

Thermal Modulation of Daphnia Cardiac Activity: A Microscopic Assessment of Heart Rate Responses

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Abstract

Daphnia is a freshwater planktonic organism that can be used to observe physiological responses to environmental changes, particularly temperature. Its transparent body allows heart activity to be observed microscopically. This study aimed to investigate the effect of temperature on the heart rate of Daphnia. A quantitative experimental method was employed by observing Daphnia at different temperature conditions. Heartbeats were observed using a microscope for 15 seconds and repeated three times at each temperature condition. Observations were conducted at initial temperatures of 10°C, 15°C, 20°C, and 25°C and corresponding final temperatures of 20°C, 25°C, 30°C, and 35°C. The results showed variations in the mean heart rate of Daphnia across temperature conditions. The mean heart rates at the initial temperatures were 76.33, 88.67, 76.33, and 56.00 beats per 15 s, respectively, while those at the final temperatures were 89.67, 108.67, 109.00, and 95.67 beats per 15 s, respectively. The Q10 values obtained were 2.349, 2.042, 2.142, and 2.39. The results indicate that temperature was associated with variations in Daphnia heart rate, although the response did not consistently increase with increasing temperature. Therefore, controlled temperature conditions during microscopic observation are important for obtaining reliable measurements of Daphnia heart rate.

1. Introduction

Daphnia is a small planktonic organism belonging to the genus Daphnia and the group Cladocera (Pereboev et al., 2025). This organism is commonly found in freshwater ecosystems, such as ponds, lakes, and relatively stagnant water bodies. Daphnia has a transparent body, allowing several internal organs, including the heart, to be observed using a microscope. This characteristic makes Daphnia a suitable organism for observing physiological responses to changes in environmental conditions (Reilly et al., 2023). In addition, Daphnia has the ability to adapt to various environmental factors, such as temperature, salinity, photoperiod, ultraviolet radiation, the presence of predators, and heavy metal pollution (Ebert, 2022).

Microscopic observation provides a direct means of visualizing biological processes that are otherwise difficult to perceive, making it valuable for connecting theoretical concepts with observable physiological phenomena. In science education, such visualization can strengthen the representation and interpretation of abstract concepts by transforming invisible or microscopic processes into observable evidence. This approach has been demonstrated through microscopic visualization of plasmolysis in *Rhoeo discolor*, where cellular changes provide a direct representation of the physiological process of osmosis (Fitriyani & Firdaus, 2026). Similarly, visualization has been used to support the representation and interpretation of scientific concepts that are difficult to observe directly (Firdaus et al., 2024). In this context, the transparent body of Daphnia offers a particularly useful biological model because its cardiac activity can be observed microscopically, enabling physiological responses to environmental changes to be examined through direct visual observation.

The heart is one of the important organs involved in the circulatory system of animals. In *Daphnia*, the heart functions to pump hemolymph throughout the body, supporting the distribution of oxygen and substances required by the organism (Pass et al., 2026). Cardiac activity can be observed through heart rate, which indicates the number of heart contractions per unit of time. Heart rate can be used as one of the physiological indicators to determine an organism's response to changes in environmental conditions (Beine et al., 2024). Changes in external factors that directly or indirectly affect the physiological condition of an organism can lead to changes in cardiac activity (Tuaputty et al., 2024).

One environmental factor that can affect heart rate is temperature. Environmental temperature can influence physiological processes because it is closely related to metabolic activity. At higher temperatures, metabolic activity tends to increase, resulting in greater oxygen and energy requirements (Glazier & Gjoni, 2024). This condition can cause an increase in heart rate. In contrast, at lower temperatures, metabolic activity may decrease, resulting in a lower heart rate (Kraskura et al., 2023). Therefore, changes in environmental temperature can cause changes in heart rate as a physiological response to environmental conditions (Rejeki et al., 2021).

Understanding physiological responses to environmental changes is also relevant to broader ecological education because environmental conditions can influence living organisms at multiple levels of biological organization. Ecological education emphasizes the importance of developing awareness of environmental conditions and their consequences for living systems (Firdaus, 2025). From this perspective, observing the physiological response of an aquatic organism such as *Daphnia* to temperature variation can provide a concrete biological context for understanding the relationship between environmental conditions and organismal responses.

The response of *Daphnia* to temperature changes is important to observe because this organism lives in environments where temperature conditions can fluctuate (Maszczyk et al., 2024). *Daphnia* is generally found in freshwater environments within a certain temperature range and has the ability to adapt to environmental changes (Rebelo et al., 2025). However, temperatures outside the optimal range may affect its physiological activity. Excessively high temperatures can increase metabolic activity and place physiological stress on the organism (Bechtel & Bich, 2024). Conversely, excessively low temperatures can reduce metabolic activity and other physiological processes. Therefore, observing the heart rate of *Daphnia* under different temperature conditions can provide information about the physiological response of the organism to changes in environmental temperature (Hearn et al., 2025).

