Biology 3A Laboratory
Lab 4: Morphology: The shape and form of biological structures

For the harmony of the world is made manifest in *form* and *number*, and the heart and soul and all the poetry of Natural philosophy are embodied in the concept of mathematical beauty (Thompson, 1971).

Objectives
- To learn and understand organismal symmetry
- To understand the difference and relationships between three dimensional and two dimensional representations of biological organisms and structures
- To “visualize” three dimensional relationships from two dimensional graphics

Introduction
Two-dimensional representations of three-dimensional objects abound in our world. Whether you are looking at a drawing in your textbook, a photograph, or even at a cell on a microscope slide, the image you are observing has no actual depth. In the lab on microscopes, you learned about depth of field. If you are knowledgeable about photography, you will also have some understanding of this concept. In fact, the great struggle in the history of art was the creation of depth, and three dimensionality in paintings and drawings. Flat work artists have quite a bag of tricks from which to select. They use shading, size, focus, color differences, and several other techniques to allow the viewer that there is depth in their piece. But the work is still really flat.

In biology, understanding the three dimensional structure of cells, organs or even entire organisms is critically important. We all know that cells are not flat. Yet they are always drawn on the blackboard, in your lab manual, and on tests as flat objects (Fig. 1). Understanding the three-dimensional nature of a cell is critical to understanding how that particular cell functions. For instance, the endoplasmic reticulum seen in Figure 1 actually exists as a flat series of interconnected chambers made of plasma membrane that extend into and out of the plane of

**Figure 1.** A typical animal cell drawn in the usual flat style

**Figure 2.** Transformed coordinates create Mola Mola from Puffer (from Thompson, 1971).
the paper on which it is printed. This creates an incredible amount of surface area, which is critical to the function of this organelle.

The ability to “see” three-dimensional structures when looking at flat sectional drawings can be learned. For some people, it seems to be rather easy, for the rest of us it is a struggle. But it is a worthwhile struggle. Today, modern computational, diagnostic and research techniques allow incredible views (and reconstructions) of the three-dimensional structure of molecules to the three-dimensional reconstruction of the head of a sperm whale from photographs of serial sections. There is even a field of biology that merges with mathematics called Geometric morphology. Perhaps the “father” of this field was D’Arcy Thompson, a Scotsman from St. Andrews University. In his 1917 book, On Growth and Form, he discussed just about every morphological problem in biology. His most impressive work however, was in the area of transformed coordinates. In Figure 2, taken from his book, we see a puffer fish on the left. On the right is a Mola Mola, whose body shape can result from a transformation of the coordinates drawn through the puffer. Of course Thompson related this to the evolutionary process; and today we understand that such transformation may result from subtle selection pressures on a small set of genes.

Finally, when we look at plants and animals, we can see certain similarities between groups. Certain generalities of form become obvious. For more than 100 years biologists have attempted to group organisms by form. One of the simplest categories of form is symmetry. Based upon the basic geometry, we can categorize (in a general sense) plant or animals (Fig. 3). For instance, animal body form is often described in terms of symmetry. Spherical symmetry describes an animal that is ball-shaped. Radial symmetry describes an animal that in which the body parts are arranged in roughly equal segments radiating from a central axis. Bilateral symmetry describes animals that have a head end and roughly equal right and left sides. Finally, some animals are simply asymmetrical. There are systems for describing symmetry in plants, as well. However, we will simplify our lives; in today’s lab we will look only at animal symmetry.

1. Looking at Animal Symmetry
In the lab you will find several animal specimens. Observe one of each species and decide whether the symmetry is radial, bilateral or asymmetrical. Each of the specimens is labeled. Record your choice of symmetry and the specimen names in Table One.

