?** | **Bag B** Sorted by Weight | **Where do the new cells fit?** |
| **Bacteria**Erythrocytes |  | Muscle fibers |  |
| Endothelial cells**Leukocytes** | Adipocytes**Hepatocytes** |
| **Hepatocytes**Epidermal cells | **Glial cells**Erythrocytes |
| **Glial**Neurons | Epidermal cells**Bacteria** |
| Adipocytes | Neurons |
| Muscle fibers | Endothelial cells**Leukocytes** |

Calculate the missing values for the table below

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Cell type** | **Number of cells in the human body** | **Average volume of one cell (mL)** | **Average density for one cell (g/mL)** | **Average mass of one cell (g)** | **Total weight from cell type in human body (g)** |
| **Bacteria** | 1.00\*1014 | 1\*10-12 | 1.00 | 1.00\*10-12 | **1.00\*102**  |
| **Glial cells**  | 9.47\*1010 | 9.60\*10-9 | 1.10 | **1.06\*10-8** | 1.0\*103 |
| **Leukocytes** | 4.71\*1011 | **2.1\*10-10**  | 1.02 | 2.15\*10-10 | 1.01\*102 |
| **Hepatocytes** | 2.70\*1011 | 4.90\*10-9 | 1.10 | 5.39\*10-9 | **1.45\*103** |

## Post-Assessment Answers

1. List two things you learned in this activity?
2. Newly born infants have a blood volume of 0.9 L, while adults have an average blood volume of 4.9 L. Which of the following variables are most likely be different between infants and adults?
3. Relative Percentage of cell types in the body
4. Density of cells in the body
5. Volume of cells in the body
6. **Total weight of cells in the body**
7. Liposarcoma is a type of cancer of adipocytes. Assume that adipocytes afflicted with liposarcoma are only 10% of the size of the non-cancerous versions with a 10% increase in their density. What would the expected weight of a single cancerous cell be?
8. **2.97 x 10-8 grams (correct: 2.93x10-8 x 1.012)**
9. 2.70 x 10-8 grams (didn’t use the correct density)
10. 2.97 x 10-7 grams (didn’t use the correct volume)
11. 2.90 x 10-8 grams (right order of numbers but divided instead of multiplying)
12. 3.45 x 108 grams (wrong order of numbers and divided instead of multiplying)

4. Assume you are a scientific researcher conducting research, as part of a team, on elephants in a very remote region. After collecting blood samples from many elephants, you are most unfortunately attacked by a rabid mongoose. You quickly lose the majority of your blood. To keep you alive while you await transport to a hospital, your peers make a shocking decision. They conduct a temporary blood transfusion with the recently collected elephant blood to keep you alive. Due to the severity of your wounds, after a few minutes of transfusion, every erythrocyte in your body is now completely from an elephant. After transport to hospital and transfusion with human blood, you make a full recovery.

4.A. Elephant erythrocytes have an average weight of 1.26 x 10-10 g for a single cell with no change in density. What would the volume of an individual erythrocyte be? Please show your work for full credit.

$$volume =\frac{mass}{density}$$

$$volume=\frac{1.26×10^{-10}}{1.01}$$

**1.25 x 10-10 mL, about 3 times larger**

4.B. With a replacement of elephant erythrocytes with human erythrocytes, what total amount of weight would these cells have in a human body? Please show your work for full credit.

**Number of erythrocytes in humans x mass of elephant erythrocytes**

$$\left(2.49×10^{13}\right)×\left(1.26×10^{-10}g\right)$$

**Answer - 3140 g (3.14x10^3)**

4.C. We cannot emphasize strongly enough the horrible health consequences that would arise for a human attempting to live with elephant erythrocytes. What issues would likely occur due to the change in size?

**Answer - the larger cells wouldn’t be able to fit through the capillaries causing: 1. loss of oxygen to many cells, and 2: microclots and clogs in capillaries.**