The heart rate of *Daphnia* can be measured by observing the movement of the heart under a microscope and counting the number of heartbeats per minute (Rizzato et al., 2025). This observation method allows changes in heart rate to be directly observed after *Daphnia* is exposed to different temperature treatments. Differences in heart rate under different temperature conditions can be used to determine the physiological response of *Daphnia* to changes in environmental temperature (Hoffschroer et al., 2024). Thus, heart rate observations not only indicate cardiac activity but can also be used to describe the organism's response to changes in environmental conditions (Bedrossiantz et al., 2023).

Based on the above explanation, research on the effect of temperature on the heart rate of Daphnia is important to investigate the physiological response of Daphnia to changes in temperature. This study was conducted by providing different temperature conditions, with an initial temperature of 25°C and a final temperature of 35°C, followed by observations of changes in the heart rate of Daphnia. This study aimed to determine how the heart rate of Daphnia can be measured, identify the heart rate of Daphnia, and determine the effect of temperature changes on the heart rate of Daphnia. The hypothesis of this study is that there are differences in the heart rate of Daphnia under different temperature conditions, with a tendency for heart rate to increase as environmental temperature increases up to a certain limit. However, excessively high temperatures may disrupt the physiological condition of Daphnia and potentially lead to mortality.

2. Research Methodology

2.1 Research Design

This study employed a quantitative experimental design to investigate the effect of temperature on the heart rate of Daphnia. The experiment was conducted under controlled conditions by exposing Daphnia to two different water temperatures, namely 25°C as the initial temperature and 35°C as the final temperature. The independent variable was water temperature, while the dependent variable was the heart rate of Daphnia. The controlled variables included the observation duration of 15 seconds and the heat exposure from the microscope light.

2.2 Materials and Instruments

The materials used in this study included Daphnia obtained from the available Daphnia culture, normal water, ice cubes, and hot water. Normal water was used as the medium for preparing the experimental temperature, while ice cubes and hot water were used to adjust the water temperature according to the treatment conditions. The instruments used included a microscope for observing the heart movement of Daphnia, object glasses for placing the organism during observation, beakers for preparing the water at different temperatures, a dropper pipette for transferring Daphnia, and a thermometer for measuring and monitoring the water temperature. A smartphone was also used to record the heart movement of Daphnia during microscopic observation.

2.3 Experimental Procedure

The experiment began by preparing all materials and instruments. Water was first prepared and adjusted to the initial temperature of 25°C using a thermometer. A Daphnia specimen was then transferred from the culture using a dropper pipette and placed into the prepared water. The Daphnia was allowed to acclimatize to the experimental temperature for 1 minute. After acclimatization, the Daphnia was transferred to an object glass using a pipette and placed on the microscope stage. The microscope was adjusted until the heart of Daphnia could be clearly observed. The heart movement was then recorded using a smartphone for 15 seconds, and the observation was repeated three times.

Following the observation at 25°C, the water temperature was increased by 10°C to obtain a final temperature of 35°C. The Daphnia was transferred from the object glass into the water adjusted to 35°C and allowed to acclimatize for 1 minute. The organism was subsequently transferred to an object glass and placed under the microscope. The microscope was adjusted to obtain a clear view of the heart, and the heart movement was recorded using a smartphone for 15 seconds. This observation was also repeated three times. The number of heartbeats was determined from the recorded videos. The videos were slowed down when necessary to facilitate accurate counting.

2.4 Data Collection and Analysis

Data were collected by counting the number of heartbeats of Daphnia observed during each 15-second recording. The number of heartbeats from each observation was recorded and subsequently converted into heart rate expressed as beats per minute (bpm). The heart rate was calculated by converting the number of heartbeats observed within 15 seconds into the equivalent number of beats per minute using the following equation:

$$\text{Heart rate (beats/minute)} = \text{Number of heartbeats} \times 60/15$$

The heart rate data obtained from the observations at 25°C and 35°C were compared to determine the changes in Daphnia heart rate in response to temperature variation. In addition, data from other experimental groups that used different temperature conditions were collected and combined with the experimental data. The resulting data were then analyzed descriptively to identify differences in Daphnia heart rate under different temperature conditions.

3. Result

3.1 Daphnia Heart Rate under Different Temperature Conditions

The results of the observation of Daphnia heart rate at different temperature conditions are presented in Table 1. Heart rate was recorded three times for each temperature condition, and the mean value was calculated from the three observations.

