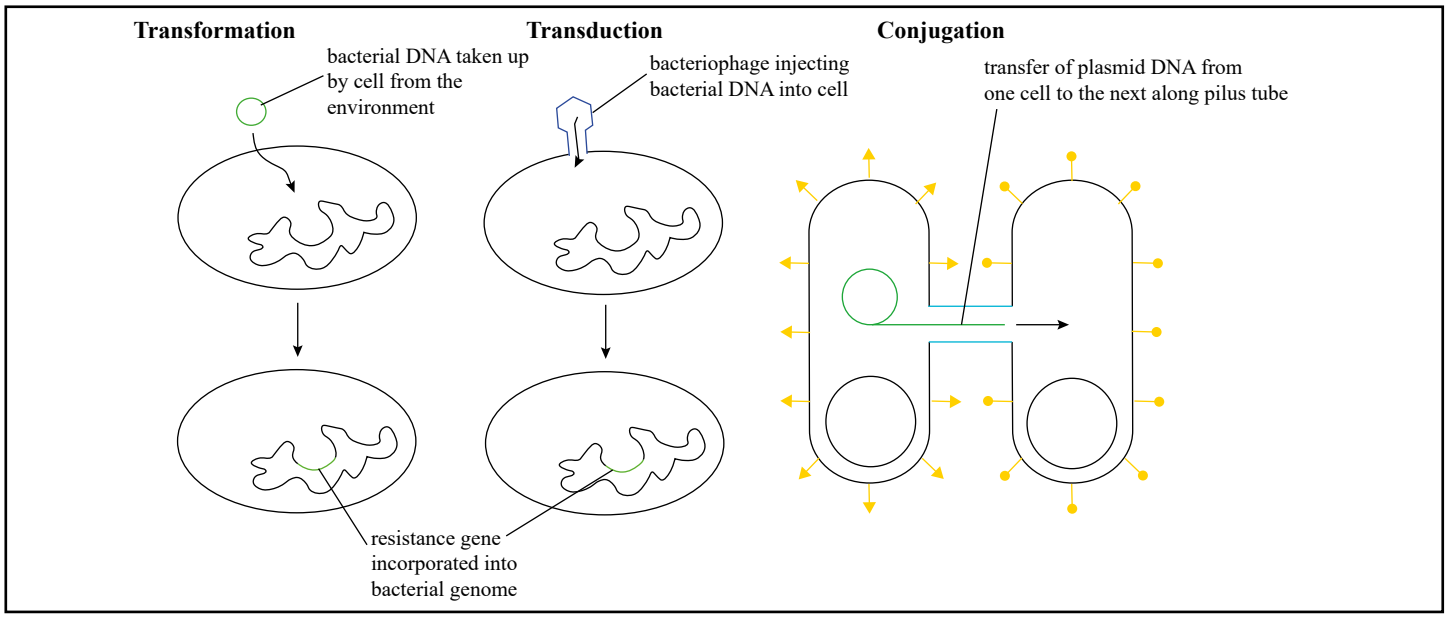
1. Transformation
   Transformation takes place when pieces of DNA enter a bacterial cell. This rogue DNA may be the remnants left over from the death and breakdown of bacteria in the environment. This DNA may become part of the bacterial chromosome. If this DNA has genes for antibiotic resistance, the cell it enters will also gain resistance.

2. Transduction.
   Transduction occurs when a **bacteriophage** transfers pieces of DNA from one bacterial cell to another. A bacteriophage is a virus which will attack bacteria.

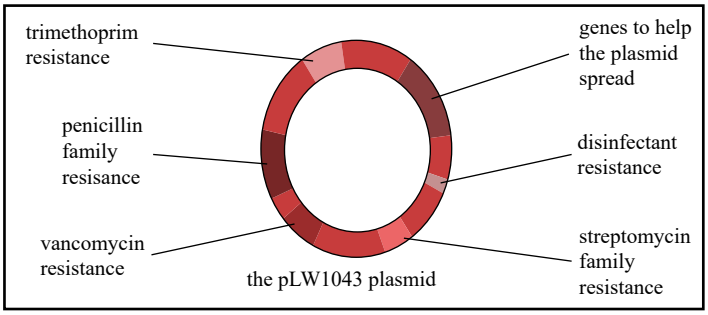
Fig 4 Summary of how resistant genes are transferred between bacteria through horizontal transfer



There are many resistant genes which have accumulated in bacterial populations.

