Burning Calories—Literally!

Name: _____

Date: _____

Group members: _____

Student worksheet — Answer key

Directions: Finish the assignments below in preparation for the experiment.

1. Your teacher will show you 100 grams of the different food items you will study later in this lesson. Make a prediction and add arguments for your predictions.

   Which food item do you think contains the most energy (or Calories) for the 100 grams of food?

   Food item:

   Reasoning:

   Which food item do you think contains the least energy (or Calories) for the 100 grams of food?

   Food item:

   Reasoning:

2. Design a calorimeter.
   a. Brainstorm ideas on:
      - how you can release the food energy in your calorimeter
      - how your calorimeter will capture the released energy
      - what you can measure
      - how this measurement can give you a measure of the food energy
   b. Narrow the ideas down to something that is possible with the materials you are given.

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Student worksheet — Answer key

Directions: Finish the assignments below in preparation for the experiment.

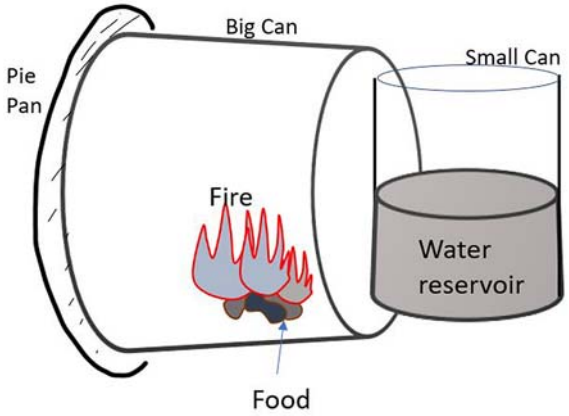
Make a sketch of what the calorimeter will look like.

Answer:

The sketched calorimeter:

- *displays and labels a food item that can be put on fire*
- *displays and labels a water reservoir to catch the released energy*
- *is made of provided materials*

A sketch might look like this:



Label the following items in your sketch:

- ☐ Food item
- ☐ Water reservoir to capture released energy
- ☐ Materials used

Explain how this calorimeter will work.

The answer about how the calorimeter works should include the following:

- *Fire releases the energy stored in food.*
- *The released energy heats up a reservoir of water.*
- *You measure the change in temperature of the water to know how much energy it absorbed.*

Checklist

Did I include:

- ☐ How food energy is released
- ☐ What happens to the released energy
- ☐ What is measured

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Name: _____

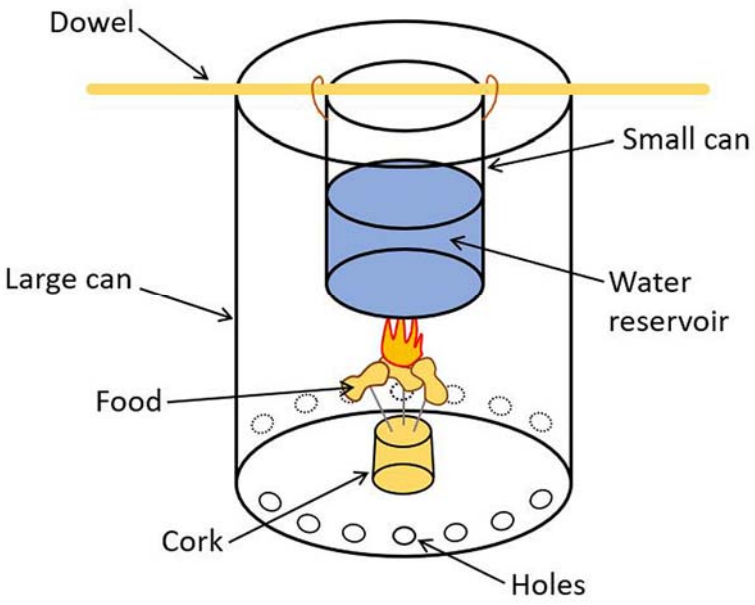
Student worksheet — Answer key

Directions: Finish the assignments below in preparation for the experiment.

3.

Sketch the calorimeter the class will build.

Below is the diagram of a calorimeter the Science Buddies team built with the materials provided. Your class can build this calorimeter or one that was designed by a group in the class.



Label the following items in your sketch:

- ☐ Food item
- ☐ Water reservoir to capture released energy
- ☐ Materials used

Checklist:

- ☐ Food items are accessible.
- ☐ Food will burn up completely. (Note: Fire needs air in addition to fuel.)
- ☐ The water in the reservoir captures most of the released energy.
- ☐ You can measure the temperature change of the water in the reservoir.

