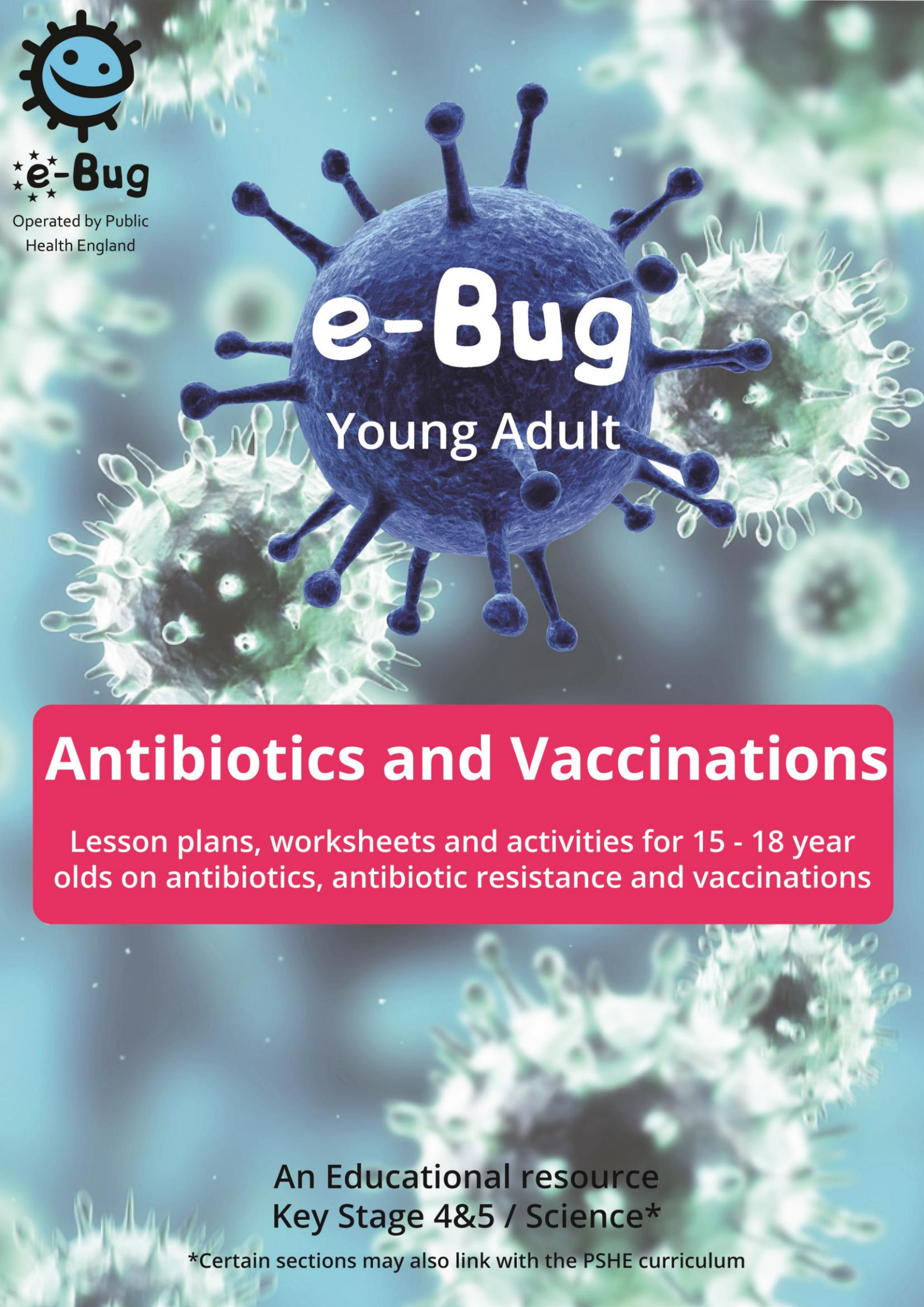

e-Bug
Operated by Public Health England
e-Bug
Young Adult
Antibiotics and Vaccinations
Lesson plans, worksheets and activities for 15 - 18 year olds on antibiotics, antibiotic resistance and vaccinations
An Educational resource
Key Stage 4&5 / Science*
*Certain sections may also link with the PSHE curriculum

Contents

This pack contains a series of educational resources for young adults aged 15-18 years on the topic of antibiotics, antibiotic resistance and vaccinations. The resources are outlined below:

Antibiotics

Vaccinations

Antibiotics

Lesson plans, worksheets and activities

Introduction

This lesson plan covers antibiotics and explores the use of antibiotics and the rise of resistant bacterial strains. An animation and presentation is provided to introduce how antibiotics work, how resistance arises and how resistance spreads. Students can then test their knowledge on antibiotic use in the common misconceptions quiz, before comparing their answers to a wider population. Worksheets cover key topics and students are asked to analyse data through tables and graphs.

Learning Outcomes

- Antibiotics do not work on viruses, as bacteria and viruses have different structures.
- Bacteria are continually adapting to develop ways of not being killed by antibiotics, this is called antibiotic resistance.
- Taking antibiotics also affects your useful bacteria, not just the ones causing an infection.
- Antibiotic resistant bacteria can be carried by healthy or ill people and can be passed on silently to others.
- Antibiotic resistance spreads between different bacteria within our body.
- Controlling antibiotic resistance is everyone's responsibility including you.

Exam Specification Links

This lesson plan covers several topics found in the AQA, OCR, Edexcel and WJEC exam specification for A-level Biology, Human Biology and related subjects. More information can be found on our 'Examination Links' webpage.

Key Words

Antibiotic, Antibiotic resistance, Antibiotic development, Broad spectrum, Narrow spectrum, Viruses, Horizontal gene transfer, Vertical gene transfer

Materials required

Graph paper for completion of SW2

Available web resources

Animation and presentations available on the e-Bug Young Adult teacher website

Background Information

Antibiotics are used to treat bacterial infections such as meningitis, tuberculosis and pneumonia. They do not work on viruses, so antibiotics cannot treat viral infections such as colds and flu. Antibiotics work by targeting structures unique to bacteria; thereby they do not cause damage to human cells and they do not kill viruses.

Antibiotics are either bactericidal, meaning they kill the bacteria, or they are bacteriostatic, meaning they slow the growth of bacteria. Penicillin is an example of a bactericidal antibiotic, which targets the peptidoglycan layer in the cell wall leading to cell death. Bacteriostatic antibiotics interfere with processes the bacteria need to multiply, such as protein production, DNA replication or metabolism.

Antibiotics can be narrow spectrum, affecting only one or two species of bacteria, or broad spectrum, affecting many different species of bacteria in the body, including useful bacteria in the gut. As a result of killing many bacteria in the gut, broad spectrum antibiotics are more likely to cause diarrhoea.

Bacteria are continually adapting to develop ways of not being killed by antibiotics. This is called antibiotic resistance. Resistance develops due to mutations in the bacterial DNA. The genes for antibiotic resistance can spread between different bacteria in our bodies through horizontal gene transfer, which includes transformation, transduction and conjugation. Resistance genes can also spread by vertical gene transfer when genetic material in chromosomes is passed from parent to offspring during reproduction.

Antibiotic resistant bacteria can be carried by healthy or ill people and can spread to others just as other types of microbes would, for example by shaking hands or touching all types of surfaces on animals, vegetables or food where bacteria are present.

Antibiotic resistance arises in our bodies bacteria, or in animals, due to the overuse and misuse of antibiotics. The more often a person takes antibiotics, the more likely they are to develop antibiotic resistant bacteria in their body. To prevent resistance, antibiotics should only be taken as prescribed by a doctor or nurse. The important points to remember are:

1. antibiotics do not need to be taken for colds and flu or most coughs, sore throats, ear infections or sinusitis as these usually get better on their own

2. it is important to take the antibiotic exactly as instructed and complete the course of antibiotics, to decrease the risk of emergence of resistance

3. antibiotics are personal and prescribed for individuals and for a particular infection. They should not be shared or taken for a different illness

Introduction (20mins)

1. Explain that students are going to learn about how antibiotics work to kill bacteria and how the bacteria are fighting back and becoming resistant to the antibiotics. Antibiotic resistance is becoming an increasing problem worldwide and it can affect everyone – antibiotic resistant bacteria can easily spread from person to person. It is everyone's responsibility to ensure antibiotics are used correctly.
2. Show the students the 2 minute Antibiotic Guardian video to introduce the topic. The video is available at http://antibioticguardian.com.
3. Watch the e-Bug animation on antibiotics. Throughout the animation there are choice points to allow for a pause and discussion with the students. A teacher sheet to accompany the animation is available, should you wish to provide extra information.
4. Following the animation, view the PowerPoint on antibiotic discovery and development.
5. Highlight that the discovery of new antibiotics has slowed down and explain that many pharmaceutical companies are no longer spending money on developing new antibiotics, due to the increasing problem of resistance.

Main Activity (15-20 mins)

1. View the PowerPoint quiz on common misconceptions associated with antibiotics.
2. Ask the students to vote on true/false before the answer to each question is revealed.
3. Show the students the survey data and discuss how their answers correlate with the rest of the population.
4. Highlight data from the 15-24 age group – this group has a lower understanding of antibiotics than the older population.
5. SH1, containing the quiz answers, can be given to students at the end of the exercise.
6. Provide students with a copy of SW1 and/or SW2 worksheets. SW1 has questions based on the animation, whereas SW2 contains a series of Maths questions around antibiotic resistance rates. Graph paper will need to be provided for completion of SW2.
7. Ask the students to complete the worksheets.

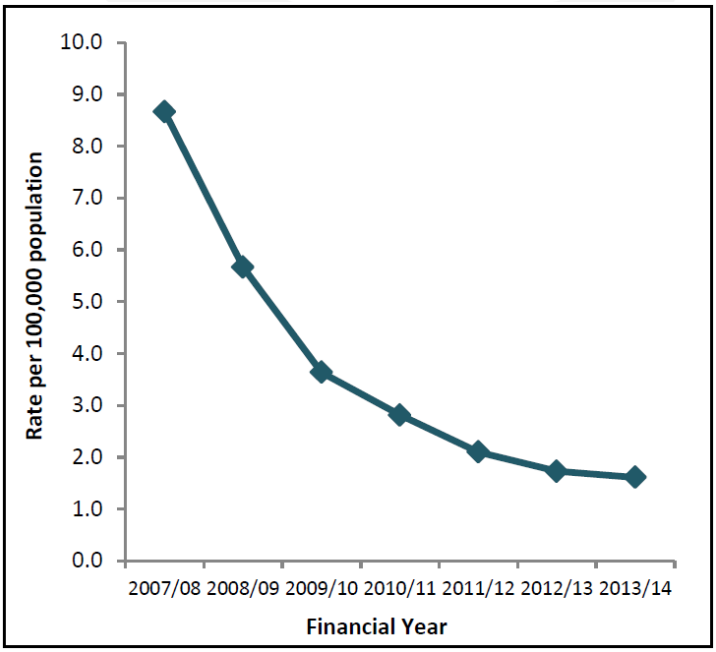
Optional: One or both worksheets can be provided for homework, should time be restricted. The final question on SW1 asks students to create a slogan or poster title that can be used to promote correct antibiotic use to the public and other members of the school community. Students could be asked to design the full poster as homework.

Plenary (10 mins)

1. Discuss the worksheet answers with the students.
2. What is their understanding of antibiotic resistance?
3. Ask what resistant bacteria they have heard of? Describe Methicillin-resistant *Staphylococcus aureus* and tuberculosis as two examples:

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a bacterial strain that is resistant to beta-lactam antibiotics, flucloxacillin and cephalosporins. MRSA infections can be very difficult to treat. MRSA infections are more common in people in hospitals or care settings, but they can also occur in the community. MRSA rates have fallen in the last few years, due to increased awareness, efforts to tackle infection control in hospitals e.g. thorough handwashing and swabbing patients, and reduction of broad spectrum antibiotic use. In 2006, 1.8% of hospital patients were reported to have MRSA and this fell to 0.1% in 2012.

