# OLFACTORY FATIGUE AND MEMORY

## *Directions for Teachers*


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### SYNOPSIS
In this activity, students will examine olfactory fatigue by smelling different aromatic oils. They will then design experiments to examine other factors that may affect olfactory fatigue and memory.


### LEVEL
Exploration, Concept/Term Introduction Phases

Application Phase

### STUDENT PRIOR KNOWLEDGE
Before participating in this activity, students should be able to:

- Describe basic nerve cell structure and function, and nerve transmission of messages.

### INTEGRATION
*Into the Biology Curriculum*

- Biology I, II
- AP Biology
- Human Anatomy and Physiology

*Across the Curriculum*

- Mathematics
- Psychology

### OBJECTIVES
At the end of this activity students will be able to:

- Describe the relationship between length of exposure time to an odor and olfactory fatigue.
- Design experiments to determine the relationship between olfaction and memory and/or other factors, such as gender.

## Getting Ready
See sidebars for additional information regarding preparation of this lab.

## Directions for Setting Up the Lab

### E Exploration

- Locate materials and equipment.
- Call the gas company and request mercaptoethanol scratch and sniff samples.

### A Application

- Prepare the concentrations of vanilla solutions using the following ratios:

| Vanilla Solution Concentration | mL Vanilla | mL Distilled Water |
|---|---|---|
| 0.1% | 1 mL | 999 mL |
| 1.0% | 1 mL | 99 mL |
| 5.0% | 5 mL | 95 mL |
| 10% | 10 mL | 90 mL |

## Teacher Background
Olfaction refers to the sense of smell, which has similarities in all terrestrial and many aquatic vertebrates. The mechanisms that control olfaction are divided into distinct regions. The olfactory epithelium, located in the roof of each nasal cavity in humans, is the organ of smell. See Figure 1.

## LENGTH OF LAB

A suggested time allotment follows:

E *5–10 minutes* — Introduce the activity.

*25 minutes* — Conduct initial activity.

C *15 minutes* — Develop explanations for the initial activity.

*15 minutes* — Answer the **Focus Questions**.

A *15 minutes* — Brainstorm hypotheses.

*45 minutes* — Design and conduct experiments.

*30 minutes* — Analyze experimental data and discuss results.

## MATERIALS NEEDED

You will need the following for the teacher-led demonstration:

- 25 mL of suntanning oil containing coconut oil
- 1 evaporating dish (25 mL)

E You will need the following for each group of four students in a class of 24:

- 1 watch/clock with a second timer
- 1 scratch and sniff mercaptoethanol sample
- 4.5 mL oil of peppermint
- 3.5 mL oil of cloves
- 1 ruler

A

- 25 mL each of vanilla solutions with the following concentrations: 0.1%, 1.0%, 5.0%, and 10% (optional)

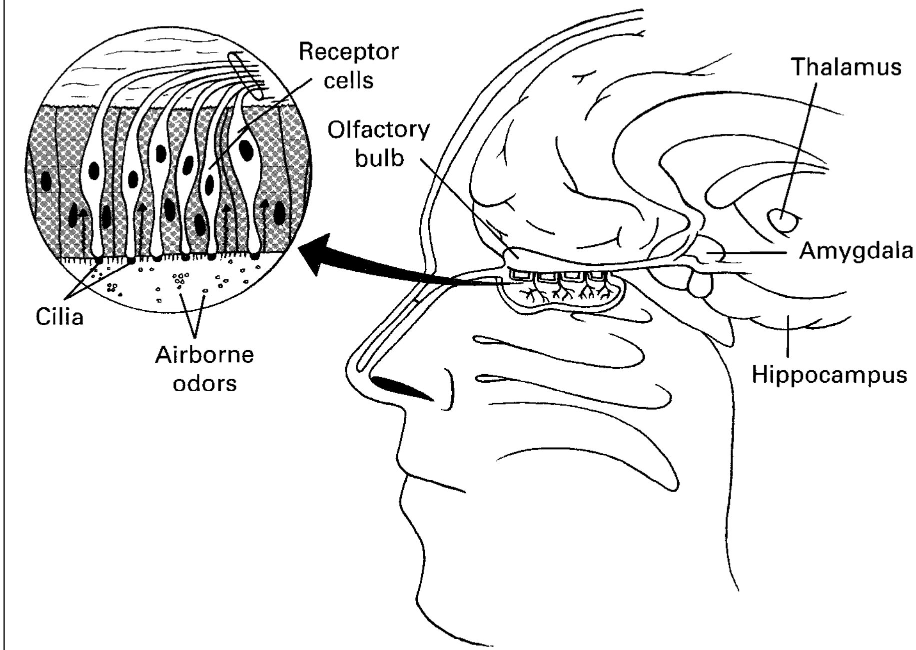


*Figure 1. Locations of structures within the olfactory tract.*

Special olfactory receptor cells, numbering about 25 million, make up the bulk of this epithelium. See Figure 2. Smells, in the form of individual molecules, are bound to receptor molecules in the membranes of the cilia that extend into the fluid mucus layer that coats the epithelium. The

