STUDENT HANDOUT

GRADES 6–12

SCIENCE LAB

EXPLORING DDT'S EFFECT ON RAPTOR POPULATIONS

New York State Museum

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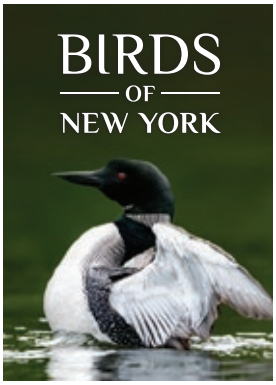

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PROBLEM:

Raptor populations were declining. How did scientists determine what was causing the decline?

LAB PROCEDURE

- **STEP 1 –** Read background material about studies of eggshell thicknesses and DDT.
- **STEP 2 –** Analyze data provided from Peregrine Falcon egg specimens and plot the data from these eggs directly on the D. A. Ratcliff graph.
- **STEP 3 –** Measure the volume and mass of a raw egg and determine its surface area.
- **STEP 4 –** Prepare the eggshells for day 2 of the lab.
- **STEP 5 –** Weigh the empty eggshells and determine their thicknesses.

STEP 1: LEARN ABOUT THE DISCOVERY OF DDT'S EFFECT ON EGGSHELL THICKNESS

In August 1965, biologists and experts on birds of prey gathered at a conference at the University of Wisconsin to discuss the causes and possible remedies for recent declines in Peregrine Falcon populations. Surveys had shown that falcons, eagles, and other raptors had been disappearing from dozens of nesting sites in the United States, Canada, and Great Britain. Scientists observed that nesting failures were caused by the parent birds crushing their own eggs when they incubated them, and they wondered if eggshells were becoming thinner for some reason. Some suspected that the cause was exposure to an environmental toxin. Research involving egg specimens from museum collections published in the years following the Wisconsin conference would establish the link between eggshell thinning and population declines and would identify the agricultural pesticide DDT as the cause of eggshell thinning.

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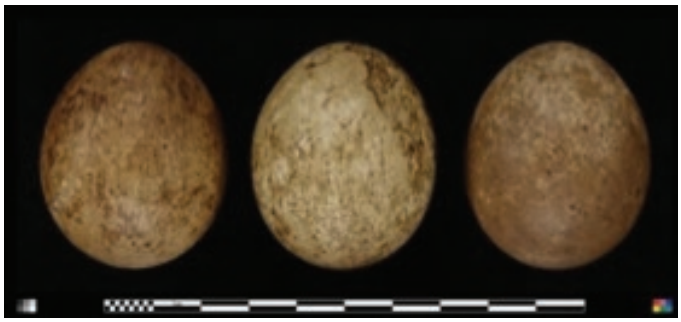
STUDENT HANDOUT

GRADES 6–12

Museum Egg Collections Provide the Proof

In the 1800s and early 1900s, egg collecting was a popular hobby in Europe and North America. It sounds strange today, but people would go out in nature to find wild bird nests, take the eggs home, carefully blow the contents out of the shell, and keep the shells in their own private collections. These private collections ended up in natural history museums when laws were passed to protect wild birds. When scientists wished to test the hypothesis that eggshells of raptors had become thinner at the same time that populations began to decline, they used the specimens in museums as a baseline for comparisons with modern eggs.



Peregrine Falcon egg specimens housed at the New York State Museum (NYSM 10502) were used in the DDT studies of the 1960s and 1970s.

In 1967 the British scientist D. A. Ratcliff published a study in which he demonstrated that Peregrine Falcon eggshells suddenly became thinner beginning in the mid-1940s. He estimated the thickness of eggshells from three simple measurements: the mass of the empty eggshell, the length of the egg, and the breadth of the egg. His eggshell-thickness index is the mass divided by the size of the empty egg:

EQUATION 1: Thickness index = Mass / (Length x Breadth)

Here is a graph from Ratcliff's 1967 paper showing that the drop in eggshell thickness began suddenly around the same time that farmers began using DDT in their fields.