Figure 1. Trend in rates of MRSA bacteraemia between 2007 and 2014. Data taken from the Public Health England Annual Epidemiology Commentary 2013/14



Some antibiotic resistant strains of tuberculosis (TB) are known as Multi-drug-resistant tuberculosis (MDR-TB). These strains are resistant to the two most commonly used antibiotics to treat TB. As of 2013, 3.6% of new tuberculosis cases are caused by MDR-TB. The WHO estimates that there were almost 0.5 million new MDR-TB cases in the world in 2012. MDR-TB can have a mortality rate of up to 80% and the drugs used to treat MDR-TB are more expensive than those used to treat TB and they can have more adverse side effects. To treat TB well you need to take 2, 3 or 4 antibiotics at once. Not taking them correctly (due to lack of money in developing countries or counterfeit antibiotics) has led to increased resistance, so it has now become a major problem.

Extension activity

1. Ask the students to write an essay based on the message from the animation and the common misconceptions they have learnt about during the lesson.
2. They should consider the following points:
    a. What are the most common misconceptions around antibiotics and why might there be such widespread misunderstanding?
    b. How would tackling common misconceptions around antibiotics help to slow or prevent the rise of resistance?
    c. What methods or approaches should be used to tackle misconceptions?
    d. Personal, family or friends experiences of antibiotics can also be included, such as why antibiotics were taken and if the user thought they may have been unnecessary. What would have helped in this situation?

Advance Preparation

1. Locate the animation on the Young Adult Teacher e-Bug website
2. Download the presentations from the Young Adult Teacher e-Bug website
3. Copy SW1 and SW2 for each student

Student Worksheet 1

1. Ciprofloxacin is an antibiotic which kills multiple species of bacteria by inhibiting DNA replication. Is it:

   a. Bactericidal or bacteriostatic? _____

   b. Broad or narrow spectrum? _____

2. Draw an outline of a bacterial cell, including the cellular contents, and label all the areas. Circle areas where antibiotics are active.

3. How do viruses differ from bacteria?

4. What is the difference between conjugation and transformation?

5. How are resistant bacteria spread throughout the community? List as many methods of transmission as you can think of.

6. The correct use of antibiotics can prevent the increase in antibiotic resistance. How should antibiotics be used correctly?

7. Create a slogan or poster title that can be used to promote correct antibiotic use to the public.

1. The data in Table 1 provides information on the number of coliform bacterial strains that were found to be antibiotic resistant in Wales in 2013 (coliforms are a group of bacteria found in the gut). The strains are resistant to amoxicillin, nitrofurantonin or trimethoprim. *E. coli* is a member of the coliform group. The data shows urinary tract infection coliform rates by age group and antibiotic resistance. Data has been provided by Public Health Wales.

Table 1

Year	Antibiotic name	Age group (years)	Number sampled	Number antibiotic resistant	%Resistant
2013	Amoxicillin	<15	4743	2507	
2013	Amoxicillin	15-24	5882	2899	
2013	Amoxicillin	25-49	13746	7282	
2013	Amoxicillin	50-79	36915	21308	
2013	Amoxicillin	80+	20383	13186	
2013	Nitrofurantoin	<15	4712	329	
2013	Nitrofurantoin	15-24	5875	267	
2013	Nitrofurantoin	25-49	13684	827	
2013	Nitrofurantoin	50-79	36799	4453	
2013	Nitrofurantoin	80+	20419	3785	
2013	Trimethoprim	<15	4718	1398	
2013	Trimethoprim	15-24	5880	1636	
2013	Trimethoprim	25-49	13716	4114	
2013	Trimethoprim	50-79	36871	12281	
2013	Trimethoprim	80+	20454	9119	

a. Using the data provided, calculate the % resistance for each age group and add into the table.

b. Describe how resistance varies between antibiotics and between age groups.

c. Describe why antibiotic resistance is higher in the elderly and young.

2. The data in Table 2 shows antibiotic prescription rates and % resistance for the 15-24 age group. The % prescription rates are for all antibiotics across Wales in 2008.

Table 2

Antibiotic	% of total prescriptions	% resistance for 15-24 age group
Amoxicillin	33	
Nitrofurantoin	4	
Trimethoprim	9	
Fluoroquinolones	3	4.3
Cephalosporins	8	4.5
Co-amoxiclav	6	6.0

a. By looking at the data in Table 2 and your % resistance values from question 1, do you think there is a correlation between antibiotic prescribing and antibiotic resistance?

b. Calculate the Spearman's rank coefficient for these two sets of data.

c. What do your results show? Is there a significant correlation between antibiotic prescribing and antibiotic resistance?

3. Table 3 shows the number of urinary tract coliform infections resistant to Trimethoprim by age group and year over the past 5 years. Data has been provided by Public Health Wales.

Table 3

Year	Antibiotic name	Age group (years)	Number sampled	Number antibiotic resistant	%Resistant
2013	Trimethoprim	<16	5318	1567	29.5
2013	Trimethoprim	16-29	8939	2537	28.4
2013	Trimethoprim	30-49	11877	3555	29.9
2013	Trimethoprim	50-64	14755	4659	31.6
2013	Trimethoprim	65-79	25455	8690	34.1
2013	Trimethoprim	80+	22290	9859	44.2
2012	Trimethoprim	<16	5023	1362	27.1
2012	Trimethoprim	16-29	8848	2595	29.3
2012	Trimethoprim	30-49	11411	3355	29.4
2012	Trimethoprim	50-64	14002	4327	30.9
2012	Trimethoprim	65-79	23913	8072	33.8
2012	Trimethoprim	80+	20966	8923	42.6
2011	Trimethoprim	<16	4839	1298	26.8
2011	Trimethoprim	16-29	8298	2291	27.6
2011	Trimethoprim	30-49	11085	3173	28.6
2011	Trimethoprim	50-64	13296	4064	30.6
2011	Trimethoprim	65-79	21673	6935	32.0
2011	Trimethoprim	80+	19492	7843	40.2
2010	Trimethoprim	<16	4401	1126	25.6
2010	Trimethoprim	16-29	7991	2146	26.9
2010	Trimethoprim	30-49	10389	2791	26.9
2010	Trimethoprim	50-64	12286	3667	29.8
2010	Trimethoprim	65-79	19991	6317	31.6
2010	Trimethoprim	80+	18026	6987	38.8
2009	Trimethoprim	<16	4338	1099	25.3
2009	Trimethoprim	16-29	8232	2192	26.6
2009	Trimethoprim	30-49	10473	2826	27.0
2009	Trimethoprim	50-64	12312	3493	28.4
2009	Trimethoprim	65-79	19510	5933	30.4
2009	Trimethoprim	80+	17431	6813	39.1

[Questions overleaf]

a. Using this data, plot a graph of % resistance by year, including data for each age group.

b. Calculate the % change in resistance between 2009 and 2013 for the over 80 age group.

c. Estimate the % resistance in 2017 for Trimethoprim in the over 80's.

d. What is the mean change in resistance per year for Trimethoprim for the 16-29 age group?

e. Between 2010 and 2011, which age group had the largest increase in resistance?

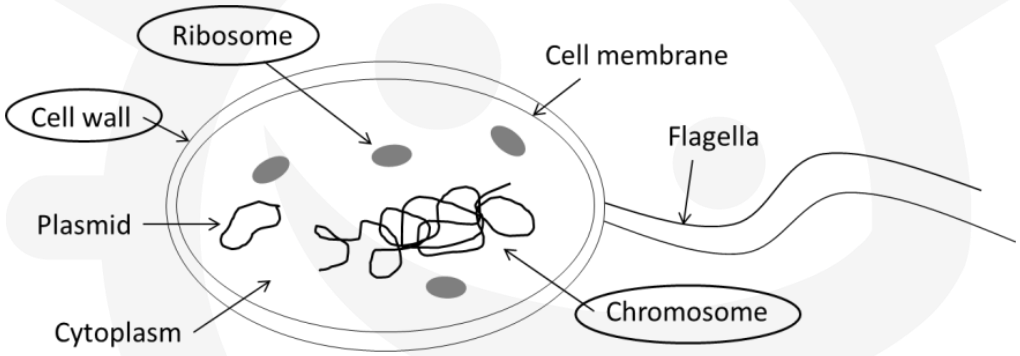
Student Worksheet 1 Answers

1. Ciprofloxacin is an antibiotic which kills multiple species of bacteria by inhibiting DNA replication. Is it:

   a. Bactericidal or bacteriostatic? Bacteriostatic

   b. Broad or narrow spectrum? Broad spectrum

2. Draw an outline of a bacterial cell, including the cellular contents, and label all the areas. Circle areas where antibiotics are active.



3. How do viruses differ from bacteria?

Viruses do not have their own cell machinery for DNA replication, protein synthesis or metabolism. Viruses rely on a host cell for survival. Viruses also do not have a cell wall, unlike bacteria. The virus structure is composed of a capsid, glycoproteins and nucleic acid.

4. What is the difference between conjugation and transformation?

Conjugation: direct transfer of genetic material and DNA between two bacterial cells

Transformation: DNA is released from one bacterium and taken up by another, and there is no direct contact between the two bacteria.

5. How are resistant bacteria spread throughout the community? List as many methods of transmission as you can think of.

Direct skin to skin contact

Touching surfaces, including vegetables and raw meat

Breathing in microbes in the air

Sexual contact

Poor hygiene after visiting the toilet

Water in countries without good sanitation or contaminated with animal slurry

Eating food containing or contaminated with resistant bacteria

Contact with animals carrying resistant bacteria

6. The correct use of antibiotics can prevent the increase in antibiotic resistance. How should antibiotics be used correctly?

Take as prescribed by a doctor or nurse

Do not take for mild infections. Self-care first before going to the GP.

Only take for bacterial infections and not viral infections

Do not share antibiotics or take them for a different infection

Finish the course of antibiotics

7. Create a slogan or poster title that can be used to promote correct antibiotic use to the public.

Student Worksheet 2 Answers

1. The data in Table 1 shows urinary tract infection coliform rates by age group and antibiotic resistance. Data has been provided by Public Health Wales.

a. Using the data provided, calculate the % resistance for each age group and add into the table.

Table 1

Year	Antibiotic name	Age group (years)	Number sampled	Number antibiotic resistant	%Resistant
2013	Amoxicillin	<15	4743	2507	52.9
2013	Amoxicillin	15-24	5882	2899	49.3
2013	Amoxicillin	25-49	13746	7282	53.0
2013	Amoxicillin	50-79	36915	21308	57.7
2013	Amoxicillin	80+	20383	13186	64.7
2013	Nitrofurantoin	<15	4712	329	7.0
2013	Nitrofurantoin	15-24	5875	267	4.5
2013	Nitrofurantoin	25-49	13684	827	6.0
2013	Nitrofurantoin	50-79	36799	4453	12.1
2013	Nitrofurantoin	80+	20419	3785	18.5
2013	Trimethoprim	<15	4718	1398	29.6
2013	Trimethoprim	15-24	5880	1636	27.8
2013	Trimethoprim	25-49	13716	4114	30.0
2013	Trimethoprim	50-79	36871	12281	33.3
2013	Trimethoprim	80+	20454	9119	44.6

b. Describe how resistance varies between antibiotics and between age groups.

Resistance to amoxicillin is much higher than the other two antibiotics. Nitrofurantoin has the lowest resistance. Resistance for all antibiotics is highest in the over 80's.

c. Describe why antibiotic resistance is higher in the elderly and young.

Prescribing of antibiotics is higher in the elderly and young, due to their weakened immune system. Also the elderly have had a lifelong exposure to antibiotics – repeated courses of antibiotics leads to an increase in resistance.

2. The data in Table 2 shows antibiotic prescription rates and % resistance for the 15-24 age group. The % prescription rates are for all antibiotics across Wales in 2008.

