

THINKING AND ACTING  
LIKE A  
SCIENTIST

TEACHER'S GUIDE

# The Effects of Drugs on *Daphnia*

How does (alcohol or caffeine) affect the heart  
rate of *Daphnia*?

GRADES 6–8

Earth & Space





# The Effects of Drugs on *Daphnia*

<b>Grade Level/ Content</b>	6–8/Earth and Space Science	
<b>Lesson Summary</b>	In this lesson, students observe how <i>Daphnia</i> , a small freshwater crustacean, responds to drugs within its environment.	
<b>Estimated Time</b>	3, 45-minute class periods	
<b>Materials</b>	Kit: <a href="#">WARD'S Effects of Drugs on <i>Daphnia</i> Lab Activity</a> , <a href="#">Daphnia (200-300) (200-300)</a> , turkey baster (for collecting <i>Daphnia</i> ), <a href="#">Diagram of <i>Daphnia</i> Anatomy</a> , pipettes with large openings (to pipette <i>Daphnia</i> ), small containers for holding <i>Daphnia</i> while observing, recovery tank(s), countdown timers, iPad counting app, netting and scissors, microscope, microscope slides, well slides, testing chemicals: alcohol and caffeine, <a href="#">Investigation Plan</a> , Journal	
<b>Secondary Resources</b>	<a href="#">Tiny water flea, many genes</a> <a href="#">Using Model Organisms to Study Health and Disease</a> <a href="#">Drugs and their effects</a>	<a href="#">Caffeine</a> <a href="#">Effect of Alcohol</a> <a href="#">The Complicated Question of Drugs in the Water</a> <a href="#">Drugs Contaminate Lake Michigan</a>
<b>NGSS Connection</b>	<b>MS-ESS3-3</b> Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	
<b>Learning Objectives</b>	<ul style="list-style-type: none"> <li>Students will clarify the cause and effect relationship between alcohol or caffeine and <i>Daphnia</i> heart rate.</li> <li>Students will design and conduct an experiment showing how other water contaminants or changes to the environment affect the physiological responses of <i>Daphnia</i>.</li> </ul>	

## How does (alcohol or caffeine) affect the heart rate of *Daphnia*?

*Daphnia*, commonly known as water fleas, are transparent freshwater crustaceans that are about the size of a pin head. Don't let their small size fool you. *Daphnia* are incredibly fast swimmers and extremely resourceful. They have been found to respond to chemical signals from predators and adapt by growing protective body armor. They also have the ability to adapt to toxic changes within their environment.

Scientists have sequenced the water flea's genome (approximately 31,000 genes, compared to our 23,000) in hopes of understanding how the genes are expressed when exposed to toxic environments. Scientists believe that within these genes lie the key to the *Daphnia*'s ability to adapt to freshwater contaminants. *Daphnia* are considered model organisms due to their ability to reproduce quickly, similarity to the human genome, and inexpensive price tag. Maybe one day water quality will be measured not by scientific equipment, but by the speedy, freely swimming and highly sensitive *Daphnia*!

## Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science.

In all investigations:



Students don't know the "answer" they are supposed to get.



Students play a driving role in determining the process for learning.



Teachers and students construct meaning together by journaling.



Students are working as hard as the teacher.

# Part 1

## INVESTIGATION SETUP

Students will need the following materials to complete this investigation:

- Microscopes
- Kit: [WARD'S Effects of Drugs on \*Daphnia\* Lab Activity](#)
- [Daphnia \(200-300\) \(200-300\)](#)
- Turkey baster (for collecting *Daphnia*)
- [Diagram of \*Daphnia\* Anatomy](#)
- Pipettes with large openings (to pipette *Daphnia*)
- Small containers for holding *Daphnia* while observing
- Recovery tank(s)
- Countdown timers
- iPad counting app (optional)
- Netting and scissors
- Microscope slides; well slides
- Testing chemicals: alcohol and caffeine
- [Investigation Plan](#)
- Journal

# Part 2

## INVESTIGATION FACILITATION

Before you introduce the investigation question, conduct a mini-investigation (**Messing About**) for students to develop the knowledge and skills required to perform the investigation.

