Vaccinations
Lesson plans, worksheets and activities for 15-18 year olds on vaccinations.

An educational resource
Key Stage 4&5 / Science*
* certain sections may also link with the PSHE curriculum
This pack contains a series of educational resources for young adults aged 15-18 years on the topic of vaccinations. The resources are outlined below:

**Vaccination Lesson Plan**

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**Vaccination Animation**

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Introduction

This lesson plan covers immunity and vaccinations, and highlights the importance of getting vaccinated, not just for an individual’s health but for others in the population. Interactive slides help students to clarify common myths and misconceptions about vaccinations. Students learn the impact the media may have on vaccine uptake through the example of the measles, mumps and rubella (MMR) scare in the early 2000s.

Learning outcomes

- Vaccination helps individuals to develop immunity against an infection(s) and helps to fight off the infection(s)
- Why vaccines are important to students now and throughout their life
- The important diseases prevented by vaccines, and why these are important to young people, including students
- How the media, and epidemics, can affect vaccine uptake positively and negatively

Exam specification links

This lesson plan covers several topics found in the AQA, OCR, Edexcel and WJEC exam specifications for A-level Biology, Human Biology and related subjects. For more information, please visit the ‘Examination links’ webpage.

Key words

Antibodies, Antigen, Vaccination, Immunisation, Innate immunity, Acquired immunity, Immune system, Herd immunity

Available web resources

Animations, interactive slides, PowerPoint presentations and many other resources are available in the young adult vaccination section at [www.e-Bug.eu](http://www.e-Bug.eu).

Materials required

Graph paper for completion of the main activity.
Vaccinations have been one of the most effective methods to prevent disease and have helped to lower mortality associated with infectious diseases worldwide.

**How vaccines provide immunity**

Vaccines are preventative, that is, they only protect the individual before they get an infectious disease. When an individual is vaccinated, the processes in the immune system that are stimulated to mimic the body's natural immunity include: antigen recognition, antibody production and formation of a memory response. These processes occur without causing the damage that an infection usually causes because the vaccine contains the antigen of the infectious disease, or a toxoid (an inactive version of a toxin) in an inactive, safe form. These infectious agents have been inactivated by being killed or denatured by heat, radiation or other harmful conditions. The antigen is the same but the microorganism can no longer cause the infectious disease.

Vaccines provide immunity by stimulating the immune system to produce antibodies to fight a particular infection or prevent the effects of a toxin. These antibodies stay in the body and provide long term protection. Antibodies fight a particular infection or toxin by identifying a matching antigen. Antigens are a pattern or structure found on the microorganism or toxin, and the antigen is a complimentary match for the antibody that will be produced.

**Types of immunity**

If an individual has not been vaccinated against a disease and they have contact with it, they will usually acquire some **natural active immunity** through exposure to antigens of the microorganism or toxin. However, there are risks associated with contracting an infection as some can leave the individual with long term complications, or worse, cause death. **Artificial active immunity** occurs through vaccination or inoculation. **Passive immunity** arises through acquisition of protective antibodies (most commonly through injection or transfusion of blood products) that will help fight the infection without the individual having had exposure to the infection or having been vaccinated. Natural passive immunity can also occur between mum and baby through the placenta during pregnancy or through breast feeding. In some cases, passive immunity can be artificially acquired through the transfer of antibodies from other humans or animals into an individual's bloodstream. Passive immunity is used when there is no time for an individual to generate their own specific antibodies to microorganisms. An example of this is after a gardening injury when there is a danger of tetanus, so a tetanus anti-toxin is given to those who have never had the tetanus vaccination.
Herd Immunity

If enough of a population is vaccinated, herd immunity is attained. Herd immunity in a population prevents outbreaks of an infection. This is due to the inability for the disease to infect vaccinated individuals and through the inability for unvaccinated individuals 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 immune-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, can cause genital warts and if left unmonitored in women, can lead to cervical cancer. The new HPV vaccination can prevent cervical cancer in women, but it will also reduce 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 http://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.

Some diseases require boosters to maintain antibodies at a high enough level to prevent infection. Boosters maintain high antibody levels in the blood. An example is the pneumococcal vaccines. The genetic make-up of some microorganisms mutates quickly, leading to changes in their antigen structure, and so these infections require annual vaccinations. This is why annual flu vaccines are developed to prevent infection from new flu strains circulating in the community.
Introduction (15mins)

1. Provide an introduction for students, describing that they are going to learn about vaccinations, and why vaccination is so important. Students will be learning the truth about common myths and misconceptions surrounding vaccinations, and the influence of others when making decisions about vaccinations. Students will learn about the influence of the media on vaccine uptake, subsequent disease rates and herd immunity.