Table 2

Antibiotic	% resistance for 15-24 age group	% of total prescriptions
Amoxicillin	49.3	33
Nitrofurantoin	4.5	4
Trimethoprim	27.8	9
Fluoroquinolones	4.3	3
Cephalosporins	4.5	8
Co-amoxiclav	6.0	6

a. By looking at the data in Table 2 and your % resistance values from question 1, do you think there is a correlation between antibiotic prescribing and antibiotic resistance?

The data appears to show a correlation between antibiotic prescribing and antibiotic resistance. Amoxicillin has the highest prescribing rate and also the highest resistance.

b. Calculate the Spearman's rank coefficient for these two sets of data.

Antibiotic	% resistance for 15-24 age group (X)	% of total prescriptions (Y)	Rank X	Rank Y	*d*	d^2
Amoxicillin	49.3	33	6	6	0	0
Nitrofurantoin	4.5	4	3	2	1	1
Trimethoprim	27.8	9	5	5	0	0
Fluoroquinolones	4.3	3	1	1	0	0
Cephalosporins	4.5	8	3	4	-1	1
Co-amoxiclav	6.0	6	4	3	1	1
						$\Sigma d^2 = 3$

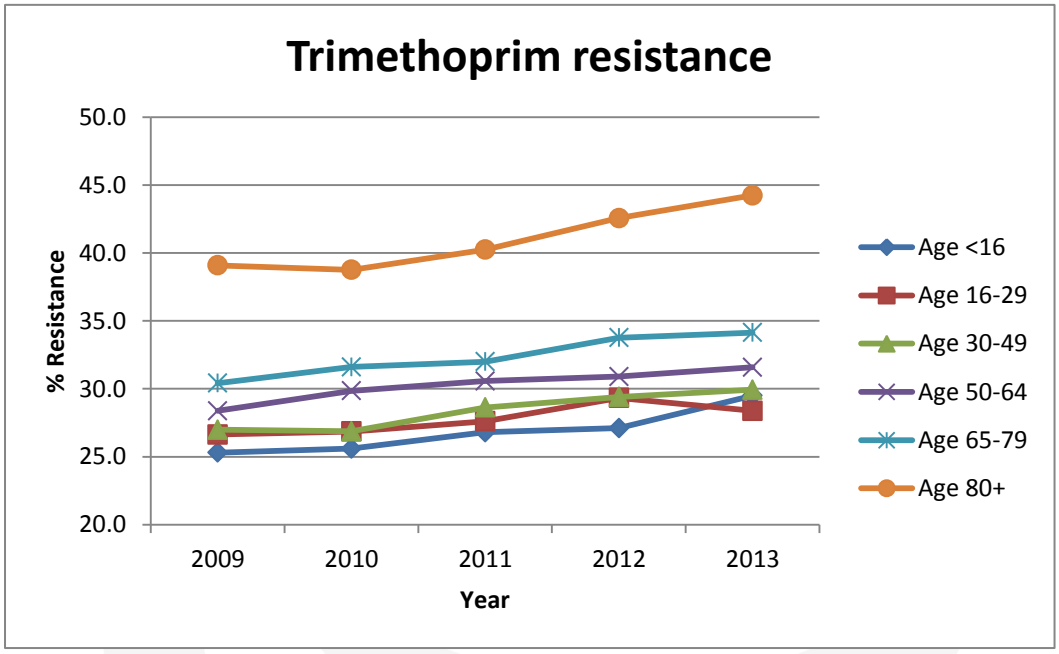
$$p = 1 - \frac{6 \Sigma d2}{n(n2-1)} = 1 - \frac{(6x3)}{6 \times (62 - 1)} = 0.914$$

c. What do your results show? Is there a significant correlation between antibiotic prescribing and antibiotic resistance?

The results show that there is a significant correlation between antibiotic prescribing and antibiotic resistance (p is close to 1)

3. Table 3 shows the number of urinary tract coliform infections resistant to Trimethoprim by age group and year over the past 5 years. Data has been provided by Public Health Wales.

a. Using this data, plot a graph of % resistance by year, including data for each age group.



b. Calculate the % change in resistance between 2009 and 2013 for the over 80 age group.

[(44.2 – 39.1)/39.1] x 100 = 13%

c. Estimate the % resistance in 2017 for Trimethoprim in the over 80's.

If resistance increased by another 13%, in 2017 the resistance for trimethoprim in the over 80's would be 50%

d. What is the mean change in resistance per year for Trimethoprim for the 16-29 age group?

2009-2010 = 1.1% change
2010-2011 = 2.6% change
2011-2012 = 6.2% change
2012-2013 = 3% change
Average = 3.2% change in resistance

e. Between 2010 and 2011, which age group had the largest increase in resistance?

The 30-49 age group.

Antibiotics Fact or Fiction Quiz – Answer sheet

Antibiotics can kill viruses – **False**

Antibiotics can only be used to treat bacterial infections due to the different structures of bacteria and viruses. Antibiotics work by targeting specific parts of the bacteria, e.g. the cell wall, or only parts of the ribosome that are found in bacteria, and therefore are only effective against bacterial infections.

You don't need to finish a course of antibiotics if you are feeling better – **False**

Taking an antibiotic incorrectly increases the risk of the bacteria in your body developing antibiotic resistance. If you do not complete the course the infection may also not be completely killed. You should always take antibiotics as instructed by the nurse or doctor and ensure you complete the course.

Not taking the correct dose (one or two capsules a day instead of three) means you get less antibiotic in the area of the infection. These lower concentrations can encourage the multiplication of resistant strains.

Left over antibiotics can be saved for use at a later date – **False**

You should not have any leftover antibiotics if you complete the course as prescribed, however if you do, take the unwanted antibiotics to a pharmacy to be disposed of safely.

You should not share antibiotics – **True**

Each antibiotic that is prescribed is personal to you and specific to your type of infection. Therefore antibiotics taken for one infection will probably not work for another.

Taking antibiotics weakens your immune system – **False**

Most antibiotics do not negatively affect your immune system, so do not reduce your ability to fight off future infections. Antibiotics are designed to target bacteria, by directly killing them or slowing their growth.

The body does not become resistant to antibiotics. It is the bacteria that become resistant through genetic mutations.

Healthy people carry antibiotic resistant bacteria – **True**

Antibiotic resistant bacteria can be carried by healthy or ill people. Antibiotic resistant bacteria can be passed on easily to others through contact (sneezes and coughs), everything we touch or even our poo!

It is everyone's responsibility to help control antibiotic resistance.

Antibiotic use in animals is causing most of the antibiotic resistance seen today – **False**

The use of antibiotics in animal feed to promote growth has been banned in the EU since 2006, due to concerns about increasing antibiotic resistance.

Increasing scientific evidence suggests that antibiotic resistance in humans is primarily the result of antibiotic use in people, rather than in animals.

Antibiotic use in hospitals is causing most of the antibiotic resistance seen today – **False**

Hospitals are not responsible for the high antibiotic use in humans. In 2013, 79% of all antibiotics consumed were prescribed in the community, by your GP.

Only 15% were prescribed by hospitals, with 6% from other community prescribers such as dentists.

Washing my hands helps to reduce antibiotic resistance – **True**

Hand washing is the most important thing we can do to prevent the spread of infection. Antibiotic resistance bacteria can spread from person to person just as any other type of bacteria would. This includes through skin to skin contact and by touching surfaces where bacteria are present.

Antibiotic resistant bacteria can spread more easily in hospitals, as many patients are having complex treatments which require many different staff to be involved. Hand washing is therefore particularly important in hospitals and other healthcare settings.

Teacher Sheet

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

The animation is divided into 4 clips.

Clip 1

The body contains many different types of bacteria, not all of which are pathogenic. If a person is infected by pathogenic bacteria, the infection can be treated with antibiotics. Antibiotics can be bacteriostatic or bactericidal.

Bacteriostatic antibiotics:

Static means to stop. Bacteriostatic antibiotics slow the growth of bacteria by interfering with processes the bacteria need to multiply. Bacteriostatic antibiotics work with the body's immune system to remove the bacteria. Processes affected by bacteriostatic antibiotics include:

1. Protein production: Antibiotics that inhibit or slow protein synthesis target the ribosome and bind to either the 30S or 50S subunit, depending on the class of antibiotic. The antibiotic can block the initiation step, elongation step or peptide release step of protein synthesis. Examples of bacteriostatic antibiotics that target protein synthesis include tetracyclines and oxazolidinones. These antibiotics are toxic to bacterial cells and not human cells due to the faster rate of protein synthesis seen in bacteria.

2. DNA replication: Some antibiotics slow down DNA synthesis by binding to components involved in the process, such as DNA gyrases or topoisomerases. Quinolones are antibiotics which target DNA replication. Quinolones are selective for bacteria as they do not affect human DNA gyrases or topoisomerases.

3. Metabolism: Antibiotics can affect metabolic enzyme activity, most notably by disrupting the folic acid pathway. Sulfonamides and trimethophrim prevent the production of folic acid by targeting and binding to the dihydropteroate synthase and dihydrofolate reductase enzymes respectively. Humans do not synthesis folic acid and so these antibiotics have no effect on human cells.

Bactericidal antibiotics:

Cidal means to kill. Bactericidal antibiotics kill bacteria, for example by preventing bacteria from making a cell wall. Humans do not have a cell wall, so this class of antibiotics is selective for bacteria. Penicillins disrupt cell wall formation in bacteria by binding to the DD-transpeptidase enzyme which forms crosslinks between peptidoglycan in the cell wall. Without these crosslinks the bacterial cell bursts, leading to cell death.

It is important to note that some antibiotics which are bacteriostatic against one species of bacteria, may be bactericidal against a different species. The concentration of antibiotic also determines whether it will have a bacteriostatic or bactericidal effect. This is one reason why taking the antibiotic exactly as prescribed is so important – for example, a 3x daily dose of antibiotic taken only twice daily will lead to a lower concentration at the site of infection.

Broad spectrum antibiotics affect many different species of bacteria, including useful bacteria in the human gut. Narrow spectrum antibiotics only affect one or two types of bacteria.

Viruses rely on a host cell for replication. They do not have their own cell machinery for DNA replication, protein synthesis or metabolism and so are not affected by bacteriostatic antibiotics. They also do not have a cell wall. Antibiotics therefore only affect bacterial cells.

Clip 2

Bacteria naturally develop resistance to antibiotics. Resistance arises due to mutations in the bacterial DNA. These mutations can affect antibiotic action by:

1. Causing inactivation of the antibiotic, for example some penicillin-resistant bacteria produce β-lactamases which deactivate penicillin G
2. Altering the target site that antibiotics bind to
3. Altering metabolic pathways in order to survive, despite the inhibition of key enzymes by antibiotics
4. Preventing antibiotics entering the cell, or pumping antibiotics out of the cell

It is important to highlight to students that people do not become resistant to antibiotics. It is the bacteria within the body that develops resistance.

When bacteria are exposed to antibiotics, resistant strains have a selective advantage and they survive and multiply. The more often that bacteria are exposed to antibiotics, the quicker the resistant strains multiply. Therefore the overuse and misuse of antibiotics speeds up the development and spread of resistance.

Clip 3

Antibiotic resistance can spread between different bacteria in the body via the transfer of genetic material. This can happen between different species of bacteria. There are two ways in which resistance can spread – horizontal gene transfer and vertical gene transfer.

Horizontal gene transfer occurs when mobile genetic elements are transferred from one bacterium to another. The bacteria do not need to be of the same species or genus. Much of this gene transfer activity goes on in the human gut. Horizontal gene transfer can occur through:

1. Transformation – the direct uptake of short DNA fragments from the surrounding environment. These DNA fragments contain antibiotic resistance genes and are released from one bacterium before being taken up by another. The DNA crosses the cell membrane and is then integrated into the recipient bacterium's chromosome.
2. Transduction – the injection of DNA, containing antibiotic resistant genes, into a bacterium by a bacteriophage virus. The phage infects a bacterium and replicates. During this replication, pieces of the bacterial DNA may be inserted into the phage genome. The phage is then released and it infects a second bacterium, transferring the DNA.
3. Conjugation – the direct transfer of DNA between two bacterial cells. A pilus forms between two bacterial cells, allowing direct cell-to-cell contact. A plasmid contacting the antibiotic resistant gene is then transferred from the donor bacterium to the recipient bacterium. Conjugation differs from transformation and transduction in that direct contact is required between the two bacteria.

