Workshop title: The Immune System and Vaccination (KS3)
Document: Facilitator Guide

1. The KS3 science curriculum asks students to:

Make **predictions**, **test** them and **evaluate** variables. This session will do this through modelling an outbreak:

- Hypothesis – will the pathogen spread?
- Test – outbreak modelling (in pairs)
- Variables – different vaccine coverage rates (95%, 80% and 50%)
- Further work – further infection rates

Make and record **measurements.** The session will do this by asking the students to:

- Record pathogen transmission with different vaccination rates
- Record pathogen transmission for different infection rates (further work)

Analysis - Calculate results and present them. The session will cover this by asking:

- Does the % vaccinated population stop the pathogen spreading?

Evaluation – interpret data and relate to hypotheses, identify further questions. This will be introduced in the conclusion section:

- Compare your data to the class average. Does this match your hypothesis?
- Is this a fair test?
- Why did we make the class average?
- How could this experiment be improved?
- What further experiments could you perform?

Develop scientific vocabulary - the presentation will introduce new vocabulary. This will be reinforced during the experimental work.

Pathogen, immune system, innate immune response, adaptive immune response, antibody, antigen, vaccines, herd immunity.

2. Session learning objectives

- Understand the role the immune system plays in protecting the body from pathogens.
- Understand the types of vaccines and how they protect the body from pathogens
- List types of pathogens
- Recognise the importance of vaccination in stopping pathogen spread and providing herd immunity

3. Equipment needed

- Computer for PowerPoint presentation
- Coins or 6-sided dice (1 between 2)
- Deck of cards for the further experiments (1 between 2)
- Green colouring pens/pencils
- Printed copies of the experimental student handout
- Printed copies of the further experiments
- Printed copies of the 95%, 80% and 50% vaccinated population work sheet (1 between 2). Extra 80% and 50% sheets needed for the further experiments

4. Timings and step-by-step delivery 60-minute session

Minutes	**Instruction**
00 - 15	**Presentation** The facilitator will start the session by giving the presentation. Suggested script for each slide: 1. Introduce yourself and the topic. 2. Ask for suggestions about what the pathogens shown are. Click to reveal the names of the pathogens 3. Although there are pathogens all around us, we don't get sick because of the immune system. 4. Talk through text on slide. Elaborate on organs/tissues/cells for older students. Click to reveal what the immune system can do. Click again to reveal examples of when immunity can go wrong. 5. The immune system is split into two aspects, innate and adaptive 6. Describe innate immune system. It is non-specific – meaning it can distinguish between human ('self'= blue cell) and pathogen ('non-self'=red cell) but not between different pathogens. 7. The innate response is fast but the body doesn't remember the pathogen or how to fight it 8. Describe adaptive immune system. It is specific – meaning it can distinguish between different pathogens based on shapes on their surface (called antigens). The response is slower, but the body remembers how to fight specific pathogens

9. Ask – does anyone know how the immune systems fights pathogens? Click to reveal answer – white blood cells
10. Describe the innate immune response in terms of myeloid cells ‘swallowing’ pathogens…
11. Describe how the myeloid cells show antigens to lymphoid cells of the adaptive immune system
12. The lymphoid cells then make specific antibodies to fit the shapes of antigens. Click to reveal that this signals the body for destruction.
13. Some cells form memory cells for future protection
14. You have a healthy population
15. But one person gets sick (green face) with a pathogen. Ask for suggestions of specific pathogens.
16. Here are some pathogens to mention in case the students don’t have an answer
17. When you are sick you can spread the pathogen to the people around you as shown by the box and arrows
18. A coin was tossed to see if a connected healthy person was infected or not (50% chance of infection). Infected person 1 infected 4 new people (green faces 2-5)
19. This was repeated for infected person 2, who infected 4 new people (light green faces 6-9)
20. This was repeated for infected person 3, who infected 3 new people.
21. This process can go on until there are no new infections. Highlight that some people were not infected.
22. Pathogens can kill. Typhoid mortality is 10% and shown as missing faces.
23. Ebola death rate can be up to 90%
24. While some pathogens make you sick and infectious for a long time, most people recover and are protected by antibodies from their immune system.
25. Vaccines are used to protect us from pathogens. Ask for examples they might know of or have had. Click to reveal some vaccine examples.
26. Vaccines expose the immune system to pathogens safely and without having to catch the disease first
27. Describe the 3 types of vaccine in terms of what they contain, then name them. Click again to discuss that vaccines contain antigens (red arrows) which trigger the immune system to create antibodies
28. List the Benefits and ask what type of pathogen polio and smallpox are (answer is viruses). Ask if anyone knows what ‘Eradication’ means. List the Risks. Vaccines produce immunity in 85% to 95% of people. If you are very unlucky and still catch the disease, the symptoms are often milder.
29. Make it clear that the benefits (in saving lives) outweigh the risks and that there is on-going research into new vaccines. Maybe bring up your own research if applicable.
30. Some people like very young babies, the very old, people with certain diseases or allergies, pregnant women, and people with damaged immune systems can’t be vaccinated

