The Effect of Different Water Temperature on the Rate of Movement of *Dugesia*

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***Abstract*:** *The purpose of this study was to find whether the water temperature has an effect on the rate of movement of Dugesia spp. We conducted a measured-response experiment to observe their response at different water temperatures. We set up 3 treatments, 4ºC, 17ºC and 30ºC water. 17ºC is the control treatment. We poured 50ml dechlorinated water of certain temperature in the Petri dish. We transferred Dugesia into a Petri dish and at the same time, we started the timer and began to draw the moving route of Dugesia. After a certain time, we stopped the timer and used a string to match the route. Then we measured the moving distance and divided it by the certain time to get the rate of movement. We conducted 2 trials. In the first trial, the highest rate of movement was shown in the control treatment and lowest rate of movement was shown in 4ºC water. In second trial, we found that the higher the temperature is, the higher the rate of movement is. Data analysis in both trials is statistically significant to the results. We support the hypothesis that the temperature has an effect on the rate of movement.*

Keywords: *Dugesia, water temperature, rate of movement*

1. Introduction

The research organism our group studying is *Dugesia spp.* or common known flatworms. Its body size is about 8~12mm in length and 2~3mm in width. It has triangle-shaped heads with a narrow body which is about 2~3 times longer than its head. *Dugesia* generally have dark brown or black colors. They have two eyespots on head which can sense the light intensity (Smales & Blankespoor 1978) [1]. *Dugesia* have a nerve system that consists of subepidermal nerve plexus and five pairs of longitudinal nerve cords under the muscle layer (Hickman *et al.* 2008)[2]. These nerves form a “ladder type” pattern (Hickman *et al.* 2008). They also have a brain which consists of ganglion cells. They have tactile cells and chemoreceptive cells over the body as its sensor (Hickman et al. 2008), so *Dugesia* can make proper response to environmental conditions. That is why when a probe is touched on their bodies; they will contract its body to avoid the stimulus. The mouths of *Dugesia* on the ventral side has tube-like pharynx to suck up food like some smaller freshwater animals, such as small crustaceans, nematodes, rotifers, and insects (Hickman *et al.* 2008). They also feed dead animal tissues as a detritivore. When a piece of food is added, *Dugesia* will get close to the food and move around the food with its body attaching to the food to let the pharynx touch and ingest the food (Hickman et al. 2008). *Dugesia* seldom swim in water. Instead, they move along the surface of objects. They are creeping forms. They have muscle combined with cilia that help them move forward (Hickman *et al.* 2008).

Dugesia live in freshwater on the substratum because they can only creep for movement (Folsom 1976)[3]. They are widespread in North America, Africa, Asia, Europe, Middle East and Australia, from tropic zone to temperate zone (Schockaert et al. 1998)[4]. The geographic regions and climatic regions cover a large range of area. That is why their survival temperatures vary from different species living in different places.

In our experiment, we select the water temperature as investigating abiotic factor to observe the rate of movement of *Dugesia* as the response. British Columbia is in the temperate zone, the lake temperate is 4~18ºC (Claussen *et al.* 2003) [5]. If we choose *Dugesia* from local place as our research material, their living temperature range is about 4~18ºC. Though the living temperature is moderate in all, the tolerant temperature for *Dugesia* is in a wide range. Some species can have a high tolerate temperature. *Dugesia japonica*, a flatworm living in Japan, can survive in 30ºC environment (Si 2012)[6]. Their tolerant temperatures vary from different species living in different places because of wide range of distribution (Charni *et al.* 2004) [7].

http://dx.doi.org/10.17758/ER615037

Temperature can vary because of many external variables. The time of the day will cause the variation of water temperature because the time of absorbing solar energy and transforming solar energy to heat will be reduced if the daytime gets shorter. The season also will affect the water temperature. In different seasons, the different daytime will cause different intensity of absorbing solar energy. Also, various air temperatures in different seasons will also affect water temperature. Water temperature varies at different locations. The temperature will drop with the increasing depth. When the depth exceeds a specific line, the temperature will not change and maintain 4ºC (Upstate Freshwater Institute [online]) [8].