1  
2  
3

### Investigation Plan

Students perform trials to understand how to work with *Daphnia*.

- Before students conduct the investigation, they will need to know how to correctly capture, view, and measure heartbeats of *Daphnia*.
- Divide students into teams of two. Review the materials as a whole class. Review *Daphnia* anatomy (particularly where they can find the heart) and provide images of what the *Daphnia* looks like under the microscope. Ask students: *What can I learn about Daphnia by observing it?*
- Have students observe *Daphnia* by completing Part I of the [Investigation Plan](#).
- Students practice preparing *Daphnia* on a microscope slide and making observations. Encourage students to identify as many parts of the *Daphnia* as possible (refer to [Diagram of \*Daphnia\* Anatomy](#)). Have them record observations, draw diagrams, and write questions they have in their journal.
- Students then locate the heart of the *Daphnia* and determine the heart rate (in beats per minute). Have them do this as many times as they feel necessary. A counter app, such as *Tap Counter*, will help students make accurate observations.
- Encourage students to record qualitative and quantitative data in their journal.

**INVESTIGATION PLAN**  
**THE EFFECTS OF DRUGS ON DAPHNIA**

**Part I: Observing *Daphnia***

1. Use the baster to collect 5-10 *Daphnia* in a small glass cup.
2. Choose a microscope slide to view the *Daphnia*.
3. Put a piece of mesh on the slide (if necessary).
4. Use a pipette with tip cut off to transfer *Daphnia* from the small cup to the microscope slide.
5. Use the microscopes to make initial observations. Compare what you see to the Diagram of *Daphnia* Anatomy. What do you see? What parts of the *Daphnia* can you identify? What questions do you have?
6. Locate the heart of the *Daphnia* and count heart rate in beats per minute (bpm). Record your quantitative (beats per minute) and qualitative (pregnant/not pregnant, large in size, color of excretions, etc.) observations.
7. Return *Daphnia* to recovery tank.
8. Repeat Steps 4-7 with a new *Daphnia* as many times as necessary.

**Part II: The Effect of Drugs on *Daphnia***  
(Use the same procedure for capturing, viewing, and recovery of *Daphnia* as above.)

1. Add one drop of *Daphnia* culture water to a prepared slide.
2. Add one *Daphnia*. Determine and record the heart rate in beats per minute (bpm).
3. Add a single drop of the selected drug.
4. Wait one minute. Determine and record the heart rate for 10 seconds.
5. Return *Daphnia* to the recovery tank.
6. Repeat steps 1-5 with a new *Daphnia* nine more times.
7. Record your quantitative and qualitative observations.

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### Investigation Plan

**DIAGRAM OF DAPHNIA ANATOMY**  
**THE EFFECTS OF DRUGS ON DAPHNIA**

**Diagrammatic Anatomy of a female *Daphnia***

1. Thoracic organ	16. Crayfish
2. Infracapitulum muscle	17. 2nd maxilla (mandible)
3. Anterior median muscle	18. 2nd maxilla (mandible)
4. Anterior lateral muscle	19. 2nd maxilla (mandible)
5. Anterior lateral muscle	20. 2nd maxilla (mandible)
6. Anterior lateral muscle	21. 2nd maxilla (mandible)
7. Heart	22. 2nd maxilla (mandible)
8. 2nd maxilla (mandible)	23. 2nd maxilla (mandible)
9. 2nd maxilla (mandible)	24. 2nd maxilla (mandible)
10. 2nd maxilla (mandible)	25. 2nd maxilla (mandible)
11. 2nd maxilla (mandible)	26. 2nd maxilla (mandible)
12. 2nd maxilla (mandible)	27. 2nd maxilla (mandible)
13. 2nd maxilla (mandible)	28. 2nd maxilla (mandible)
14. 2nd maxilla (mandible)	29. 2nd maxilla (mandible)
15. 2nd maxilla (mandible)	30. 2nd maxilla (mandible)
16. Crayfish	31. 2nd maxilla (mandible)

The illustration of "crayfish" (Daphnia) was prepared by Van Andel Education Institute (VAEI) and is not intended to be used for any other purpose without the written permission of VAEI.