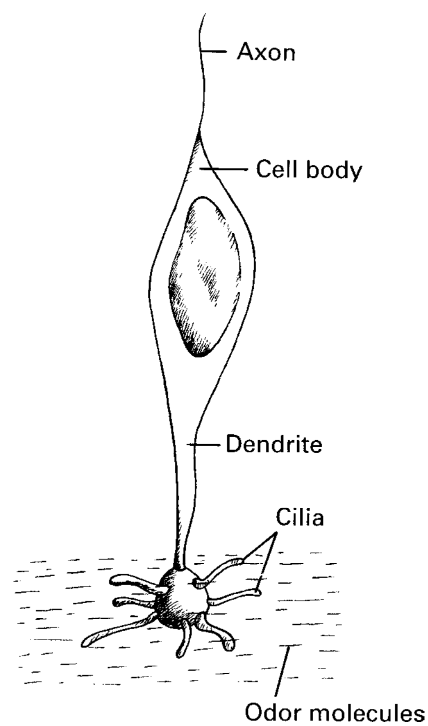


*Figure 2. Diagram of the human olfactory receptor.*

membranes of the nose secrete these fluids to keep the molecules in solution to facilitate smell.

Axons from the receptor cells lead to and synapse with the olfactory bulb that lies just under the frontal lobe of the brain. Special cells in the bulb are activated by smell stimuli and carry impulses toward the olfactory tubercle, where the impulse is sent to the limbic system, thalamus, and cortex. In evolutionary terms, the limbic system is one of the oldest parts of the brain. It contains such structures as the hippocampus, amygdala, fornix, and mammillary bodies, and is extremely important to the emotional aspects of our experiences. This fact explains why smells often evoke emotional memories. See Figure 3. Other fibers terminate in the olfactory cortex at the front of the cerebrum and are interpreted as the tens of thousands of chemical scents that humans are capable of identifying.

Exactly how smells are perceived, stored in memory, and then recalled many years later is not yet fully understood. Much of what we know about olfaction has been learned from animal studies that may or may not be applicable to olfaction in humans. It is thought that the memory of odors is important for several survival functions such as avoiding danger, seeking food, fighting, and mating. Memory of odors is thought to be a function of both the limbic structures of the brain and the cerebral cortex. See Figure 3.

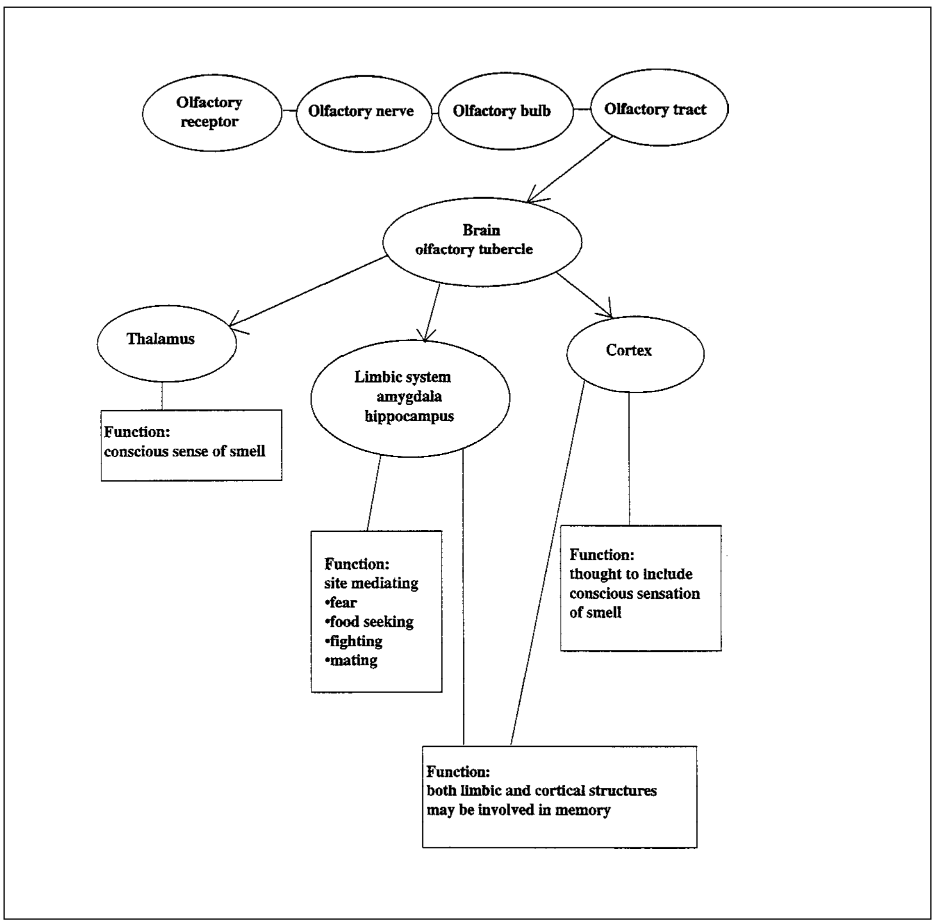


*Figure 3. Flow chart for olfaction and memory.*

## PREPARATION TIME REQUIRED

E & A *1 hour* to locate and obtain materials, and make up solutions

C *15 minutes* to photocopy Figure 1

## SAFETY NOTES

- Do not allow any eating or drinking in the laboratory.
- Have students wash their hands before and after the laboratory.
- Keep flammable solutions, such as perfume, away from open flames.
- Require everyone to wear safety goggles.
- Check for any allergies to the extracts used.
- Warn students to never open a vial and smell a solution by holding it directly under their noses. Show them how to waft solutions. See Figure 5.
- Do not use oil of wintergreen, as it is highly toxic by ingestion.