Provide a short answer:

How is food energy released in this calorimeter?

Food energy is released by burning the food.

What will you measure to quantify the released food energy?

The temperature change of the water in the reservoir will quantify the released food energy.

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Name: _____

Student worksheet — Answer key

Directions: Finish the assignments below in preparation for the experiment.

4. State the independent dependent, and control variables of your calorimeter.

   Independent variables:

   Food type

   Dependent variables:

   Temperature change of the water

   Control variables:

   Amount of water in the reservoir, amount of energy lost to the environment, air flow in the calorimeter, etc.

5. The calorimeter functions because energy changes from one form to another.

   Add labels to the calorimeter you drew in question 3 that show:

   - where chemical energy is stored
   - where thermal energy is stored

   Add an arrow showing how energy is transferred (as heat) from the chemical energy to the thermal energy reservoir. Label this arrow "heat." *[Answer: See sample diagram on the last page of this answer key.]*

6. Briefly explain the processes that allow a calorimeter to measure the energy stored in food. Use the words *chemical energy*, *thermal energy*, and *heat* in your explanation.

The answer should include the following:	**Checklist**
• *Fire releases the chemical energy stored in food as heat.* • *Heat spontaneously flows from warmer to colder areas.* • *Heat delivers the released energy to the water reservoir, where it is stored as thermal energy.* • *As a result, the temperature of the water in the reservoir changes.*	Did I include: ☐ How chemical energy is released ☐ What happens to the released energy ☐ What is measured

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Name: _____

Student worksheet — Answer key

Directions: Follow the steps below to conduct the experiment and record the data.

SAFETY INFORMATION

Remember to obey these safety rules at all times while performing the experiment:

- Work on a non-flammable surface.
- Long hair needs to be tied back.
- All students must wear safety glasses.
- Always use oven mitts to handle items that may be hot.

Data Table 1: Measurements

Food Item	Food: M_i (g)	Food: M_f (g)	Water: T_i (°C)	Water: T_f (°C)	Food: $M_i - M_f$ (g)	Water: $T_f - T_i$ (°C)
Almonds	*1.5*	*.4*	*20*	*33*	*1.1*	*13*

One row of data and a possible amount of water is provided in Table 1 and Step 7. The example calculation uses these measured values. Your students' results may be different.

7. Note the amount of water contained in the reservoir: _____*150*_____ milliliter (mL).

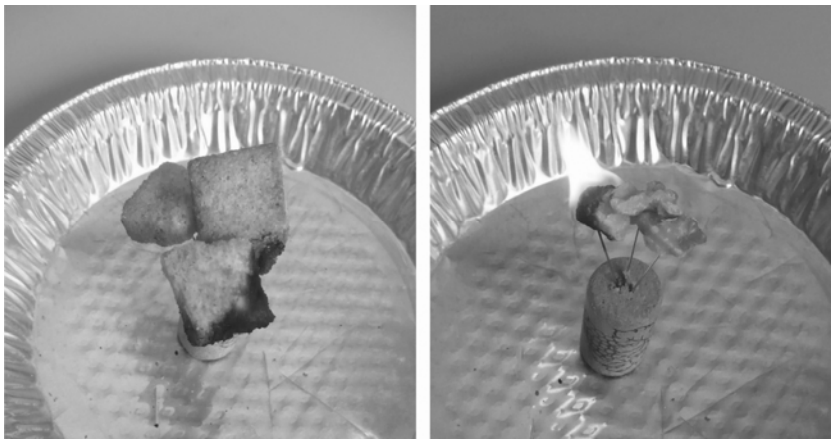
   Note: the mass of 1 mL of water is 1 gram.

Name: _____

Student worksheet — Answer key

Directions: Follow the steps below to conduct the experiment and record the data.