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### Diagram of *Daphnia* Anatomy

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## STUDENT ENGAGEMENT

Place small containers of *Daphnia* at student tables. Have students make observations of the *Daphnia* at their table before starting the investigation. Ask students: *What observations can you make? What do you wonder about?*

## PERSEVERANCE

Students may find it difficult to locate and count the heartbeats of the *Daphnia*. Encourage students to concentrate and practice counting the heartbeats.

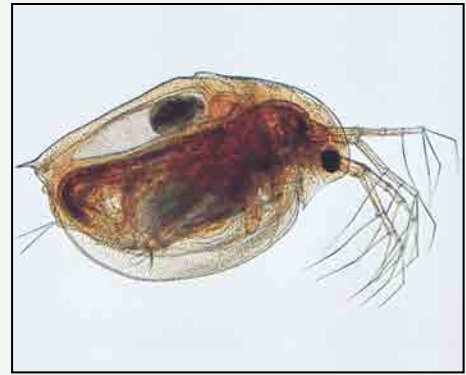


Image of *Daphnia*



## Observation

*Students document their observations.*

- Have students create a data table to record both quantitative (beats per minute) and qualitative data. Qualitative data should include things like if the *Daphnia* is pregnant, large in size, color of intestine, etc. Instruct students to record things they observe that could differentiate one *Daphnia* from another.
- Once students understand how to work with *Daphnia*, they are ready to begin the investigation.

## INTEGRITY

Compile a class list of data. Encourage students to use integrity as they share their results. Discuss how to avoid their results being influenced by the results of others.



## Question

*Introduce the investigation question.*

**How does (alcohol or caffeine) affect the heart rate of *Daphnia*?**

## STUDENT CHOICE

Ask each team to choose whether they want to investigate with caffeine or alcohol. Half the teams are to investigate with alcohol, half with caffeine.



## Personal Knowledge

*Students capture what they already know about model organisms, *Daphnia*, the effects of drugs on an organism, and water contamination by drugs.*

- Find out what students already know about model organisms, *Daphnia*, water contamination by drugs, and the effects of their chosen drug on an organism.
- Generate a class list. (List may include: *I drink caffeine, soda has caffeine in it, caffeine affects calcium absorption, Daphnia's heart rate is about 4x mine*)

## DISCOURSE

In their journals, students list a minimum of three things they know about model organisms, *Daphnia*, and the effect of drugs on an organism. Each student shares one thing that they wrote down with their partner. The team then shares a summary of what they know with another team and then the whole class.



## Prediction

Students write a prediction about what they think will happen based on prior knowledge.

Have students write a prediction based on the investigation question using the following format:

I predict \_\_\_\_\_ because \_\_\_\_\_.



## Investigation Plan

Students perform trials to determine the effect of their chosen drug on *Daphnia* heart rate.

- Review the materials again as a whole class.
- Remind students to use the same protocol for handling *Daphnia* as they did in Part 1 of the **Investigation Plan**.
- Have students complete Part 2 of the **Investigation Plan**.
- Have students record heart rate for 10 seconds. (They can calculate this in beats per minute during the Data Analysis.)
- Students conduct 10 trials for their control (water) and variable (caffeine or alcohol) and record their results.

### CRITICAL THINKING

Use the [Fair Test](#) checklist to help students think critically about the investigation plan. Help them understand that a good investigation plan must include a test that is repeatable, generates quality data, and minimizes error. The more critically students think about their investigation plan, the more confident they can be in their results.



## Observation

Students document their observations.

- Have students create a data table to record both quantitative (beats per minute) and qualitative data. Qualitative data should include things like if the *Daphnia* is pregnant, large in size, color of intestine, etc. Instruct students to record things they observe that could differentiate one *Daphnia* from another.
- Remind students to label their columns with their chosen substance (alcohol or caffeine).