**TEACHING TIPS**

- Aromatic oils can be found at most pharmacies and in the spice section of grocery stores. The cost should range from $1.00–3.00 for each oil. Each group of students will be required to have two oil samples. **Do not use oil of wintergreen as it is highly toxic by ingestion**. Keep the containers tightly stoppered when not in use.
- Alternative substances that may be used for the suntan oil used in the teacher-led introductory activity would be:
  - Cologne or perfume. Caution should be exercised, as some students may be allergic to certain fragrances.
  - Freshly popped popcorn.
  - Melted baker's chocolate.
- Alternative substances to use for the aromatic oils would be:
  - "Scratch and sniff" samples of mercapto-ethanol, the ingredient put into natural gas to allow people to detect leaks in gas lines. These may be provided by local gas companies in limited numbers. If you decide to use them in place of the aromatic oils, be sure to contact the company well in advance.
  - Mouthwash.
- Label the substances tested with codes so that subjects will not know the contents of the containers. Knowing the contents of the containers in advance could cause students to recall memories of the substances before they smelled them.

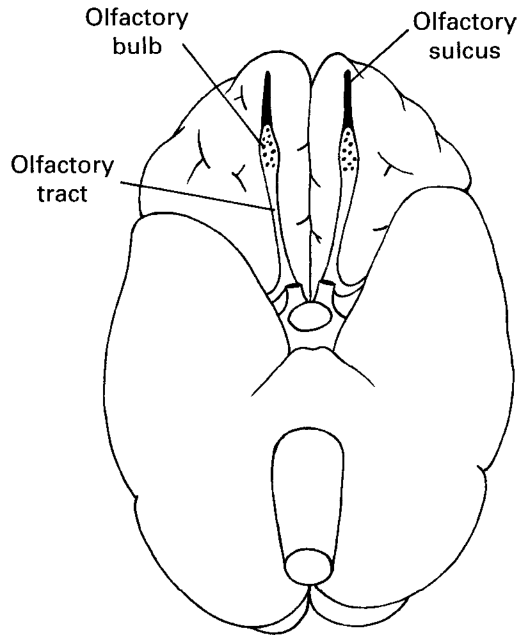


*Figure 4. Basal surface of the brain showing the location of the olfactory sulcus.*

Damage to the olfactory receptors or nerves, obstruction of the air passages, and either permanent or transient chemical interference with olfactory receptors may result in the permanent or temporary loss of olfaction. The general term used to describe the loss of all ability to smell is *anosmia*, while *specific anosmia* refers to the loss of olfaction for one or a few related compounds. Other common terms related to olfaction are *hyposmia*, a mild loss of olfactory sensitivity, such as when one experiences a head cold; and *hyperosmia* that occurs when one is overly sensitive to some or all smells. Among individuals with normal olfaction, sensitivity can vary a thousand-fold (Dodd & Castellucci, 1991).

Olfaction is reported to be linked to the endocrine system (Engen, 1982). A classic example that links the loss of olfaction to the endocrine system is Kallman's syndrome. The syndrome is inherited through an autosomal dominant gene with incomplete expressivity and affects mainly men. Kallman's appears to be related to problems in the hypothalamus, the brain center essential to normal production of the sex hormones and the reproductive cycle. Individuals with this syndrome have poorly developed genitals (hypothalamic hypogonadism) and usually exhibit anosmia. Magnetic resonance imaging (MRI) studies indicate that the "interruption or total absence of the olfactory sulcus is a primary defining characteristic of the disorder" (Klingmuller et al., 1987). See Figure 4. The olfactory sulcus is necessary for the detection of odor. When missing or interrupted, anosmia occurs.

Other olfactory dysfunctions are reported to occur with the following diseases:

- *Parkinson's disease:* Studies by Ansari and Johnson in 1975 showed deficits in the ability to smell in individuals with Parkinson's disease. This was reinforced by the study of Ward et al. in 1983 that showed decreased ability to smell in their patients. In one test, 36 out of 72 patients could not smell coffee. Doty et al. in 1988 confirmed deficits in odor detection by Parkinson's patients.
- *Addison's disease:* Henken and Bartter's study in 1966 showed that individuals with Addison's disease may be as much as 100,000 times more sensitive to odors than individuals without the disease due to their adrenal insufficiency.

In addition to the detection of smell, the trigeminal (V cranial) nerve endings in the nasal cavities are stimulated by some irritating or painful chemical stimulants. Stimulation of the trigeminal receptors elicits some of the strongest physiological responses in the body. A question for students might be, "Can you think of a reason why trigeminal nasal sensations may be helpful for detecting some types of chemicals?" An answer to the student question would be that this response helps us avoid injury from noxious chemicals such as acids, and perhaps acrid smoke. In a study done by Cain and Murphy in 1980 on individuals with normal trigeminal nerves, "the degree of irritation was found to increase with repeated inhalation." This response differs from olfactory fatigue and may be explained by the fact that the trigeminal receptors are deeper in the skin than the olfactory receptors.

Olfactory fatigue can be explained partially by phenomena occurring within actively working nerves. When a series of stimuli of similar strength bombard nerve receptors, the nerves become accustomed to the stimulus. This phenomenon appears to happen because the rate of change within the nerve's membrane is inadequate to keep up with continuous stimulation. Examples of olfactory fatigue in everyday life are the smoking odors in a person's house or on his/her clothing that go unnoticed by the smoker, but are detected easily by the nonsmoker. Explanation of the exact biochemical basis for these changes is beyond the scope of this activity.

