ScienceCube

Respiration Rate According to Temperature

Checking the respiration status using peas and observing how respiration rate changes with temperature.

Fundamental Concept

1. Cellular Respiration

A part of the metabolic process in which living organisms break down organic compounds to obtain energy. Organisms use the energy obtained through cellular respiration for other life activities. Cellular respiration can be divided into aerobic respiration (using oxygen) and anaerobic respiration (not using oxygen).

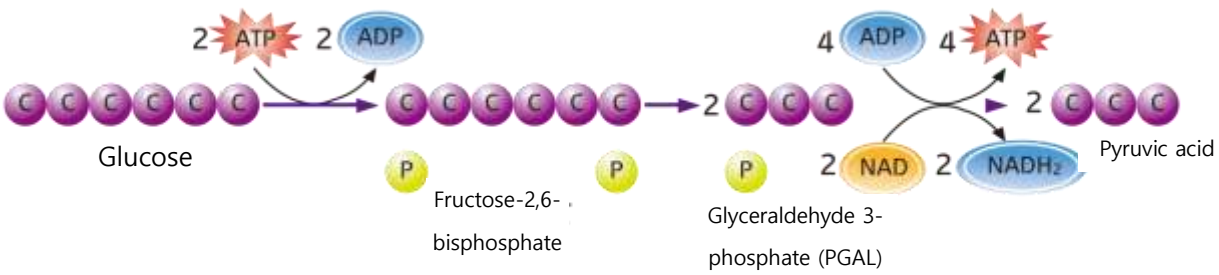
Glucose + Water + Oxygen → Carbon Dioxide + Water + Energy for Life

$C_6H_{12}O_6 + 6H_2O + 6O_2 \rightarrow 6CO_2 + 12H_2O + 38ATP$

2. Aerobic Respiration

A complex process in which organic nutrients are oxidized and broken down, divided into glycolysis, TCA cycle, and electron transport chain..

A. Glycolysis



① Respiratory substrate: Carbohydrates (mainly glucose)

② Location: Cytoplasm

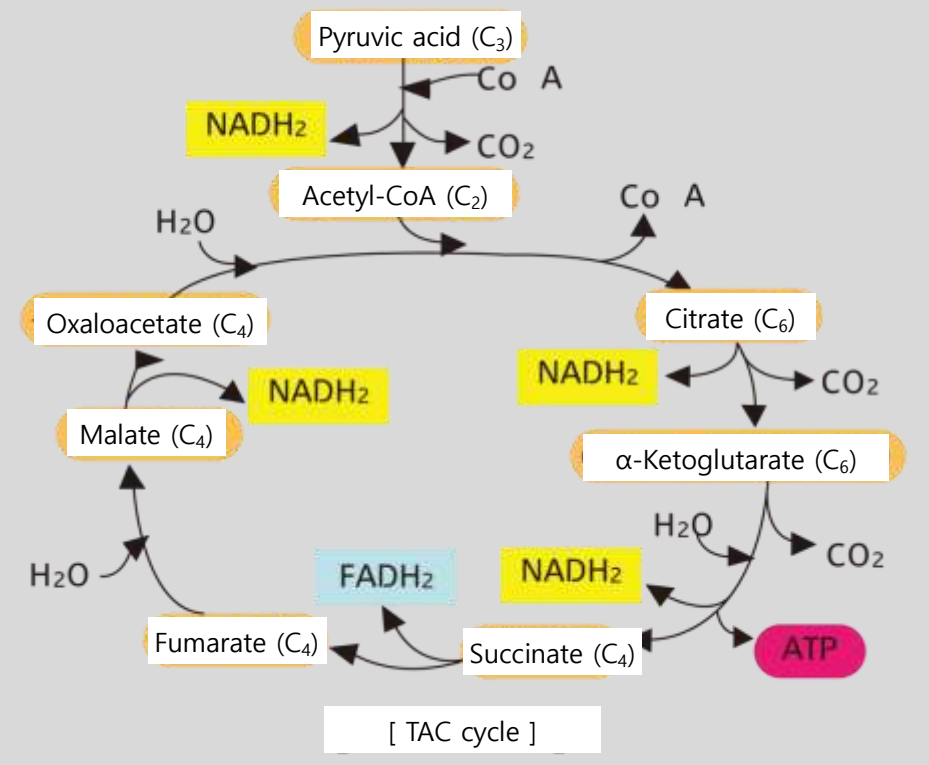
③ Process: Produces 2 ATP at the substrate level and forms 2 molecules of pyruvate

B. TCA Cycle,

The pyruvate produced in glycolysis enters the mitochondria and is oxidized and broken down into CO2 and H2O through the TCA cycle by decarboxylase and dehydrogenase enzymes.

