

Temperature and Metabolic Activity

In the [Cellular Respiration laboratory](#), you experimented with peas and saw how the rate of oxygen consumption during cellular respiration varied with temperature. In that lab, you experimented with peas to see how the rate of oxygen consumption during cellular respiration increased with temperature.

In animals, an increase in cellular respiration triggers [homeostatic](#) mechanisms that increase both breathing and heart rate, resulting in more oxygen being available to cells.

In the second part of this lab, you will study the relationship between temperature and metabolic activity in an ectothermic animal. An [ectotherm](#) is an animal whose body temperature is much the same as its surroundings, such as a frog, a cricket, or a snake.

Thermoregulation

[Thermoregulation](#) is the maintenance of internal temperatures within a range that allows cells to function. It may involve both physiological and behavioral adaptations. For example, humans thermoregulate by sweating and shivering, dogs by panting, and snakes by basking on sunny rocks.

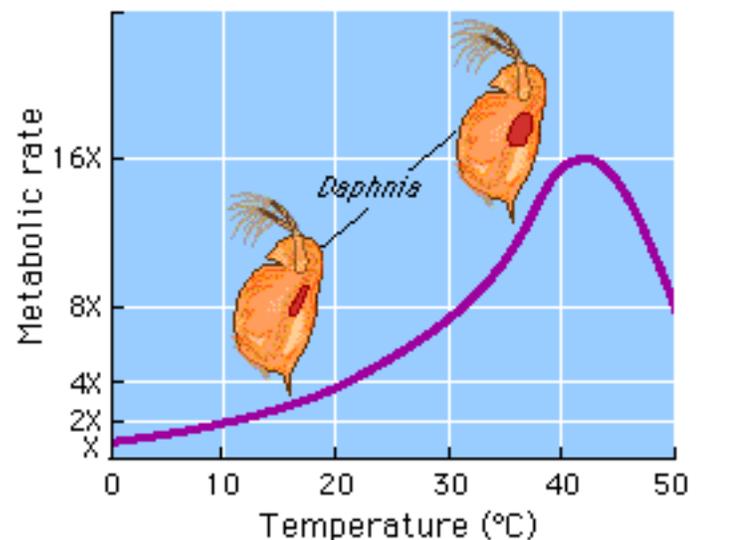
Because **ectotherms'** temperature remains close to that of their environment, they face special challenges in thermoregulation. Ectotherms exhibit a variety of behaviors that allow them to gain or lose heat. Examples include basking in the sun and burrowing in mud. Because metabolic rate increases with increasing temperature, ectotherms do not become active until their body has absorbed heat and warmed up. This accounts for the sluggish early morning behavior of ectotherms such as snakes.

Measuring Temperature and Metabolic Rate

The rate of metabolism in **ectothermic** animals increases as the environmental temperature increases. This rise occurs because the reactants in the cell have greater thermal energy, and many cellular enzymes are more active as temperature increases. This effect is noticeable in a range from approximately 5°C to 35°C; at temperatures much higher than this, enzymes become denatured.

The graph below illustrates the effect of increased temperature on metabolic rate in an aquatic ectotherm, *Daphnia magna* (water "flea"). Go to the following website so you can see the animation of the heart rate of the Daphnia and then answer the questions on the following page.

http://www.phschool.com/science/biology_place/labbench/lab10/temprate.html



Count the heart beats (they represent metabolic rate). What is the relationship between metabolic rate and a 10°C increase in temperature?

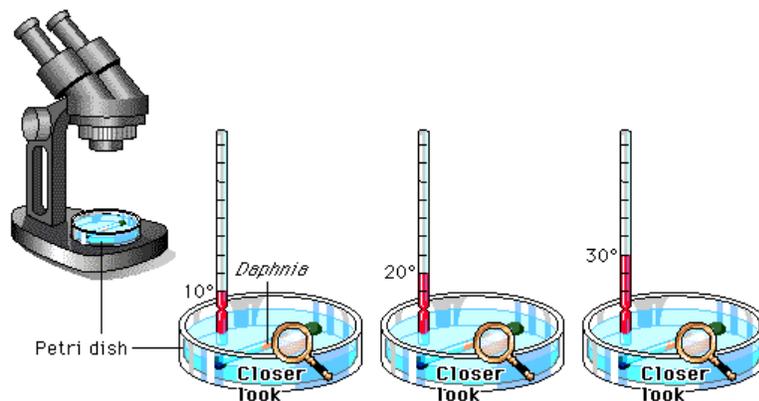
The relationship between temperature and metabolic rate is often measured as Q_{10} . If the metabolic rate doubles with a 10°C increase in temperature, then $Q_{10} = 2$.

Design of the Experiment

It is possible to measure metabolic rate indirectly by measuring heart rate. In this activity, you will gauge the effect of temperature on metabolic rate by counting the heartbeats of *Daphnia*.

There are a number of possible procedures for "trapping" the *Daphnia* so that you can observe its heart under a dissecting microscope. Your instructor will show you the procedure to use.

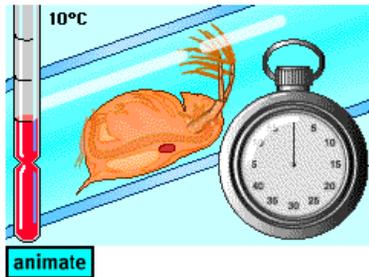
Observe the *Daphnia* in a petri dish of water at three different temperatures. Select each magnifying glass to practice timing the *Daphnia* heart rate. **Hint:** The temperature of each water bath does not have to be precise, just within the recommended range. Record the exact temperature as you collect your data.



