An Emotional Heart

The Hidden Motion Of The Heart

Gymnasium Kirschgarten, Basel, Class 3AB

1. Introduction: Pumping Action

Everything moves! From the tiny cells in our body to the rotation of the earth around the sun. Without motion, there would be no life on earth as we know it. One of Albert Einstein's well known quotes is, "Nothing happens until something moves." [1] Motion is life. Lack of motion is death.

A heartbeat can be extremely fast and is in most organisms a "hidden" motion, thus making it difficult to measure. Although our heart moves all the time, it's muscle cells never get tired and they never suffer from Delayed Onset Muscle Soreness.

Since the heart is hidden in humans, we decided to choose animals, whose heartbeat is visible. These animals are small and have a fast heartbeat, making us have to work with slow motion video.

2. Materials

- Water fleas (*Daphnia magna*)
- Yolk sac Rainbow Trout (*Oncorhynchus mykiss*)
- Oysters (*Crassostrea gigas*)
- Plastic pipettes (3ml)
- Petri dishes (3cm and 8cm diameter)
- Cavity slides, Vaseline
- Water and ice, beakers
- Digital thermometers attached to a tripod
- Light microscope (with up to 400x magnification)
- Digital camera mounted on the light microscope
- Binocular eyepiece (14x magnification)

3. Methods

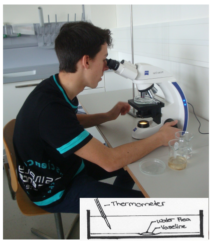

Fig. 1a: The microscopic setup
Fig. 1b: The mounting of the specimen in detail

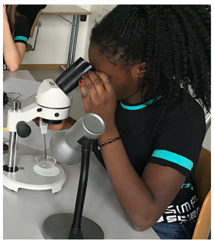

Fig. 2: The Yolk sac Rainbow Trout are examined with a binocular eyepiece

- For *Daphnia*, a cavity slide is prepared with a thin film of Vaseline [2,3]
- The Daphnia is gently glued onto the Vaseline without harming it
- The slide is placed in a petri dish and flooded with water
- For *Oncorhynchus* Vaseline is not needed and the specimen is directly put into a small petri dish
- The *Daphnia* specimen is observed under the high power objective of the light microscope (400x) and filmed with the digital camera
- Water temperature is changed with the help of ice and warm water
- High heart rates need to be counted in slow motion mode

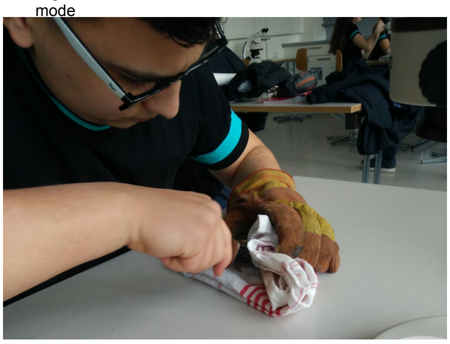

Fig. 3: An oyster is opened carefully (compare also Fig. 7). In some pre-tests we came to the conclusion that we couldn't establish a stable system in order to measure the mussel's heartbeat. So we gave up on a second invertebrate.

4. Question & Hypothesis

How does the temperature affect the heart rate of model organisms?

Temperature changes affect physiologic processes in different animals. An increase in temperature (up to an optimum) often results in an increase in the rate of reaction[4]. Most metabolic activities are enzyme-catalysed and therefore susceptible to such changes. The effect is expressed in terms of the temperature coefficient Q10 (= the ratio of the rate activity at one temperature compared to its rate at 10°C higher).

So we expect an increase in heart rate with higher temperatures. Our hypothesis states a Q10 value of 2, thus a duplication of the heartbeat per minute.