	31. The really clever bit is that these people are still protected because they are surrounded by people that can't catch the disease. This is known as herd immunity. 32. But how many people (that can be vaccinated) need to be vaccinated to stop a pathogen spreading and generate herd immunity? 95% 33. 80%? 34. 50%? 35. Let's find out! Give experimental handouts to each student. 36. Leave this slide up while the students are doing the experiments
15 – 35	**Experiments 1, 2, 3** • Split the class into pairs for the experimental work and filling out the student experimental handout • The students can work in pairs, but everyone has to fill out their own handout. E.g. one person will roll the dice and the other will colour in the result, but both should fill out the results tables and answer the handout questions • Detailed instructions for the handouts are on the presentation. This section should take approximately 20 minutes and the sheets can be glued into subject workbooks. **Experiment Method** The method detailed below is the same for experiments 1, 2 & 3. 1. Students should select one of the unvaccinated people (clear faces on relevant vaccinated population sheet), label that person 1 and colour them in green. 2. If they are connected to another unvaccinated person – the students will flip a coin or roll a 6-sided dice so they have a 50% chance of infecting them a. Heads or Even numbers = Infected b. Tails or Odd numbers = Uninfected 3. Infected people are coloured in green and numbered. The students will write the number of new infections in the relevant results table in their handout 4. If the newly infected people are connected to unvaccinated people – repeat steps 2 and 3. The number of infections will vary throughout the class, but this is addressed later 5. Once there are no new possible infections, the students will write the number of infected people in the Total Number of Infected People box on their handout **Note** – an unvaccinated person can risk infection on more than one occasion if they are connected to more than one infected person. A successful 'uninfected' roll does not protect them in the future. If the students are unclear on this, slides 18, 19, 20 of the presentation show that infected person 12 risked infection from infected person 1 but were uninfected (slide 18). They were later challenged by infected person 3 and were infected (slide 20).

	During the experimental work the facilitator will talk to students and answer any questions about the presentation subject material, the experiment, or their own work in immunology. Guidance is in the 'Expected results and model answers' section of this document.
35 - 45	**Collecting data and calculating the average** When the students are finished with experiments 1, 2 and 3, the data should be collected and used to form a class average (mean) for each experiment. This can be done on the 'Average infections Spreadsheet' if applicable, or a white board. The example data on the spread sheet is intended to show that there will be variation. If time allows, a simple graph could be made in Excel to visually show the data which has been collected. This should take 10 minutes.
45 - 55	**Conclusions** The conclusion section of the student handout should be completed with the class average. This should take 10 minutes. The facilitator can help the students though this section, guidance is in the 'Expected results and model answers' section of this document.
55 - 60	**Summary** During the final **5 minutes** of the session, finish the class with a quick discussion of results and the facilitator can present the final summary slide of the presentation

5. Expected results and model answers

Experiment 1 – 50% vaccinated population

Results: Pathogen should spread as most unvaccinated people are connected to other unvaccinated people. There will be large variation within the class data set due to which person they chose to infect and how many unvaccinated people they are connected to. (Demonstrated in example 1 of the 'average infection spreadsheet')

Analysis: Does not provide herd immunity. Why? 50% vaccinated population is too low and the pathogen can spread.

Experiment 2 – 80% vaccinated population

Results: Pathogen should spread as most unvaccinated people are connected to 1 or more unvaccinated people. There will be variation within the class data set due to which person they chose to infect and how many unvaccinated people they are connected to. (Demonstrated in example 2 of the 'average infection spreadsheet')

Analysis: There should be a mix within the class of whether or not 80% vaccinated population is sufficient to provide herd immunity and prevent pathogen spread.

Experiment 3 – 95% vaccinated population

Results: Pathogen should not spread because the unvaccinated people are not connected. There will be a slight chance of spread to one other person as 2 unvaccinated people are connected. This should provide an opportunity to talk about >95% vaccine coverage.

Analysis: Should provide herd immunity as almost every unvaccinated person in surrounded by vaccinated people.

Conclusions to experiment 1, 2 and 3

Q What percentage of vaccinated population is needed to stop it spreading?
A 95% of the possible vaccinated population is needed to stop the spread of the pathogen and generate herd immunity in these experiments

Q Why did we take the class averages?
A The introduction of chance through the coin toss or dice roll introduces variability. By taking the average they should have greater confidence in their results.

Q Is this a fair test?
A To an extent this test is fair. For example, they rely on random chance to determine if a person is infected or not but the allocation of vaccinated/unvaccinated was outside their control and might not be fair. The students chose the 1st infected person which might not be fair.

Q How could this experiment be improved?
A Each pair could have a randomly generated vaccinated population and 1st infected person. Each pair could repeat their experiment with a different 1st infected person and see if they get the same result.

Q What further experiments could you perform?
A Further experiments could include other vaccinated population percentages (75%/25%?). Increased or decreased percentage chance of infecting new people is explored in experiments 4 and 5 but could be talked about here.

6. Further work

If time allows, students can cover further experiment 4 and 5 which covers another variable of an outbreak model – changing the percentage chance of infecting a new person (infectivity of a pathogen). The experiment method is the same apart from the use of special deck of cards for section 2 of the method, and not calculating a class average.

Experiment 4 – 25% chance of infection

If they are connected to another unvaccinated person – the students will draw a card so they have a 25% chance of infecting them

a. Spades or clubs = Infected
b. Hearts or diamonds = Uninfected

Results: Total number of infected people at 50% and 80% vaccinated populated should be lower than in experiments 1 and 2.

Analysis: 50% population coverage should not stop the pathogen from spreading and not generate herd immunity. 80% might stop the pathogen from spreading but there will be class variation

Conclusion: Number of new infections should be lower compared to experiments 1 and 2. This means the percentage of vaccinated population needed to stop pathogen spread is lower.

Experiment 5 -75% chance of infection

If they are connected to another unvaccinated person – the students draw a card so they have a 75% chance of infecting them

c. Spades, clubs or hearts = Infected
d. Diamonds = Uninfected

Results: Total number of infected people at 50% and 80% vaccinated populated should be higher than in experiments 1 and 2.

Analysis: Neither 50% nor 80% vaccinated population should stop the spread of the pathogen and generate herd immunity

Conclusion: Number of new infections should be higher compared to experiments 1 and 2. This means the percentage of vaccinated population needed to stop pathogen spread is higher.