Trial	Control Water - Beats	Time Counted (seconds)	Caffeine - Beats	Time Counted (seconds)	Qualitative Observations
1	42	10	46	10	not pregnant, Large
2	46	10	48	10	not pregnant, Large
3	44	10	49	10	not pregnant, Very Large
4	42	10	46	10	Pregnant, 2 eggs, Very Large
5	45	10	51	10	Pregnant, 4 eggs, Large
6	33	10	51	10	not pregnant, Large
7	38	10	43	10	not pregnant, Large

Sample Data



## Data Analysis

Students make sense of their data by organizing it and representing it visually.

Have students analyze their data from Part II of the **Investigation Plan**. They may wish to use the [Data Analysis](#) prompt as a guide.

- Have students **evaluate** their data for trustworthiness. Ask students:
  - *Are you confident in how you counted the heartbeats?*
  - *What data do you wonder about? (Have students identify the data they wonder about on their data table.)*
- Then, have them analyze their data to find patterns and trends. They may **organize** the data and/or **represent** it visually to construct meaning. They may use math as appropriate (*beats per minute, average and/or range of Daphnia heart rate, etc.*).
- Have students **interpret** what the identified patterns or trends mean. Students should find that the *Daphnia's* heart rate increased with caffeine and decreased when alcohol was added.
- Ensure they have enough data that it can be used as evidence to support a claim.

### DISCOURSE

If your students are new to the process, it may be helpful to have students share examples with a *Research in Progress*. After each of the steps of data analysis (evaluation, organization, representation, and interpretation), have groups share their progress.

### CREATIVE THINKING

Encourage students to think creatively as they decide how to organize and represent their data by asking, "*Is there another way to show this information?*"



## Secondary Knowledge

Students use secondary sources to learn about their selected drug, model organisms, and *Daphnia*.

Have students use these resources (or your own) to learn about their selected drug, model organisms, *Daphnia*, and water contamination by drugs.

[Tiny water flea, many genes](#)

[Using Model Organisms to Study Health and Disease](#)

[Drugs and their effects](#)

[Caffeine](#)

[Effect of Alcohol](#)

[The Complicated Question of Drugs in the Water](#)

[Drugs Contaminate Lake Michigan](#)

*Continued*

## COLLABORATION

- Have students conduct a *Jigsaw* as they gather secondary information. Have each team join another team that has chosen the same drug to test. Each student chooses one of the articles to read and lists a minimum of three things they learned from reading their article. Students share their lists within their group and the group provides a summary for the whole class. (Example student responses could include: *caffeine is a drug, caffeine is a stimulant, drugs are contaminating freshwater, unclear of the effect of drugs in the water on fish and other creatures, Daphnia reacts to chemical signals*)



## Explanation

*Students write a claim and provide evidence and reasoning to support it.*

- Have students use what they've discovered from their analyzed data to write an explanation that answers their investigation question. Students may wish to use the [Explanation](#) prompt as a guide. Have them write their explanation in their Lab Journal.
- Have students develop a **Claim** to answer the question: How does (alcohol or caffeine) affect the heart rate of *Daphnia*?
- Then, have them add **Evidence** (the analyzed data) to support their claim.
- Finally, have them add **Reasoning** to their claim. Reasoning should include the information obtained from this investigation as well as science principles they have learned.

### Claim

*We claim that caffeine increases the heart rate of Daphnia.*

### Evidence

*For every trial, the heart rate increased when caffeine was given to the Daphnia. On average, caffeine caused Daphnia heart rate to be 38 bpm higher.*

### Reasoning

*Investigation: We did a fair test. We conducted seven trials with consistent results. We followed the investigation plan and accurately recorded our information. We had the same person measure the heartbeats each time.*

*Science: Science concepts support our results. Our reading indicated that caffeine is a stimulant and stimulants increase heart rate. We also learned that Daphnia are model organisms that can be studied to learn more about biological processes in other living things, including humans.*

- Once the explanation is written, have students discuss their results using a [Present and Defend](#).

## DISCOURSE

Have students conduct a [Present and Defend](#) to develop presentation skills as well as audience participation. Research teams present a summary of their investigation to the class. The class analyzes the information presented and asks clarifying questions, challenges and/or supports the arguments made, and even presents alternative explanations as appropriate. Research teams defend their explanation with evidence and reasoning. If students are doing the same investigation plan, choose 1 or 2 groups to share.