Plasmids may carry several separate antibiotic resistant genes. A plasmid has been found that carried **methicillin** resistance as well as resistance to **penicillin** and **streptomycin**.

Fig 5 A plasmid can carry many different resistance genes



These genes are passed randomly from one bacterial cell to another. This means that individual bacteria do not have to develop their own random mutations to make them resistant. They simply gain resistance through horizontal transfer. Horizontal transfer has significantly increased the rate of evolution of antibiotic resistance.

Evolution of Methicillin Resistant *Staphylococcus aureus* (MRSA)

Staphylococcus aureus is a bacterium that is found on the skin, in the nose and in the throat of many healthy people. It is transmitted in droplets of moisture by coughing or sneezing. This bacterium causes problems when it breaks through the skin, often through open wounds. In people with a weakened immune system, an infection of *Staphylococcus aureus* can be life threatening.

MRSA developed over a twenty-year period:

- In the early 1940s penicillin was used to treat *Staphylococcus aureus* infections. Penicillin resistant strains of *S. aureus* bacteria were unknown.
- By the 1950s penicillin resistant strains of *S. aureus* were appearing in hospitals.
- The antibiotic **methicillin** was used to kill these resistant bacteria.
- By the 1960s, methicillin resistant *Staphylococcus aureus* (MRSA) had developed.

MRSA is a superbug which is very difficult to treat. This bacterium is resistant to the antibiotic methicillin as well as a wide range of other drugs. This bacterium has continued to evolve through random mutations and is now resistant to virtually all modern antibiotics.

Treating the Superbugs

As resistance spreads and superbugs increasingly develop, doctors will start using more expensive, less common antibiotics like **vancomycin**. Some of these drugs may have undesirable side effects. In the near future medical procedures which rely on antibiotics may become impossible. Some bacteria cannot be destroyed by all the drugs that once could kill them readily. New antibiotics need to be found, but discoveries in the past 25 years have been scarce.

There are several simple steps that can be taken to help the spread of antibiotic resistance in bacteria.

- Antibiotics should only be taken for very serious bacterial infections.
- Any course of antibiotics should be completed to ensure that all bacteria have been eradicated from the body.
- The routine dosing of farm animals with antibiotics should be reduced.
- It is essential that washing hands and good hygiene should be practiced – particularly in hospitals.

The Future

Superbugs are on the increase and it is essential that new methods of killing bacteria must be found.

- New sources of antibiotics are being investigated. German scientists have recently discovered that a bacterium living in the human nose produces an antibiotic. This bacterium ***Staphylococcus lugdunensis*** produces **lugdunin**, an antibiotic that kills MRSA.
- Protein synthesis inhibitors, which slow down the growth of cells, could be developed to stop bacterial cells reproducing.
- Bacteriophages – the viruses that infect bacteria – could also be **engineered** to kill bacteria. These viruses would have to be made safe and not kill off any protective bacteria.

Practice Questions

1. Give one reason why antibiotics are effective against bacteria but not viruses.

2. Treating *Mycobacterium tuberculosis* infections can be a problem as the bacteria are resistant to many antibiotics. There are many strains of *M. tuberculosis*. Different strains are resistant to different antibiotics or combinations of antibiotics. The percentage of strains of *Mycobacterium tuberculosis* resistant to an antibiotic called INH has increased. Suggest how natural selection could have resulted in this increase.

Answers

1. Antibiotics kill bacteria or damage their structure. They are chemicals that can disrupt the metabolism of the living bacterial cells. Viruses are non-living. They do not carry out any metabolic processes so antibiotics do not affect them.

2. Bacteria have a mutation in DNA or a gene which gives antibiotic resistance.
   The presence or use of the antibiotic INH acts as a selection pressure.
   The allele for resistance is passed on to the next generation.
   Bacteria divide rapidly by asexual reproduction (binary fission) to produce identical copies or clones.
   The process of rapid cloning increases the allele frequency.
   The more resistant bacteria there are, the more likely it will be that new strains will acquire the resistance gene.

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