When we introduce the structure of *Dugesia*, we know that the *Dugesia* have a nerve system and sensory cells to sense the external environment change. Neurons in nerve system are widespread in the brain, optic nerves, ventral nerve cords, and pharyngeal nerve plexus (Nishimura et al. 2010)[9]. Neurons in *Dugesia* are organized into many types for sensory, motor, and association. The emergence of neurons is an important development in evolution of nervous systems. The nerve system of *Dugesia* is in the mesenchyme, nerve cords are just beneath the layer of circular muscle cells (Hickman et al. 2008)[2]. When the external temperature changes, *Dugesia* will sense this change as a specific physical signal. Then the neurons to transform this signal from an electron form into a chemical form alternately. Neuron cells will transmit this signal to the nerve cords just beneath the muscle cells and finally cause the contraction of muscles (Nishimura et al. 2010)[9]. Muscle cells will drive the cilia just outside the epidermis to move so that *Dugesia* can creep forward. *Dugesia* have a cholinergic nervous system (Nishimura et al. 2010). In the synaptic cleft, the electron signal will transform into the chemical signal as acetylcholine, this chemical will attach to the presynaptic membrane of the next neuron (Nishimura et al. 2010). This is how the signal transmission works (Nishimura et al. 2010). The temperature also affects reproduction of *Dugesia*. *Dugesia* can reproduce asexually or sexually. High temperatures (~26ºC) permit asexual transverse fission, while lower temperatures (~20ºC) have a preference for sexual reproduction (Yowinckel & Marsden 1971)[10]. Asexual transverse fission is preferable in the adversity because it costs less energy and spend less time for reproduction. We want to observe their rate of movement as the response to variation in the factor because the rate of movement can indirectly reflect the contraction of muscles and the response of nerve system.

In the experiment, we observe response of Dugesia to abiotic factors. We choose one abiotic factor, the water temperature and one response, rate of movement of *Dugesia* in experiment. We make a hypothesis that the rate of movement of *Dugesia* will be affected by the temperature. The null hypothesis is that the water temperature has no effect on the moving speed of *Dugesia*. The alternate hypothesis is that the water temperature affects the moving speed of *Dugesia*.

2. Methods

To observe the rate of movement of *Dugesia* at different temperatures, we conducted a measured-response experiment. We had two separate trials. Figure 1 shows the equipment setup and the procedure of experiment. The experiment consisted of 3 treatments, 4ºC, 17ºC and 30ºC. The control treatment was 17ºC because the most appropriate temperature for *Dugesia* survival is 16~18ºC, the temperature was similar to what their natural habitat is like. We set up 5 replicates for each treatment in first trial and 7 replicates every treatment in second trial. The more replicates were set, the more confidence we could get. Biotic factors like size and age of individuals can be biological variations for the response. To measure the moving speed in different temperature, we chose to measure the distance that *Dugesia* move in a certain time. We transferred *Dugesia* into 50ml dechlorinated water of certain temperature, and then we began to start the timer and drew the route of *Dugesia* movement. In first trial, we set 1 minute as the limit. To reduce the change of temperature, we shortened the time to 40 seconds in second trial. We used a string to match the route and then stretched the string straight to measure the length. This was the distance they moved. We divided the distance by the time and got the rate of movement. Light intensity and temperature are abiotic factors to affect the result. To minimize the variation of light intensity, we used light meter to control the light intensity and placed the petri dish at the same place. To maintain the temperature at a certain degree, we used a thermometer to monitor the change of temperature during the procedure and reduced the time of measurement. We also used some methods to reduce uncertainty. To minimize the timing error, we set up certain time countdown previously instead of counting the time by experimenter. To minimize the length measurement error, every experimenter read the length and then used the average as the final length.