Vertical gene transfer occurs during reproduction as genetic material, containing antibiotic resistance genes, is passed from parent to offspring. Vertical gene transfer only occurs between the same bacterial species.

Antibiotic resistant bacteria are carried silently by healthy and ill people. After finishing a course of antibiotics, resistant bacteria can remain in our bodies for at least a year. These bacteria can spread to others just as any other microbes would, for example through person to person contact such as touch.

Clip 4

This clip describes two studies that investigated the use of antibiotics.

Study 1: A study looked at a population with a sore throat. 246 patients in the study were treated with antibiotics and 230 patients were prescribed rest and fluid. After 3 days, 37% of those treated with antibiotics were feeling better and 35% of those treated with rest and fluid were feeling better. What conclusions can be drawn from this study?

The study demonstrates that many infections get better on their own without the need for antibiotics. Sore throats can often be caused by viral infections, and as such antibiotics will have no effect on the time of recovery. You should care for yourself at home for most sore throats, earache, coughs, colds and flu using painkillers and other remedies to reduce symptoms.

Study 2: A second population has a bacterial infection which requires antibiotics. 95 patients take antibiotics for 10 days, whereas 96 patients only take antibiotics for 7 days. At the end of the course of antibiotics, the reoccurrence of the infection was assessed. 18% of those who took antibiotics for 10 days had a reoccurrence of infection, whereas 31% of those who only took antibiotics for 7 days had a reoccurrence. What conclusions can be drawn from this study?

This study demonstrates the importance of completing the course of antibiotics. By not completing the course, bacteria may remain in the body and cause a reoccurrence of the infection. This bacteria is also at risk of becoming antibiotic resistant, due to exposure to the antibiotics. It is important to take the full course of antibiotics as prescribed by your doctor or nurse.

References and additional reading

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Introduction

Within this lesson plan, students aged 16-18 years will run a 1 hour lesson with other young people. The lesson can be delivered to students in key stage 2 (ages 7-11), key stage 3 (ages 11-14), key stage 4 (ages 14-16), or even other key stage 5 students.

Information for Teachers

Value of peer education

Peer education is becoming an increasingly popular educational tool due to the benefits for all involved. For the peer educators, benefits can include positive changes in knowledge, skills, attitudes and confidence, and development of key communication and social skills. By teaching others, students gain a deeper understanding of the topics covered, and have increased knowledge in the area, when compared to didactic learning.

Students taught by their peers may identify more closely with their educator, which allows the development of positive relationships and a greater level of trust between educator and student.

What is covered?

Within this lesson plan, all students will cover the important topics of antibiotics and antibiotic resistance. Not only will students learn the science behind how antibiotics work and how resistance to antibiotics comes about, they will also learn essential health information, such as how to take antibiotics correctly, which is important for PSHE education.

The lesson plan is designed to cover topics in key stage 5; these topics are then presented in a simplified and understandable way for younger students, allowing both the students and peer educators to learn key information around this area.

Running the lesson

The lesson set-up is flexible and can be arranged to suit any educational establishment. Peer educators could be split up to teach all classes across a year group, for example with five to six key stage 5 students teaching each class. The peer educators should work in small teams, of between 2 and 6 students, to deliver the lesson, deciding between themselves how to divide up the lesson delivery.

A range of activities are provided in this lesson plan and peer educators should choose the activities which best suit the age and ability of their audience. The peer educators should be encouraged to adapt the activities and script to suit their own style. The information provided here can be used as a guide. Allow the peer educators time to prepare and practice before the lesson delivery.

Optional homework is also provided for those being peer educated. This could be marked by the peer educators, allowing them to receive feedback on their lesson.

Introduction

National curriculum/exam specification links

Key Stage 5 (age 16-18):

This lesson plan covers several topics found in the AQA, OCR, Edexcel and WJEC examination specification for Biology, Human Biology and related subjects. More information can be found on our 'Examination Links' webpage.

Key Stage 3/4 (age 11-15):

Biology –

- Working Scientifically – Scientific Attitudes, Experimental skills and investigations, Analysis and evaluation
- Structure and Function of Living Organisms - Cells and Organisations

PSHE - Core Theme 1: Health and Wellbeing

Key stage 2 (age 7-11):

Science –

- Working Scientifically
- Animals, including humans

PSHE – Core Theme 1: Health and Wellbeing

Introduction

Learning outcomes for key stage 5

- Many infections get better on their own without the need for antibiotics
- Bacterial and viral infections may cause similar symptoms
- Antibiotics work on bacteria and have no effect on viruses
- Bacteria are continually adapting to develop ways of not being killed by antibiotics (known as antibiotic resistance)
- Antibiotic resistance can spread between different bacteria in our body
- Antibiotics can affect all the bacteria in your body, not just the ones which cause an infection.
- Antibiotic resistant bacteria can be carried by healthy or ill people and passed on silently to others
- The more often you take antibiotics, the more likely you are to have an antibiotic resistant infection
- You should not share antibiotics as each antibiotic is personal to you and your infection.
- Antibiotics should always be taken as instructed by a doctor or nurse, because overuse may make the antibiotics less effective against the bacteria, and then the next time we have an infection they may not work.

Background information for Peer Educators

Antibiotics are special medicines which can only be prescribed by a doctor or nurse. Antibiotics are used to treat bacterial infections such as meningitis, tuberculosis and pneumonia. They do not work on viruses, so antibiotics cannot treat viral infections such as colds and flu. Penicillin was the first antibiotic to be discovered in 1928 by Alexander Fleming and is still used to treat some sore throats and pneumonia today. Other examples of antibiotics include amoxicillin for chest infections, flucloxacillin for skin infections and trimethoprim for urine infections.

Antibiotics can be broad spectrum, affecting many different species of bacteria, or narrow spectrum, affecting only one or two. Antibiotics work by targeting structures unique to bacteria, so they are not dangerous to human cells and they do not kill viruses. Targets include the bacterial peptidoglycan cell wall, the ribosome (needed for protein production), DNA replication (needed for cell division) and metabolic enzyme activity (needed for cell growth).

Bacteria are continually adapting to develop ways of not being killed by antibiotics. This is called antibiotic resistance. Resistance develops due to a change in the bacterial DNA. These genes for antibiotic resistance can then spread between different bacteria in our bodies. Antibiotic resistant bacteria can be carried by healthy or ill people and can spread to others just as other types of microbes would, for example via hands or by touching surfaces where bacteria are present.

Antibiotic resistance arises due to the overuse and misuse of antibiotics. The more often a person takes antibiotics, the more likely they are to develop antibiotic resistant bacteria in their body. To prevent resistance, antibiotics should only be taken as prescribed by a doctor or nurse. The important points to remember are:

1. Many infections get better on their own, without the need for antibiotics
2. Antibiotics should only be taken for bacterial infections and not viral infections such as colds and flu, and most coughs, sore throats, ear infections or sinusitis
3. It is important to take antibiotics exactly as instructed (for example three times daily), to ensure all bacteria within your body are killed and to prevent the development of antibiotic resistance
4. Antibiotics are personal and prescribed for individuals and for a particular infection. They should not be shared or taken for a different illness

Section 1: Introducing Antibiotics (15-20 mins)

Materials required: Student hand out on the three types of microbes and their relative sizes – available on the e-Bug Senior Teacher Microbes website (Microbe Fact Sheet SH1).

Begin by asking the students if they know three types of microbes that can cause infections – bacteria, virus and fungi, and explain the relative sizes of the microbes. A student hand-out is available to help with this explanation. Explain that infections are treated differently depending on the microbe that has caused it.

Introduce antibiotics – ask who has heard of them and if anyone knows which microbe they affect.

Choose the activity below which best suits the age and ability of your audience.

1a. KS2 Activity (ages 7-11):

Background: This demonstration will help you to show the students the difference in sizes between the microbes.

Materials required: Balloons, funnel and glitter

Preparation: Using a funnel, pour some glitter inside a balloon and blow the balloon up.

Tell the students that you are now going to use a demonstration to show the sizes of the different microbes. Explain that microbes are found everywhere but they are too small to be seen with the naked eye.

1. Ask students which microbe is the largest? Give examples of useful and harmful fungi such as Penicillium (useful) and athlete's foot (Harmful).
2. Next ask which the middle size microbes are. Again give examples of useful and harmful bacteria such as bacteria used in food production, such as yoghurt (useful), and bacteria which cause chest infections (harmful). Explain that bacteria come in different shapes: rods, balls or spirals.
3. Tell students to imagine a fungus the size of the room they are in. If a fungus is this big, how big do they think the bacteria would be? Show the students the balloon – the bacteria would be about the size of the balloon.

4. Ask students which microbes are the smallest. Viruses are generally harmful and cause illnesses like colds and flu.
5. Now ask students how big a virus would be if the balloon represented the size of bacteria. Pop the balloon and explain that a virus would be the size of a piece of glitter, and that viruses can only survive inside other living things such as human cells or bacteria. Remind students that antibiotics only work on bacteria, as bacteria differ to other microbes. This is why antibiotics cannot be used to treat colds and flu which are caused by viruses.

KS3/4/5 Activity (age 11-18):

Background: Explain that they are now going to look in more detail at the differences between human cells, bacterial cell and viruses, to try and understand why antibiotics only affect bacteria.

Materials required: Paper, pencils and scissors

Preparation: Research the role of microbe cellular components. Research illnesses causes by viruses and bacteria, whether you can easily tell the difference, and how you would treat them.

Give the students 3 pieces of paper, one for a bacterium, a virus and a human cell. Ask the students to work in pairs to fill in the cells with the correct cellular contents (these can be drawn in or cut out from additional pieces of paper). The cells should contain:

- Human cell contains: a nucleus, a mitochondria, a cell membrane (for KS5 also include ribosome)
- Bacterial cell contains: free DNA plasmid (not in nucleus), a cell wall, a cell membrane
- Viral cell contains: free DNA (not in nucleus), a protein coat

Ask students if they know the function of the different microbe cellular components?

Explain that antibiotics target structures unique to the bacteria and this is why they do not harm human cells, and why they do not work on viruses.

Ask the students if they know any illnesses caused by viruses? Is it easy to tell the difference between bacterial and viral infections? How should viral infections be treated?

It is also important to say that many bacterial infections get better on their own without antibiotics.

Section 2: Antibiotic Resistance (15-20 mins)

Materials Required: Antibiotic resistance presentation – available on the e-Bug Senior Teacher Antibiotic website.

Preparation: Research information on MRSA and TB. Information can be found on the Public Health England, NHS Choices, MRSA Action UK and the Stop TB Partnership websites.

Prepare a short presentation on the discovery of antibiotics and antibiotic resistance. The presentation available on the senior student e-Bug website may be used, or alternatively you can use a presentation that you have prepared yourself. It is important to make the presentation fun without too many words and appropriate for the age group you are teaching.

Introduce antibiotic resistance by explaining that bacteria are continually developing ways to avoid being killed by antibiotics, and that this is known as antibiotic resistance. Antibiotic resistant bacteria can be very dangerous as they cannot be treated.

Ask if anyone has heard of MRSA? Describe MRSA and antibiotic resistant TB.

Next, give the students the short presentation on the discovery of antibiotics and antibiotic resistance.

Now explain that you will show a demonstration to describe antibiotic resistance.

2a. Activity: Demonstrating antibiotic resistance using balloons

Materials required: Balloons, sellotape or parcel tape, pin, glitter

Preparation: Blow up around 4 balloons in one colour and 2 balloons in another colour (yellow and red are used here to describe the demonstration). Add a strip of sellotape or parcel tape to the end of the two balloons which are a different colour. Clear parcel tape works the best; if sellotape or brown parcel tape is used, several layers may be required for the experiment to work. The sellotape is best placed on the end of the balloon where the balloon is thickest. You could also put glitter in the balloons before you blow then up, to represent viruses.

