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Measuring is believing: quantifying adaptation behaviour of *Hydra*

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Amazing *Hydra*: A spineless creature with astounding regenerative properties that can adapt to changing environments.

This module describes an activity on *Hydra* behaviour that is designed to teach students the scientific method via hands-on experiments and the value of quantitative measurements in biology. *Hydra* provides a simple model for students to understand organismal interactions with the environment.

Students will measure changes in *Hydra's* body shape in response to mechanical stimuli. The activity thereby explores how structure relates to function, a core concept from introductory biology, as well as how the nervous system senses external stimuli and triggers a behavioural response. This is achieved through hands-on experiments using a low-cost microscope and quantitative analysis.

The experiments are easy to implement and modular, so they can be fitted into various time constraints. *Hydra* can either be obtained from local streams[1], from a *Hydra* research lab or obtained commercially (table 1). *Hydra* can be maintained in bottled spring water, and the cost and complexity of their care and handling is low, as described in this protocol.[2] The activity is aimed at students aged 11–19 years. Instructions for implementation, as well as worksheets and ideas to include independent inquiry and discussions about the ethics of animal research, are also provided.

Location	Source
Europe	EduScience UK[3] Blades Biological Ltd[4]
United States	Carolina Biological Supply[5]

Table 1: Distributors of commercial Hydra

Activity: Mimicking river conditions

Hydra contract in response to sudden changes in water movement or current, possibly as an escape mechanism and/or to prevent detachment from the substrate. After prolonged exposure to a new water current intensity, *Hydra* habituates, ceases contraction and elongates to its resting state.[6] This habituation behaviour reflects *Hydra's* adaptability to changes in its environment. Students create water movement at two different frequencies (every 5 s and every 30 s for 2.5 min) through mechanical movement (moving the stage of the microscope) and record when and how often *Hydra* contracts. They take notes on their observations in worksheets and analyse and interpret their data.

The activity will take approximately 60 minutes.

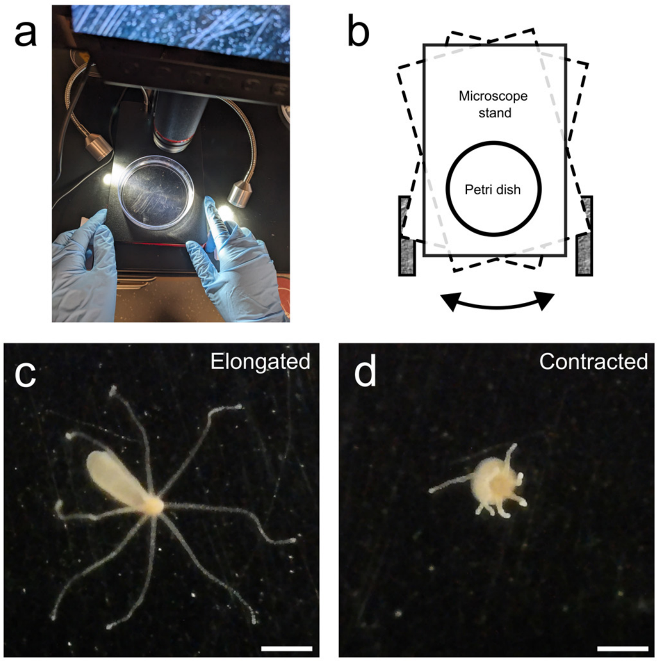

Figure 2: a) A top-down view of the experimental setup. b) A schematic illustration of the motion required to move the microscope stand back and forth between the lab tape lines to generate flow. The stand is moved from the centre to either the right or the left side and back in a single smooth motion. Elongated c) and contracted d) *Hydra* for reference when analysing data. Supplemental movies show behaviour for 5 s and 30 s stimuli. Scale bar: 1 mm

Image courtesy of the authors

Safety notes

Moving the microscope stage poses the risk of spilling water and Hydra, thus electronics should be positioned in a safe distance. With the exception of locally collected Hydra, Hydra should not be released into the environment after completion of the activities but discarded according to the protocol.[2]

Materials (per two students)

- 2 deep petri dishes (Simport®, 100 x 20 mm polystyrene) with lids
- 2 intact *Hydra* per dish in ~20 ml of bottled spring water
- 1 microscope with built-in LED screen (we used the Andonstar 5-inch screen, 1080p digital microscope) – set to video recording
- 1 stopwatch
- 32 GB mini-SD card to record data on the microscope
- *Hydra* info sheet
- Scientific method info sheets
- Worksheet 1
- Worksheet 2

Technology-free activity

The activity can be performed without the microscope. Hydra are visible to the naked eye, so students can observe the animals by eye against a dark background, such as a piece of construction paper. A magnifying glass would be helpful to enlarge it.

Pre-class preparation instructions

1. The microscope stage has non-slip feet. Use tape to stick a piece of felt to the front feet of the stage, so it can be moved back and forth by the students.
2. Put a piece of tape at each side of the microscope to act as limits for the motion.
3. To transfer the *Hydra* to the dishes, use a disposable glass or plastic pipette and gently suction the *Hydra* through the pipette tip.[2] To avoid distraction, do not initially provide the petri dishes with *Hydra* to the students.

Procedure

1. Explain the activity and spend 5–10 minutes reviewing the info sheets (*Hydra* and scientific method info sheet) as a class.
2. Distribute the dishes with the *Hydra* to each pair of students.
3. Show students how to position one petri dish on the microscope (figure 2a).
4. Guide the students through the observation questions on worksheet 1, then let them work on it individually for a few minutes before discussing as a class.
5. Using the *Hydra* info sheet and students’ responses to the observation activity, create a class hypothesis about *Hydra’s* ability to respond to its environment. Ask students to predict the time period that activates an adaptation response. Prompt students to identify which step of the scientific method they are on.
6. Demonstrate how to use the stopwatch and how to record a video (see video guide).
7. Demonstrate how to move the microscope stage to the tape and back at a fixed speed (either centre-left-centre or centre-right-centre) to generate water movement (figure 2b).

