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ANTIBIOTIC RESISTANCE: CALLING ON CITIZENS TO HELP TACKLE THE PROBLEM

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Good evening, ladies and gentlemen, and welcome to the first Frank Jackson Foundation Lecture on the Environment in this series on Frontiers – Emerging Issues of Global Environmental Concern. Over the six lectures, I will be looking at a range of issues that need our attention. Some have emerged as a result of new scientific findings or a better understanding of their consequences, others are persistent issues but there are new technologies and approaches which can provide practical solutions, whilst others can only be seen locally but have the potential to become a global issue if left unattended.

This evening I am going to talk about the environmental dimensions of antimicrobial resistance, look at the science behind pathogenic bacteria and antibiotic resistance, and explore what we can do as citizens to help tackle the problem to safeguard our future health. Let me just say, that the topic of antimicrobial resistance is not new to Gresham College. Professors William Ayliffe and Christopher Witty have both looked at this growing issue: so please do listen to their lectures on line.

To begin tonight, I would like to put up a short quiz about antibiotics and antimicrobial resistance; I will show the answers at the end.

Question 1: Antibiotics are powerful medicines that help fight:

(a) Viruses
(b) Bacteria
(c) All microbes

Question 2: Antibiotic resistance happens when my body becomes resistant to antibiotics:

(a) True
(b) False

Question 3: Antibiotic-resistant bacteria can spread to humans through:

(a) Contact with a person who has an antibiotic-resistant infection
(b) Contact with something that has been touched by a person who has an antibiotic-resistant infection (e.g. a health-workers' hands or instruments in a health facility with poor hygiene)
(c) Contact with a live animal, food or water carrying antibiotic-resistant bacteria.
(d) All the above

Question 4: What can happen if I get an antibiotic-resistant infection?

(a) I may be sick for longer
(b) I may have to visit my doctor more or be treated in hospital
(c) I may need more expensive medicines that may have side-effects
(d) All the above

Question 5: I can help tackle antibiotic resistance if I:

(a) Share my antibiotics with my family when I am sick

(b) Get antibiotics as soon as I feel sick - either directly from the pharmacy or someone with the same symptoms
(c) Throw away any left-over antibiotics into the toilet
(d) Stop taking the antibiotics as soon as I feel well
(e) Keep my vaccinations up to date.

Microbes and Bacteria

Microbes have been with us for billions of years. Bacteria were one of the first life forms to appear on Earth. They are typically a few micrometres in size, and come in a wide variety of shapes - spheres (cocci), rods (bacilli), spirals and vibrio. Bacteria are found everywhere - in soils, freshwater, the oceans, hot-springs, radioactive waste, up in the atmosphere and deep into the Earth's crust. They can live symbiotically and parasitically.

The science of microbiology started nearly three hundred and fifty years ago, with Anton van Leeuwenhoek's first observations in 1673 when he used his microscope to see "many living animalcules" in his tooth plaque. Before that however, many herbalists were aware that various plants had properties that could help fight infections and diseases. A beautiful example of the period is John Parkinson's *Theatrum Botanicum* published in 1640. Plants such as hyssop, sage, savoury, lemon balm and motherwort were all known for their properties to treat wounds and a range of diseases that we now recognise as being caused by bacterial infections.

Although our knowledge of bacteria has developed since then, most have not been assayed because of the difficulty of culturing them in the laboratory. What we do know is that some bacteria are very helpful. They can secrete essential vitamins, for example – Vitamin K and B12 and prevent colonisation of our bodies by nastier ones, especially in the intestine. They can stimulate the development of tissues and the production of natural antibodies. They are essential for making delicious cheeses – Emmentaler and Jarlsberg rely on pure cultures of *Streptococcus thermophilus, Lactobacillus bulgaricus* and *Propionibacterium shermanii* to control the development of acid, holes and flavour.

What are pathogenic bacteria?