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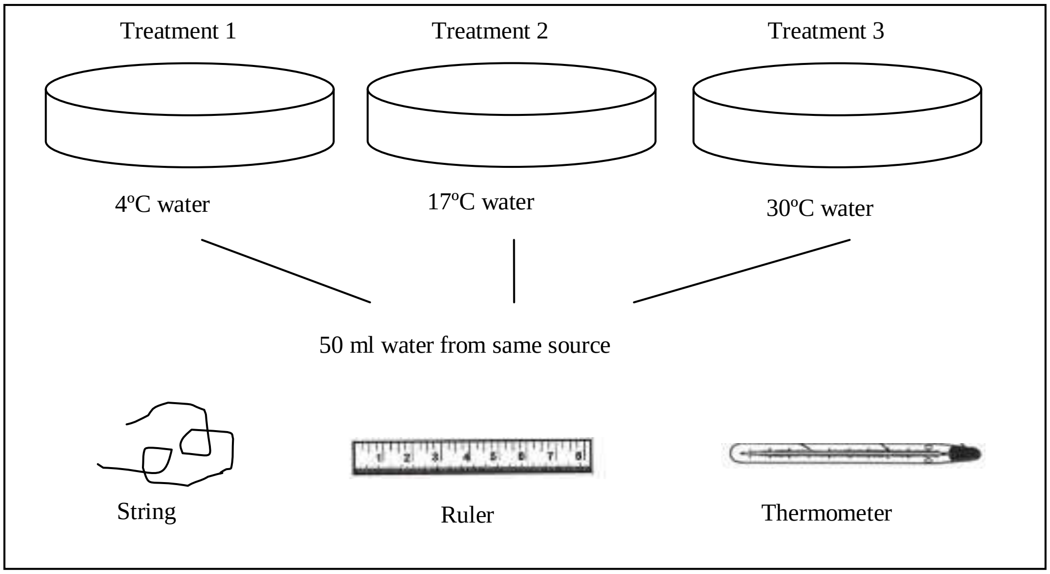

Fig. 1: Experiment setup for moving rate of *Dugesia* in different temperature environment.

3. Results

In the first trial, we found that *Dugesia* move the fastest in 17ºC. They move the slowest at 4ºC. The rate of movement in 30ºC is faster than that at 4ºC but slower than the speed at 17ºC, as seen in Figure 2.

The calculated F value is 5.354 and the critical F value is 3.885. Since the calculated F value is larger than the critical F value, there is a significant difference between treatments in trial 1.

In the second trial, we found that *Dugesia* move the fastest in 30ºC water and the slowest in 4ºC water. The rate of movement in control treatment is faster than that in 4ºC but slower than the rate in 30ºC, as we can see in Figure 3.

The calculated F value is 28.199 while the critical F value is 3.555, so the calculated F value is larger than the critical F value. There is a significant difference between treatments on trial 2.

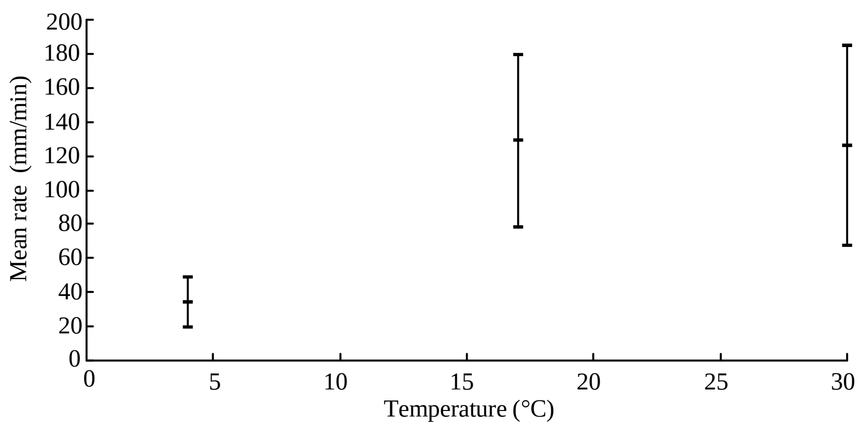

Fig. 2: Mean moving rate of *Dugesia* in different temperature water in 1 minute in Trial 1. F value = 5.354, n=5.

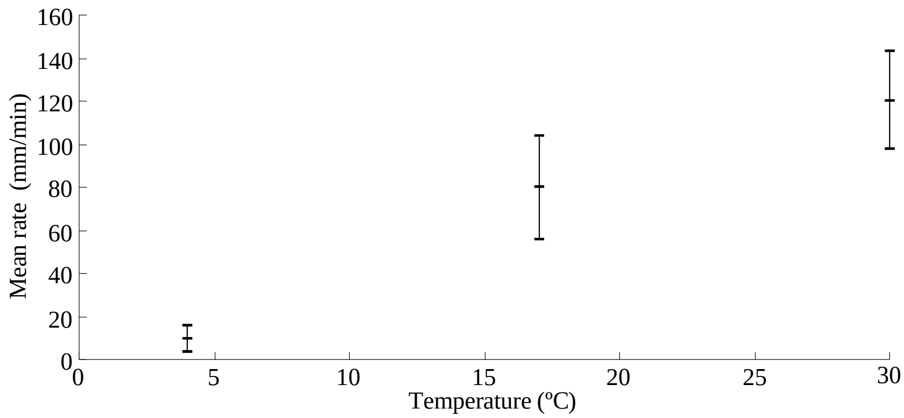

Fig. 3: Mean moving rate of *Dugesia* in different temperature water in 40 seconds in Trial 2. F value =28.199, n=7.