① Location: Mitochondrial matrix

② Process: Pyruvate from glycolysis produces 3 molecules of CO2, 4 NADH2, 1 FADH2, and 1 ATP.

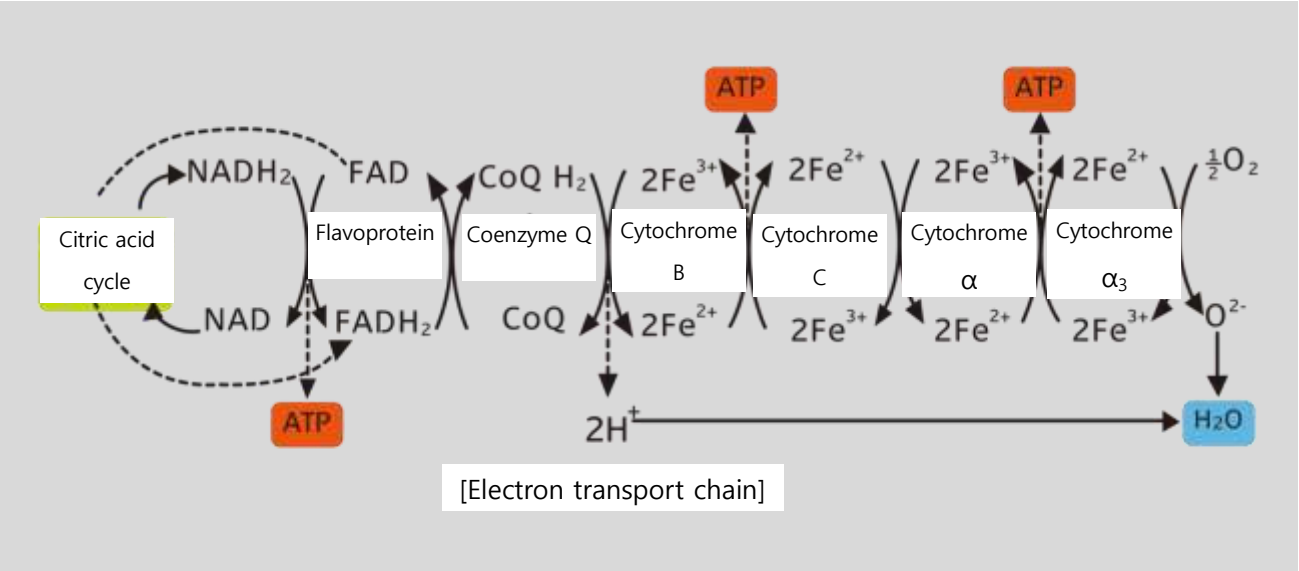


[TAC cycle]

C. Electron Transport Chain

① Location: Inner mitochondrial membrane

② Process: NADH2 produced in glycolysis and NADH2 and FADH2 produced in the TCA cycle transport hydrogen and high-energy electrons through the electron transport chain. Ultimately, hydrogen and electrons combine with O2 to form H2O..



[Electron transport chain]

3. Respiration Rate

(1) Respiration rate: The ratio of the volume of O2 consumed to the volume of CO2 produced when a respiratory substrate is oxidized.

Respiration Rate= (Volume of CO2 produced) / (Volume of O2 consumed)

(2) The respiration rate varies depending on the type of respiratory substrate due to differences in the composition ratio of C, H, and O.