Fatigue of sensory receptors can be demonstrated easily with other senses, such as touch. Our clothing is in constant contact with the nerves of our skin that respond to the stimulus of touch, but people rarely think consciously about their clothing being in contact with their skin. When we put on different clothes, the level of stimulus changes and we are more aware of our clothing next to our bodies. The senses of taste, hearing, vision, and smell respond similarly. The first taste of a food or drink is the most acute and dulls within several bites. We are aware of music when we first turn on the radio, and then it tends to blend into the background until there is a news bulletin. A person becomes accustomed to the smell of a new car until someone reminds him/her of the smell, and the individual becomes aware of it once more.

## SUGGESTED MODIFICATIONS FOR STUDENTS WHO ARE EXCEPTIONAL

Below are possible ways to modify this specific activity for students who have special needs, if they have not already developed their own adaptations. General suggestions for modification of activities for students with impairments are found in the AAAS *Barrier-Free in Brief* publications. Refer to p. 19 of the introduction of this book for information on ordering **FREE** copies of these publications. Some of these booklets have addresses of agencies that can provide information about obtaining assistive technology, such as Assistive Listening Devices (ALDs); light probes; and talking thermometers, calculators, and clocks.

### Blind or Visually Impaired

- For students who are blind, provide braille or other tactile symbols on dropper bottles so that the students will be able to identify them.
- A student who is blind can participate as a timer by using a talking clock or braille wristwatch.
- Students who are blind can complete the graphs using embossed graph sheets, available from the American Printing House for the Blind in 1/2-, 3/4-, and 1-inch squares.
- For students with low vision, use different colors of tape or marks on dropper bottles so that the students will be able to identify them.

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**SUGGESTED MODIFICATIONS — Continued**

**Mobility Impaired**

- A student with limited use of his/her arms may need help in wafting the odors from the dropper bottles.

(Special caution: This lab could be a problem for someone with multiple chemical sensitivity [MCS]. Such a student is increasingly sensitive to chemicals in the environment and may need to be excused from class.)

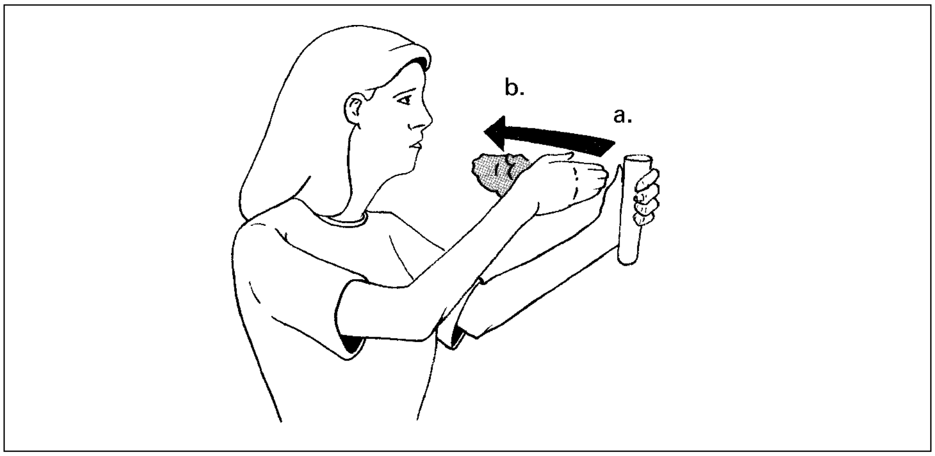


*Figure 5. Demonstration of the wafting procedure. (a) Hold the vial of "scent material" approximately 30 cm in front of and slightly below the nose. (b) Use your free hand to fan the scent from the open vial toward your nose.*

## Procedure

Introduce the activity by setting out an evaporating dish of suntan oil containing coconut. Make sure that it is not visible to students as they enter the classroom. Students will probably comment on the odor as they enter the classroom. Continue with your class administrative duties and make no mention of the odor. You may need to restrict air flow in your classroom during this time. After students have been in the room two or three minutes, ask them if they notice the odor as much as they did when they first entered the room. Then ask the students if the odor reminded them of any past experiences.

## E Exploration

The ***Exploration*** activity demonstrates the concept of olfactory fatigue and the relationship between smell and memories using aromatic oils based on the teacher-led introduction. See **Teaching Tips** for alternative suggestions for the aromatic oils. A suggested procedure for the ***Exploration*** phase is as follows:

1. Assign each student in a group of four one of the following roles:
   - Time keeper
   - Data recorder
   - Subject
   - Group manager.
2. The manager should obtain two different bottles of aromatic oils, such as peppermint and cloves.
3. The subject should close the left nostril by pressing his/her left index finger against the outside of the nostril. The time keeper should indicate to the subject to begin smelling the oil through the open nostril as described in Figure 1 in **Directions for Students**. The data recorder should record this time as the starting time in his/her data journal. The subject should keep the oil at a consistent distance (about 30 cm) from his/her nose with his/her mouth closed.

4. The subject should continue to smell the oil until the odor is no longer noticeable. At this time, he/she should indicate this to the time keeper and the data recorder should record this as the ending time.
5. Steps 3 and 4 should be repeated immediately with the same subject using a different aromatic oil.
6. After completing Steps 3 and 4 for the different aromatic oil, the subject should release the closed nostril and waft the scent of the second aromatic oil under the newly opened nostril and indicate if it is difficult to detect the odor. These observations should be recorded.
7. The group should indicate any memories that either of the aromatic oils brought to mind and compare to see whether they had the same memories.