4. Discussion

In both trial 1 and trial 2, the calculated F value is larger than the critical F value, we reject the null hypothesis and we support the alternate hypothesis. Our original prediction was that *Dugesia* will move the fastest at 17ºC. The rate of movement at 30ºC will be the second greatest. They will move the slowest in 4ºC. This prediction corresponded to our results for trial 1, but it did not match results for trial 2 that the greatest rate of movement of *Dugesia* was at 30ºC, and then was at 17ºC, the last was at 4ºC. Though the result did not appear as predicted, there were significant differences between control and other treatments to prove that the water temperature will affect the rate of movement.

First, how *Dugesia* sense the temperature can be a reason to explain why they move differently in different temperature. As is mentioned in the introduction, the nerve system of *Dugesia* is under the layer of circular muscle cells (Hickman et al. 2008)[2]. When the external temperature changes, *Dugesia* will sense this change as a physical signal. Neuron cells will transmit this signal to the nerve cords just beneath the muscle cells and finally cause the contraction of muscles and drive the cilia to move (Nishimura et al. 2010)[2].

Second, the metabolism of *Dugesia* can affect their movement. *Dugesia* move quite slowly in cold water temperature, this reflects that the biophysical activity of *Dugesia* is at a very low level in cold environment (Alberts et al. 2013) [11]. The metabolic rate of aquatic organisms is the lowest at low temperature (Fundamental of environmental measurements), therefore these organisms will decrease their respiration rate and therefore, the energy that their bodies produce will also decrease (Alberts et al. 2013)[11]. Their movement decreases because they do not have energy to support them to move.

Third, the movement may also be related to the water viscosity, high water viscosity may reduce the movement of small aquatic animals (Claussen et al. 2003)[5]. Also, the increasing water temperature can decrease water viscosity (Claussen et al. 2003)[5], this physical condition provides a possibility for *Dugesia* to move more quickly in water of higher water temperature.

The biological variation played a role in our results. During our experiment, we observed that the rate of movement is also related to *Dugesia* body size. The larger the size, the faster it moves in water. This observation also corresponds to the experiment conducted by Classen et al. (2003)[5]. Though the measurement of *Dugesia* body size was a little difficult because *Dugesia* shrank and stretched in the water, we always cannot decide under which state as the body length, we still can recognize their overall size by observation.

We compare our experiment with two similar experiments. The first one is conducted by Classen and his team (Classen et al. 2003)[5]. His experiment researched more than a number of abiotic factors including temperature, nutrients and salinity and studied effects that were caused by the combination of several factors (Classen et al. 2003)[5]. Our experiment only researched the relationship between the temperature and the rate of movement. Their experiment found that *Dugesia* move faster in the temperature range of 15-22ºC than in the environment of 30ºC (Classen et al. 2003)[5]. In our experiment, *Dugesia* move fastest in 30ºC. Though there is a difference of results, but methods of how to quantify the response in both experiments are the same, also their discussions on how the abiotic factors affect the movement and the biological variation can support our experiment. The second experiment we find to make a comparison is conducted by Landers and his team

(Landers & Tones 1962)[12]. This experiment researched flatworms of different species, *Stylochus ellipticus* (Landers et al. 1962)[12]. They studied the effects of temperature and salinity on the survival and movement of flatworms (Landers & Tones 1962)[12]. Though their research organism is a different flatworm of another species, we still can use their experiment methods, their background information for the features of flatworms and the mechanisms of movement of flatworms as the support for our experiment. In their experiment, they found that the rate of movement increased with the temperature increase (Landers et al. 1962)[12]. This is the same pattern as we did. Both experiments we compare show the certainty that the cold temperature largely affect the movement of flatworms due to decreasing metabolism, we can confirm that the temperature does have an impact on the movement of *Dugesia*.

5. Conclusion

We can reject the null hypothesis in both Trial 1 and 2. The water temperature has an effect on the rate of movement of *Dugesia*.

6. Acknowledgements

The authors would like to thank Tanvi Vaidyanathan for her support in the laboratory by answering all the questions. Finally, the author would like to thank Dr. Carol Pollock and the University of British Columbia for the opportunity and materials to conduct this experiment.

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