However, bacteria are also the cause of distress and destruction, pestilence, pandemics, epidemics, and outbreaks of diseases. The number of these harmful bacteria is only about a 100, but from a medical and public health perspective they cause some of the most alarming and deadly diseases we know of. One of the best known is *Mycobacterium tuberculosis*. This causes tuberculosis and kills about 2 million people a year, mostly in sub-Saharan Africa. Pathogenic bacteria have damaged human societies, sometimes irreparably because of famines and wars. In fact, you could say that human history has been driven by bacteria.

Globally pathogenic bacteria contribute to millions of deaths each year, are key to the high infant mortality rates in developing countries and cause widespread diseases, such as pneumonia, foodborne illnesses, and can cause infections such as tetanus, typhoid fever, diphtheria, syphilis, and leprosy. The stories of the scientists tackling these diseases, have been inspirational and accorded Nobel prizes both in real life, such as Alexander Fleming's work on penicillin in 1929, and in novels such as the young, medical hero, Doctor Juvenal Urbino, committed to the eradication of cholera in the Gabriel Garcia Márquez 1985, *Love in a Time of Cholera*. The list of bacterial infections and diseases is a long one – some of the most famous include:

- *Staphyllococcus* (the reason why we swab the noses of surgeons and nurses and patients before going into operations is to identify a particular organism called Methicillin-resistant *Staphylococcus aureus*, MRSA, that is genetically distinct from other strains of *Staphylococcus aureus* and which is responsible for several difficult-to-treat infections in humans because of its multiple drug resistance to broad spectrum group of beta-lactam antibiotics such as penicillin);
- *Streptococcus* (the cause of Strep throat and pneumonia);
- *Salmonella* (this deadly strain of bacteria has two forms, the enterica, and the typhi. Typhoid fever is caused by *Salmonella typhi*, which was responsible in 2017 for more than 200,000 deaths. The contamination spreads through faeces and urine of the infected person. Today, some people are asymptomatic carriers);

- *Haemophilus* (of which the species *H. influenzae* is a cause of sepsis and bacterial meningitis in young children and *H. ducreyi*, the causative agent of chancroid);
- *Aspergillus* (causes pulmonary and blood infections, which can lead to death if not treated properly. It is common in cancer patients or the patients with other diseases. It is found in air conditioning systems and it is the place from where it spreads through air ducts);
- *Brucella (*whose species cause Brucellosis in people who have contact with infected animals or drink the milk without boiling)
- *Vibrio cholera* (this bacterium causes cholera and other diseases and is spread mostly by unsafe water and food contaminated by faeces, including seafood);
- *Pasteurella* (whose species *P. multocida* is the cause of a range of diseases in mammals and birds, such as fowl cholera in poultry, atrophic rhinitis in pigs, and bovine haemorrhagic septicemia in cattle and buffalo. It can also cause a zoonotic infection in humans, which typically is a result of bites or scratches from domestic pets. Many mammals, including domestic cats and dogs, and birds harbour it as part of their normal respiratory microbiota);
- *Campylobacter* (whose species are found mainly in poultry, can infect humans from eating food contaminated with them or being in contact with infected animals. *C. jejuni* is now recognized as one of the main causes of bacterial foodborne disease in many developed countries, and infections can spread to the blood in individuals with AIDS. *C. lari* is a known cause of recurrent diarrhoea in children, and *C. fetus* a cause of spontaneous abortions in livestock, as well as being an opportunistic pathogen in humans);
- *Legionella* (whose species *L. pneumophila*, causes legionellosis including a pneumonia-type illness called Legionnaires' disease and a mild flu-like illness called Pontiac fever);
- *Treponema* (whose species *Treponema pallidum*, is responsible for a number of human diseases such as syphilis, bejel, and yaws);
- *Rickettsia* (whose species are transmitted by arthropods such as chiggers, ticks, fleas, and lice, and are associated with both human and plant disease, most notably, typhus, rickettsial pox, Boutonneuse fever, African tick bite fever, Rocky Mountain spotted fever, Flinders Island spotted fever and Queensland tick typhus. *Rickettsia* bacteria do not cause rickets, which is a result of vitamin D deficiency);
- *Chlamydia* (a sexually transmitted infection caused by the bacterium Chlamydia trachomatis); and
- *Listeria* (whose species *L. monocytogenes* is usually the causative agent of the relatively rare bacterial disease listeriosis, the result of eating food contaminated with the bacteria. Listeriosis is a serious disease for humans; the overt form of the disease has a case-fatality rate around 20%. The two main clinical manifestations are sepsis and meningitis which is often complicated by encephalitis).

