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Modeling Pollen-Mediated Virus Spread in Bee Colonies as a Classroom Activity †

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Using a hands-on approach, this activity introduces students to the concept of viral spread and honey bee pathogenesis by illustrating pathogen transmission throughout the hive. This viral transmission activity, designed for introductory biology, virology, or microbiology classes, can be used in laboratory or lecture settings. Students are provided with information on viral transmission and hive structure. Students then retrieve "pollen" and distribute it to the colony. A UV light passed across students' hands determines which hive was infected, indicating the viral transmission pathways among bees. Students then discuss how viruses impact bees, how long it would take an infected hive to succumb to the pathogen, and what can be done to prevent viral spread.

INTRODUCTION

This article describes an interactive activity aimed at high school and college students to be used in either lecture or laboratory settings. Its hands-on approach to active learning is suitable for multiple subject areas, including introduction to biology, virology, and microbiology, in which student engagement is key. It introduces the concept of viral spread and honey bee pathogenesis by illustrating pathogen transmission throughout the hive.

Honey bees (*Apis mellifera)* are vital to global agriculture as pollinators of a wide variety of economically important crops, along with being valued for pollen products such as honey and wax. Honey bees also help to shape natural ecosystems by facilitating gene flow for certain flowering plants (1–3). Declines in the numbers of both wild and managed populations have increased public interest in and awareness of bee health issues. While researchers and beekeepers have already been tracking bee health due to Varroa mites and colony-collapse disorder, these factors only account for a small portion of global bee losses (1, 2, 4). Therefore, research efforts are increasing to understand the factors driving this decline.

Thus far, nearly 20 RNA viruses have been described that affect honey bees. Belonging to families *Dicistroviridae, Iflaviridae, Nodaviridae,* these viruses affect the morphology, physiology, and behavior of the colony (1, 5). With many different pollinators using common foraging areas, the potential for interspecies viral transmission increases. Infected insects visit a plant where they may leave behind virus-containing saliva or feces on plant parts (5). Healthy worker bees foraging on contaminated plants pick up infected pollen and deliver it back to the colony (5). At the colony, pollen is prepared into food products by workers, and then distributed to different members of the hive (4, 5). The path viral transmission takes can be either horizontal or vertical. Vertical transmission occurs when the queen bee lays eggs or is inseminated by a drone. Horizontal transmission can occur with other types of colony interactions, including food preparation and distribution and hive cleaning (4–7).

This activity explores how viruses are spread via pollen to all levels of the colony by horizontal and vertical transmission. It uses easy-to-obtain materials and is suitable for educational or community teaching settings. Teams that make up a hive work together to demonstrate viral transmission routes. This activity is aimed at high school and college students who have little to no knowledge of bees, but some virology background, or those who can conceptualize viral spread following a short presentation on the information provided above.

PROCEDURE

Materials

The materials listed are required for four teams of six people working together to complete the activity.

- 4 sets of printed and laminated player cards (see Appendix 1 (i))
- 4 printed and laminated transmission pathway cards (see Appendix 1 (ii))

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- 2 lbs of elbow macaroni (or other dried pasta), uncooked
- 1 8-oz bottle of GLO GERM lotion
- 1 UV light
- 5 2-qt or larger plastic containers
- 3 different colors of construction paper
- 1 pair of scissors
- 1 roll of tape
- 24 pairs of latex-free gloves are optional if hand washing facilities are not readily available. GLO GERM is non-toxic and can be removed from hands by washing after the activity.

Safety issues

Although all materials used are non-toxic, supervision is required as there is a small risk of participants ingesting the GLO GERM and pasta required for activities.