Explain to the students that the yellow balloons represent bacteria and the red balloon with tape on represents antibiotic resistant bacteria. The pin represents the antibiotic.

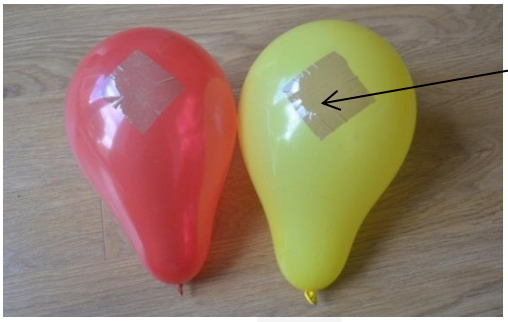
Brown tape is used for demonstration but clear parcel tape is ideal to use as resistant is carried slightly/invisibly in people who are not ill.

When we give an antibiotic, bacteria are killed or damaged – pop some yellow balloons with the pin. If you put glitter in the balloon it also demonstrates that viruses are not killed by antibiotics and can continue to spread. In particular, one group of antibiotics (the penicillins) damage the bacterial cell wall. However in bacteria that are antibiotic resistant, the cell walls are now not affected by the antibiotics – put the pin through the sellotape in the red balloons, it will not pop.

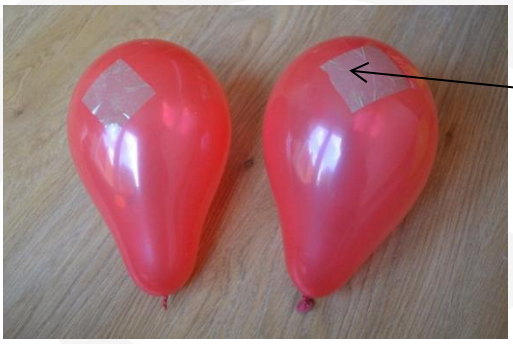
This makes it more likely for the resistant bacteria to survive and reproduce. They have a selective advantage.

Ask if anyone knows where resistance comes from? Explain it is due to a change in the bacterial DNA/genes that tell the bacteria how to make the cell wall or enzyme.

Explain that bacteria can pass these resistant genes on to other bacteria – put sellotape on a remaining yellow balloon, which represents the transfer of antibiotic resistance to another bacterium. This can happen in our body



Resistance is also passed on when bacteria reproduce – demonstrate this by blowing up another red balloon and putting sellotape on in.



Explain that resistant bacteria can be passed from person to person just as normal bacteria can be. Ask how these bacteria can spread? The easiest way is via our hands. Examples include direct skin to skin contact or touching surfaces which may contain bacteria.

The next activity demonstrates how easily resistant bacteria spread.

2b. Activity: Demonstration of spread of antibiotic resistance using coloured glitter

Background: This activity demonstrates how microbes, including antibiotic resistant bacteria, spread easily from person to person.

Materials required: Red and gold glitter. Six steps of handwashing handout – available on the e-Bug Junior Hand Hygiene Teacher website.

Use red and gold glitter, or 'dust', to demonstrate the spread of microbes. Gold glitter represents bacteria and the red glitter represents the antibiotic resistant bacteria. Remind participants that microbes are found everywhere and can spread easily through touching surfaces and person-to-person contact.

Put both gold and red glitter on one or two participants' hands and ask them to touch various things around the room and shake hands with other members of the group.

Look at how far the coloured glitter has spread and discuss with the group that bacteria and antibiotic resistant bacteria both spread very quickly. Remind everyone that antibiotic resistant bacteria spreads just as easily as any other type of microbe.

Explain to students that washing our hands is the best way to remove microbes from our hands before they spread to others. We should wash our hands before and after preparing food, after using the toilet, after touching animals and after coughing or sneezing.

Demonstrate how we should wash our hands properly using the 6 steps of handwashing handout. Ask the students to wash their hands using the 6 steps to remove the glitter.

For older students, you may wish to use the following activity.

2c. KS3/4/5 Activity (ages 11-18): Antibiotic resistance debate

Materials required: Antibiotic Resistance debate kit – available on the e-Bug Young Adult Teacher website.

The e-Bug debate kit on antibiotic resistance may be used to help stimulate discussion on the topic. The debate kit has eight character cards, each with facts about antibiotic resistance and use for the students to read and questions for discussion. The debate kit has full instructions for how to run the activity.

Section 3: Taking Antibiotics Correctly (15 mins)

To prevent bacteria becoming resistant to antibiotics, we should always take antibiotics correctly, as the doctor or nurse prescribes.

The more often we take antibiotics, the more likely we are to have antibiotic resistant bacteria in our bodies. Therefore overusing antibiotics may make them less effective.

Ask if anyone knows what we mean by responsible use of antibiotics?

Choose the activity below which best suits the age and ability of your audience.

3a. KS2 Activity (age 7-11): Antibiotic cartoon storyboard

Materials required: Cartoon storyboard– available on the e-Bug Young Adult Teacher website (Student Handout 1)

The cartoon storyboards shown in student handout 1 describe how antibiotics should be taken. Discuss these with the students. The correct ways are:

- Only using antibiotics for infections that need them, not for viral infections such as colds and flu or for mild sore throats, ear ache or skin infections
- Antibiotics should never be shared with other people or used on other infections. An antibiotic given to you by your doctor or nurse is personal to you and to your infection.
- Always take antibiotics exactly as prescribed, for examples 3 times a day. If you forget to take a dose, take it as soon as you remember even if it means taking two at once. Then continue with the rest of the course.
- You should always complete the full course of antibiotics prescribed to, even if you are feeling better before the end.

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3b. KS3/4/5 Activity (age 11-18): Antibiotic scenarios

Materials required: Student scenarios– available on the e-Bug Young Adult Teacher website (Student Handout2)

For older students, the scenarios in student handout 2 can be used to teach about how to take antibiotics correctly.

Give each student a copy of the worksheets. The worksheets have three scenarios, which teaches the group not to take antibiotics for coughs and cold, to take antibiotics as prescribed and not to use other people's or left-over antibiotics.

For each scenario, discuss with the students the possible correct and incorrect answers. An answer sheet is provided to aid discussions.

3c. Activity: Taking the full course of antibiotics

Background: This demonstration is suitable for all ages and will help the students understand why the full course of antibiotics should be taken.

Materials required: Plastic pipettes, vinegar, phenol red indicator, test tubes and test tube holder

Preparation: Prepare test tubes (enough for two test tubes per group) by filling a third full with water and adding a drop of phenol red indicator. This will turn the water red. Dilute vinegar in a small bowl with water (only a few drops of vinegar are required). This will represent the antibiotics. Test the experiment to see how many drops of vinegar are required to turn the solution in the test tube yellow. Ideally this should be around 7. Strengthen or dilute the vinegar solution as required. Keep the yellow solution as a 'healthy person' to show the students.

Show the students a test tube containing the yellow solution and explain that it represents a healthy person's body with no bacterial infection. The test tube with the red solution represents an ill person who has a bacterial infection. See 'Advance preparation' for details on how to make the solutions.

Say that the doctor has prescribed the ill person a course of 7 days of antibiotics to take (adjust to your test of the solution). Start to add drops of the dilute vinegar using a pipette and ask the children to count with you. Halfway through the dosage show the students that some of the solution has turned yellow – say that this shows that the person is feeling better.

Then mix the solution with a pipette (it will stay red) and say that even though the person is feeling better, the solution is still red showing the bacteria are still there, so they must keep taking their antibiotics until they are completely healthy. Finish adding the dose and mix to make the solution yellow.

Tell the students that because they finished the whole course of antibiotics, the person is completely healthy. Explain that if the person didn't finish the whole course of antibiotics, the bacteria could have come back stronger.

End by repeating the ways antibiotics should be taken correctly.

For older students, the following activities may be used.

3d. KS3/4/5 Activity (age 11-18): Antibiotics "Right" or "Wrong"?

Materials required: Right or Wrong worksheet – available on the e-Bug Young Adult Teacher website (Student Handout 3)

Use the 'right or wrong' worksheet provided to learn about how to take antibiotics correctly.

Give each student a copy of the worksheet (student handout 3). The worksheet has 8 statements, which teaches the students how to take antibiotics correctly. For each statement, discuss with the group the whether they are right or wrong and reasons why. An answer sheet is provided to aid discussions.

3e. KS3/4/5 Activity (age 11-18): Managing Your Infection leaflet

Materials required: Managing Your Infection leaflet – available on the e-Bug Young Adult Teacher website

Show the students the 'Managing your Infection' leaflet, which is designed to be printed as an A5 booklet. Discuss the information in the leaflet, including:

- How long common infections usually last
- How you can self-care at home
- When you should seek further help from a medical professional

Optional: Extension activity

As an extension, show the students the Antibiotic Guardian video, available at http://antibioticguardian.com. The clip can be used to stimulate a discussion between the students. Ask the students to become an Antibiotic Guardian by pledging to use antibiotics responsibly.

Optional: Homework

Ask the students to create a poster promoting the correct use of antibiotics. This can cover any of the topics they have learnt in the lesson.

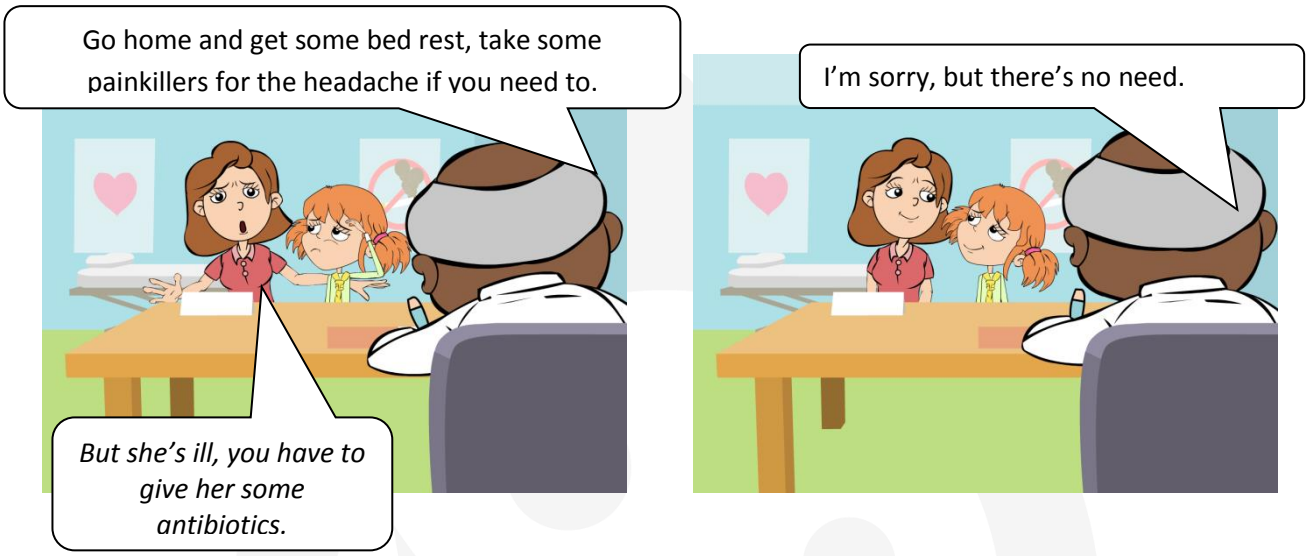
Ask the students to take the Managing Your Infection leaflet home to discuss with their family