## Evaluation

*Students reflect on the investigation.*

- Ask students what were sources of error in their investigation.
- Ask students what they would do differently next time.
- Ask students what question they would like to pursue next.

## Part 4

### INVESTIGATION ASSESSMENT AND EXTENSION



## Application

*Students demonstrate understanding of how an organism can be used to test its physiological responses to changes in its environment.*

### Open Investigation

- Have students apply their learning by designing and conducting their own investigation to identify the physiological response of *Daphnia* to another water contaminant or change in the environment. (This question may come from the evaluation component.)

### Example ideas:

- *How does temperature affect the heart rate of Daphnia?*
- *How does salinity affect the mobility of Daphnia?*
- *How does aspirin affect the heart rate of Daphnia?*

### Engineering Application

- Have students design a monitoring solution for minimizing water pollution.

### Assessment

- Students provide an explanation (**claim, evidence, and reasoning**) that clarifies the cause and effect relationship between alcohol or caffeine and *Daphnia* heart rate.
- Students design and conduct an experiment to identify the physiological response of *Daphnia* to a different water contaminant or change in environment.
- Students explain how *Daphnia* can be used as a model organism to determine water quality.



# INVESTIGATION PLAN

## THE EFFECTS OF DRUGS ON *DAPHNIA*

### Part I: Observing *Daphnia*

1. Use the baster to collect 5–10 *Daphnia* in a small plastic cup.
2. Choose a microscope slide to view the *Daphnia*.
3. Put a piece of mesh on the slide (if necessary).
4. Use a pipette with tip cut off to transfer *Daphnia* from the small cup to the microscope slide.
5. Use the microscopes to make initial observations. Compare what you see to the Diagram of *Daphnia* Anatomy: What do you see? What parts of the *Daphnia* can you identify? What questions do you have?
6. Locate the heart of the *Daphnia* and count heart rate in beats per minute (bpm). Record your quantitative (beats per minute) and qualitative (pregnant/not pregnant, large in size, color of intestine, etc.) observations.
7. Return *Daphnia* to recovery tank.
8. Repeat Steps 4–7 with a new *Daphnia* as many times as necessary.

