Laboratory 5

Plasticizoa: Volume and Surface

5.1 Background

Why must a sparrow, relative to size, eat more than a lion? Why don't we see insects bigger then a rat? Why then, in Carboniferous period, were insects bigger than a rat? Why are dinosaurs suspected to be warm-blooded? Why are leaves of plants flat and often dissected?

To answer these, and many more, questions, you need to understand one of the deepest laws of biology, the **law of volume and surface**.

We want you to start before the lab time, with your own simple experiment. Take two cans, one big and one small. Boil water in both. Simultaneously take them from the fire to a cooler place. Wait 30 minutes. Which can is now warmer? Why?

The explanation lays in geometry. When the linear size grows, the volume of an object grows as the *cube* of it, whereas the surface area grows only as *square*. As a result, there will be more and more volume on the surface of object. The relative surface area will shrink when size grows!

This is the true limit to the life on Earth. In general, evolution always tries to make organisms *bigger*. It is beneficial for everybody: bigger predators catch more prey; bigger prey escape from predators better; bigger plants take in more sun and shade more competitors; and so on.

However, a *bigger organism will have more volume per surface area* (i.e., smaller relative surface). Therefore, the most important feature of life, the gas exchange between an organism and its environment, will be hindered, assuming respiration is cutaneous. The pressure of weight (which corresponds tightly with volume) will also increase. How might an organism overcome these restrictions?

Today we will practice the laws of surface area to volume using two "organisms" made from the modeling clay. We will call them **Plasticizoans** since they are made from plasticine.

5.2 Procedure

1. The instructor will provide everybody with two differently colored Plasticizoans and a ruler.

   Shape them, as instructed, into cylinders, one about 30 mm in height ("Short"), and another about 70 mm in height ("Tall"). Do your best to make the ends as flat as possible, and the circumference equal throughout each organism.

2. **Measure** them with a ruler: height (h) in mm, and diameter (d) which is a distance across the cylinders base, also in mm. Record this data.

3. **Convert** diameter into radius (r) by dividing diameter by 2: $d = 2r$ so $r = \frac{d}{2}$. **Record** the radius.

4. Now, **calculate** volume and surface area for each of the two organisms.

Formulas for the cylinder:

to calculate volume, use

$$V = \pi r^2 h \tag{1}$$

and to calculate surface, use

$$A = 2\pi rh + 2\pi r^2 \tag{2}$$

5. **Calculate** the *relative surface area* (a.k.a surface area to volume ratio):

$$R = A/V \tag{3}$$

6. Now, **transform** your short cylinder *to make the relative surface as small as possible.* This will decrease contact with the environment. What shape is it now?

   ... Yes, it is a sphere! This shape has the absolute lowest surface area to volume ratio possible. As in, it has the very least contact with the environment.

7. As before, **measure** the radius. To do so, you will have to cut the sphere in half with your scalpel, measure the diameter, and divide by two. Record the diameter and radius.

8. **Calculate** volume, surface area, and relative surface area for the sphere.

Formulas for the sphere:

to calculate volume of sphere, use

$$V = \frac{4}{3}\pi r^3 \tag{4}$$

and to calculate surface of sphere, use

$$A = 4\pi r^2 \tag{5}$$

9. We transformed the short cylinder, which started out with a high surface area to volume ratio, into a sphere, which had a low surface area to volume ratio. (We reduced the contact with the environment.)

   Now we **transform** the *tall cylinder*, which started out with a low surface area to volume ratio, into another shape that has a **really high surface** area to volume ratio, the highest ratio you can achieve. What might this shape be?

Lab 5 report

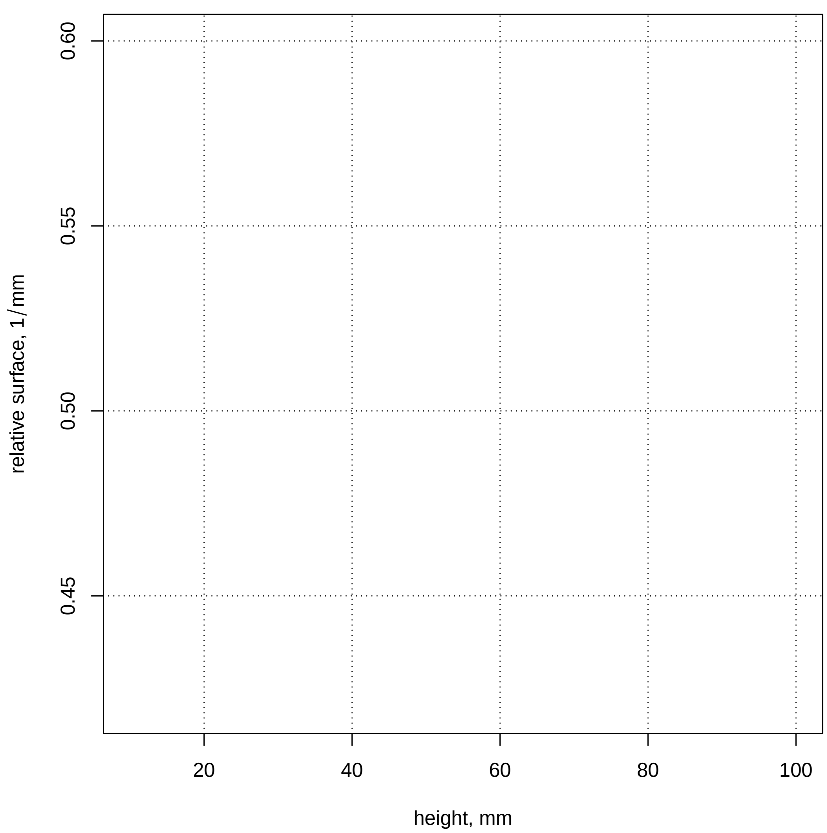
Your name ____

1. In many languages, there is a saying "To make an elephant out of a fly" (i.e., "To make a mountain out of a molehill", "exaggerate"). How will this desk-size, Highly Magnified Fly feel? Provide two reasons why this creature will probably not survive. Explain your reasoning. (2 pts)

2. Insert below volumes, surfaces, and relative surfaces of three plasticizoans. Which of them is most isolated from the environment? Why? (3 pts)

	Short	Tall	Spheric
volume V, mm^3			
surface A, mm^2			
relative surface R, mm^{-1}			

3. Using the formulas above, calculate relative surfaces of plasticizoans similar to Tall but with heights exactly 10, 30, 60, 80 and 100 mm and base diameter exactly 10 mm each. Make the plot below. If the relative surface is *less* than 0.45, cylindric plasticizoan *will not survive*. Somehow show this on the plot (5 pts).



4. **On the other side of this paper**, *sketch* your transformation of Tall cylinder. Imagine it as a living thing. What is it good at? What does it struggle with? Where might it live on our planet? (5 pts).