Acknowledgements

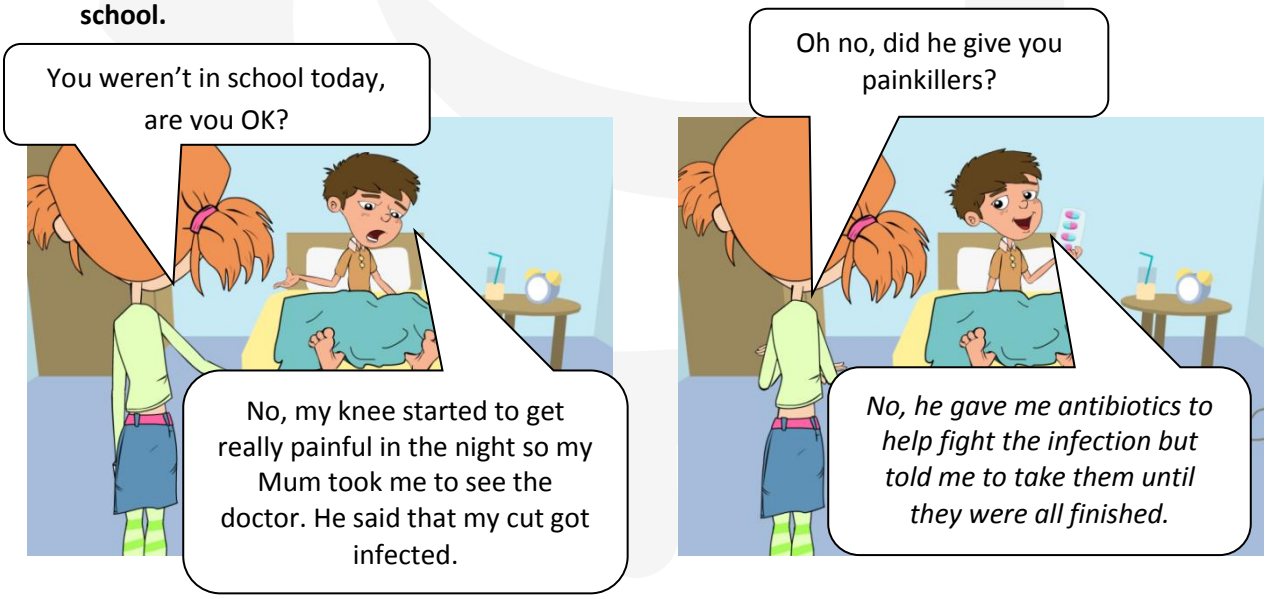
This lesson plan was written by Dr Vicki Young and the activities in Section 1 and 2 were devised by Dr Carwyn Watkins

Student Handout 1

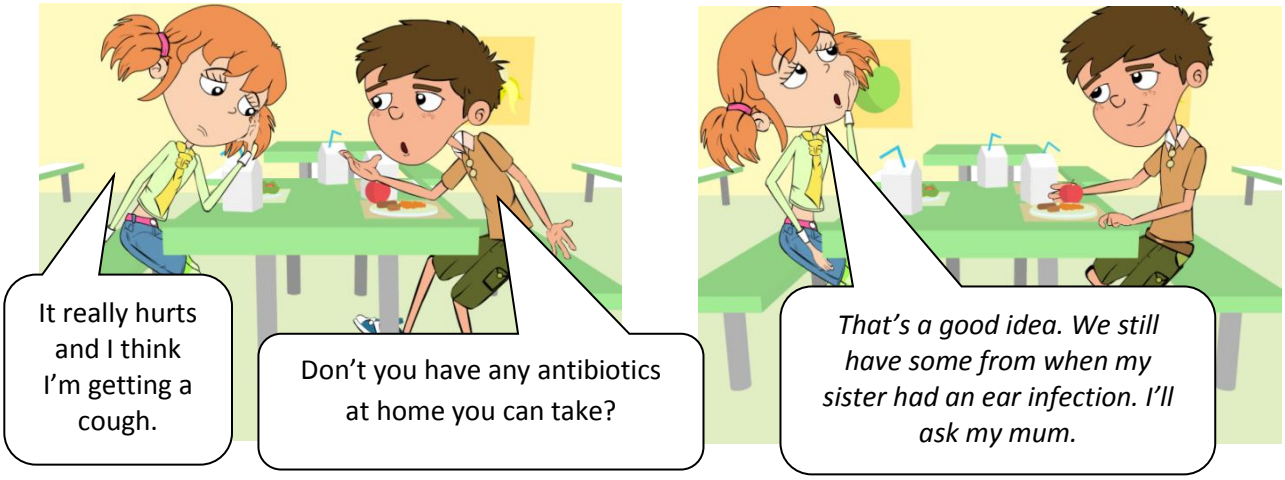
When Amy got home, her mother decided to take her to the doctor. He said that she had a bad cold.



Harry didn't come to school the next day so Amy called around to see him on her way home from school.

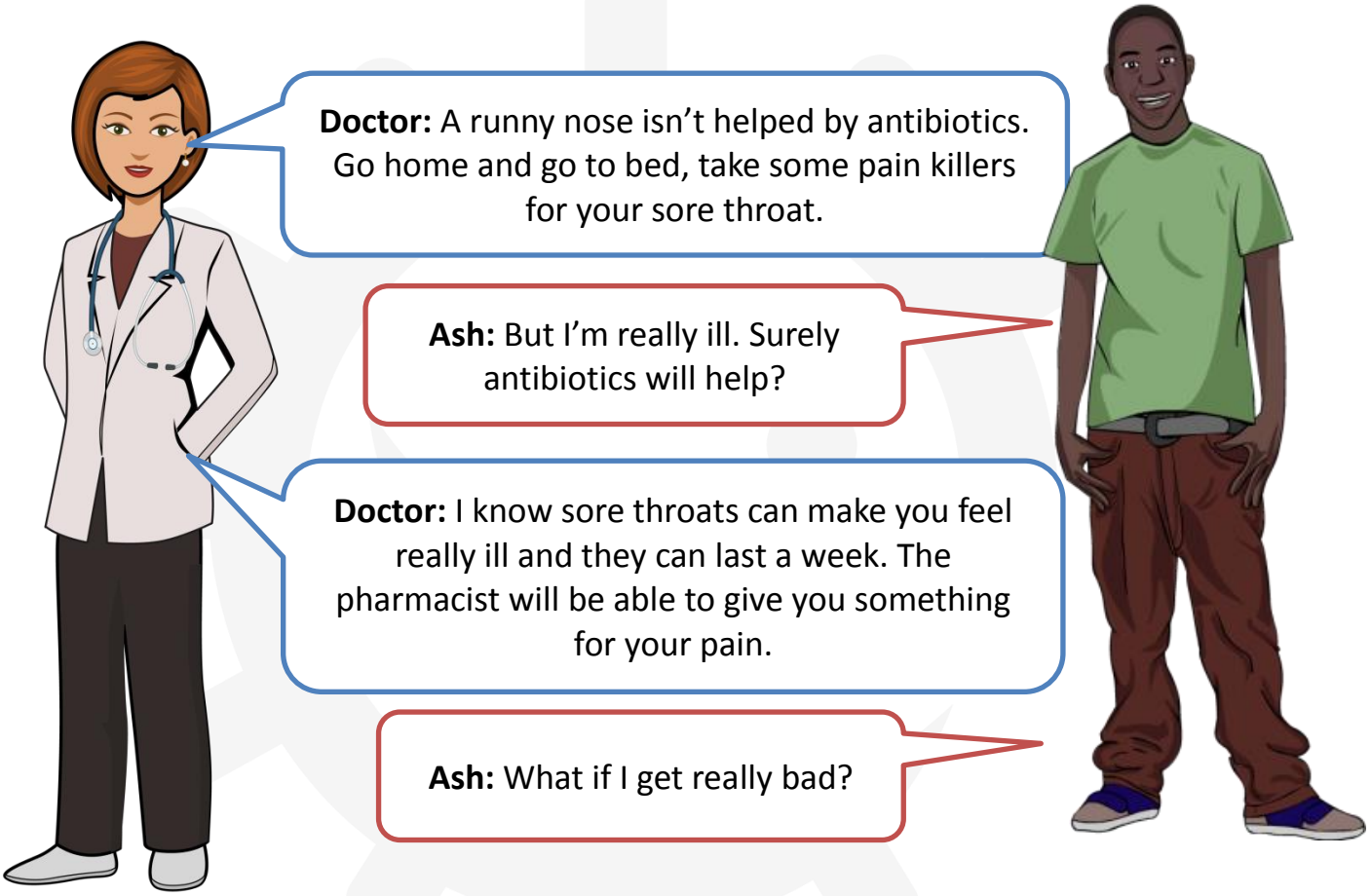


During lunch Amy was talking to her friend Harry about her headache and runny nose.



Antibiotic Scenarios

Scenario 1: Ash had a runny nose and really sore throat so he went to the doctor.



DISCUSSION

Discuss whether you agree or disagree with Ash going to the pharmacy?

Discuss what you think Ash might be worried about?

Antibiotic Scenarios

Scenario 2: Alisha is talking to her friend Anna about her urine infection. Alisha has been prescribed antibiotics by her doctor.

Alisha: I've been given antibiotics for my urine infection. The doctor told me to take them for 3 days, morning and evening. After 3 days I've still got some left, what shall I do with the ones left over now I feel better?

Anna: Why don't you just take them, it will make sure you get rid of all the infection.

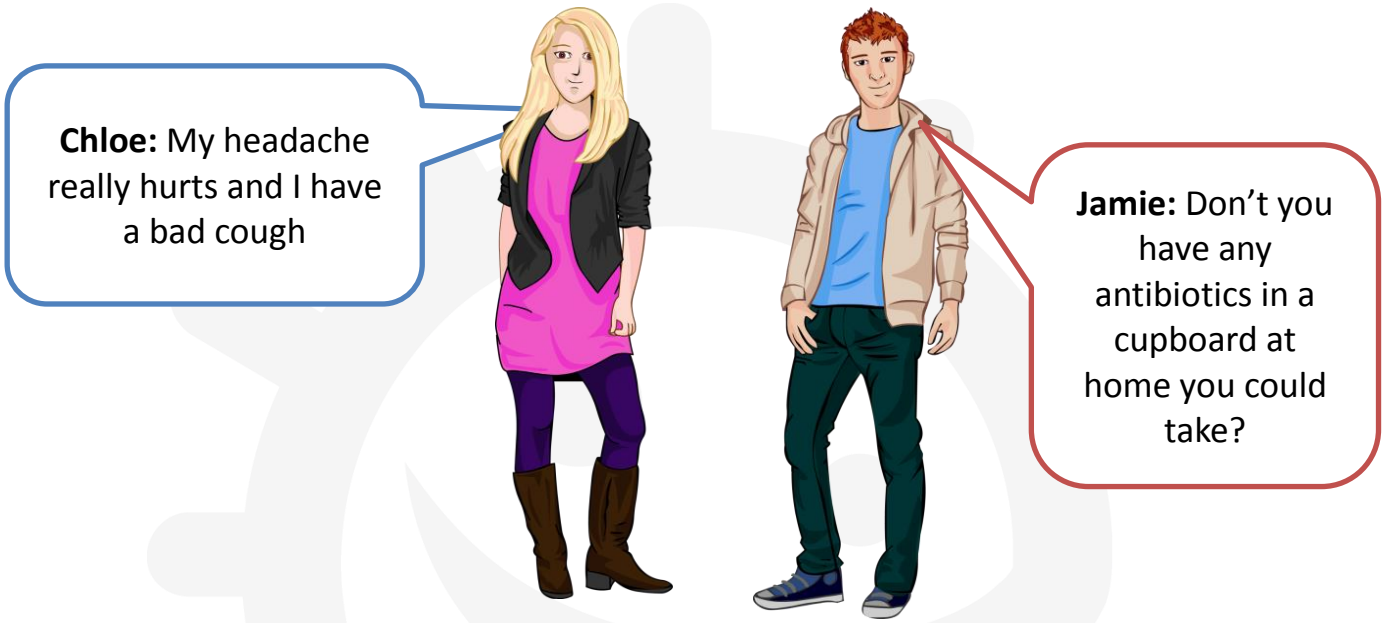
DISCUSSION

Discuss whether you agree or disagree with Anna?