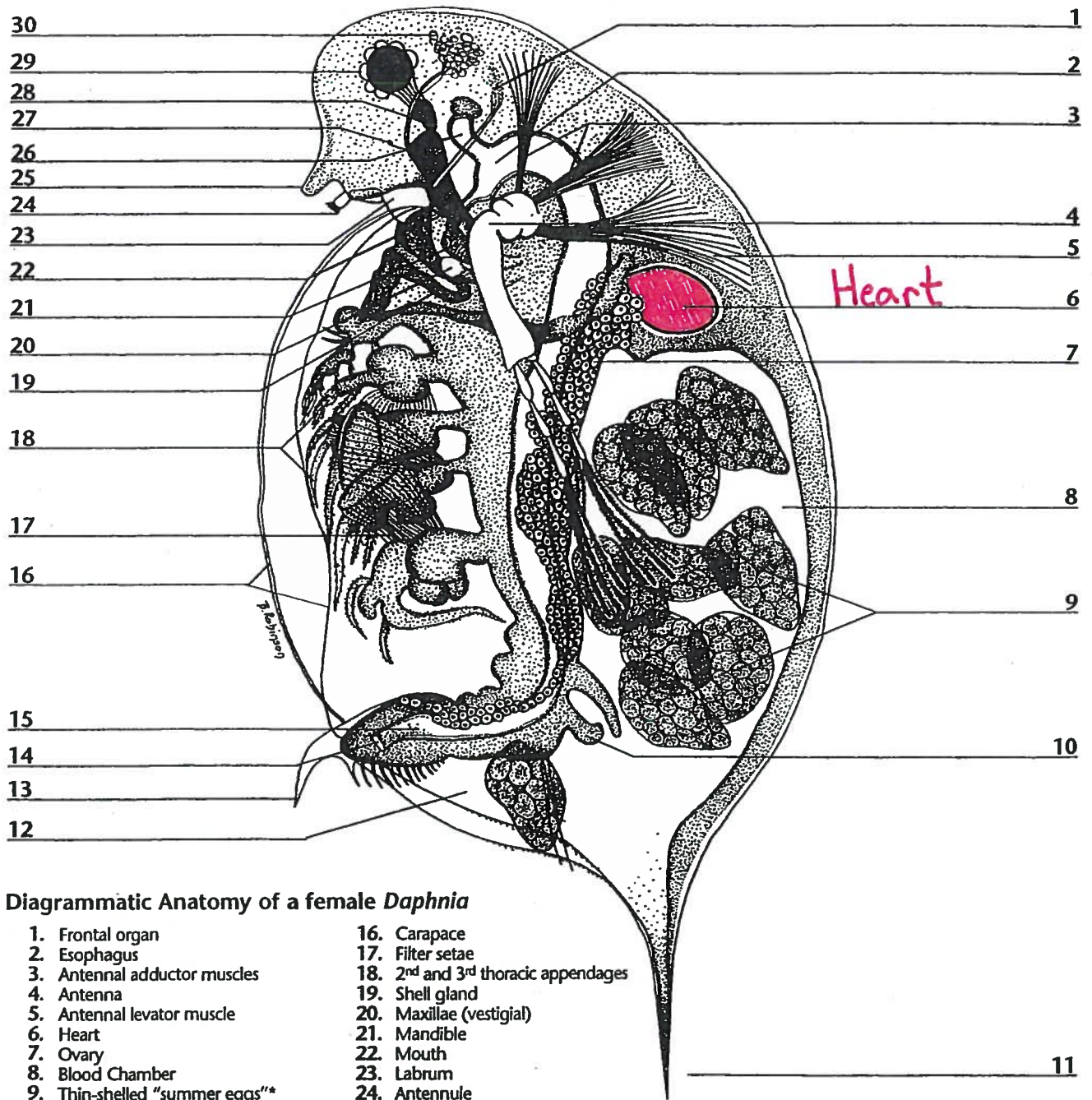
### Part II: The Effect of Drugs on *Daphnia*

(Use the same procedure for capturing, viewing, and recovery of *Daphnia* as above.)

1. Add one drop of *Daphnia* culture water to a prepared slide.
2. Add one *Daphnia*. Determine and record the heart rate in beats per minute (bpm).
3. Add a single drop of the selected drug.
4. Wait one minute. Determine and record the heart rate for 10 seconds.
5. Return *Daphnia* to the recovery tank.
6. Repeat steps 1–5 with a new *Daphnia* nine more times.
7. Record your quantitative and qualitative observations.

# DIAGRAM OF *DAPHNIA* ANATOMY

## THE EFFECTS OF DRUGS ON *DAPHNIA*



### Diagrammatic Anatomy of a female *Daphnia*

- |                                  |   |
|----------------------------------|---|
| 1. Frontal organ                 | 16. Carapace  |
| 2. Esophagus                     | 17. Filter setae  |
| 3. Antennal adductor muscles     | 18. 2 <sup>nd</sup> and 3 <sup>rd</sup> thoracic appendages |
| 4. Antenna                       | 19. Shell gland   |
| 5. Antennal levator muscle       | 20. Maxillae (vestigial)                                    |
| 6. Heart                         | 21. Mandible  |
| 7. Ovary                         | 22. Mouth   |
| 8. Blood Chamber                 | 23. Labrum  |
| 9. Thin-shelled "summer eggs"*   | 24. Antennule   |
| 10. Abdominal process            | 25. Rostrum   |
| 11. Apical spine                 | 26. Hepatic caecae  |
| 12. Post abdomen                 | 27. Ocellus or nauplius eye                                 |
| 13. Post abdominal claw (paired) | 28. Optic ganglion  |
| 14. Anus                         | 29. Compound eye with optic nerve                           |
| 15. Rectum                       | 30. Nuchal or neck organ                                    |

\* See illustrations of "summer eggs" (developing parthenogenetically) and "winter eggs" (develop after being fertilized) on page 3. Winter eggs have thick shell and are produced in smaller numbers; brood chamber is molted to form a protective ephippium.