### C Concept/Term Introduction

In small groups, have students develop explanations for what occurred in the ***Exploration*** activity. Have them consider the following questions about olfactory fatigue in their small groups:

- How long did it take before you could no longer smell the first aromatic oil?
- Could you smell the second oil when it was wafted to your nose immediately after the first oil?
- How do the fatigue times of the two odors compare when you smell one immediately after the other?
- Did opening the second nostril allow you to smell the aromatic oil? What might account for your observations?
- Explain what happened to the smell over a period of time.
- Did the smell remind you of anything?
- Give examples of smells that go unnoticed by some individuals, but that are detected easily by others, such as the smell of cooking oil on a fast-food restaurant worker's uniform.

As students develop their explanations, have them answer the **Focus Questions**. It may be helpful to have them watch all or part of the video *Mystery of the Senses: What Smells?* Have them locate the olfactory bulb and tract in Figure 1. The visuals may help students relate learning to neuron activity and interaction and to develop an understanding of olfactory fatigue. Have each group share its explanations with the class.

### A Application

Students can now build on their previous experiences to extend the experiment and learn more about olfaction. Have them work in their groups to design and conduct their experiments and analyze their data. Afterwards, each group should share its results with other members of the class. Suggested questions students may wish to investigate include the following:

- Does gender affect the ability to detect odor?
- At what level of concentration are certain common aromatic oils detectable?
- Does time of exposure until fatigue vary by gender?

**SAMPLE HYPOTHESES**

● If the concentration of a vanilla solution that is smelled is increased, then it will take a longer time for olfactory fatigue to occur.

▲ If a vanilla solution of a given concentration is smelled by a sample group of individuals, then more than 50% of the group will recall the same memory first.

**SAMPLE PROCEDURES**

● 1. The group manager should obtain a bottle of each of the following concentrations of vanilla solution: 0.1%, 1.0%, 5.0%, and 10%.

2. The subject should close one nostril as done in the ***Exploration*** phase of this activity. The time keeper should note the time and the data recorder should record the starting time. The subject should remove the cap of the bottle and waft the scent of the 0.1% solution under the open nostril as explained in Figure 1 in **Directions for Students.** The subject should indicate to the time keeper when he/she can no longer smell the odor. The data recorder should record this as the ending time.

3. The subject should repeat Step 2 using each of the remaining concentrations of vanilla solutions. The subject should wait three minutes before testing each different concentration, and test them in

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**SAMPLE PROCEDURES — Continued**

order of increasing concentration.

4. The group should graph the data with the concentration of the vanilla solution on the x-axis and the time for olfactory fatigue to occur on the y-axis.

▲ 1. The group manager should obtain two bottles of 10% vanilla solution, one for each subject.

2. Two subjects should each close one nostril as done in the ***Exploration*** phase of this activity. The subjects should be far enough away from each other so that each is smelling the odor from his/her own bottle. The subjects should remove the caps of the bottles and waft the scent of the 10% solution under their open nostrils as explained in Figure 1 in **Directions for Students**. Each subject should indicate to the data recorder in writing the first memory that is recalled when smelling the vanilla solution. The data recorder should record this information.

3. The class should pool their data and make a bar graph of the results.

- Does a certain odor cause the recall of the same memories in all individuals?
- How do drugs, such as antihistamines and lidocaine, an anesthetic, affect olfaction, if at all?

Your students probably will develop other questions related to olfaction and memory. In the sidebar on page 181 are sample hypotheses and procedures that students might derive related to this activity. These examples have been included as suggested outcomes of the activity and are not meant to be given to the students. Students should develop their own hypotheses and procedures. Make sure they understand that there is not just one correct hypothesis and procedure.

## Answers to Questions in "Directions for Students"

### C Concept/Term Introduction

### Focus Questions

1. Although the molecules responsible for smell are perceived initially in the nose, odors are interpreted as particular smells in the brain. Refer to the **Teacher Background** for more information.
2. If there is no need to be aware of an odor, the nervous system puts this sensory information in the background so that other significant odors may be detected if necessary. Olfactory fatigue is homeostatic in that it allows effective use of energy to detect odor stimuli.
3. Yes, but it probably does not fatigue as completely. This phenomenon could be tested as an additional ***Exploration*** activity.
4. Yes, sensory endings are located in the skin of the fish. For example, catfish have sensory endings for smell/taste on the skin of the belly; they are bottom feeders, so they literally "smell" the bottom for potential food sources.
5. Answers will vary depending on individual backgrounds and experiences of students. Possible answers, however, might include the smells of certain foods, such as roasted turkey, and the smells of certain plants, such as an evergreen tree.
6. For the stimulation of salivary secretions to occur, one must recall the scent from memory, and also its association with fast-food hamburger restaurants must be recalled from memory. The exercise demonstrates that the mere thought or memory of the hamburger is sufficient to initiate salivary secretion. The example given here is a Pavlovian conditioned response.
7. Antihistamines are vasoconstrictors and reduce blood flow to surface vessels. In a healthy person, this could cause drying of the nasal membranes and reduce olfaction. If a person has a cold, on the other hand, antihistamines may improve the sense of smell due to the unblocking of nasal passageways. Lidocaine is an anesthetic that deadens nerves and could cause significant reduction in olfaction.
8. Student designs will vary. A search of the literature concludes that females at any age are able to identify odors better than men (Velle, 1987). One possible design would be two groups, one with 10 males and

one with 10 females. Members of each group could smell 10 common odors and respond whether they were able to identify the odor or not.