Discuss what you think Alisha should do with her leftover antibiotics?

Antibiotic Scenarios

Scenario 3: Chloe was talking to her friend Jamie about her headache and cough.



What should Chloe say? Discuss the correct and incorrect options

Statement	Correct	Incorrect
Gosh no, I shouldn't take anyone else's antibiotics.		
Great idea – we have some left-over from when my sister had an ear infection.		
Yes I had a cough a few weeks ago and went to the out of hours and they gave me a prescription, but I didn't bother to cash it in. I'll do it now!		
I don't have any antibiotics in the cupboard – don't you always take them back to the chemist?		
I've never had any antibiotics – so we don't have any in the cupboard.		
I had a water infection last month. I'll use the left-over antibiotics from them.		
I shouldn't take antibiotics that are left over.		
I don't have any at home, but I'll ask Josie, she is always at the doctor with her coughs.		
I only take antibiotics if the doctor prescribes them.		
I think I should just take some pain relief and go to bed.		

Antibiotic Scenarios – answer sheet

Scenario 1

Amy had a runny nose and really sore throat so she went to the doctor

Discussion points:

- Many infections get better on their own without the need for antibiotics.
- Antibiotics won't make a difference to how long your symptoms/illness/infection lasts.
- All runny noses are caused by viruses which antibiotics do not work on – so there is no point having an antibiotic.
- If you become ill very quickly, have a really red throat or pus on your tonsils with high temperature and no cough or runny nose, you are more likely to benefit from antibiotics.

Scenario 2

Alisha has a urine infection and has been prescribed antibiotics by her doctor

Discussion points:

Correct options:-

- Do what the doctor says and take them for the 3 days.
- Take the left-overs back to the chemist (do not flush antibiotics down the toilet otherwise antibiotics get into the water system).
- If you take more days, your bugs are more likely to become resistant, and the antibiotics are less likely to kill the bacteria the next time you need them.
- Don't take any extras as that will kill more of your useful bugs in your gut too.

Incorrect options if needed:-

- Keep the rest for next time.
- Stop taking them now. What's the point in taking them if you are feeling better?
- Take the whole pack and then you'll definitely kill the bugs.

Scenario 3

Chloe was talking to her friend Jamie about her headache and cough

	Correct	Incorrect
Gosh no, I shouldn't take anyone else's antibiotics.	✓	
Great idea – we have some left-over from when my sister had an ear infection.		✓
Yes I had a cough a few weeks ago and went to the out of hours and they gave me a prescription, but I didn't bother to cash it in. I'll do it now!		✓
I don't have any antibiotics in the cupboard – don't you always take them back to the chemist?	✓	
I've never had any antibiotics – so we don't have any in the cupboard.	✓	
I had a water infection last month. I'll use the left-over antibiotics from them.		✓
I shouldn't take antibiotics that are left over.	✓	
I don't have any at home, but I'll ask Josie, she is always at the doctor with her coughs.		✓
I only take antibiotics if the doctor prescribes them.	✓	
I think I should just take some pain relief and go to bed.	✓	

Discussion points:

- If you have taken an antibiotic in the last 6 months a bacterial infection is twice as likely to be antibiotic resistant
- Repeated courses of antibiotics are associated with a greater risk of antibiotic resistant bacteria
- Antibiotics are specific for each infection, for example an antibiotic for a sore throat will not work for a urine infection and vice versa, so you should never share others antibiotics or left-overs
- Pain relief such as paracetamol help cold, flu, sore throat and ear-ache symptoms and help bring down a temperature
- The dose of antibiotic is specifically chosen for each infection, so that the antibiotic reaches the infection and kills the bacteria

Antibiotics Right or Wrong?

Discuss: Which of these statements are right or wrong?

1. He was coughing and sneezing everywhere. You would have thought the doctor would have given him antibiotics!

2. My doctor told me to take my antibiotics for 5 days so that is what I did.

3. When my friend was ill, I gave her my old antibiotics. I like helping my friends.

4. Antibiotics don't help coughs and colds; you just need bed rest, lots of fluids and eat healthily.

5. All drugs are bad for you. I can't see the point in taking antibiotics.

6. My doctor gave me antibiotics to take for 10 days but I feel better after 3 days so I'm going to stop taking them.

7. My headache and flu symptoms are really getting me down. I think I need antibiotics!

8. I don't take antibiotics unless I really need them as they might not work in the future.

Antibiotics Right or Wrong– answer sheet

Statement	Right or Wrong	Reason
He was coughing and sneezing everywhere. You would have thought the doctor would have given him antibiotics!	Wrong	Most common infections will get better by themselves through time, bed rest, liquid intake and healthy living. Antibiotics do not work on viruses.
My doctor told me to take my antibiotics for 5 days so that is what I did.	Right	Take antibiotics exactly as given by your doctor or nurse.
When my friend was ill, I gave her my old antibiotics. I like helping my friends.	Wrong	You must not use other people's or any leftover antibiotics.
Antibiotics don't help coughs and colds; you just need bed rest, lots of fluids and eat healthy.	Right	Most common infections will get better by themselves through time, bed rest, liquid intake and healthy living. Antibiotics do not work on viruses.
All drugs are bad for you. I can't see the point in taking antibiotics.	Wrong	Antibiotics can help severe infections such as meningitis, pneumonia or kidney/urine infections.
My doctor gave me antibiotics to take for 10 days but I feel better after 3 days so I'm going to stop taking them.	Wrong	Take antibiotics exactly as given by your doctor or nurse. Even if you feel better after 3 days you might still have the infection.
My headache and flu symptoms are really getting me down. I think I need antibiotics!	Wrong	Most common infections like flu will get better by themselves through time, bed rest, liquid intake and healthy living. Antibiotics do not work on headaches you get with colds and flu or viruses.
I don't take antibiotics unless I really need them as they might not work in the future.	Right	If you over use antibiotics they might not work when you really need them for a severe infection.

Vaccinations

Lesson plans, worksheets and activities

Lesson Plan

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 at the e-Bug Young Adult Teacher vaccination webpages.

Materials required

Graph paper for completion of the main activity.

Background information

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 on the e-Bug Young Adult Teacher website 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 on the e-Bug Young Adult Student website 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 on the e-Bug Young Adult Teacher website.

In preparation for the lesson, you can ask students to complete their own personalised vaccination timeline, available on the e-Bug website. 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.

Student worksheet 1

1. 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).

Year of 2nd birthday	MMR 1st dose (%)
1996-97	91.5
1997-98	90.8
1998-99	88.3
1999-2000	87.6
2000-01	87.4
2001-02	84.1
2002-03	81.8
2003-04	79.9
2004-05	80.9
2005-06	84.1
2006-07	85.2
2007-08	84.6
2008-09	84.9
2009-10	88.2
2010-11	89.1
2011-12	91.2
2012-13	92.3
2013-14	92.7

The table below provides numbers of confirmed cases of measles in England by age, between 1997 and 2013. This data is from Public Health England.

Year	< 1 year	1 – 9 years	10 – 19 years	20 + years	Not known	Total cases
1997	4	101	46	22	4	177
1998	2	26	12	16	0	56
1999	6	35	11	38	2	92
2000	11	52	14	23	0	100
2001	5	26	13	26	0	70
2002	33	171	58	43	3	308
2003	34	264	71	64	5	438
2004	24	108	25	31	3	191
2005	7	47	6	17	0	77
2006	76	389	129	144	2	740
2007	91	558	210	131	0	990
2008	112	649	380	229	0	1370
2009	84	603	331	125	1	1144
2010	33	128	112	107	0	380
2011	57	358	401	271	0	1087
2012	215	743	674	398	0	2030
2013	163	548	769	363	0	1843
2014	17	41	16	47	0	121

2. Using the data provided, plot a single graph showing MMR vaccination uptake and measles cases in England between 1997 and 2014. Plot the MMR vaccination uptake as a bar graph and the number of measles cases overtop as a line graph.

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?

6. Divide the measles cases data into three periods: 1997-2002, 2003-2008 and 2009-2014. What trend do you notice in the overall numbers and individual age groups?

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?

Student worksheet 2

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?

c) Plasma 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

Student worksheet 1 answers

1. 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).

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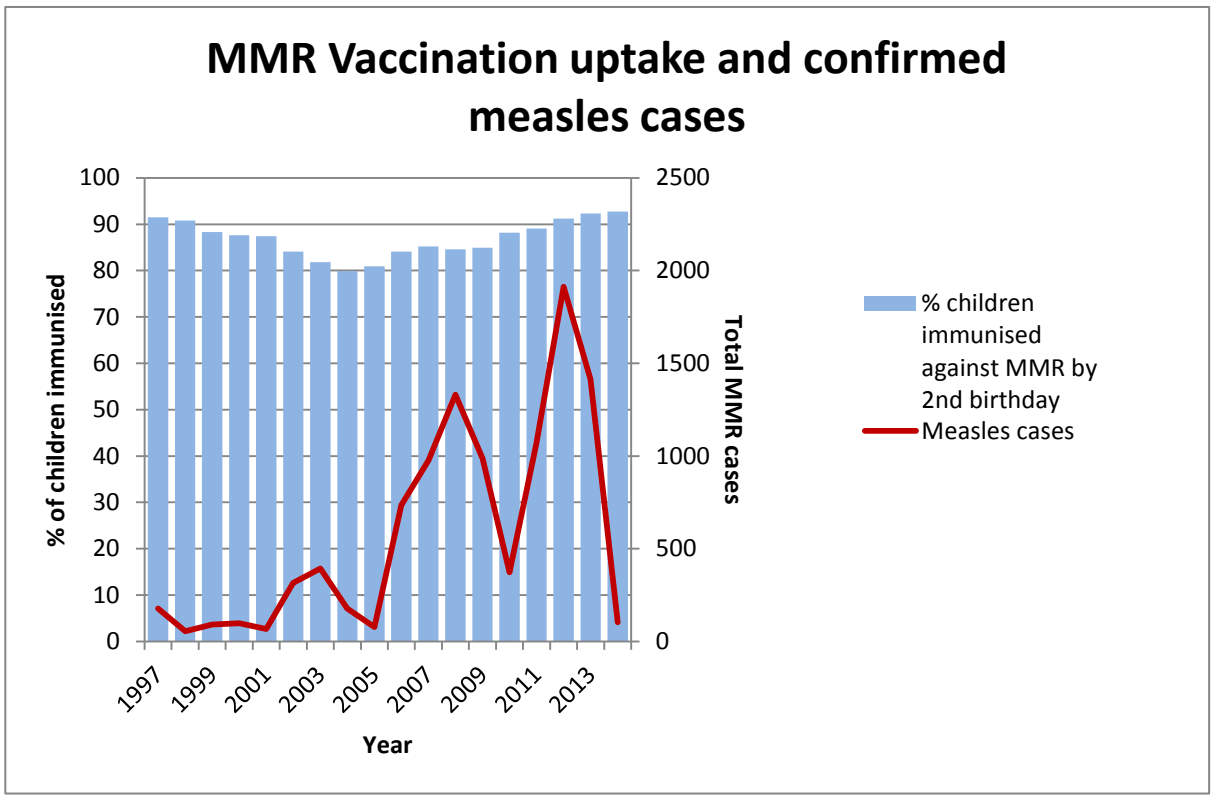
2014	17	41	16	47	0	121

2. Using the data provided, plot a single graph showing MMR vaccination uptake and measles cases in England between 1997 and 2014. Plot the MMR vaccination uptake as a bar graph and the number of measles cases overtop as a line graph.



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.

6. Divide the measles cases data into three periods: 1997-2002, 2003-2008 and 2009-2014. What trend do you notice in the overall numbers and individual age groups?

period	< 1 year	1 – 9 years	10 – 19 years	20 + years	Not known	Total cases
1997-2002	61	411	154	168	9	803
2003-2008	344	2015	821	616	10	3806
2009-2014	569	2421	2303	1311	1	6605

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.