8. Perform a trial:
    a. Select a few pieces of the same food item; using a few pieces (not just one) allows you to burn a larger mass.
    b. Weigh the food pieces to be burned and record the initial total mass in the "Food: *Mi*" column.
    c. Put the pieces of food in place. Make sure all the pieces touch. This will allow the flame to go from one piece to the next.
    d. Place your thermometer in the small can, so it can adjust its temperature to the water inside.
    e. Light the food with the long matches, Bunsen burner, or lighter.
    f. *Instantly* stir the water in the small can and read the initial temperature (*Ti*). Record this temperature in the "Water: *Ti*" column. Remove the thermometer from the can as the metal might get hot.
    g. Allow the food to burn itself out. If smoke is coming out, the burning is still in progress. Hints: If the food stops burning too early, experiment with putting it in with a real flame instead of smoldering, as shown in the figure. Increasing the air flow can help keep the fire going, too.



    h. As soon as the food stops burning, carefully stir the water and measure the final temperature (*Tf*). Make sure the thermometer has reached a steady level before reading the temperature. Record the value.
    i. Weigh the remains of any food that was not completely burned (not including ashes). Record the mass in the "Food: *Mf*" column. If all the food burned up, record a final mass "Food: *Mf*" of 0 g.
    j. This completes one trial for this food item.

Name: _____

Student worksheet — Answer key

Directions: Follow the steps below to conduct the experiment and record the data.

9. Calculate the change in mass (*Mi* - *Mf*) and change in temperature (*Tf* - *Ti*). Write these values down in Data Table 1.
10. Repeat steps 8 and 9 for each food item. The extra rows in Data Table 1 can be used for extra trials. Do not erase data if you mess up a trial; just take a new row and try again.
11. Clean up the workspace.
12. Use the measured values and the formulas given to calculate the energy used to heat up the water (Q_{water}), the energy released by the food (Q_{Food}), and the energy contained in 1 gram of food ($Q_{Food,\ 1g}$). Write the results in data table 2.

Formulas	*Variables*
$Q_{water} = m_{water}\ c\ (T_f - T_i)$	Q_{water} : heat captured by the water when heated (Cal) m_{water} : mass of the water that is heated (g) c : specific *heat capacity* of water (0.001 Cal/(g°C)) T_i : initial temperature of the water (°C) T_f : final temperature of the water (°C) Q_{Food} : energy released when burning the food (Cal) $Q_{Food,1g}$: energy released when burning 1 gram of food (Cal/g) M_i : initial mass of food burned (g) M_f : final mass of food burned (g)
$Q_{water} = Q_{Food}$	
$Q_{Food,1g} = \dfrac{Q_{Food}}{(M_i - M_f)}$	

Calculations for Almonds:

Q_{water} = 150g × 0.001 Cal/(g°C) × (33.3 °C − 20.0 °C) = 2.0 Cal

$Q_{Food,\ 1\ g}$ = 2.0 Cal/1.1 g = 1.8 Cal/g.

Data Table 2: Calculations

Food Item	Q_{water} (Cal)	Q_{Food} (Cal)	$Q_{Food,1g}$ (Cal/g)
Almonds	*2.0*	*2.0*	*1.8*

Name: _____

Student worksheet — Answer key

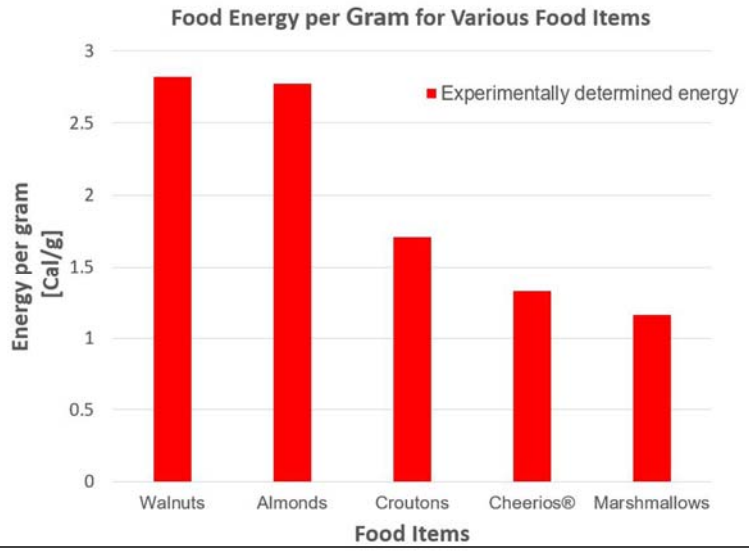
Directions: Follow the instructions below about your experiment.

13. Collect data from other groups and calculate the average.

Data Table 3: Results $Q_{Food,1g}$							
Food Item	**Group 1 (Cal/g)**	**Group 2 (Cal/g)**	**Group 3 (Cal/g)**	**Group 4 (Cal/g)**	**Group 5 (Cal/g)**	**Group 6 (Cal/g)**	**Average (Cal/g)**
Almonds	***1.8***	***…***	***…***	***…***	***…***	***…***	

14. Graph the average measured $Q_{Food,1g}$.

This is an example graph. Your graph might look different.