9. Student designs will vary. Ability to smell tends to decrease with age. Students could have four different age groups of all one gender perform an olfaction test.

## A Application

### Analysis

1–5. Answers will vary with the student design of the experiment.

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### Audiovisuals


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### Suggested Reading


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# OLFACTORY FATIGUE AND MEMORY

## *Directions for Students*

### Introduction

Do you know anyone who always smells like very strong perfume or aftershave lotion? Do you think they can smell how strong it is? Have you ever noticed that smells seem to disappear after you have been exposed to them for a while? For example, perfumes and colognes that you put on in the morning may smell quite strong to you at first, but:

- What happens to this odor after a few minutes?
- Is the odor as noticeable after 10 minutes as it was when you first put it on?
- Is the odor as noticeable after several hours?
- What might happen if you applied fresh cologne or a different cologne?
- Would the fresh cologne's odor be as strong as when you applied it the first time?
- Why are smells less noticeable when you have a cold or allergies?
- What would your world be like if you lost your sense of smell completely?

These are some of the questions you will be exploring during this activity.

### Procedure

#### E Exploration

After your teacher introduces the lab, you will conduct a simple activity. Follow the directions your teacher gives you.

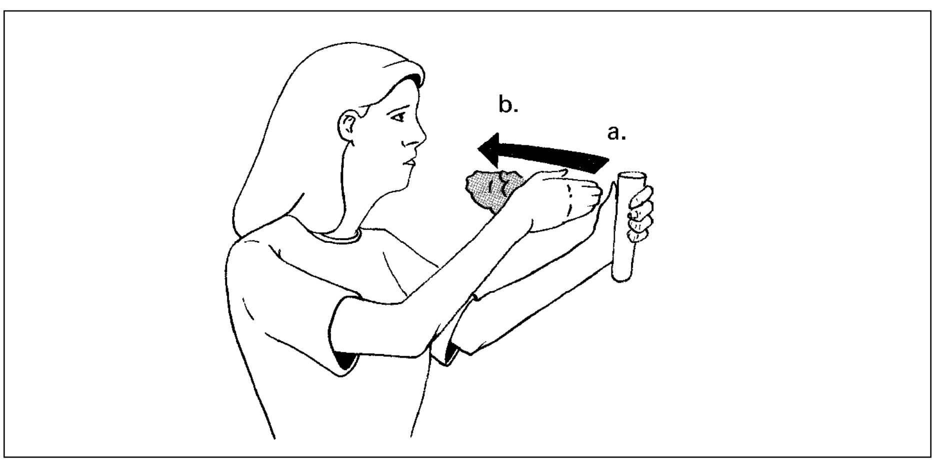


*Figure 1. Demonstration of the wafting procedure. (a) Hold the vial of "scent material" approximately 30 cm in front of and slightly below the nose.*
*(b) Use your free hand to fan the scent from the opened vial toward your nose.*

### MATERIALS

Materials will be provided by your teacher and consist of the following per group:

E
- 1 watch/clock with a second timer
- Various types of scents
- 1 ruler

### SAFETY NOTES

- Do not eat or drink in the laboratory.
- Wash your hands before and after the laboratory.
- Keep flammable solutions, such as perfume, away from open flames.
- Wear goggles.
- Inform your teacher immediately if you have allergies to any fragrances.
- Never open a vial and hold it directly under your nose to smell a solution. Waft solutions. See Figure 1.

## Concept/Term Introduction

Work with your teacher and other students to analyze the data just gathered. Develop an explanation for what occurred. Answer the following questions in your groups:

**FOCUS QUESTIONS**

1. Consider what is happening once the odors are delivered to the nose. Is smell occurring in the nose or does it actually occur somewhere else?
2. What is the adaptive value of olfactory fatigue? How is olfactory fatigue a homeostatic mechanism?
3. Does your sense of taste fatigue like your sense of smell?
4. Do fish have a sense of smell? If so, where is it located?
5. What scents do you associate with the winter holiday season?
6. Now, think about driving by a fast-food hamburger stand.
   - Does the thought make your mouth water? Why or why not?
   - Eating a hamburger stimulates salivary secretions as the beginning of digestion. What brain function is required for the thought of a scent/taste to stimulate salivary secretions in the mouth when no hamburger is actually present?
7. What effects might administration of the antihistamines or lidocaine have on the sense of smell? You may need to research this question by consulting your textbook, visiting a library, or searching through materials that your teacher has available.
8. Many authorities believe that there is a gender difference in the ability to smell certain odors. How could you test for these differences?
9. Age is a factor that seems to affect olfactory abilities. How could you test for the influence of age on olfactory ability?

## Application

Think of questions that arose as you conducted your ***Exploration*** activity, discussed your results as a class, and answered the **Focus Questions**. You may wish to draw on information you gathered to develop your explanation earlier. Decide as a group what question you wish to test. Then design and carry out your own experiment that tests another aspect of smell, olfactory fatigue, and/or frequency of exposure. Write your procedure in a numbered list. Make sure that your group does the following:

- Writes the question as a hypothesis or in the form of an "if... then" statement.
- Gathers quantifiable data.
- Decides what variables must be controlled and plans how to control these.