2. Ask students what they already know about vaccinations. Questions to be discussed could include:
   - Do you know what a vaccination is? How does a vaccination work?
   - What vaccinations do children usually have, and at what ages?
   - What vaccinations have you had?
   - Why do you think you need vaccinations against diseases such as the flu, or measles, mumps and rubella (MMR)?
   - Do students know what herd immunity is? Ask students to describe this in their own words. (The herd immunity animation at www.e-Bug.eu could be used if students are still confused about herd immunity).

Main activity (20-25 mins)

1. Present the interactive vaccination myth slides from the e-Bug young adult website. These cover five myths and misconceptions about vaccines that young people may have, and provide answers based on the students views. Involve the students in answering yes or no to each myth and then review the background information provided.

2. Provide students with student worksheet 1, which contains data related to the MMR scare and controversy. Begin the PowerPoint about the influence of the media on vaccines.

3. Ask students to complete the worksheet and use the provided data to plot a graph.

4. After students have completed the worksheet, finish the PowerPoint and review the correct graph with the students.
Plenary (10 mins)
Discuss the worksheet answers with the students.

What are the student’s different interpretations of the graph?

Reflect back on herd immunity. Ask the students to describe how herd immunity was impacted in this example, and what the result of this was.

Extension activity

1. There is currently no vaccine for HIV or Ebola. Choose an infection that is prevented by vaccines and write a research report outlining and comparing why some infections, like HIV or Ebola, are still not prevented by vaccines.
2. A zombie apocalypse has infected the earth. Public Health England (PHE) is working on a vaccine to combat the infection that causes humans to become zombies, and you are a vaccine scientist working on this vaccination. Write a news article to describe the plan you and your team at PHE are working on to stop the spread of the zombie apocalypse.
3. Assign students to watch the immunisation animation clips available at www.e-Bug.eu as homework. Ask students to complete student worksheet 2, which accompanies these animations.

Acknowledgements

This lesson plan was written by the e-Bug team. The activities were devised by Dr Carwyn Watkins. Very special thanks to Antoaneta Bukasa from the immunisation team at Public Health England.

Advance preparation

Locate and download the interactive vaccination myth slides and the PowerPoint presentation at www.e-Bug.eu.

In preparation for the lesson, you can ask students to complete their own personalised vaccination timeline, available at www.e-Bug.eu. This timeline will detail all the vaccinations students should have had, and they can discuss this at home with their parents. However, the immunisations that students have or have not had are not for class discussion. Students may be very surprised at the number of immunisations they have had.

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3a. Interpret your graph showing MMR vaccine uptake and measles cases in England. What has happened?

3b. Why do you think there were changes in the vaccination uptake rates and cases of measles? What influenced the changes?
4. What is the relationship between these two figures? How do they impact each other?

5. What were the ages of individuals who had measles in 2002? Explain why that may be?


7. What conclusions can you draw from the ages of the confirmed cases of measles?

8. How was herd immunity affected by the media in this example?
1. We have various types of physical barriers to prevent invasion by a microorganism. Name three of these barriers and explain how they are specialised to prevent infection.

2. If a microorganism isn’t cleared from the body by the innate response, what happens next?

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 it’s nutrients to stay alive.
   
   a) Why can’t B cells recognise the *L. pneumophila* antigens?
   
   b) How would the immune system identify *L. pneumophila* and how is it removed from the body?
   
   c) Why would someone with a deficiency in T cells be more prone to intracellular microorganism infection?
4. Once the acquired immune response is initiated, plasma cells can produce antibodies. Explain why antibodies will only be effective against one pathogen.

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

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 microorganisms.

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

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

7. What is the function of the following cells:

   a) Cytotoxic T cells?

   b) Helper T cells?
8. Explain why vaccines are preventative in protecting against infection.

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

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) MMR

   b) Cholera
The table below provides the percentage of children immunised by their second birthday against measles, mumps and rubella (MMR) between 1996 and 2014 (England only). This data is from the Health & Social Care Information Centre (available from http://www.hscic.gov.uk/catalogue/PUB14949/nhs-immu-stat-eng-2013-14-rep.pdf). Copyright © 2014, re-used with the permission of the Health and Social Care Information Centre. All rights reserved.

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3a. Interpret your graph showing MMR vaccine uptake and measles cases in England. What has happened?

The graph indicates that there was an immediate decline of MMR vaccination rates starting in 1998 when the first paper was published. The rates continued to drop until they reached their lowest point in 2003/04, below 80%. After 2004, the rates steadily increase and in 2014 they are at a historic high of 92.7%.

