Antibiotics
Lesson plans, worksheets and activities for 15-18 year olds on antibiotics and antibiotic resistance.

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

Antibiotics Lesson Plan

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Antibiotics Animation

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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
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 (20 mins)

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 resistance 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](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 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 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
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, nitrofurantoin 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>
<thead>
<tr>
<th>Year</th>
<th>Antibiotic name</th>
<th>Age group (years)</th>
<th>Number sampled</th>
<th>Number antibiotic resistant</th>
<th>%Resistant</th>
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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

<table>
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<tr>
<th>Antibiotic</th>
<th>% of total prescriptions</th>
<th>% resistance for 15-24 age group</th>
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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>
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<th>Year</th>
<th>Antibiotic name</th>
<th>Age group (years)</th>
<th>Number sampled</th>
<th>Number antibiotic resistant</th>
<th>%Resistant</th>
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<th>Number antibiotic resistant</th>
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</table>

[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?
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.

   ![Diagram of a bacterial cell]

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>
<thead>
<tr>
<th>Year</th>
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<td>2013</td>
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<td>50-79</td>
<td>36799</td>
<td>4453</td>
<td>12.1</td>
</tr>
<tr>
<td>2013</td>
<td>Nitrofurantoin</td>
<td>80+</td>
<td>20419</td>
<td>3785</td>
<td>18.5</td>
</tr>
<tr>
<td>2013</td>
<td>Trimethoprim</td>
<td>&lt;15</td>
<td>4718</td>
<td>1398</td>
<td>29.6</td>
</tr>
<tr>
<td>2013</td>
<td>Trimethoprim</td>
<td>15-24</td>
<td>5880</td>
<td>1636</td>
<td>27.8</td>
</tr>
<tr>
<td>2013</td>
<td>Trimethoprim</td>
<td>25-49</td>
<td>13716</td>
<td>4114</td>
<td>30.0</td>
</tr>
<tr>
<td>2013</td>
<td>Trimethoprim</td>
<td>50-79</td>
<td>36871</td>
<td>12281</td>
<td>33.3</td>
</tr>
<tr>
<td>2013</td>
<td>Trimethoprim</td>
<td>80+</td>
<td>20454</td>
<td>9119</td>
<td>44.6</td>
</tr>
</tbody>
</table>

   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>
<thead>
<tr>
<th>Antibiotic</th>
<th>% resistance for 15-24 age group</th>
<th>% of total prescriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amoxicillin</td>
<td>49.3</td>
<td>33</td>
</tr>
<tr>
<td>Nitrofurantoin</td>
<td>4.5</td>
<td>4</td>
</tr>
<tr>
<td>Trimethoprim</td>
<td>27.8</td>
<td>9</td>
</tr>
<tr>
<td>Fluoroquinolones</td>
<td>4.3</td>
<td>3</td>
</tr>
<tr>
<td>Cephalosporins</td>
<td>4.5</td>
<td>8</td>
</tr>
<tr>
<td>Co-amoxiclav</td>
<td>6.0</td>
<td>6</td>
</tr>
</tbody>
</table>

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.

\[
p = 1 - \frac{6 \sum d^2}{n(n^2 - 1)} = 1 - \frac{(6x3)}{6 \times (62 - 1)} = 0.914
\]

\[
\sum d^2 = 3
\]

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.

![Graph of Trimethoprim resistance by age group and year](image)

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

\[
\frac{(44.2 - 39.1)}{39.1} \times 100 = 13\%
\]

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 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.
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 gyrase or topoisomerases. Quinolones are antibiotics which target DNA replication. Quinolones are selective for bacteria as they do not affect human DNA gyrase or topoisomerases.

3. **Metabolism:** Antibiotics can affect metabolic enzyme activity, most notably by disrupting the folic acid pathway. Sulfonamides and trimethoprim 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.

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.

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.

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


Within this lesson plan, students aged 16-18 years will run a 1 hour lesson with students in the same educational establishment or a linked organisation. The lesson can be delivered to students in key stage 3 (ages 11-14), key stage 4 (ages 14-16), or even other key stage 5 students.

**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 5-6 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.

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. See Advance Preparation for information on what is required before the lesson.

Optional homework is also provided for those being peer educated. This could be marked by the key stage 5 students, allowing them to receive feedback on their lesson.
National curriculum/exam specification links

Key Stage 5:
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:

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

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.
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 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)

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. 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.

Activity:

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
- **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

Prior to the lesson, research the role of each cellular component. Ask students if they know the function of the different 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)

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

Next, give the students 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.

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

Activity:

Line up around 4-6 balloons, mostly yellow with one or two red ones (different colours may be used but yellow and red will be used here to describe the demonstration). Put sellotape or parcel tape on the red balloons. 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. 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. 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.
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?

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.

To demonstrate the last point, explain that you are going to show an experiment which will help the students understand why the full course should be taken.

Activity:

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 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.

*Optional: Extension activity*

As an extension, show the students the Antibiotic Guardian video, available at [http://antibioticguardian.com](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.
Advance Preparation

**Section 1:** Research the role of cellular components in human, bacterial and viral cells.

**Section 2:** Research information on MRSA and TB. Information can be found on the [Public Health England](https://www.england.nhs.uk/), [NHS Choices](https://www.nhs.uk/), [MRSA Action UK](https://www.mrsa.org.uk/) and the [Stop TB Partnership](https://www.stoptb.org/) websites.

*Optional:* Make a 5 minute presentation on antibiotic discovery and resistance. Alternatively download the ‘Antibiotic use and resistance’ presentation from the [e-Bug website](https://www.e-bug.net/), which is suitable for key stage 3 students. Blow up around 4 balloons in one colour and 2 balloons in another colour. Add a strip of sellotape or parcel tape to the end of the two balloons which are a different colour.

**Section 3:** 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.

### Materials required

- **Section 1:** paper, pencils and scissors
- **Section 2:** antibiotic discovery and resistance presentation, balloons, sellotape or parcel tape, pin
- **Section 3:** student handout 1, plastic pipettes, vinegar, phenol red indicator, test tubes and test tube holder

### Available web resources

- Antibiotic discovery and resistance presentation – available [here](https://www.e-bug.net/)
- Student Hand-out 1 – available [here](https://www.e-bug.net/)
- Student hand out on the three types of microbes and their relative sizes – hand out SH1, available [here](https://www.e-bug.net/).

### Key words

- Bacteria, Virus, Antibiotic, Antibiotic resistance, Disease, Infection

### Acknowledgements

This lesson plan was written by Dr Vicki Young and the activities in Section 1 and 2 were devised by Dr Carwyn Watkins.
When Amy got home, her mother decided to take her to the doctor. He said that she had a bad cold.

Go home and get some bed rest, take some painkillers for the headache if you need to.

But she’s ill, you have to give her some antibiotics.

I’m sorry, but there’s no need.

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.

You weren’t in school today, are you OK?

No, my knee started to get really painful in the night so my Mum took me to see the doctor. He said that my cut got infected.

Oh no, did he give you painkillers?

No, he gave me antibiotics to help fight the infection but told me to take them until they were all finished.

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

It really hurts and I think I’m getting a cough.

Don’t you have any antibiotics at home you can take?

That’s a good idea. We still have some from when my sister had an ear infection. I’ll ask my mum.