Table 1
Heart Rate of Daphnia at Different Temperature Conditions

Initial Temperature (°C)	Heart Rate Observations	Mean	Final Temperature (°C)	Heart Rate Observations	Mean	Q ₁₀
10°C	83	76,33	20°C	90	89,66	2,349
	75			94		
	71			85		
15°C	95	88,66	25°C	95	108,66	2,042
	76			111		
	95			120		
20°C	83	76,3	30°C	109	109	2,142
	71			111		
	75			107		
25°C	50	56	35°C	82	95,6	2,39
	60			106		
	58			99		

The results showed variations in Daphnia heart rate across the observed temperature conditions. At the initial temperatures of 10°C, 15°C, 20°C, and 25°C, the mean heart rates were 76.33, 88.66, 76.33, and 56.00, respectively. At the corresponding final temperatures of 20°C, 25°C, 30°C, and 35°C, the mean heart rates were 89.66, 108.66, 109.00, and 95.60, respectively.

The highest mean heart rate was recorded at 30°C, with a value of 109.00, whereas the lowest mean heart rate was recorded at 25°C under the initial temperature condition, with a value of 56.00. The calculated Q₁₀ values for the four temperature intervals were 2.349, 2.042, 2.142, and 2.390, respectively.

3.2. Microscopic Observation of Daphnia Heart Activity

Microscopic observations were conducted to visualize the heart activity of Daphnia under different temperature conditions. The observations were performed at four initial temperatures (10°C, 15°C, 20°C, and 25°C) and four corresponding final temperatures (20°C, 25°C, 30°C, and 35°C). The microscopic observations are presented in Fig. 1.

Figure 1 shows the microscopic observations of Daphnia heart activity under the different temperature conditions. The observations were conducted by recording the heart movement of Daphnia for 15 seconds at each temperature condition. The recorded observations were used to count the number of

heartbeats and calculate the mean heart rate. The observed differences in heart activity correspond to the heart rate data presented in Table 1.

4. Discussion

4.1. Effect of Temperature on Daphnia Heart Rate

The results showed variations in the heart rate of Daphnia under different temperature conditions. At the initial temperature, the mean heart rates were 76.33 beats per 15 s at 10°C, 88.67 beats per 15 s at 15°C, 76.33 beats per 15 s at 20°C, and 56.00 beats per 15 s at 25°C. At the final temperature, the mean heart rates were 89.67 beats per 15 s at 20°C, 108.67 beats per 15 s at 25°C, 109.00 beats per 15 s at 30°C, and 95.67 beats per 15 s at 35°C.

These results indicate that temperature was associated with variations in the heart rate of Daphnia. However, the heart rate did not consistently increase with increasing temperature. The highest mean heart rate was observed at 30°C, while the lowest mean heart rate was recorded at 25°C under the initial temperature condition. This variation suggests that the physiological response of Daphnia to temperature differed across the observed temperature conditions (Sun et al., 2024).

4.2. Heart Rate Response of Daphnia to Temperature Changes

The observations showed that, in several temperature comparisons, the heart rate at the lower initial temperature was higher than that recorded at the corresponding higher temperature. This finding differs from the physiological response described by Rejeki et al. (2021), who stated that lower environmental temperatures generally result in lower body temperature and heart rate, whereas higher environmental temperatures tend to increase heart rate. This response is related to physiological adaptation to changes in environmental temperature, including changes in blood flow (Bonell et al., 2024).

Based on this theoretical relationship, an increase in environmental temperature would generally be expected to increase the heart rate of Daphnia within an appropriate temperature range. However, the present observations did not consistently show this pattern. For example, the mean heart rate at the initial temperature of 10°C was higher than that at 25°C. This difference may be related to experimental conditions during microscopic observation, particularly the prolonged exposure to microscope light, which could increase the temperature around the Daphnia. Consequently, the actual temperature experienced by Daphnia during observation may have differed from the intended experimental temperature and affected the recorded heart rate.

4.3. Q10 Value of Daphnia Heart Rate

The Q10 calculation was used to describe the change in Daphnia heart rate associated with a 10°C increase in temperature. The reported Q10 values were 2.349 for Q10(1), 2.042 for Q10(2), 2.142 for

Q10(3), and 2.39 for Q10(4). The variation in these values indicates differences in the response of *Daphnia* heart rate across the observed temperature intervals.

The Q10 results should be interpreted together with the observed heart rate data and experimental conditions. Variations in temperature during microscopic observation may influence the recorded heart rate and subsequently affect the calculated Q10 values. Therefore, the Q10 values obtained in this experiment provide an indication of the temperature response of *Daphnia* but should be considered in relation to the consistency of temperature control during the observation process.