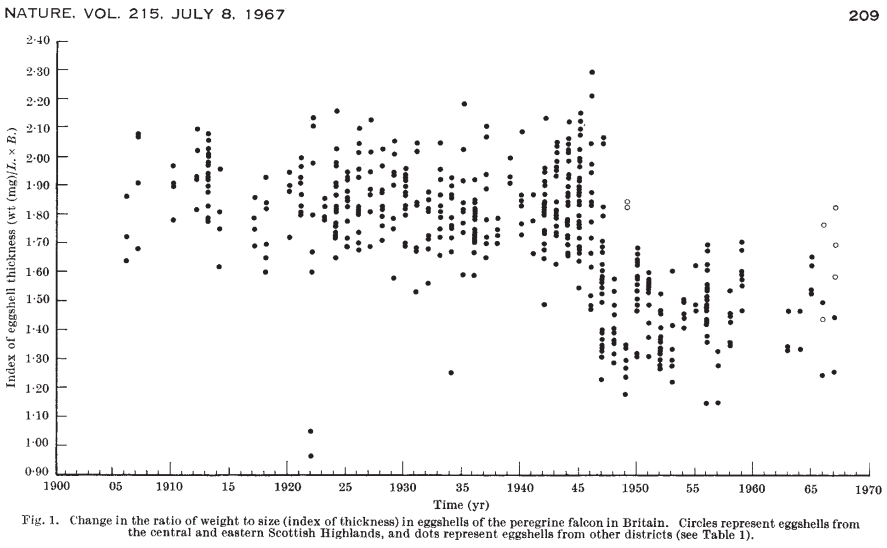


Fig. 1. Change in the ratio of weight to size (index of thickness) in eggshells of the peregrine falcon in Britain. Circles represent eggshells from the central and eastern Scottish Highlands, and dots represent eggshells from other districts (see Table 1).

Figure 1. Ratcliff diagram showing Peregrine Falcon eggshell thickness from 1900–1970.

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STUDENT HANDOUT

GRADES 6–12

Finding the Culprit

Egg specimens from museums were also used by biochemists who carefully measured the amount of DDT residues in the eggshell membranes and the thickness of eggshells. David Peakall, a researcher at the Cornell Laboratory of Ornithology in the late 1960s and early 1970s, was one of the people performing this work. He used specimens from many museums, including the Peregrine Falcon eggs now on exhibit at the NYS Museum, to establish the link between DDT (short for Dichlorodiphenyltrichloroethane) exposure and eggshell thinning. Here is a graph from one of his papers, showing that even a tiny amount of DDT has a drastic effect on eggshell thickness.

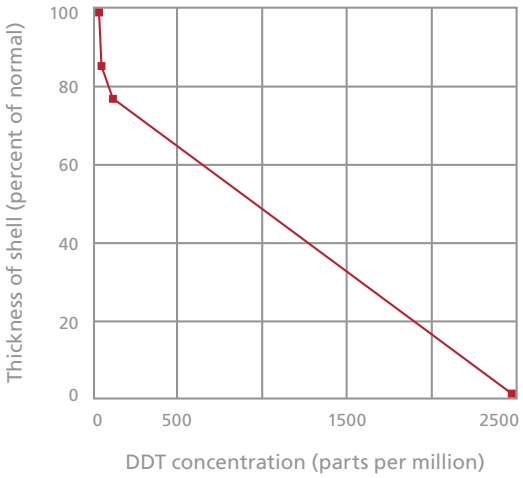

Figure 2. Graph from Dr. Peakall's study comparing the thickness of Peregrine Falcon eggshells when effected by different amounts of DDT.

STEP 2: ANALYZE THE PEREGRINE FALCON SPECIMEN DATA

Calculate the relative eggshell thickness for these specimens housed at the NYS Museum, using the measurements provided in the table below. These samples were measured with calipers and weighed on a digital scale at the Museum. Input your solution in the "Relative Thickness" column of Figure 3.

$$\text{Thickness index} = \frac{\text{Mass (mg)}}{\text{(Length (mm) x Breadth (mm))}}$$

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Peregrine Falcon specimen number and location	Year Collected	Length (mm)	Breadth (mm)	Mass (mg)	Relative thickness
NYSM 12222 Pribilof Islands, AK	1900	51.9	41.9	4100	
NYSM 15283 Englewood Cliffs, NJ	1920	51.6	41.2	4000	
NYSM 15284 Hook Mountain, NY	1923	53.2	41.2	4500	
NYSM 15285 Englewood Cliffs, NJ	1924	52.6	41.4	4200	

Figure 3. Peregrine Falcon egg data and measurements from items in the NYS Museum ornithology collection.

Compare the relative thickness of these NYS Museum eggshells to those measured by D. A. Ratcliff by adding dots (or stars, etc.) to his graph on page 3. Eggshell-thickness index is on the Y-axis and the year is on the X-axis. How do your measurements compare with Ratcliff's measurements of Peregrine Falcons from Britain? Have the State Museum eggs been affected by DDT?

MATERIALS NEEDED FOR STEP 3:

- One egg for each pair or group of students
- Electronic balance(s) capable of measuring within a tenth of a gram (0.1 g)
- Petri dishes or low, small containers to keep the eggs from rolling off the scale
- Graduated cylinder or graduated beaker large enough to measure volume displacement with units in milliliters if possible
- Rulers or calipers

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GRADES 6–12

STEP 3: MEASURE THE VOLUME AND MASS OF A RAW EGG

Scientists working in well-equipped laboratories have measured eggshell thickness using magnetic micrometers that are accurate to 0.001 mm! Today, we are using simple tools, combined with some mathematics, to calculate the thickness of eggshells from chicken eggs.

To accomplish this task, we need to know the surface area of the eggshell, the mass of the empty eggshell, and the density of the eggshell material. Measuring the surface area (SA) of a curved object is difficult, but you can calculate SA from egg volume (V), which can be measured by displacement in water, or from egg mass (M), which can be measured on a scale.