What have scientists done to fight pathogenic bacteria?

The first place that scientists turned to for antibacterial agents was amongst the vast array in the natural world. Probably the best known was the penicillin fungus *Penicillin notatum*: found in the mould found on bread and in Roquefort cheese. When Alexander Fleming discovered it in 1929, on his return from the August Bank holiday, it was in the form Penicillin G, inhibiting the growth of *Staphylococcus*. It works by blocking the division of bacteria, as well as the photosynthetic organelles in lower order plants. Most critically, it can inhibit the growth of many Gram-positive bacteria such as those causing scarlet fever, pneumonia, meningitis and diphtheria, but not Gram-negative ones such as *Typhus*. Penicillin went into commercial use in 1942 and was available in sufficient quantities at the time of the 1944 devastation at Pearl Harbour.

Penicillin remains on the World Health Organization's List of Essential Medicines, the most effective and safe medicines needed in a health system, even the numbers of penicillin-resistant bacteria are increasing. This is because penicillin can still be used to treat a wide range of infections caused by certain susceptible bacteria, including *Streptococci*, *Staphylococci*, *and Listeria.* Commercial production came from a mouldy cantaloupe in a Peoria, Illinois market but now semi-synthetic forms are available. The wholesale cost in the developing world is about 0.24 to 2.72 USD per day compared to 100-200 USD per treatment in the developed world.

Another second group of natural antibiotics, discovered in 1945 were the tetracyclines. These were the first broad spectrum antibiotics, and were effective against Gram-positive bacteria, Gram-negative bacteria, and bacteria lacking cell walls. Chlortetracycline came into hospitals the clinic in 1948, followed by tetracycline in 1953. To date, at least ten members of the tetracycline family have been used in human medicine, and they are heavily used

in veterinary medicine, both for the treatment of bacterial infections and as feed additives. Today, because of their good safety profile, abundant supply, and broad-spectrum activity, tetracyclines remain first line agents for a variety of diseases such as cholera, Lyme disease, and pneumonia and even for certain protozoan diseases such as malaria.

The thiopeptide family of antibiotics appeared on the scientific scene with the isolation of micrococcin in 1948, and since then, approximately thirty different sub-families spanning over 75 thiopeptide natural products have been discovered, They work through the inhibition of bacterial protein biosynthesis and mainly target Gram-positive bacteria; they are highly effective against methicillin-resistant *Staphylococcus aureus* making them attractive potential drug leads in the face of growing bacterial resistance to existing antibiotics. Thiostrepton is currently used as a topical antibiotic in animal health care, but its low water solubility and poor bioavailability has precluded, its use in humans.

Other naturally occurring antibiotic agents followed. One key group is the quinolones, found in a number of plants and used, without the benefit of advanced biochemical analysis by indigenous peoples in different parts of the world. Other antibacterial agents that have been isolated over the past fifty years include siomycin-A, similar to thiostrepton, thiopeptide factors, pseudomonic acids, kinamycin C, vancomycin and teicoplanin and ramoplanin A, lysobactin, absyssomycins, fatty acid biosysnthesis inhibitors, cerulenin and thiolactomycin.

Industrial Production of Antibiotics

Chemical synthesis has also played an important role in the discovery and development of useful antibacterial agents.