Checklist

Did I include:

- ☐ The horizontal axis displays the independent variable
- ☐ The vertical axis displays the dependent variable
- ☐ The graph has a title
- ☐ Axes are labeled
- ☐ All food items are included

Name: _____

Student worksheet — Answer key

Directions: Follow the instructions below about your experiment.

15. Use the food label provided by the teacher for the following assignment.

    List the Calorie content per serving ($Q_{Food,1\ serving}$) and calculate the Calorie content per gram ($Q_{Food,1g}$) for the food item.

$$Q_{Food,1\ serving} = \frac{Q_{Food,1\ serving}}{\text{Mass of 1 serving in g}}$$

Answer:

In this case the student was given a food label of walnuts listing 186 Cal per serving and a serving size of 1 oz or 28.35 gram.

$Q_{Food,1\ serving}$ = _____*186 Cal* _____ $Q_{Food,1g}$ = _*186/28.35 Cal/g = 6.54 Cal/g*_

16. Collect data from other groups to complete Table 4.

Example data is provided in Table 4.

Data Table 4: Values calculated or copied from food labels

Food Item	$Q_{Food,1\ serving}$ (Cal/serving)	$Q_{Food,1g}$ (Cal/g)
Walnuts	**186**	**6.54**
Almond Nuts	**160**	**5.78**
Crouton	**56**	**4.28**
Cheerios®	**113**	**3.57**
Marshmallow	**110**	**3.18**

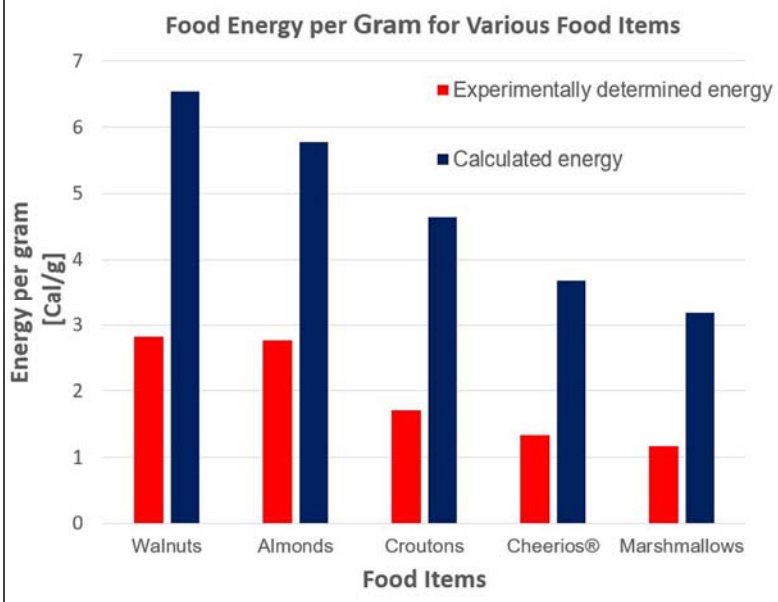
Directions: Follow the instructions below about your experiment.

17. Create a new graph containing the average experimentally determined $Q_{Food,1g}$ as well as the $Q_{Food,1g}$ obtained from information listed on the food labels and listed in Table 4.

Note:

You expect the average experimentally determined $Q_{Food,1g}$ to be lower than the $Q_{Food,1g}$ obtained from information listed on the food labels for all food items. If this is not the case, check if there was an error made in the calculation of the experimentally determined $Q_{Food,1g}$ or in the calculations made from information listed on the food labels.

This is an example graph. Your graph might look different.



Checklist

- ☐ The horizontal axis displays the independent variable
- ☐ The vertical axis displays the dependent variable
- ☐ The graph has a title
- ☐ Axes are labeled
- ☐ All food items are included
- ☐ Legend included

Name: _____

Student worksheet — Answer key

Directions: Follow the instructions below about your experiment.

18. **Claim:** Our homemade calorimeter has a low efficiency, which means its measured values are lower than the actual Calorie content.

    Is the graph made in question 17 evidence for this claim? Why or why not?