Measuring Temperature and Metabolic Rate

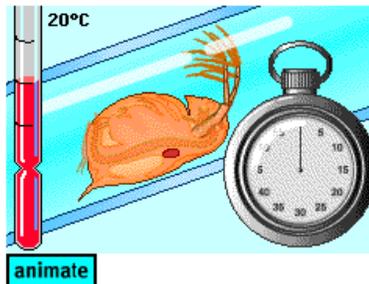
The time on the stopwatch represents 10 seconds. Count the number of heartbeats during this time and multiply by six to get the heart rate for one minute. Record the number; you will need it for the next exercise.

At 10 degrees Celsius



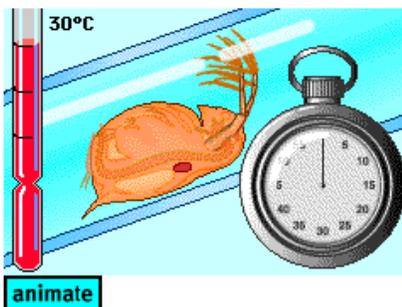
DATA:

At 20 degrees Celsius



DATA:

At 30 degrees Celsius



DATA:

This is the equation you will be given on the AP Biology test.

Temperature Coefficient Q_{10}

$$Q_{10} = \left(\frac{k_2}{k_1} \right)^{\frac{10}{t_2 - t_1}}$$

Watch this video to learn how to use this equation:

<http://www.bozemanscience.com/q10-the-temperature-coefficient>

k_1 is the first rate, k_2 is the second rate

Practice Question

Data was taken to determine the effect of temperature on the rate of respiration in a goldfish. It is in the table below. Calculate the Q_{10} for this data. Round to the nearest whole number.

Temperature (C)	Respiration Rate (Min)
16	16
21	22

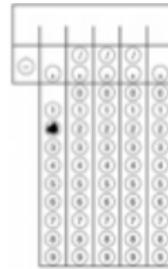
(-)	(.)	(/)	(/)	(/)	(.)
	(0)	(0)	(0)	(0)	(0)
(1)	(1)	(1)	(1)	(1)	(1)
(2)	(2)	(2)	(2)	(2)	(2)
(3)	(3)	(3)	(3)	(3)	(3)
(4)	(4)	(4)	(4)	(4)	(4)
(5)	(5)	(5)	(5)	(5)	(5)
(6)	(6)	(6)	(6)	(6)	(6)
(7)	(7)	(7)	(7)	(7)	(7)
(8)	(8)	(8)	(8)	(8)	(8)
(9)	(9)	(9)	(9)	(9)	(9)

Answer

$$Q_{10} = (22/16)^{10/(21-16)}$$

$$Q_{10} = (1.375)^2$$

$$Q_{10} = 2$$



Lab Quiz

1. Which of the following organisms would show the greatest fluctuation in body temperature hour by hour?

- a. dolphin
- b. mouse
- c. lake trout
- d. rattlesnake

2. What is the relationship between metabolic rate and body temperature in *Daphnia*?

- a. As the body temperature increases, the metabolic rate decreases.
- b. An increase of 10°C results in a doubling of metabolic rate.
- c. Heart rate increases as body temperature decreases.
- d. Cellular enzymes are less active at 35°C than at 20°C, resulting in decreased metabolic rate.

3. If $Q_{10} = 2$, then an enzymatic reaction that takes place at a given rate at 5°C would take place approximately how many times faster at 25°C?

- a. Twenty times
- b. Eight times
- c. Four times
- d. Three times
- e. Two times

4. Which of the following experimental conditions would be most life-threatening for an ectothermic organism?

- a. Temperatures that exceed 40°C
- b. Temperatures that are between 3°C and 8°C

Lab Quiz II

1. Which of the following organisms would show the greatest fluctuation in body temperature hour by hour?

- a. dolphin
- b. mouse
- c. lake trout
- ✓ d. rattlesnake

Correct! Although a lake trout is also ectothermic, its aquatic habitat results in fewer temperature fluctuations than the snake's.

2. What is the relationship between metabolic rate and body temperature in *Daphnia*?

- a. As the body temperature increases, the metabolic rate decreases.
- ✓ b. An increase of 10°C results in a doubling of metabolic rate.
- c. Heart rate increases as body temperature decreases.
- d. Cellular enzymes are less active at 35°C than at 20°C, resulting in decreased metabolic rate.

Correct! It is the only statement to correctly link an increase in body temperature with an increase in metabolic rate.

3. If $Q_{10} = 2$, then an enzymatic reaction that takes place at a given rate at 5°C would take place approximately how many times faster at 25°C?

- a. Twenty times
- b. Eight times
- ✓ c. Four times
- d. Three times
- e. Two times

Correct! Each 10°C increase in temperature results in a doubling of the metabolic rate.

4. Which of the following experimental conditions would be most life-threatening for an ectothermic organism?

- ✓ a. Temperatures that exceed 40°C
- b. Temperatures that are between 3°C and 8°C

Correct! High temperatures result in permanent changes to enzyme structure that disrupt normal cellular functions.