The first general purpose antibiotic used in modern medicine was prontosil, which was discovered by Gerhard Domagk in 1932 and developed and launched by the Bayer Laboratories in 1935. Prontosil is a synthetic diazo dye containing a sulfonamide functionality, and the first member of a large class of antibacterial agents known as sulfonamides or sulfa drugs. Though largely supplanted by later antibiotics, sulfonamides still have some limited use today. Domagk was awarded the Nobel Prize in Physiology or Medicine in 1939 "for the discovery of the antibacterial effects of prontosil." The sulfonamides were followed by synthetic quinolones in 1962, and included ciprofloxacin, now widely used throughout the developing world. Four decades later, the next synthetic antibiotic, oxazolidinone linezolid, was introduced, approved by the U.S. Food and Drug Administration (FDA) in 2000.

Even though today few clinical antibiotics are manufactured by total synthesis, the *de novo* synthesis of naturally occurring antibiotics is important for understanding the way in which many naturally occurring antibiotics work. Medicinal chemistry on naturally occurring antibiotics has yielded anti-infective agents with improved properties, whilst semi-synthesis has provided a direct and cost-effective process for the large-scale production of compounds. In other cases, such as chloramphenicol, total synthesis is the preferred way to produce naturally occurring antibiotics because of the inefficiencies of fermentation.

Poor Management of Antibacterial Agents

The volume of semi-synthetic and synthetic agents being produced a shot up with the use of tetracyclines as feed additives to prevent and combat infections of commercially valuable livestock, fish, trees, and insects. This was first reported in 1949, and subsequently approved by the US Federal Drug Administration in 1951. Tetracyclines are now used pervasively, with an estimated 5000 metric tons of tetracyclines consumed annually. It's hardly surprising then that antibiotics are everywhere. The problem now is how to manage them in the volumes that now exist in our waters, soils and air. And what happens to them once they are released?

Just as in all living kingdoms, in the microbial world, there is competition amongst different bacteria. This generally shows up in the form of antibiotic molecules that inhibit others from growing. Some bacteria and fungi however, have developed defence mechanisms to resist this type of attack and have become antibiotic resistant.

Antimicrobial, or antibiotic, resistance occurs when microorganisms, that cause infection, survive the medicines intended to kill them or stop their growth. They then go on to grow and increase in the environment.

Resistance can be intrinsic or acquired through a mutation in the bacterial DNA with the resistance genes being passed on to the next generation. Alternatively, resistance can be gained by horizontal gene transfer where DNA moves from one bacterium to another, even to an un-related one. Of the 59 pathogenic species commonly known to have clinical characteristics, 11% are known to be able to undergo genetic transformation transferring DNA from one cell to another. This process includes the uptake of exogenous DNA from a donor cell by a recipient cell and its incorporation into the recipient cell's genome by recombination. Normally, transformation is an adaptation for repairing damage in the recipient cell's DNA, but among pathogenic bacteria, transformation capability likely serves as an adaptation that facilitates survival and infectivity.

Where is multi-strain antibiotic resistance likely to occur?

The main places where antibiotics and their antibiotic resistant bacterial counterparts come together is in hospitals and in the environment. Looking at the environment, wastewater, animal manures and agricultural run-off, which contain many types of antibiotics, also contain antibiotic resistant bacteria. So, the discharge of untreated sewage and the poor disposal of drugs are important drivers of increasing antibiotic resistance in the environment and back again into ourselves through the food and water we consume. Even where there is a high level of investment in cleaning and managing wastewater, antibiotic resistant bacteria can be found. Wastewater treatment plants and sewage sludge are almost certainly hot spots for horizontal gene transfer because of the high density of bacteria and nutrient richness.

The overloading of the environment with so many different forms of antimicrobial substances simply increases the chances multi-resistant strains, known as superbugs, to evolve. What is most worrying is the number of substances that can trigger or play a role in building up antibiotic resistance in bacteria - they include biocidal substances, heavy metals and even fluoxetine, a previously unknown effect of an ingredient commonly used in anti-depressants.