5. Subjects of investigation

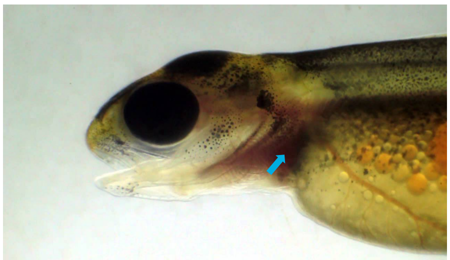

Fig. 4: The Yolk-sac Rainbow Trout: The arrow indicates the position of the heart

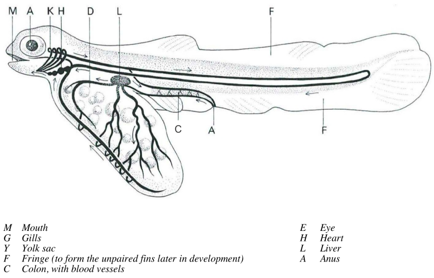

Fig. 5: Schematic picture of a yolk sac Rainbow Trout [5]: The yolk sac contains the reserves for the development of the young fish. Nutrients from the yolk sac are transported to the organs with the blood stream.

Fig. 6: *Daphnia magna*: The arrow indicates the position of the heart

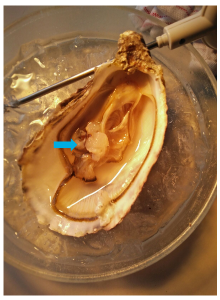

Fig. 7: An open Oyster: The arrow indicates the position of the heart

6. Results

Daphnia magna's heartbeat was measured by using videomicroscopic methods. The films were thus a source for collecting raw data. The heartbeat of the yolk sac rainbow trout was a little slower and could therefore be counted directly under the binocular eyepiece. Using the recorded heart rates and their respective temperatures, the Q10 values were calculated using the formula: $Q10 = (R2/R1)^{10/(T2-T1)}$, where R is the heart rate and T the temperature. Q10 Calculations were determined at different intervals (5°C – 15°C / 10°C – 20°C / 15°C – 25°C).

7. Presenting The Data

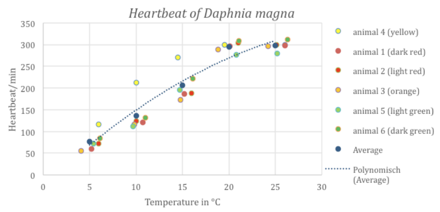

Fig. 8: The set of data is plotted into a X-Y-System: An increase in temperature results in a higher heart rate. The dotted line shows a best fit line for the average values.

The *Daphnia* data show an almost linear increase of the heartbeat rate between 5°C and 20°C. The Q10 value in the first interval (5°C to 15°C) is 2.81, in the second it sinks to 2.27. The heartbeat rate at 25°C is almost the same as at 20°C. The difference of the mean values is less than 2 beats per minute. The Q10 value of the third interval (15°C – 25°C) is also lower and reaches only half of the Q10: 5-15 value.

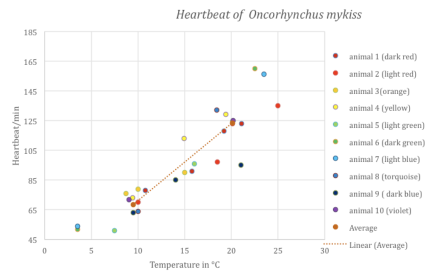

Fig. 9: The graph shows plotted data of 10 selected animals which were exposed to different water temperatures. The dotted line represents the linear best fit line from 10°C to 20°C.

8. Discussion

The abiotic factor temperature exhibits variations especially in smaller freshwater bodies. *Daphnia magna* is both ectothermic and poikilothermic. That means it's body temperature and therefore it's metabolic rate are directly affected by the environmental temperature[6]. The water flea itself consists 73.9% of water[7]. Our data show an interesting effect: The Q10 gets lower with higher temperatures. The heartbeat seems to come to a maximum of around 300 beats per minute. A further increase in temperature might even have an inhibiting effect, as protein structure might suffer or might even be degraded.

The rainbow trout is also ectothermic and poikilothermic, so it is susceptible to temperature changes comparable to the water flea. Being a vertebrate, the size and the complexity of the trout is bigger and might thus show different results. The blood runs through a closed vessel system and the heart shows distinct chambers (ventricle, atrium, sinus venosus, bulbus arteriosus[8] (compare Fig. 5). The *Oncorhynchus* data imply a linear increase of the heart rate. The Q10 value lies at 1.787, indicating that the heart rate almost doubles within the given temperature difference and thus confirming our hypothesis. Compared with the water flea, the heartbeat of the rainbow trout is generally slower. This finding corresponds to the fact, that the basal metabolic rate (BMR) per kilogram of body mass is higher in small animals [6].

9. Reference List

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