① Respiration Rate of Glucose

$C_6H_{12}O_6 + 6H_2O + 6O_2 \rightarrow 6CO_2 + 12H_2O$

Respiration Rate = $(6CO_2)/(6O_2)$ = 1.0

② Respiration Rate of Amino Acids

$2C_6H_{13}O_2 + 15O_2 \rightarrow 12CO_2 + 10H_2O + 2NH_3$

Respiration Rate = $(12CO_2)/(15O_2)$ = 0.8

③ Respiration Rate of Fatty Acids

$2C_{51}H_{98}O_6 + 145O_2 \rightarrow 102CO_2 + 98H_2O$

Respiration Rate = $(102CO_2)/(145O_2)$ ≒ 0.7

Experiment

Materials Needed

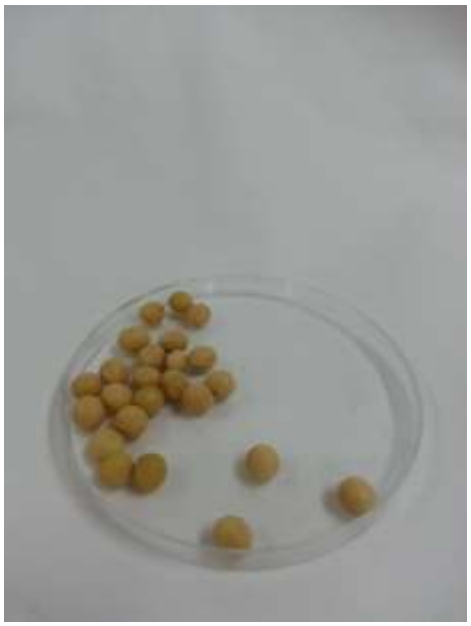
Interface, Science# program, Temperature sensor, CO2 sensor, 250 mL Erlenmeyer flask (2), Germinated peas, Non-germinated peas, Ice, 1 L beaker, Paper towel, Plastic bag

Experimental Setup

1. Soak peas in water two days before the experiment for about one night, then place them on a damp towel in a warm, dark place for a day to germinate.

2. Put 25 germinated peas and 25 non-germinated peas in separate plastic bags.

< Germinated Peas >



< Non-germinated Peas >

3. Run Science# and connect the temperature sensor to the interface.

4. Pour cold water into a 1 L beaker, add ice, and place the temperature sensor in the water to adjust the water temperature to around 5℃.

5. Place the plastic bags containing germinated and non-germinated peas in the beaker for 2-3 minutes..

6. Remove the peas and pat them dry with a paper towel. Divide the germinated and non-germinated peas into separate Erlenmeyer flasks.

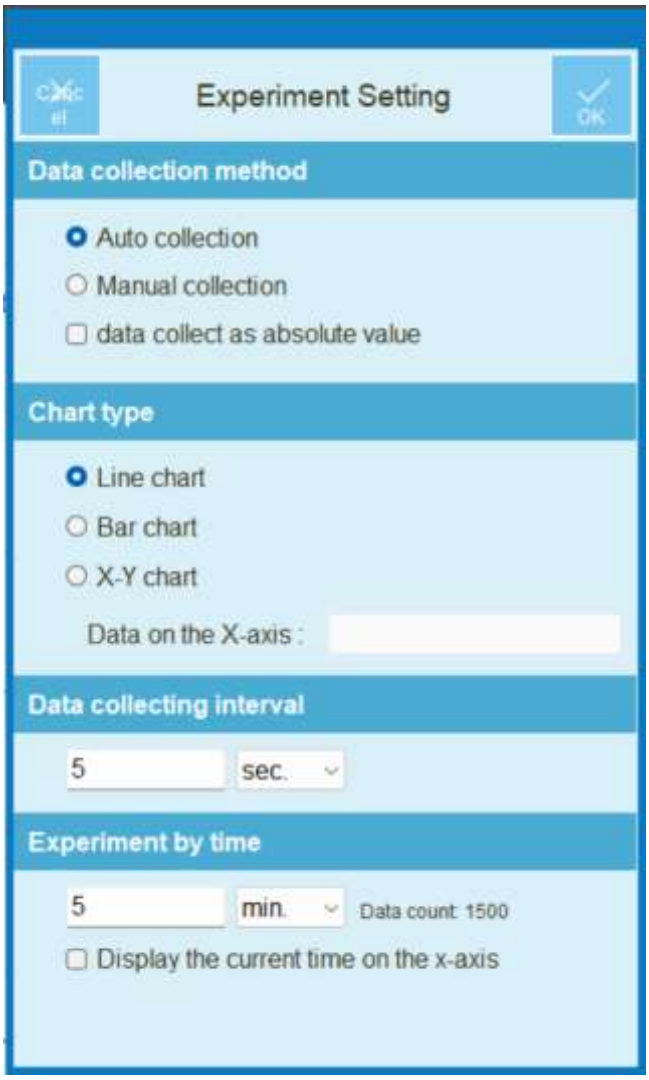
   (CO2 is well absorbed in water, so moisture must be removed from the peas before placing them in the flasks.)