The World Health Organisation released its first surveillance data on antibiotic resistance, showing that it was present in half a million people in 22 high and low-income countries. Globally, around 700,000 people die of resistant infections every year because the available antimicrobial drugs have become less effective at killing the resistant pathogens. Each year antibiotic resistance results in 8 million more hospitalisation days and 20billion USD to healthcare costs in the USA alone. The most commonly reported were *Escherichia coli*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, and *Streptococcus pneumoniae*, followed by *Salmonella* spp. *Mycobacterium tuberculosis*, which causes TB is reported separately. Even though the proportions of resistant bacteria varied a lot, resistance to penicillin – the medicine used for decades worldwide to treat pneumonia – was as high as 51% in some countries, and 65% for *E. coli* which is associated with urinary tract infections and which presented resistance to ciprofloxacin, an antibiotic commonly used to treat this condition.

The World Health Organisation now considers that "Some of the world's most common – and potentially most dangerous – infections are proving drug-resistant,". Their first estimate of a superbug annual death toll was 10 million people, and while this number is questioned by some, the dangers of not taking action far outweigh those of doing nothing.

This 'silent tsunami" as the World Health Organisation calls it, means that we are losing the ability to protect ourselves against infections such as pneumonia, tuberculosis and malaria which we previously had been able to tackle. We have got ourselves into a vicious circle where the overuse and misuse of antibiotics is increasing the selection for antibiotic resistance among bacteria. Microbiologists have been warning us, with increasing volume, about the indiscriminate use of antibiotics making them ineffective but it is only over the past few years that something is being done.

What can citizens do?

Today there are 52 countries (25 high-income, 20 middle-income and 7 low-income countries) enrolled in the Global Antimicrobial Surveillance System, so there is a long way to go in terms of reporting and tracking drug resistance worldwide. What we do know is that drug resistance surveillance programmes in TB, HIV and malaria work. They help estimate disease burden, plan diagnostic and treatment services, monitor the effectiveness of control interventions, and design effective treatment regimens to address and prevent future resistance. For

example, TB drug resistance surveillance has been implemented in 188 countries over the past 24 years. HIV drug resistance surveillance started in 2005 and by 2017, over 50 countries had reported data on pre-treatment and acquired resistance using standardized survey methods.

6.5 billion people now live in a country that has a national action plan on antimicrobial resistance; the tragedy is that many low-income countries are still struggling to get a plan in place and then to find the capacity to implement it, and yet these are the countries that bear the brunt of resistance – infectious diseases are much more common and the health systems are weaker and less able to cope as first-line antibiotics become less effective.

So what can you do?

Inappropriate use of antimicrobials drives the development of drug resistance. Both overuse, underuse and misuse of medicines contribute to the problem. Make sure that you are informed about the right dosage of the right antimicrobial and ask if there is a real need to take an antimicrobial.

Be aware, especially if you go on holiday, that some drug quality assurance systems are weak. This can lead to poor quality medicines, exposing patients to sub-optimal concentrations of antimicrobials, creating the conditions for drug resistance to develop. In some countries poor access to antimicrobials, forces patients to take incomplete courses of treatment or to seek alternatives that could include substandard medicines.

Sub-therapeutic doses of antibiotics used in animal-rearing for promoting growth or preventing diseases can result in resistant microorganisms, which can spread to humans. So buy food that has a quality assurance which avoids this form of use.

Poor infection prevention and control can increase the spread of drug-resistant infections. Hospitalized patients are one of the main reservoirs of resistant microorganisms. Patients who are carriers of resistant microorganisms can act as a source of infection for others.

The good news is that we know how to reduce antimicrobial resistance. We need to reduce the need for antimicrobials through good clinical practice, immunization, improvements in water, sanitation and hygiene, and good animal husbandry; we also need to ensure that these medicines are used more prudently in both people and animals, through better diagnostics, better access to the right drugs, and better regulation of antibiotics. We also need a much better system for monitoring supplies of drugs, where they are shipped, how they are distributed, and monitoring and reporting of the prevalence of drug-resistant infections in humans and animals.