Student worksheet 2 answers

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 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 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.

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 cell

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.

Teacher Sheet

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.

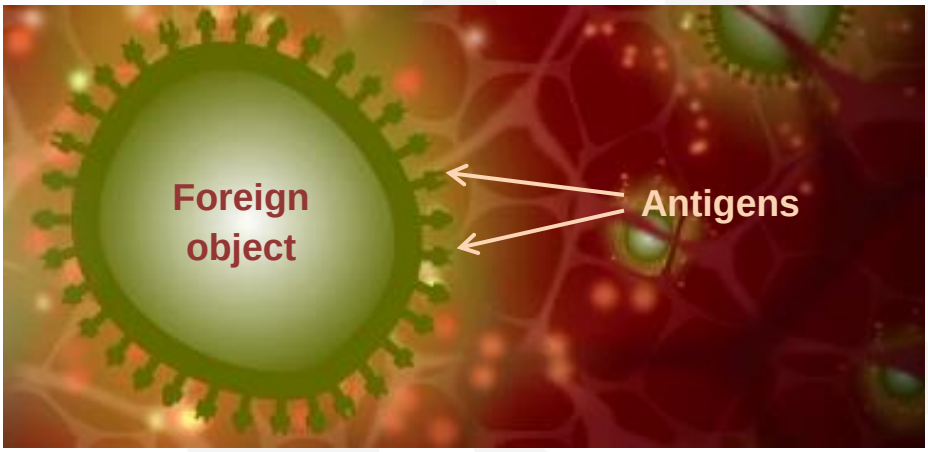
The function of the immune system is to distinguish foreign substances from substances that are part of our own bodies. The part, or parts, of any foreign substance that are recognised by the immune system are known as antigens. Antigens are present on bacteria, on viruses and on foreign cells from transfusions 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.

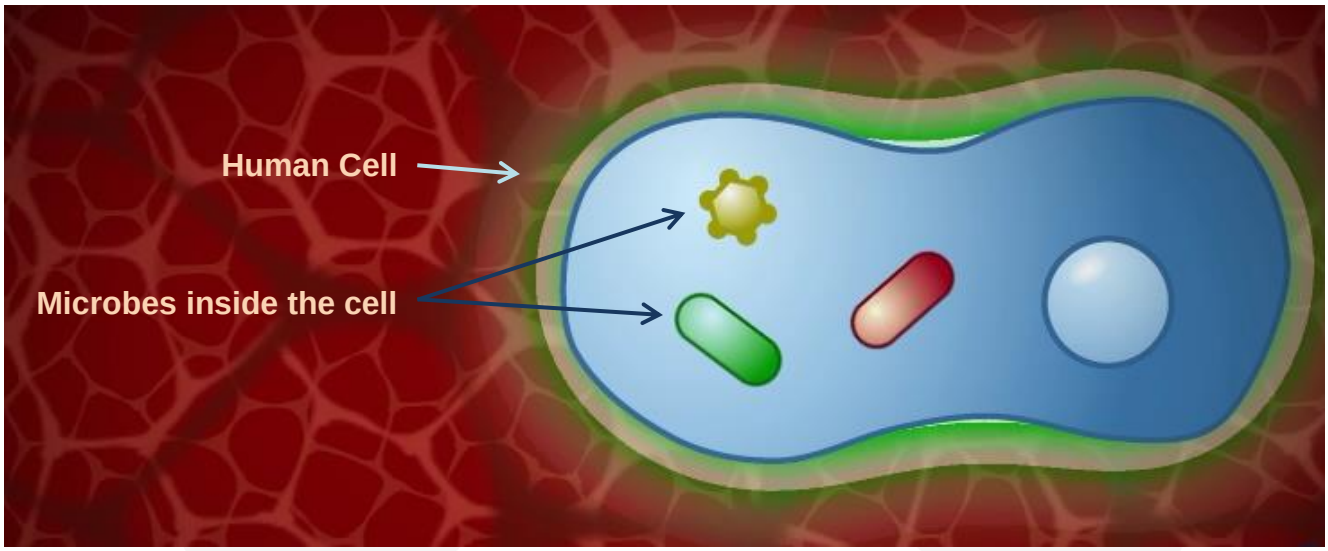
However, if these barriers are breached, for example by bacteria entering the body through the skin, the antigens encounter large cells called macrophages which are resident in the skin. The word macrophage means 'big-eater'. If a macrophage recognises the antigen as something foreign and not 'self' 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.

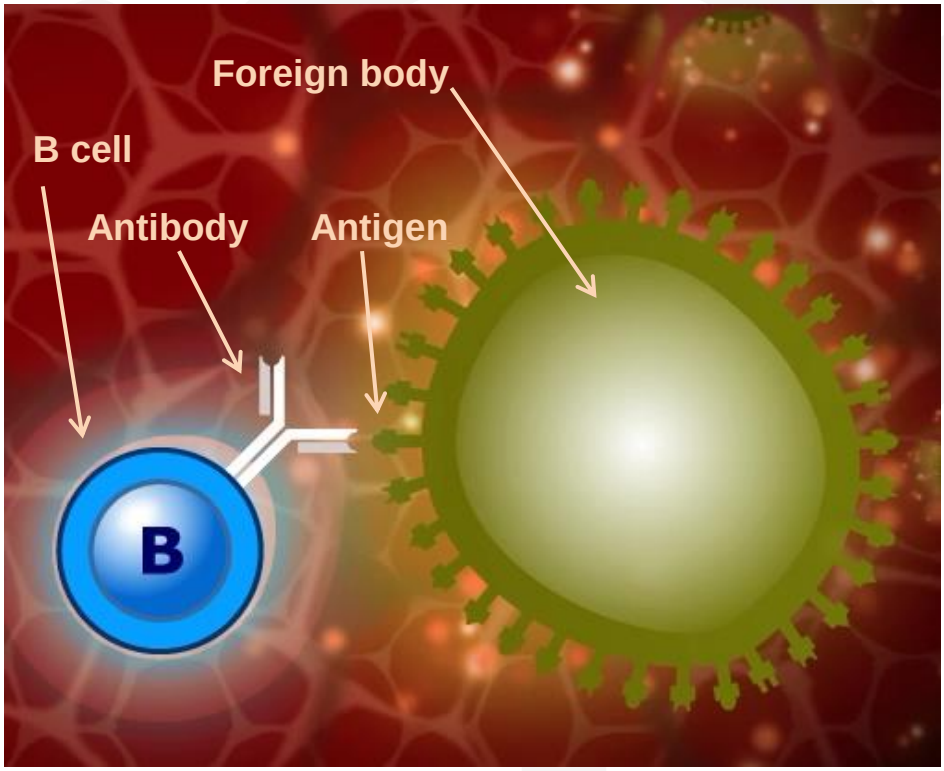
The stimulation of the lymphocytes in the lymph nodes, however, produces a strong cascade of lymphocyte activation as one APC cell can stimulate many B and T cells. T cells are specific cells that are involved in the cell-mediated response and B cells are cells involved in the humoral immune response.

Clip 2

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.

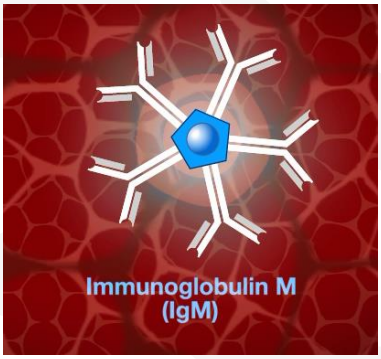


B cells manufacture antibody, however, most antigens do not stimulate B cells to produce antibody without the help of T cells. The response to these antigens is therefore referred to as T cell-dependent. Unlike B cells, T cells can recognise intracellular antigens provided they are expressed on the cell 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.

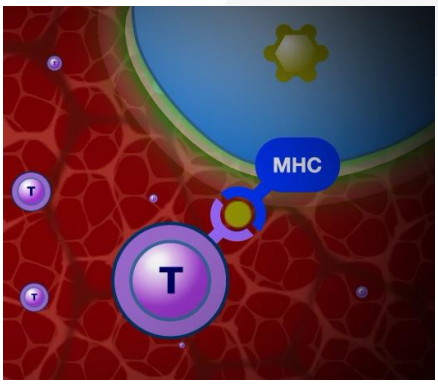
3. The complement system is activated. The complement system is a major part of the humoral response. After antibodies bind to the foreign body, the complement system can attach. The complement system is made up of complement molecules which are proteins that have protease activity, i.e. can break down other proteins.

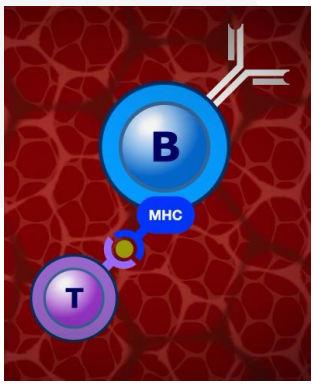
The attachment of complement molecules produce a protease cascade whereby one complement molecule breaks down the next, activating its protease activity so that it can breakdown the next complement molecule and so on. The result of the cascade is the production of molecules that can attract other immune 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.

Clip 3

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.

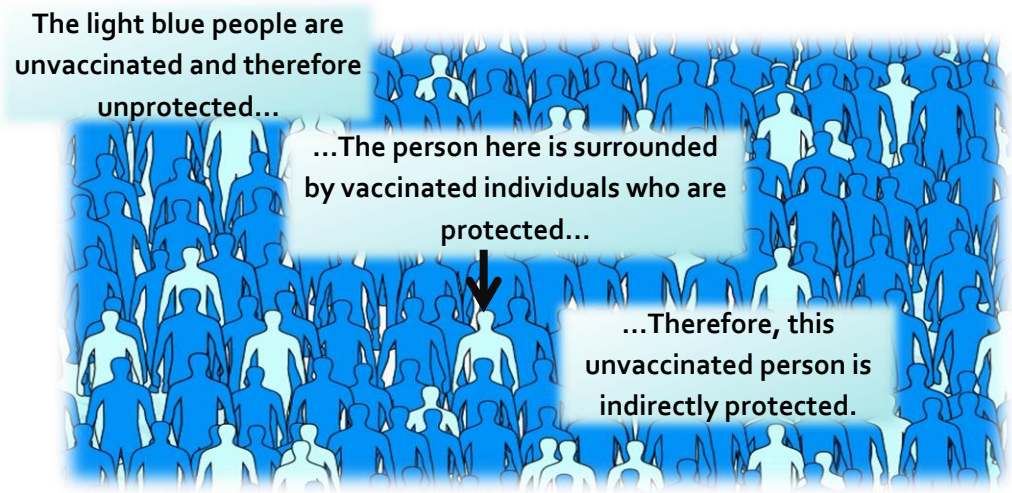
Booster vaccinations are given to keep circulating antibody numbers at high levels. If they are missed then the memory response may be weakened and may result in the individual contracting the disease.

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

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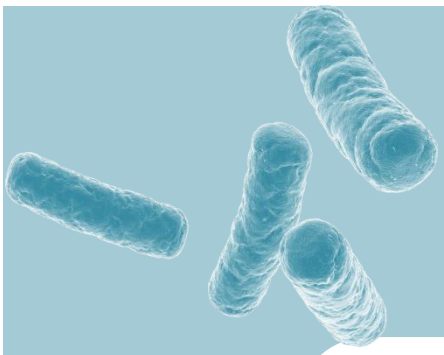
Storey, M., Jordan, S. (2008) An overview of the immune system. *Nurs Stand.* **23**(15-17):47-56 Web link

Other Web links:

WHO introduction to vaccines

NHS How vaccines work



This pack contains a series of educational resources for young adults aged 15-18 years on the topic of antibiotics, antibiotic resistance and vaccinations.

This resource pack has information, suggested lesson plans and possible activities for you to use in your classroom to help you inspire and inform your pupils.

The lesson plans cover many topics found in the AQA, OCR, Edexcel and WJEC exam specification for A-level Biology, Human Biology and related subjects.