Answer:

The answer stated below assumes the graph made in question 17 shows that the Calorie content per 1 g food calculated from information found on food labels (dark blue bars in the graph) is much higher than the measured value (red bars in the graph) for each of the food items tested.

The answer should include the following:

- *The graph is evidence of this claim.*
- *The values obtained from information listed on the food labels are derived from values that are assumed to be correct. We believe our calculations are correct, so these represent the actual Calorie content of 1 g of the food items.*
- *The graph shows that the experimentally determined Calorie content for 1 g food is lower than the value for 1 g food obtained from information listed on the food labels for all food items.*

See scoring rubric on the next page.

Label the following items in your sketch:

- ☐ Food energy or chemical energy
- ☐ Thermal energy
- ☐ Heat
- ☐ Energy loss
- ☐ Arrows to indicate energy flows

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Name: _____

Student worksheet — Answer key

Directions: Follow the instructions below about your experiment.

Scoring rubric for Step 18.

	Meets Standard	**Approaching Standard**	**Starting Standard**
Reasoning should include: • *Which values (the ones obtained from values on the label or the experimentally determined ones) are correct and why.* • *The graph shows how experimentally determined values are lower than the ones obtained from information on the label.*	Reasoning contains both arguments. The conclusion follows logically from the reasoning.	Reasoning contains one argument, but not both. The conclusion follows logically from the reasoning.	Reasoning contains some arguments. The conclusion does not follow logically from the reasoning.

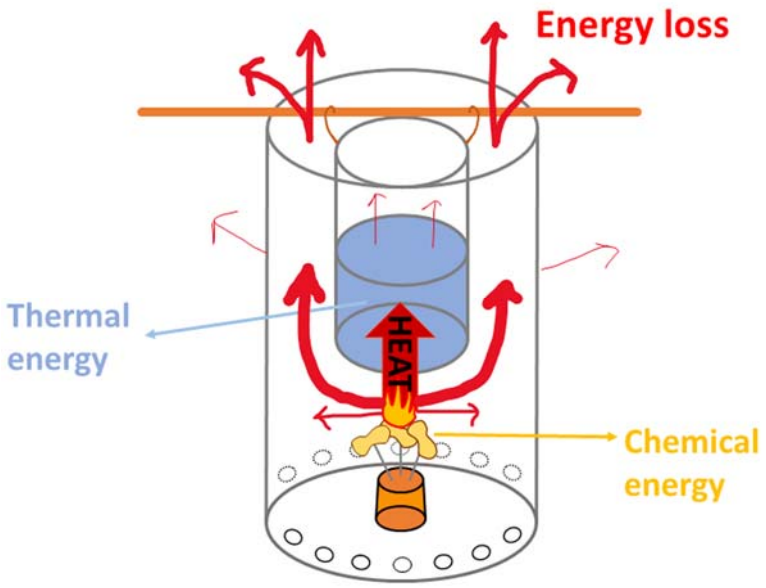
Burning Calories—Literally!
Page 13

Name: _____

Student worksheet — Answer key

Directions: Follow the instructions below about your experiment.

19. Based on your experiment, draw a new sketch of how energy flows through the calorimeter that includes energy loss.



Label the following items in your sketch:

- ☐ Food energy or chemical energy
- ☐ Thermal energy
- ☐ Heat
- ☐ Energy loss
- ☐ Arrows to indicate energy flows

The sketch should include both energy forms and energy flows.

Energy forms:

- *a food item labeled as food or chemical energy*
- *a reservoir to capture released energy labeled as thermal energy*

Energy flows:

- *heat flowing from the food to the reservoir shown by at least 1 arrow*
- *heat loss flowing towards the environment shown by several arrows*

See scoring rubric on the next page.

Name: _____

Student worksheet — Answer key

Scoring rubric for Step 19.

	Meets Standard	Approaching Standard	Starting Standard
Forms of energy stored	Food/chemical energy and thermal energy are drawn and placed correctly, and all are correctly labeled.	Food/chemical energy or thermal energy is drawn and placed correctly, but not both.	Food/chemical energy and thermal energy are drawn and labeled, both are placed incorrectly.
Energy Transfer	Arrows indicating heat transfer to the water and energy loss to the environment are present, placed correctly, and are correctly labeled.	An arrow indicating heat transfer to the water or arrows indicating energy loss to the environment is present and placed correctly, but not both.	Arrows indicating heat transfer to the water and energy loss to the environment are present but placed incorrectly.

Name: _____

Student worksheet — Answer key

Sample diagram for Question 5.