So the first step in the arsenal of citizen actions is to equip yourself and your communities with the knowledge of why and when to take antibiotics, their efficacy and how to manage them in your own household. If you have antibiotics sitting at home left over from a course of treatment take them back to the surgery or clinic for safe disposal. Generally, keep yourself healthy and vaccines up to date. Look into other drugs you may be taking as they could have an effect once released into the environment on bacterial colonies. Reduce your exposure to potential antibiotic resistant strains.

And think about the food you buy and assure yourself about any use of antibiotics in producing it.

Phage Attack – My Enemy's Enemy is My Friend

But our antibiotic resistance toolkit still has two more possibilities.

Microbes also have an enemy. The bacteriophage. It is Earth's single deadliest entity and has been waging war on our planet for millions, probably billions of years.

The bacteriophage is a virus. It is very beautiful with an icosahedron-shaped head - 20 faces and 30 edges - that contains the phage's genetic material, and a long tail with leg-like structures. Bacteriophages ONLY kill bacteria and are very specific about which ones they select as their prey. Bacteriophages need a host bacterium to survive in and reproduce, so when a bacteriophage finds its specific host, it attaches itself with receptors on its tail fibres, injects its genetic material into the bacterium and takes over the bacterial operating system. The bacterium is

forced to manufacture the bacteriophage, millions of times over, until the pressure is so high that the bacterial host punches a hole in its own cell wall and explodes, releasing millions of bacteriophages into the environment to start the process all over again.

The increasing threat of resistance has been a major driver of the renewed interest in bacteriophage development trials. The *Phagoburn* clinical trial started in July 2015. It is a randomised and monitored phase I/II single-blind trial is being conducted in 11 major burns units in France, Switzerland and Belgium, with two arms of 110 patients each: one for burn wounds infected by *Escherichia coli*, the other arm for burn wounds infected by *Pseudomonas aeruginosa*. The effect of the bacteriophages cocktails is compared to a reference antibiotic treatment (silver sulfadiazine). The Primary Outcome Measure is the time for bacteria reduction adjusted on antibiotic treatment; the Secondary Outcome Measures are the assessment of treatment tolerance, the incidence on delay of infection reduction with different bacterial species from the targets, and the number of sites cured.

The discovery of bacteriophages was reported by Frederick Twort in 1915 and the French-Canadian Felix d'Hérelle in 1917, who said that the phages always appeared in the stools of *Shigella* dysentery patients shortly before they began to recover.He "quickly learned that bacteriophages are found wherever bacteria thrive: in sewers, in rivers that catch waste runoff from pipes, and in the stools of convalescent patients". Phage therapy was immediately recognized by many to be a key way forward for the eradication of pathogenic bacterial infections. A Georgian, George Eliava, was making similar discoveries. He travelled to the Pasteur Institute in Paris where he met d'Hérelle, and in 1923 he founded the Eliava Institute in Tbilisi; phage therapy is used in Russia, Georgia and Poland. In Russia, extensive research and development soon began in this field. In the United States during the 1940s commercialization of phage therapy was undertaken by Eli Lilly and Company.

While knowledge was being accumulated regarding the biology of phages and how to use phage cocktails correctly, early uses of phage therapy were often unreliable. Due to the spectacular successes of penicillin and other antibiotics, Western scientists lost interest in further use and study of phage therapy. However, Russian scientists continued to develop already successful phage therapies to treat the wounds of soldiers in during World War II, infected with various bacterial diseases such as dysentery and gangrene. The Cold War, meant that this knowledge did not spread, but due to the work in Tbilisi, Georgia, phage therapy is widely used. Now, because of antibiotic resistance emerging worldwide, there is a renewed interest in the ability of phage therapy to eradicate bacterial infections, such as *Campylobacter*, *Listeria, Escherichia coli, Salmonella, Shigella, staphylococci and streptococci* and chronic polymicrobial biofilms. The data on these treatments is however not available. In June 2015 the European Medicines Agency hosted a one-day workshop on the therapeutic use of bacteriophages and in July 2015 the National Institutes of Health (USA) hosted a two-day workshop "Bacteriophage Therapy: An Alternative Strategy to Combat Drug Resistance".