5. Conclusion

The heart rate of *Daphnia* can be measured through microscopic observation by counting visible heartbeats for 15 seconds and repeating the observation three times to obtain a mean value. The results showed variations in *Daphnia* heart rate under different temperature conditions, indicating that temperature is associated with changes in its physiological activity. However, the observed heart rate did not consistently increase with increasing temperature across all treatments. Therefore, temperature control during observation is important to obtain more consistent and reliable measurements of *Daphnia* heart rate.

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Figures

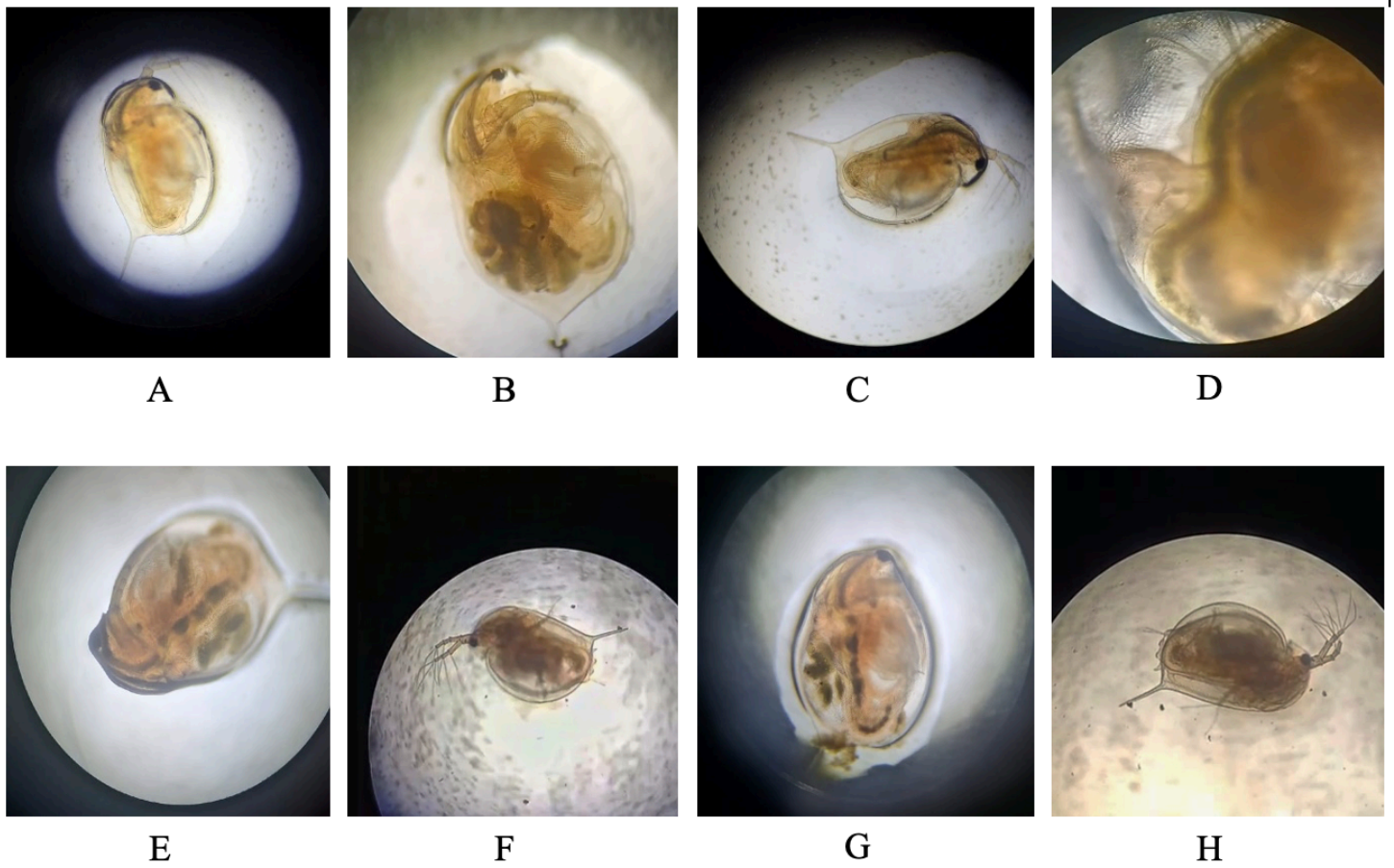


Figure 1

Microscopic observation of *Daphnia* heart activity at different temperature conditions. (A) 10°C, (B) 15°C, (C) 20°C, (D) 25°C, (E) 20°C, (F) 25°C, (G) 30°C, and (H) 35°C.