



Key Stage 4

Teacher Refresher

Information

Vaccinations have been one of the most effective methods to prevent disease and have helped to lower mortality associated with infectious diseases worldwide. They are designed to prevent disease, rather than treat a disease once you have caught it.

How Vaccines Provide Immunity

A vaccine is usually made from weak or inactive versions of the same microbes that make us ill. In some cases, the vaccines are made from cells which are similar to, but not exact copies of, the microbe cells that make us ill. Some diseases are caused by a toxin the microbe produces so some vaccines contain a substance that is similar to the toxin known as a toxoid. Examples are: Cholera and Diphtheria.

When the vaccine is introduced into the body the immune system attacks it as if harmful microbes were attacking the body. The white blood cells (WBC) create lots of antibodies to attach to the antigens on the surface of the vaccine. Because the vaccine is an extremely weakened version of the microbe the WBCs successfully eliminate all the microbial cells in the vaccine and the vaccine will not make you ill. By successfully eliminating all the vaccine antigens, the immune system remembers how to combat those microbes. The next time microbes carrying the same antigen enter the body, the immune system is ready to fight it before it has a chance to make you ill.

In some cases, the immune system needs reminding and this is why some vaccinations require booster jabs. Some microbes such as the influenza virus are tricky and change their antigens. This means that the immune system is no longer equipped to fight them. For this reason, we have annual flu vaccinations.

The live viruses in the flu vaccine that is given to school aged children are cold adapted so that they cannot replicate efficiently at body temperature (37°C). This means that the vaccine viruses will not replicate in the lungs but will reproduce at the cooler temperatures found in the nose. This allows the child to produce localised antibodies in the lining of the airways which then protect against infection if they encounter flu virus (which enters the body via the nose and mouth).

These localised antibodies are not produced in response to the inactivated flu vaccine. In addition to localised antibodies in the nose, antibodies are also produced in the blood (systemic antibodies). The use of vaccines has meant that some previously common diseases, e.g. smallpox, have now been eradicated. The re-emergence of other diseases in a population, e.g. measles, may be due to not vaccinating a large enough proportion of the population. Epidemics can be prevented by vaccinating a large enough part of the population leading to herd immunity.

Herd Immunity

Herd Immunity is a type of immunity which occurs when the vaccination of a portion of a population (or herd) provides protection to unvaccinated individuals. If enough of a population is vaccinated, unvaccinated individuals are less likely to come into contact with the disease due to its decreased prevalence. It is important to maintain herd immunity as some people are unable to have vaccinations. Individuals who may not be able to have a vaccine include those who are immuno-compromised, individuals with allergies to the components of vaccines and very young children.

Routine and Other Vaccinations

Countries have routine vaccinations for diseases that are considered to be high risk in that country. Some vaccines contain antigens for more than one disease. Examples of these include the polio, diphtheria and tetanus vaccine, and MMR (measles, mumps and rubella). In some cases, one pathogen can cause more than one disease. *Human papillomavirus* also known as HPV, is an infection caused by Human papillomavirus that can cause genital warts and if left unmonitored in women, can lead to cervical cancer. The HPV vaccination can prevent cervical cancer in women, and also protects against genital warts. International travel is increasingly popular, and it is important for students to understand that travel to different regions comes with increased risk of infection. Increased risk can be due to poor sanitation or hygiene, or higher occurrence of different infections in those countries, for example rabies, meningitis or Japanese encephalitis. Students can visit the e-Bug website for more information, their travel vaccination practitioner at their GP surgery, or visit [www.fitfortravel.nhs.uk]. Travel vaccinations are important and in some cases are required for entry into a country. An example includes the proof of vaccination against meningitis for entry into Saudi Arabia for the Hajj pilgrimage.

COVID-19

COVID-19 is the name of the disease caused by the coronavirus known as SARS-CoV-2 that causes illness in people by affecting their lungs and therefore their breathing. Most people infected with the COVID-19 virus will experience mild to moderate respiratory illness and recover without requiring special treatment. Older people, and those with underlying medical problems like cardiovascular disease,

diabetes, chronic respiratory disease, and cancer are more likely to develop serious illness.

The best way to prevent and slow down transmission is to be well informed about the SARS-CoV-2 virus, the COVID-19 disease it causes, how it spreads and to have the vaccine if it is offered to you as part of a vaccination programme. You can also protect yourself and others from infection by washing your hands or using an alcohol-based rub frequently, not touching your face, wearing a face mask, and practicing social distancing.