However, in contrast, the general trend in confirmed measles cases is increasing beginning in 2002.
3b. Why do you think there were changes in the vaccination uptake rates and cases of measles? What influenced the changes?

Media coverage of Andrew Wakefield’s flawed studies influenced the public’s view of the safety of the MMR jab. As a result, the vaccination rates decreased below the recommended 95% uptake resulting in increase of the pool of susceptible individuals to measles. Parents were unsure about the safety of the vaccine, and this resulted in not vaccinating their children. The rates of measles in England increased, and there were large outbreaks in 2008 and 2012.

4. What is the relationship between these two figures? How do they impact each other?

As the vaccination uptake decreases, measles infections in the population begin to increase. Once the vaccination uptake increases, beginning in 2005, the measles infections in the population is affected.

5. What were the ages of individuals who had measles in 2002? Explain why that may be?

The majority of the measles cases in 2002 were aged 1-9 yrs. These were children that were offered at least one dose of the MMR vaccine (1st dose of MMR should be given age 13 months, 2nd dose between the ages of 3.5 and 5yrs). Because the vaccination uptake had been falling, fewer children had been vaccinated and therefore caught measles when coming into contact with the infection.


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The number of cases of measles is increasing, between 1997-2002 and 2003-2008 the number of cases more than quadruples. In the following period, the cases double again. While in the first period there were more cases of measles in the very young age group, in the next periods there was an increase across all age groups. As the cohort of young people who were not vaccinated against MMR between 2002 and 2005 start to grow older, they are at risk of being infected with measles, mumps or rubella, and herd immunity cannot have a protective effects. Therefore, when an outbreak occurs, more of the susceptible population can be infected. The greater the pool of susceptible individuals, the larger the outbreaks and the longer the outbreak continues. Unless susceptible individuals are vaccinated the only way they can obtain immunity is through having the infection.

7. What conclusions can you draw from the ages of the confirmed cases of measles?

As the MMR vaccine uptake decreases, there is an increase in the number of children who are susceptible to catching measles. In the first period from 1997-2002, most cases of measles were in the 1-9yrs old. This is because the older age groups have had better vaccine uptake and were therefore protected by the MMR vaccine. However, in the subsequent periods, the age profile of the cases is changing as susceptible individuals (those not vaccinated) grow older.

8. How was herd immunity affected by the media in this example?

Herd immunity indirectly protects individuals in the population who have not had a vaccine. However, rates of vaccine uptake need to be very high (around 95%) for herd immunity to have an effect. Measles is very infectious and spreads easily from person to person. In this example, the MMR vaccine uptake between 2002 and 2005 is only about 80%, so many children in the population are not protected and cannot offer indirect protection to their peers and family.
1. We have various types of physical barriers to prevent invasion by a microorganism. 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 (microorganisms 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 microorganism isn’t cleared from the body by the innate 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 it's 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/microorganism 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 microorganism 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 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 which make antibody. The antibody 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 bloodstream 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 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 microorganisms.

   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 contacts 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 microorganism/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.
This sheet provides additional information for teachers and is designed to be used alongside the e-Bug vaccinations animation.

The animation is divided into 3 clips.

**Clip 1**

**Introduction:**

In order to understand how vaccines work, we first need to know how the immune system works and how vaccines stimulate the immune system to provide protection against infectious diseases. This short animation will describe how the immune system fights infection and explain how it responds to a vaccine.

The function of the immune system is to distinguish foreign substances from substances that are part of our own bodies. The part, or parts, of any foreign substance that are recognised by the immune system are known as antigens. Antigens are present on bacteria, on viruses and on foreign cells from transfusions or organ transplants. Antigens may also be chemicals such as toxins or components of vaccines.

**Innate immunity:**

The body's first line of defence against foreign substances is the variety of physical barriers it possesses in order to prevent entry. This includes tears, gastric acid, skin and tiny hairs called cilia. The specialisation of each of these barriers is explained below:

- **Skin**: Skin provides a physical barrier for our body. Entry through this barrier for pathogens (microorganisms that cause disease) can occur when the skin is broken, irritated or damaged from cuts and wounds.
- **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 such as 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.
However, if these barriers are breached, for example by bacteria entering the body through the skin, the antigens encounter large cells called macrophages which are resident in the skin. The word macrophage means ‘big-eater’. If a macrophage recognises the antigen as something foreign and not ‘self’ it engulfs it by a process called phagocytosis and can destroy it. Inflammation at the site also causes the release of small proteins called cytokines that help regulate the immune response and attract additional macrophages from the blood stream to the site. This first and immediate response is known as innate immunity. Although rapid, it is non-specific, it is the same for all antigens and the immune system does not retain any memory of the encounter with the antigen.

