Counting Keratinocytes:
Measuring Length in the Metric System

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Part I – Unit Conversion

The metric system is a standard decimal system for measurement, which is used by scientists and most of the world except for the United States. The meter (abbreviated *m*) is the standard unit for measuring length. To measure the length of small or large objects, a series of prefixes is used; for example, "kilo-" (*k*) means 1,000 times larger than a meter. Similarly, "centi-" (*c*) indicates 100 times smaller than a meter, "milli-" (*m*) is 1,000 times smaller than a meter, "micro-" (*μ*) is 1,000,000 times smaller than a meter, and "nano-" (*n*) is 1,000,000,000 times smaller than a meter.

Scientific notation is a way to write numbers that are either inconveniently large or small by using an exponent: a^n. In the metric system, numbers are frequently expressed in terms of 10^n; for example, $1,000 = 10^3$. To summarize, Table 1 shows the relationship between prefixes and and units of length measurement.

Exercise 1
Fill in the third and fourth columns of the table below.

Table 1

Prefix in Terms of Meters	*Scientific Notation*	*Meters in Terms of Prefix*	*Scientific Notation*
1 km = 1,000 m	1×10^3	1 m = km	
1 m = 1 m	1	1 m =	
1 cm = 0.01 m	1×10^{-2}	1 m = cm	
1 mm = 0.001 m	1×10^{-3}	1 m = mm	
1 μm = 0.000001 m	1×10^{-6}	1 m = μm	
1 nm = 0.000000001 m	1×10^{-9}	1 m = nm	

Conversion from one dimensional unit to another dimensional unit is a complex, but important skill for scientific investigation. Dimensional analysis, also called "factor-label method" or "unit factor method," is a widely used technique for unit conversion. Let's look at an example to understand how to use this technique. Suppose we wanted to express 1.73 meters in terms of kilometers: 1.73 m = ? km.

Since 1 m = 0.001 km, then 1.73 m × 0.001 = 0.00173 km.

Exercise 2
Use the information from the completed Table 1 above to solve the following:

21.3 mm = _____ km

139.3 cm = _____ m

9.71 cm = _____μm

0.74 m = _____ μm

Part II – Determining Size from an Image

In the picture below two women are seen talking on the steps of a school building. The person on the right-hand side of the stairs, nearest the railing, is 1.76 m tall. Given this information, can we determine the height of the building?

Figure 1. The person pictured on the right is 1.76 m tall. (Photo by the author.)

Exercise 3

How tall is the actual building shown in the picture?

First, measure the woman's height as pictured with a metric ruler. Her height in the picture (call it *a*) is _____ cm.

Next, measure the height of the school building as pictured; measure from the very bottom of the first stair to the top of the cupula. The building height in the picture (call it *b*) is _____ cm.

The size of both the woman and the school building are decreased in the same ratio in the picture. In other words, the heights of the objects in the picture and their actual heights can be expressed in a linear equation as $cx = d$, where c is the height of an object as pictured, d is the height of the actual object, and x is their ratio. This is equivalent to $x = d/c$.

Woman's height in the picture _____ (copy number *a* into the blank) represents 1.76 m in real life.

The ratio (*x*) of picture height to actual height is thus: $x = \dfrac{a}{1.76}$

We now ask, if the school building as pictured is _____ (copy number *b*), how tall is it actually? In other words:

$$\frac{a}{1.76 \text{ m}} = \frac{b}{? \text{ m}}$$

Solve!

Part III – Counting *Your* Keratinocytes

The outermost portion of human skin is composed of multiple layers of cells. The size of most human cells is usually in the micrometer (µm) range, which is beyond the resolution of a human eye, but we can use a microscope to magnify and visualize them. An image, like that in Figure 2 below, can be captured when a camera is attached to the micro-scope. This figure shows the epidermis of human skin, which has several cell layers named *stratum corneum, stratum granulosum, stratum spinosum,* and *stratum basale*. The most superficial layer of human skin, the stratum corneum, consists of layers of dead cells. Beneath the corneum is the stratum granulosum, which consists of several layers of live skin cells called keratinocytes. In this section of the case study, you are going to calculate how many keratinocytes it would take in order to make a column equivalent to your height. This will take a few steps.