At the time of writing this e-Bug pack (July 2021), several COVID-19 vaccines have been developed to help manage the outbreak, for example the Oxford/AstraZeneca vaccine that was tested on over 11,000 people, and the Pfizer/BioNTech vaccine that was tested on 43,500 people. While development of these vaccines was fast, no parts of the process were skipped and the vaccines met the rigorous standards set by the Medicines and Healthcare products Regulatory Agency (MHRA), who make sure that all medicines used in the UK are safe. COVID-19 vaccines have played a significant role in slowing the spread of infection and preventing deaths.

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Teacher Answers

SW1 Immune System Worksheet

Also available in TS2

1. We have various types of physical barriers to prevent invasion by a micro-organism. Name three of these barriers and explain how they are specialised to prevent infection.

Any three of the following: Skin, Cilia/hairs in [nose/throat/lungs], Tears, Gastric/stomach acid
Skin provides a physical barrier for our body. Entry through this barrier for pathogens (micro-organisms that cause disease) can occur when the skin is broken/ irritated/ damaged
Tears: The eye has a mechanism of cleaning itself through the movement of substances through blinking. The film of moisture over the eye can trap substances such as dust and through blinking can move it to the corners of the eye where it can be removed. Our tears also contain enzymes, called lysozyme and amylase which can kill some bacteria providing another level of protection.
Gastric acid in the stomach: The acid in our stomach not only aids digestion but can also kill some pathogens. Pathogens that are not killed by this acid can potentially cause disease, such as Salmonella which causes food poisoning.
Cilia: Cilia are small hairs found along the airways in our nose and lungs. These hairs are located next to mucosal cells which secrete mucus. The mucus can trap particles we inhale, including bacteria and viruses. The movement of the hairs in the nose stimulates sneezing and in the lungs; they can move the mucus to the throat where it can be coughed out or swallowed.

2. If a micro-organism isn't cleared from the body by the innate response (phagocyte response), what happens next?

The innate immune response may not always clear an infection. If this happens, the acquired/adaptive immunity is activated. The macrophages that have taken up the antigen can also transport the antigen to sites where an acquired immune response can be activated. When the macrophage bearing an antigen enters the lymphatic system it circulates towards the lymphoid organs which include the spleen, the tonsils, adenoids and Peyer's patches. These organs are rich in two types of specialised white blood cells called lymphocytes. Also known as B cells and T cells, these lymphocytes are distributed in strategic sites throughout the body ready to respond to antigens. There are also many B and T cells circulating in the blood.

3. *Legionella pneumophila* is a bacterium that causes Legionnaire's disease. In humans it is engulfed by macrophages but is able to evade the normal mechanisms that macrophages use to kill it. It is therefore able to live inside the macrophage and use its nutrients to stay alive.

a) Why can't B cells recognise the *L. pneumophila* antigens?

B cells cannot recognise intracellular antigens as they respond to free antigens. Free antigens are found outside our own cells or on the surface of organisms that circulate around our body. *L. pneumophila* is an intracellular pathogen/micro-organism and so does not display a free antigen to the immune system.

b) How would the immune system identify *L. pneumophila* and how is it removed from the body?

The antigen from *L. pneumophila* can be displayed on an MHC molecule on the surface of the infected cell. This means that it can be identified by the immune system. MHC molecules on our own cells are recognised by cytotoxic T cells. Once identified, the T cell can release cytokines to influence other cells of the immune system.

c) Why would someone with a deficiency in T-cells be more prone to an intracellular micro-organism infection?

T cells are crucial in identifying an intracellular infection. Without them the immune system can fail to identify and destroy these intracellular pathogens and they would be able to replicate and spread to other cells. Some examples include: viruses, mycobacteria and meningococcal bacteria.

4. Once the acquired immune response is initiated, plasma cells (lymphocytes) can produce antibodies. Explain why antibodies will only be effective against one antigen. When the receptors on the B cell surface recognise free antigens they are stimulated to become plasma cells (lymphocytes) which make antibody. The antibodies protein molecules are folded in such a way as to form a 3-dimensional cleft into which only antigens of a corresponding shape can bind.

5. Cytokines have many roles in the immune response. From the animation, can you describe two ways that cytokines help the body fight infection?

Two of the following: Cytokines can:

- Help regulate the innate immune response and attract additional macrophages from the blood stream to the site of infection.
- T cells do not manufacture antibodies but they can secrete cytokines which influence other immune cells.
- When the T cells binds to the MHC-antigen complex, the activated T cells enlarge, multiply and secrete cytokines which can then affect other immune cells nearby.
- When an antigen binds to the antibody receptor on a B cell, a bit of the antigen is also taken up into the cell and is then presented to the B cell surface by a MHC molecule. This MHC-antigen complex is recognised by a T cell, usually a T helper cell, which secretes cytokines. In this case the cytokines assist the B cells to proliferate to form identical cells producing the same antibody.