2. Looking at 2 Dimensional and 3 Dimensional Morphology
Creating Serial Sections
1. Obtain a hard boiled egg and remove the shell from the egg.
2. Using a paper towel, dry the shelled egg. Mark the short and long axis meridians using a Flair (water soluble) type marker (Fig. 4)
3. Using the egg slicer, slice egg along its long axis (Fig. 5).
4. Arrange egg slices in order on a piece of paper (Fig. 6). You should create about 6 to 7 slices.
5. Place grid on the first slice and align axis marks with the x and y axis (0,0)

6. Draw the pattern seen in section one on the serial section grid labeled “Section One” on Figure 9. Please think about this: Seven slices should result in 6 serial sections.
7. Continue for each of the other serial sections. Keep the sections in order; label each in sequence.

3. Visualizing a section in the 90 degree plane
The sections you have just drawn are in a plane known as longitudinal. You will now use these sections to create a cross section. For this assignment you should choose a plane crossing each of your sections in which there is some of the egg yolk present. For instance, suppose you are going to draw the cross section at grid line 5 as shown in Figure 7. From each section at grid line 5 you would transfer the data to that section line in Figure 7. When you are done, you smoothly connect the dots and
reconstruct the unknown cross section. Try this with your serial sections and reconstruct a 90 degree cross section in Figure 10.

![Figure 7](image)

**Figure 7.** Reconstruction of 90 degree cross section from serial section data. Dots are data from single serial sections.

### 4. Time to create your own animal

1. Take some colored clay and roll a rod about 1 cm in diameter and 10 cm long as shown in Figure 8a.
2. Create a slab from a different color of clay that measures about 10 cm by 3 cm by .5 cm thick.
3. Place the rod into the center of the slab (Figure 8b) and wrap the slab around the rod, neatly creating a sort of “hot dog in a bun” (Figure 8c).
4. Now place the rod on end and “squash” it until it is about 4 cm high (Figure 8d).

![Figure 8](image)

**Figure 8.** a. Roll 1cm x 10 cm coil of colored clay  b. Create a slab “bun”  c. Role slab around coil  d. Squash entire cylinder.
5. Finally roll the short, fat cylinder into an egg shape about the size of your original egg. The colored clay of the original rod should still be visible on the surface of the egg shape (representing the mouth and anus of your animal). What sort of symmetry have you created?

6. Using a marker or a knife to create meridian axes, one that goes from pole to pole (from mouth to anus) and one that goes around the belly of your animal.

7. Now, place your “animal” into the egg slicer in the same orientation as the original egg example and slice.

8. Record the serial sections in Figure 11.

9. Create a reconstruction (Fig. 12) of a 90 degree cross section and describe the flow of the colored clay through the animal (mouth to anus).

5. And now for something completely different… Pollen Morphology

Pollen grains (the male reproductive products of flowers) are unique to their species. The exact morphology of the pollen shape and size is related to the pollination strategy and the female flower structures. Observe the assorted pollen in the lab and draw the shapes as accurately as you can in Figure 13. Be sure to indicate the size of the pollen grains and including the magnification in which they were drawn.

Annotated Bibliography Project

Over the next few weeks you are going to write an Introduction section of a scientific paper. In order to complete this assignment you must first have a bibliography. Your assignment is to find five primary literature papers in an area of pollen morphology. Remember, you will use these to write an Introduction, so they must be related. You will articulate an hypothesis in the Introduction, so these papers will provide background in the area you choose.

The format for the annotated bibliography must include:

1. Full citation of the paper (name-year system)
2. Brief statement of the hypothesis tested by the authors
3. Brief statement of the outcome of the research.

You may use the internet to find primary literature journal articles (Science, Nature, J. Plant Physio., etc), however, you **may not** use any webpages as one of your citations for any of the papers you turn in.

The annotated bibliography is due in the second lab next week!

References
Table 1. Symmetry of animal specimens displayed in lab

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Figure 9. Serial sections through hard boiled egg
Figure 9. Serial sections through hard boiled egg (continued)

Figure 10. Reconstruction of 90 degree cross section of hard boiled egg
Figure 11. Serial sections through “created” clay animal
Figure 11. Serial sections through “created” clay animal (continued)

Figure 12. Reconstruction of 90 degree cross section of “created” clay animal
Figure 13. Pollen morphology and sizes