Even though phages are very specific, there is some evidence that they can go to specific sites such as the brain, crossing the blood brain barrier. This could mean there is a potential to tackle meningitis. There are also some research groups now looking at broader spectrum phages. We shall have to see what results come out.

Naturally Occurring Antibiotic Agents

The final tool in our medicine bag comes from the natural world itself. This is where the real source of antibiotic agents exists. As I said earlier there is a long tradition of using herb and medicines derived from them to treat a number of ailments and diseases.

In the Rift Valley of Kenya, where I live, there are hundreds if not thousands of plants which have a wide variety of agents in their bark, roots, leaves and fruits that show antimicrobial, antiviral, anthihelmithal and anti-inflammatory properties.

In the Maasai village, where I live and am married to the chief, I work with the laibon to gather and prepare medicines from on average 150 trees and plants.

These plants have been used for thousands of years and through trial and error, we know which ones work and which part of the plants are either toxic or have some efficacy for treating different conditions. My job has been to absorb this knowledge so that I can blend western and traditional medicines to best effect, and now through

the Maasai Mara University, create the scientific facilities to be able to grow the trees and plants, isolate the active agents and test their potency as antibiotics and antimicrobials. Nature's store cupboard has many more secrets to give if we use them carefully.

What do you need to know to act?

The threat from drug resistance is increasing. We will need to ensure, for as long as possible, the continuity of successful treatments and the prevention of infectious diseases using effective and safe medicines that are quality-assured, used in a responsible way, and accessible to all who need them. And at the same time, we can support communities and countries to develop new forms of naturally occurring antibiotic agents that will improve and sustain their own health whilst creating livelihoods and natural prosperity. Using combinatorial knowledge systems, we will be able to step back from this impending bacterial doomsday.

So let's conclude with the quiz. Here are the answers:

Question 1: Antibiotics are powerful medicines that help to fight: (b) Bacteria.
Antibiotics are medicines that treat bacterial infections. They do not cure infections caused by viruses, such as the common cold or flu. Taking antibiotics when you do NOT need them can prevent them working when you DO need them.

Question 2: Antibiotic resistance happens when my body becomes resistant to antibiotics: (b) False
Antibiotics target bacteria, killing or weakening them and helping you to fight off infections. Your body does not develop resistance to antibiotics; it is the bacteria which becomes resistant to antibiotics through genetic changes. This means that if you get an antibiotic-resistant bacterial infection, the usual antibiotics used to fight it will no longer be effective. A less accessible or last resort antibiotic will then need to be used, and in some cases options for potential active antibiotics could run out.

Question 3: Antibiotic-resistant bacteria can spread to humans through: (d) All of the above
Antibiotics are given to humans, animals, fish and crops. Antibiotic resistance happens when bacteria change and become resistant to the antibiotics used to treat the infections they cause. Antibiotic-resistant bacteria spread through contact with humans, animals, food or environment that are carrying them. You can help to prevent the spread of infections by regularly washing your hands, covering your nose and mouth when you cough or sneeze, and practising safer sex.

Question 4: What can happen if I get an antibiotic infection: (d) All of the above
Antibiotic resistance is happening everywhere in the world, affecting people of all ages. It is one of the biggest threats to public health today. Antibiotic resistant infections can take longer to treat, may require more frequent doctor visits, possible hospital stays, more severe side effects and expensive treatments. Serious, isn't it?

Question 5: I can help tackle antibiotic resistance if I: (c) Keep my vaccinations up to date

Taking action to prevent infections, such as by getting vaccinated, will stop you from getting sick and reduce your need for antibiotics. Even small actions can make a difference, like washing your hands regularly to prevent the spread of infection. And remember: if you do get sick, always consult your doctor about whether you need antibiotics. It is important to follow your doctor's advice, and not to share or use leftover antibiotics.

World Antibiotic Awareness Week is coming up - 12- 18th November. Please think about what you have heard tonight and see how you can help improve your own health and the health of millions of others in the poorest countries by using antibiotics wisely.

Thank you.