Optional: Show the excerpt from the supplemental movie.

8. Ask the students to choose one elongated *Hydra* and position it in the centre so that it is visible in the middle of the LED screen. The *Hydra* should be attached to the bottom of the dish with its foot.
9. Students will record two separate trials, each lasting a total of 2.5 minutes. In the first trial, they will move the stage every 5 seconds; in the second trial, they will move the stage every 30 seconds.
10. Always one student will move the stage and the other will use the stopwatch and tell their partner when to move the stage. Encourage students to take turns in their roles after completing one trial. Students need to start the video before they start moving the stage.
11. After recording the two videos data collection is completed. Show the students how to play back their videos and how to analyse their data by counting the observed contractions and how to document the data in their worksheet 1 (see video guide).
12. Once all students have completed their data analysis, the results will be discussed as a class.
13. Optional: The instructor could collect students' results on index cards and enter them in a spreadsheet that could be projected for the in-class discussion after completion of the experiments.

Answers are provided in the answer sheet 1.

Ethical concerns

While no animal welfare laws govern the use of invertebrates like *Hydra* in scientific experiments, it is still important to introduce ethical concerns of working with live organisms to student researchers. In this activity, the *Hydra* are mildly startled by the simulated river currents with no physical harm inflicted on the animals. For more involved experiments, additional considerations are required: these ideas will be explored in the "Discussion" section.

Discussion

The introduction section of the article 'Aquatic and terrestrial invertebrate welfare' may be useful reading for students prior to a discussion.[7]

Project the class data (if available) and discuss the questions below using worksheet 2. Sample responses can be found in the answer sheet 2 in the supporting material.

- What could the time periods of the movement represent in the *Hydra's* natural environment?
- How often did the *Hydra* contract in the 2.5 min of observation time? When did these contractions occur?
- Did the two animals tested for each time period respond in the same way (yes/no)? Explain your answer. How many animals do you think are ideal for this experiment?
- Why did we count the number of contractions to compare the different time period trials?
- Why would the *Hydra* not want to stay contracted forever?
- Do the results support our class hypothesis? Why or why not?
- What future experiments can you come up with to explore this topic further?
- How does *Hydra's* nerve net compare to the nervous system in the human body?
- While experiments on vertebrate animals are regulated by laws in many countries, no laws exist for invertebrates, such as *Hydra*. Given what you have learned about *Hydra's* nervous system and its ability to sense and adapt to its environment, what do you think are important factors to consider when studying *Hydra* and other invertebrates?

The last section of worksheet 1 contains a fill-in-the-blank table with steps from the scientific method that could be completed in class or given as a homework assignment. Revisiting the scientific method info sheet, students are encouraged to reflect on how their experimental process fits with the scientific method.

Extension Activity

Like *Hydra*, many other invertebrates inhabit the beds of natural freshwater sources and respond to varying conditions in their environment. The teacher can collect water samples with students from a local creek or pond and then use a microscope to study the behaviour and count the invertebrates living in the water. The abundance or absence of invertebrates can be used to assess water quality. References 8 and 9 can guide such an extension activity.[8,9] «

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References

[1] Protocol for collecting *Hydra* from fresh water: https://www.protocols.io/view/hydra-collecting-for-citizen-scientists-14egnzonpg5d/v3

[2] Low-cost methods for maintain *Hydra* cultures: https://www.protocols.io/view/low-cost-methods-for-hydra-care-b645rgy6

[3] Commercially available live *Hydra* at EduScience UK: https://eduscienceuk.com/product/live-hydra-species-10-pack/

[4] Commercially available live *Hydra* at Blades Biological: https://blades-bio.co.uk/shop/living-organisms/pond-life/hydra-species-x-100/

[5] Commercially available live *Hydra* at Carolina Biological Supply: https://www.carolina.com/invertebrates/hydra-culture-living/132800.pr

[6] Wagner G (1905) On some movements and reactions of hydra. *J. Cell Sci.* **48**: 585–622. doi: 10.1242/jcs.s2-48.192.585

[7] Lewbart GA, Zachariah TT (2023) Aquatic and terrestrial invertebrate welfare. *Animals* **13**: 3375. doi: 10.3390/ani13213375

[8] Teaching material on macroinvertebrates and indicators of water quality: https://serc.carleton.edu/sp/mnstep/activities/35675.html

[9] Teaching material on how to determine the health of an aquatic ecosystem by identifying its macroinvertebrates: https://serc.carleton.edu/sp/mnstep/activities/35485.html

Resources

- Become fascinated by *Hydra*'s regeneration and seemingly immortal processes through this short video.
- Learn about the amazing dynamics of *Hydra* mouth opening here.
- Explore historical discovery of *Hydra* and how its development breaks the rules of nature in this mini-documentary.
- Dive into the stimuli responses of a similar regenerative organism, the planarian flatworm: Faria HM, Fonseca AP (2023) Hands-on experiments with planaria. *Science in School* **64.**
- Learn why *Hydra* was selected as one of the strangest living organisms in a *Science in School* writing competition: Markowska A, Ravensdale H (2017) Student competition: the search for the strangest species on Earth. *Science in School* **42.**
- Learn how research projects are funded and the value of basic research: McHugh M (2022) What is it good for? Basic versus applied research. *Science in School* **55**.
- Meet the pond snail, another interesting invertebrate: Faria HM, Fonseca AP (2025) Snail-powered science: hands-on biology for active classrooms. *Science in School* **75**.

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