**Teacher approval must be obtained before you begin this activity!**

## Analysis

1. Did your group obtain the results you expected? How do you explain your results in terms of what you learned during group sharing?
2. Draw a concept map to explain your results.
3. How did you express your data quantitatively?
4. If you were to repeat this experiment, what would you do differently?
5. What might have been sources of error in your experiment?

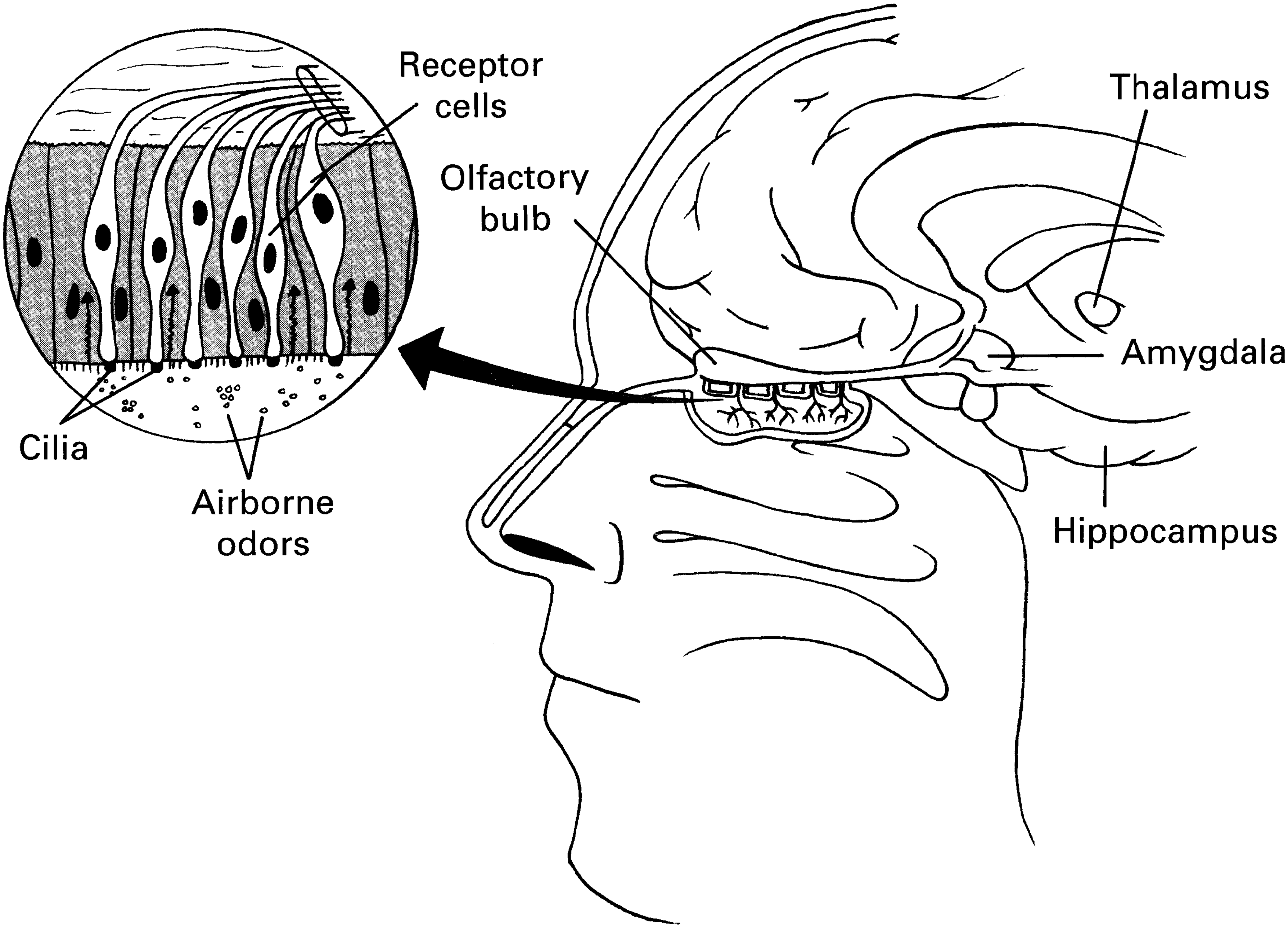


*Figure 1. Locations of structures within the olfactory tract.*

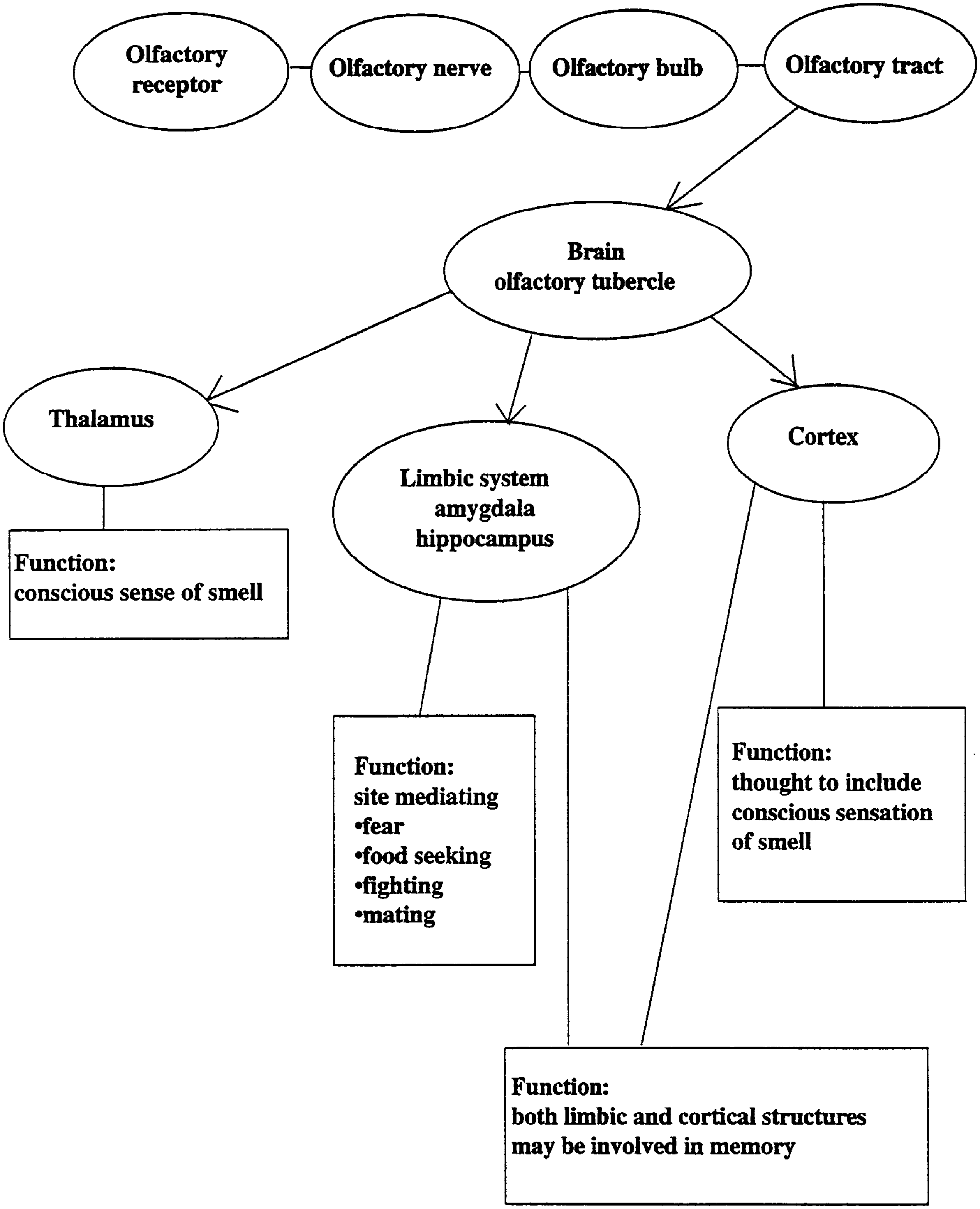


*Figure 3. Flow chart for olfaction and memory.*

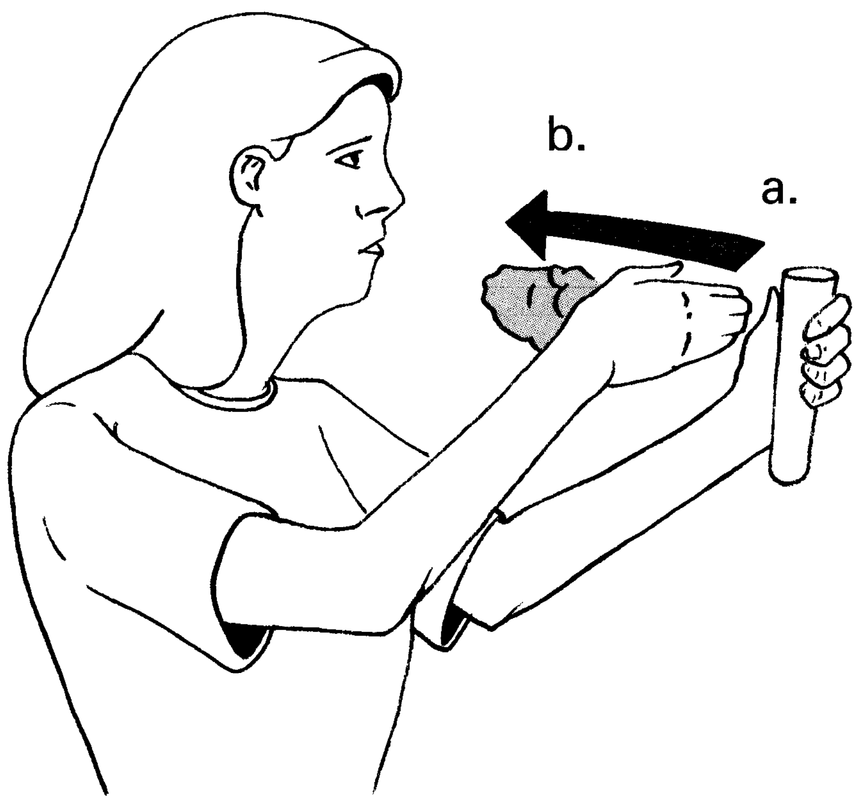


*Figure 5. Demonstration of the wafting procedure. (a) Hold the vial of "scent material" approximately 30 cm in front of and slightly below the nose. (b) Use your free hand to fan the scent from the open vial toward your nose.*