PROCEDURE FOR MEASURING THE VOLUME

To measure the volume (V) of a whole, raw egg using displacement in water you need a graduated beaker with units in mL that is large enough to fit an egg without overflowing.

Remember:

- A submerged object displaces a volume of liquid equal to the volume of the object.
- One milliliter (1 mL) of water has a volume of 1 cubic centimeter (1 cm^3).

1. Pour enough water into the graduated beaker to reach a height that will cover the egg. Read and record the volume. (Remember to read the number at the bottom of the meniscus, or curve, in the water level.)
2. Slightly tilt the graduated beaker and carefully place the egg into the water.
3. Place the graduated cylinder upright on the table and look at the level of the water. If the egg floats, use a pencil to gently push the top of the sample just under the surface of the water. Record the number of milliliters for this final water level.
4. Find the amount of water displaced by subtracting the initial level of the water from the final level. This volume equals the volume of the egg in cm^3.
5. Write down this volume; you'll use it in the calculations below.
6. Recover the egg by pouring the water back into your cup or sink and taking the egg out of your graduated cylinder or beaker.

PROCEDURE FOR MEASURING THE MASS

To measure the mass (M) of a whole, raw egg you need an electronic balance and a small petri dish to make sure the egg does not roll off. In order to get the weight of just the egg, either weigh the petri dish first and subtract that amount from the total or put the petri dish on and "tare" the scale to reset it to zero before placing the egg gently into the dish.

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Use the equations below to calculate the surface area (SA) of the egg from your measurements of V and M. You will need a scientific calculator that can do exponents:

$SA = 4.835 \times M^{0.662}$ or $SA = 4.951 \times V^{0.666}$

Trying both methods will give us a good sense of the relative difficulty of each, and of the range of variation you get from employing different methods.

Make your measurement and calculation, and record the surface area in this space:

Egg #	SA from Volume	SA from Mass

Which method (volume or mass) of calculating surface area do you think is more accurate? Why? Use the one you think is better in the calculations below.

STEP 4: PREPARE EGGSHELL FOR DAY 2 OF LAB

Following the instructions below, blow out the contents of the eggshell, and rinse it out as your teacher demonstrated.

1. Carefully make a hole in the side of the egg using a thumbtack, pushpin, or dissecting probe. Make the hole about 5 mm in diameter.
2. Insert a probe to gently break apart the yolk and scramble the egg inside the shell.
3. Use a pipette, eyedropper or needle-less syringe to push water into the hole, thinning the egg solution.
4. Gently pump the pipette in and out until the liquid starts to flow and then keep pumping water in until the egg is well rinsed inside (This takes a while).
5. Use a bowl or basin to catch the egg white and yolk.

END OF DAY 1

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GRADES 6–12

STEP 5: WEIGH YOUR EMPTY EGGSHELL AND DETERMINE ITS THICKNESS

When your eggshell is dry, measure the mass of the empty eggshell and record it here:

Mass: _____(g)

Now determine the absolute thickness of your eggshell in centimeters, using the equation below. The density of chicken eggshells is known (from repeated, detailed measurements) to be 2.24 g/cm^3. The units of density are grams per cubic centimeter, so the thickness of your eggshell (in centimeters) can be found by this multiplication operation:

EQUATION 3:

Thickness (cm) = Eggshell mass (g) / eggshell surface area (cm^2) / 2.24 g cm^{-3}

Note: Recall that dividing by cm^3 is the same as multiplying by cm^{-3}, and that dividing any number by X is the same as multiplying by 1/X. As the units cancel out in the above operation the final number is expressed in cm, which is what we want for a linear measurement of thickness.

Record the thickness of your eggshell here:

$$\text{Thickness (mm)} = \textit{eggshell mass (g)} \div \frac{\textit{surface area (cm}^2\textit{)}}{\textit{density } \left(\frac{g}{cm^3}\right)} = \_\_\_\_\_$$

After taking the measurements, gently label your egg in pencil with the number your teacher gives you, a different number for each team of students in all the classes. This will enable graphing of the results. Your teacher will gather the data from different groups for plotting and discussion. Write your answers to the questions below.

1. How much variation is there in the eggshell thickness calculated by different groups?

2. Do chicken eggshells really vary this much, or is the variation due to methodological differences?

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3. Explain how you might change the lab procedure to determine the source of variation among groups, and the true variation in eggshell thickness among eggs.

4. Why do you think it took years of research to convince the public that DDT was responsible for the decline of raptor populations?

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NYS Science Learning Standards:
MS-LS2-4; HS-LS4-5; HS-LS2-2

These activities are designed to meet lab requirements for Regents examination for the Living Environment and are appropriate for Grades 6–12.

WINTER 2021

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Cover Photo
Peregrine Falcon first-year male (holding prey), adult female, chicks and egg

Reproduction of original watercolor by
Louis Agassiz Fuertes (NYSM H-1977.74.45)

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