Preparation

Before running the simulation, it is necessary that the instructor have a basic knowledge of transmission of viral particles to bees via pollen. Sources for background information can be found in the reference section. The instructor should then make construction paper flowers and attach them to the plastic containers labeled 1 to 5 (see Appendix 2 (i)); each container represents a flower patch. Next, half of the macaroni should be mixed with GLO GERM lotion until all macaroni are coated; macaroni represent pollen and GLO GERM indicates viral infection. Allow macaroni to dry six to eight hours before use. When dry, add the "infected" macaroni to three of the containers and the "clean" macaroni to the other two containers; be sure to record which are infected vs. clean (see Appendix 2 (ii)). Flower patches are then randomly dispersed around the room. To start the activity, the basics of viral transmission, pollen dispersion, and bee colony life should be taught to the students, demonstrating how viruses may be transmitted to pollen sources and subsequently to bee colonies. Then, reinforce this knowledge by using the simulation activity.

Running the simulation

Assign students to teams of six, and then have each student choose a player card (gloves optional). Students who are worker bees will leave the hive to forage for pollen in a flower patch of their choice. Each team has two workers, so they may forage from the same or different patches. Workers will collect a handful of macaroni pollen and bring it back to their hive. Then using the transmission pathway cards to direct pollen transfer, macaroni is transferred from worker bee to the drone and queen, then the queen to the egg (Path 1), or worker bee to larva (Path 2), with each student gently rubbing the macaroni in their hands. Once each student has handled the macaroni, the instructor will turn down the room lights and go to each group with the UV light to determine which hives were infected and how. Instructors begin with the workers and follow the assigned hive transmission path (Fig. 1). When the infection assessment is completed, instructors are encouraged to discuss ideas regarding the activity, including social networks in bee colonies and how bee feeding behavior and social interactions facilitate the spread of viruses within a hive. Potential questions to be asked include how bee behavior affects the spread of pathogens in a bee colony, and how the health of the entire colony is impacted through bee food sources.

CONCLUSION

This activity is a safe and engaging educational tool. Pre-activity content can be altered to focus on different types of classroom levels ranging from middle school through college undergraduate. The bee virus activity itself may be scaled to accommodate different class sizes with an active learning setup. The minimum number of recommended participants is 12 (four students per colony, three colonies) if the drone is not included. Participant feedback showed an increase in understanding of bees, how they pollinate, socialization in the colony, and the impact of disease and viral spread in the colony. The participants expressed interest in furthering their knowledge on the problems affecting bees. Additionally, on an undergraduate virology exam, 22 out of 24 of students (92%) answered the question about bee viruses and the spread of their viruses correctly, suggesting this activity aided in learning.

SUPPLEMENTAL MATERIALS

Appendix 1: Player cards and transmission pathway card
Appendix 2: Simulation setup

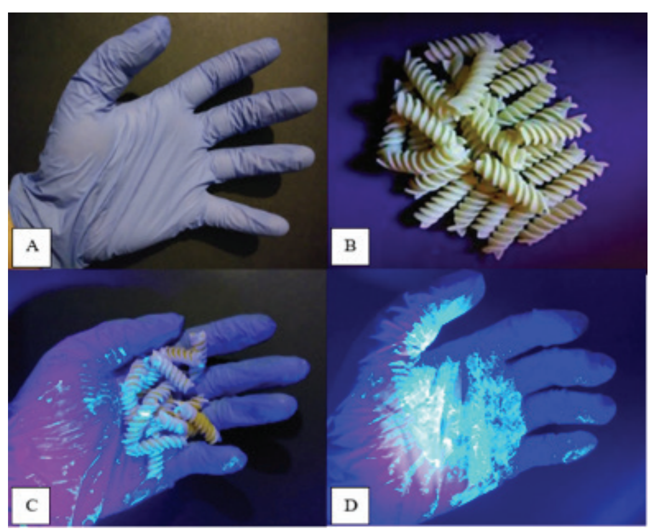

FIGURE 1. A) Non-contaminated glove. B) Non-contaminated "pollen" under UV light. C) "Pollen contaminated" with simulated virus. D) After exposure to simulated virus.

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