7. Insert the CO2 sensor into the flask containing non-germinated peas and place it in the beaker with ice water..

< Non-germinated Peas >

Interface Setup

1. Connect the CO2 sensor to the interface.
2. Press the button  to set up the experimental environment as shown below or press the button  for automatic setup.




[Automatic Setup]

Note! To measure accurate values with the CO2 sensor, it is recommended to warm up for 20-30 minutes before data collection..

Data Collection

[Respiration Rate of Peas at Low Temperature]

1. Press the button  to collect data while maintaining the ice water temperature at around 5℃ and record the CO2 data in the flask.
2. Once data collection is complete, remove the CO2 sensor from the flask and fan the sensor detection hole to reset it to the initial state.

3. Remove the peas from the flask and pat them dry with a paper towel.
4. Insert the CO2 sensor into the flask containing germinated peas and place it in the beaker with ice water. (Before inserting the CO2 sensor, fan it in a well-ventilated place to reduce the CO2 concentration.)
5. Press the button and measure the CO2 concentration using the same method as above..

< Germinated Peas >

[Respiration Rate of Peas at Room Temperature]

6. Pour warm water into a 1 L beaker until it is half full and adjust the water temperature to around 25℃. (Prepare separate beakers with cold or warm water to maintain the water temperature at 25℃.)
7. Place the germinated and non-germinated peas back into separate plastic bags and immerse them in room temperature water for 2-3 minutes.
8. Remove the peas and pat them dry with a paper towel. Divide the germinated and non-germinated peas into separate Erlenmeyer flasks.
9. Insert the CO2 sensor into the flask containing non-germinated peas and place it in the beaker with room temperature water.
10. Press the button to measure the CO2 concentration.
11. Repeat the same process to measure the CO2 concentration in the flask containing

germinated peas over a fixed period.

Note! The CO2 sensor is very sensitive, so ensure good ventilation in the laboratory by opening windows, avoid bringing the sensor close to your mouth, and minimize talking during the experiment.

Data Analysis

Recording Data

1. Display the changes in CO2 concentration for non-germinated and germinated peas at different temperatures over a fixed period in a graph.

2. Use the above data to complete the table below..

Condition	Low Temperature (Approx. ℃)		Room Temperature (Approx. ℃)	
	Minimum	Maximum	Minimum	Maximum
Non-germinated Peas				
Germinated Peas				

3. Calculate the respiration rate using the following formula. Record the respiration rate of peas under different conditions.

$$\text{Respiration Rate} = \frac{(Maximum\ Value - Minimum\ Value)}{5minutes}$$

Respiration Rate (ppm/min)	Low Temperature	Room Temperature
Non-germinated Peas		
Germinated Peas		

Data Application and Extended Activities

1. Based on the data results, indicate which peas (germinated or non-germinated) can be considered alive.

2. Explain the reasoning behind your answer based on the data results.

3. Describe how the respiration rate of germinated peas differs between low and room temperature.

4. Explain the reason for the change in respiration rate of peas with temperature..

Extended Activities

1. List at least two factors that can affect the cellular respiration rate.

2. Think of other methods to measure the respiration rate of peas and describe them.

3. The following table compares photosynthesis and respiration. Fill in the blanks with the appropriate terms..

Category	Raw Material	Product	Reaction Type	Energy Metabolism
Respiration				
Photosynthesis