6. *Clostridium botulinum* is a bacterium that produces the botulinum neurotoxin. This is commonly known in the medical industry as Botox. It is the botulinum toxin that is lethal as it causes flaccid paralysis in humans and animals. *Clostridium botulinum* that produces it however is not considered dangerous by itself. The immune system can recognise toxins as well as micro-organisms.

a) How does the immune system recognise and clear toxins?

The immune system uses the humoral response of the adaptive immunity to clear toxins. This involves the binding of an antibody to the toxin/antigen and it can be immobilised and neutralised.

b) Why would a vaccine for the *Clostridium botulinum* bacterium not be considered as effective as a vaccine against the botulinum toxin?

The toxin is the lethal component. Without the toxin the bacterium is not considered dangerous. A vaccine against the toxin is effective because it can stimulate the immune system to produce antibodies against the toxin thus preventing the harmful effects of the disease.

7. What is the function of the following cells:

a) Cytotoxic T cells? Cytotoxic T cells can recognise intracellular antigens and kill infected cells.

b) Helper T cells? *Helper T cells are involved in T-cell dependent responses. They can help stimulate B cells to proliferate and they can also help them to become plasma cells.*

c) Plasma cells? Plasma cells are derived from B cells. Once a B cell recognises a free antigen it can become a plasma cell. These plasma cells are antibody producing cells and so are large in size.

8. Explain why vaccines are preventative in protecting against infection.

Vaccines show the antigen for a particular infection to the immune system so that specific antibodies can be produced without the disease developing in the individual. If an individual contracts the disease naturally a vaccine will not help as the specific antibodies will already have been produced. Vaccines provide immunity artificially whereas a disease will give natural immunity. Contracting the disease is potentially dangerous so vaccination is safer.

9. Explain how a vaccine results in a memory response in the immune system.

A vaccine contains antigenic material/antigens for a micro-organism/disease. This results in the production of antibodies by the plasma cells/B cells that are complementary/a match to the antigen from the vaccine. The antibodies produced in a memory response are IgG/immunoglobulin G so they persist for a long time in the body. Some of the B cells and T cells involved in identifying the antigen from the vaccine differentiate/change into memory cells which will mount a quicker immune response the next time the antigen is encountered.

10. Herd immunity arises when a significant proportion of the population is vaccinated against a disease. What could happen if the vaccination rates were to fall in a population for the following vaccines? (Hint: think about their transmission methods. Measles is spread through touch and in the air through contagious droplets from infected people, and cholera is a water-borne disease).

a) Measles If vaccination rates were to fall for measles vaccines, sporadic outbreaks could occur as the measles can pass between unvaccinated and susceptible individuals in the air or through contact with an infected person.

b) Cholera Just like measles, decreased vaccination rates for cholera in countries where cholera is a major health concern, can result in outbreaks. Herd immunity is still important; however, as cholera is a water-borne disease it can still affect people who are unvaccinated even if they are around people who have been vaccinated.

SW2 Vaccine Misconceptions

Also available in TS3

1. Natural immunity is better than acquired immunity. *False. Natural immunity occurs when exposed to the actual disease. While it can prevent an individual from getting the infection again, the individual may become very ill, suffer long term health effects,*

or in some cases, risk death. Acquired immunity through vaccination does not carry these same risks.

2. The needle will hurt. True. You might face a sharp scratch, but this will go away very fast. Sometimes you will feel a sore arm after the vaccination, but this is because the body is working hard to kill or eliminate all of the vaccine organisms. It is this process which provides the individual immunity against future disease.

3. You will get side effects from the vaccination. Sometimes. Side effects are very rare and depend on the vaccine being received. A sore arm or feeling tired can be common, as the body is working to produce the antibodies required to fight the vaccine. Side effects are very carefully monitored, and a vaccination will not be approved if the risks of negative side effects outweigh the benefits.

4. The diseases we are vaccinated for are so rare, I won't get the disease. False. Diseases we are vaccinated for are rare because of vaccines. Vaccination has successfully reduced the prevalence of fatal diseases including polio, measles, and now, COVID-19 amongst many others. However, if people stop being vaccinated for these diseases, we will lose our herd immunity and the number of people infected will increase. This is why it is so important to take the vaccinations recommended by your doctor, to ensure you protect yourself and others.

5. Vaccines are not safe. False. Vaccines go through a rigorous process of trials in labs, on animals, and on humans to check that they are effective and to monitor for side effects. All vaccines delivered in the UK have to be approved by the Medicines and Healthcare products Regulatory Agency (MHRA) who make sure that all medicines and vaccines meet rigorous standards. Once approved, health officials continue to monitor the side effects of vaccines and can respond quickly if there is any evidence to suggest that a vaccine is no longer safe.