As you can see from the image below, the cells have been magnified significantly. Usually a micrometer (a special ruler) is placed under the same microscope with the same magnification power so that a scale can be determined. You can see the scale bar in the lower left corner of Figure 2, which represents the length of 15µm.
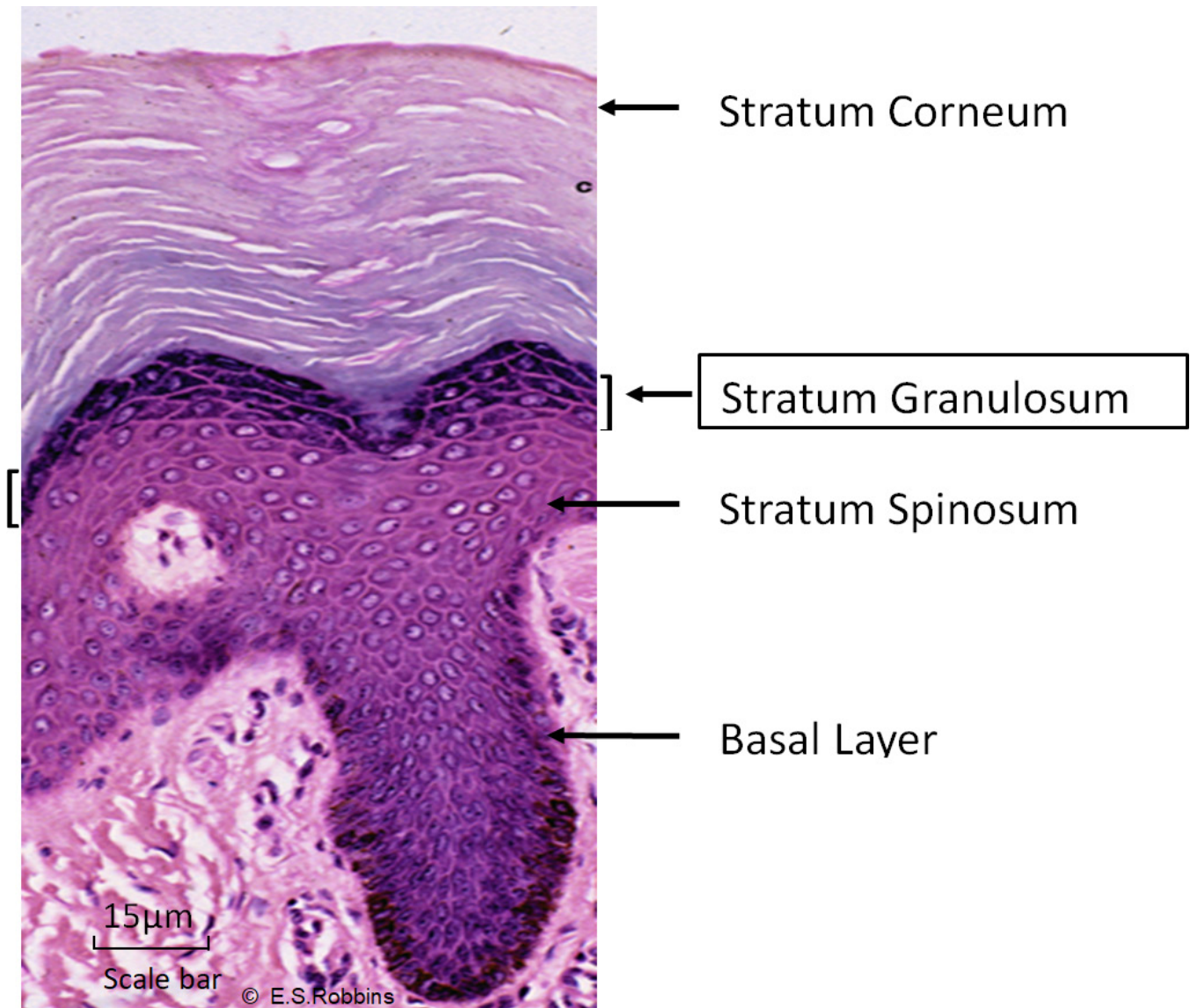

Figure 2. A section (slice) cut through human skin and stained with dyes. The layers of the epidermis are labeled. Beneath the epidermis is a layer called the dermis that attaches the epidermis to the rest of the body. ©E.S.Robbins, used with permission.

Exercise 4

We will first determine the average size of a keratinocyte. We will assume that the sizes of the keratinocytes represented in Figure 2 are the same as those in your skin. In order to know the actual average size of those cells, we need to measure and calculate following similar steps to what we did in Part II. Begin by measuring the length of the scale bar in Figure 2 in mm with a metric ruler.

Length of the scale bar in Figure 2 is _____ mm   (*a*).

In the image, the actual length represented by the scale bar is 15 µm (read directly from the figure).

Thus, _____ mm (*a*) of the image represents 15 µm in actual size.

Next, we will determine the average length of the keratinocyte images. As shown in Figure 2, the cells from the stratum granulosum are not identical in size; therefore we need to measure multiple cells to determine the average cell length. Identify at least seven individual keratinocytes in the stratum granulosum layer. Use a pencil to trace the border of each cell. Then, use a metric ruler to measure the length of each keratinocyte in mm. Fill in Table 2 with your measurements. Then calculate the average length of those keratinocytes in the picture.

Table 2

Cell Number	1	2	3	4	5	6	7	Average
Length (mm)								

The average size of a keratinocyte image in Figure 2 is _____ mm (*b*).

Now we can calculate the actual average length of a keratinocyte in the Figure 2. We use a linear equation to solve this as shown in Part II. Fill in the following blanks with the values you found for *a* and *b* and then solve the resulting equation:

$$\frac{\_\_\_\_\_\text{mm in picture } (a)}{15 \text{ µm actual length}} \quad = \quad x \quad = \quad \frac{\text{average length of a keratinocyte image is \_\_\_\_mm } (b)}{\text{average length of a keratinocyte is \_\_?\_\_µm}}$$

(scale bar) (ratio) (keratinocyte)

Thus, the actual average length of a keratinocyte is: _____ µm.

Exercise 5

Find a partner and measure your height with a metric ruler in meters; then convert it to µm.

Your height: _____ m = _____ µm

Exercise 6

Calculate the minimum number of keratinocytes to cover you from head to toe in one dimension.

The minimum number of keratinocytes to cover my length from head to toe is _____.