The different immune defences are carried out by vast selection of immune cells. The innate immune system is made up of leukocytes and other cells such as natural killer cells. Leukocytes include macrophages and neutrophils and the main characteristic of these cells is that they can carry out phagocytosis. Phagocytosis results in destruction of the foreign substance by fusing the digested material with the lysosome.

The lysosome provides harsh conditions to kill the pathogen which includes using specialised lysosomal enzymes and providing highly acidic conditions.

Natural killer cells kill other cells that are ‘stressed’ such as viral or bacterial-infected cells. This is a crucial part of the innate immune system as some bacteria and viruses can get inside cells and so are ‘hidden’ from the innate immune system, such as meningococci and mycobacteria.
The acquired immune system is specific and produces a specific response to the foreign substance that is being encountered. The acquired immune system is stimulated by the innate immune system.

**Acquired immunity:**

Sometimes, the innate response alone is not sufficient to eliminate the antigen. In addition to phagocytosis, macrophages can also transport 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.

The innate immune system stimulates the acquired immune system by showing the acquired immune cells the antigen that the foreign body has. These cells are therefore called antigen-presenting cells (APC). Dendritic cells and macrophages can carry this out and so can also be classified as APC. This occurs after the APC has travelled through the lymphatic system to where the specialised acquired immune cells reside.

The stimulation of the lymphocytes in the lymph nodes, however, produces a strong cascade of lymphocyte activation as one APC cell can stimulate many B and T cells. T cells are specific cells that are involved in the cell-mediated response and B cells are cells involved in the humoral immune response.
B cells and T cells:

B and T cells have different functions. B cells respond to free antigens or those that are on the surface of organisms that circulate outside and between cells of the body, this includes most types of bacteria. However, they cannot recognise antigens located inside cells such as viral proteins or certain bacteria such as Meningococci and Mycobacteria which have adapted to live in cells and therefore make detection by the immune system more difficult.

B cells produce a specific antibody by interacting with the antigen presented by an APC. Antibodies are a complementary match to the antigen and stimulate killing/disposal of the foreign substance.

B cells manufacture antibody, however, most antigens do not stimulate B cells to produce antibody without the help of T cells. The response to these antigens is therefore referred to as T cell-dependent. Unlike B cells, T cells can recognise intracellular antigens provided they are expressed on the cell surface. T cells do not manufacture antibodies but they do secrete cytokines which influence other immune cells.
Humoral response:

B cells circulate with a molecule of a 3-dimensional protein called antibody on their surface. The antibodies, also known as immunoglobulins, have antigen binding sites where the 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. There is also a binding site for macrophages and neutrophils. The part of the antigen that binds to the antibody is known as the epitope.

When one of the antibody molecules has a surfaced receptor with exactly the right shape to recognise the antigen, it binds to it like a lock and key. The B cells then enlarge considerably and become plasma cells which are antibody manufacturing cells capable of producing up to 100,000 antibody molecules a minute. The antibody molecules they produce have receptors with the same shape that recognise the antigen in the first place and this is known as the humoral response. The first time an infection or vaccine antigen is encountered the antibody produced is called immunoglobulin M or IgM. IgM circulates as five molecules bound together with a total of 10 binding sites for rapid and effective binding to antigen. If the same antigen is encountered again, the antibody class changes to immunoglobulin G (IgG). This is known as class switching. Class switching means that the overall structure of the antibody changes apart from the antigen binding domain which stays the same in order to match the antigen.

When an antigen binds to an antibody there can be three outcomes:

1. The binding of the antibody to the antigen will immobilise the foreign substance and neutralise it. This is the case for toxins and other harmful substances.

2. The antibodies surround the foreign substance, which can immobilise it ready for phagocytosis by a cell such as a macrophage.
3. The complement system is activated. The complement system is a major part of the humoral response. After antibodies bind to the foreign body, the complement system can attach. The complement system is made up of complement molecules which are proteins that have protease activity, i.e. can break down other proteins.

The attachment of complement molecules produce a protease cascade whereby one complement molecule breaks down the next, activating its protease activity so that it can breakdown the next complement molecule and so on. The result of the cascade is the production of molecules that can attract other immune cells to the site and also increase vascular permeability so that the immune cells can get to the site easily through the vasculature. Some complement molecules can recognise carbohydrate molecules on the surface of bacteria without the need for antibody binding and some complement binding can actually induce killing by disrupting the plasma membrane of the bacterium.

Cell mediated immunity:

When cells contain intracellular antigens a bit of the antigen is carried to the cell surface using molecules that are part of the major histocompatibility complex or MHC. T cells can recognise a combination of the MHC molecule and the antigen. When the T cells binds to the MHC-antigen complex, the activated cells enlarge, multiply and secret cytokines, which can then affect other immune cells nearby, and other toxic molecules such as granulysin. Granulysin induces apoptosis in the infected cell by generating holes in the membrane. The holes then promote unregulated ion, water and molecule entry into the cell causing cytolysis (osmotic lysis of the cell).

There are various types of T cell; among these are those that can destroy an infected cell known as cytotoxic T cells. Another sort, known as helper T cells, can help and stimulate B cells to produce antibody. 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 the 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.

MHC platforms can also mount antigens that indicate a tumour cell. To a certain extent the immune system can recognise abnormal cells and clear them by inducing apoptosis.
Memory Response:

A few of the B cells are stimulated by the T cells to remain as memory cells and to retain the memory of the antigen antibody encounter. When the memory cells meet the antigen again, either as a natural infection or in a booster dose of vaccine antibodies of the right specificity are produced much more quickly and in greater numbers than during the first response. In contrast to the first response when short lasting IgM is made, the antibody produced is mainly IgG which persists for longer. Each time the memory cells encounter the same antigen the immune response is boosted. Because a pathogen, or a vaccine, may contain many different antigens many different B cells are stimulated at once and many different antibodies may be produced. The capacity of our immune system is enormous and can make billions of different antibodies. If different vaccines are given at the same time then different antibodies are produced at the same time as well. In a similar way to B cells, there are also T memory cells made as a result of the first encounter with the antigen. When these T memory cells meet the antigen again they are able to respond more quickly and effectively. The specific humoral, cell-mediated and memory responses are known as acquired or adaptive immunity.

Vaccinations:

Vaccination stimulates the immune responses that have just been described, but importantly, it does so without the risks of the disease itself. It works by stimulating a pool of memory B and T cells to be made which, if and when the antigen is subsequently encountered, produce antigen specific responses fast enough to prevent disease developing. It also stimulates production of antigen specific antibody including IgG which persists after vaccination and provides early defence against infection. Knowledge of how vaccines work with the immune system allows us to understand the vaccine schedule more clearly.

When an individual is vaccinated, the processes in the immune system that are stimulated to mimic natural immunity are antigen recognition, antibody production and a formation of a memory response. This all occurs without disease progression. The vaccine will contain the antigen of the disease, or a toxoid (an inactive version of a toxin) if the disease in question is caused by a toxin such as diphtheria or tetanus. In some cases, the vaccination can be administered via a nasal spray like the childhood flu vaccine which means the vaccine is taken up through the nasal lining.

The antigens within the vaccine are then recognised by the immune system as described earlier, and are taken up by APC, and the APC travels and is transported to the lymph nodes. The antigen is then presented to B cells which cause the production of antibodies and generations of memory B and T cells. If the individual being vaccinated then comes into contact with the actual pathogen bearing the same antigen, a memory response is stimulated resulting in clearance of the pathogen without the occurrence of disease.
Booster vaccinations are given to keep circulating antibody numbers at high levels. If they are missed then the memory response may be weakened and may result in the individual contracting the disease.

In the case of the flu, annual/seasonal vaccinations are administered because the influenza virus is able to change its antigens on its surface resulting in the need for a different vaccination for the different antigens.

This change in antigens can arise from one of two ways; antigenic shift and antigenic drift. Antigenic shift is where two or more different strains of virus combine to form a new virus. This occurs if an individual is infected with different viruses at one time. Antigenic drift is when the antigen on the virus gradually changes over time due to a change in the genetic material inside the virus. This can occur if the genetic material undergoes a mutation.

**What is herd immunity and why is it important?**

A small proportion of people in every population does not respond to vaccines and remain unprotected despite vaccination. In addition, people who are severely immune-compromised are unable to receive live vaccines. Therefore, these people are dependent on not being exposed to infection in the first place. If a sufficient number of people are vaccinated in the population vaccine preventable infections are not able to transmit successfully because most people are immune. Therefore, people who are susceptible are indirectly protected by the presence of these immune individuals. This is known as herd immunity. High levels of vaccine coverage must be maintained in the population to achieve and preserve herd immunity and to protect those who cannot be immunised.
References and additional reading


Other Web links:

[WHO introduction to vaccines](#)

[NHS How vaccines work](#)