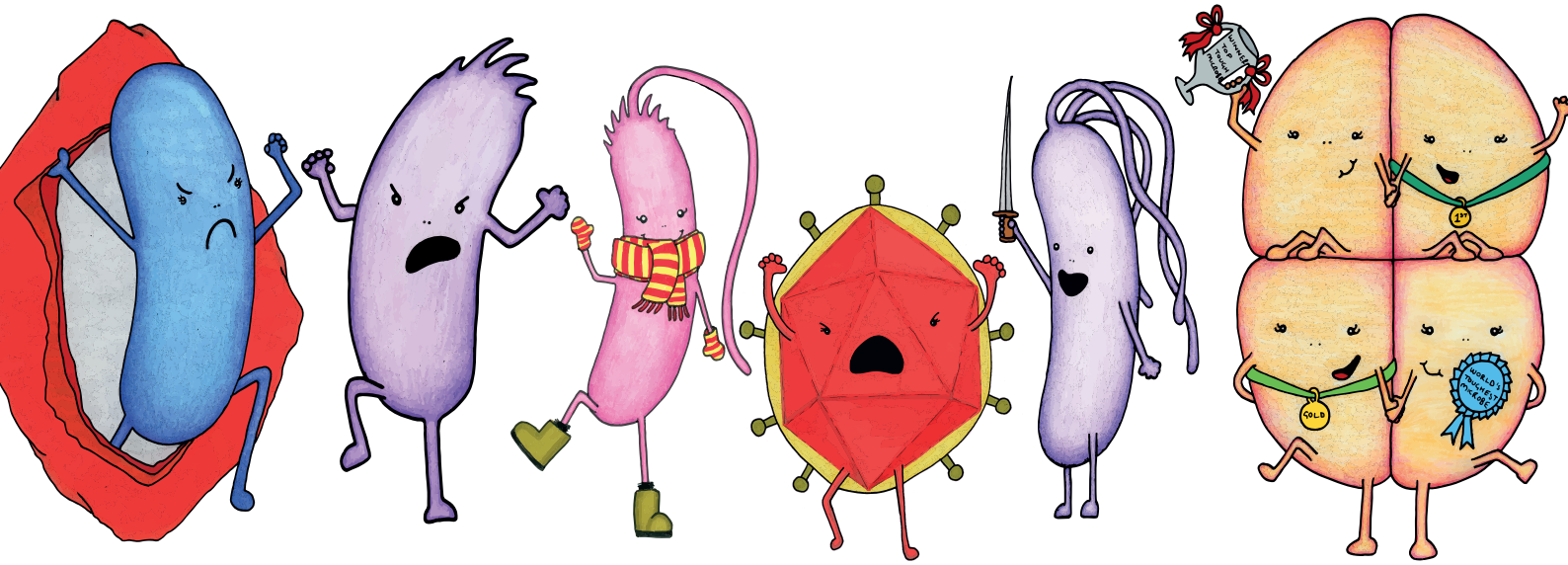
MEET THE MICROBES



BY NAOMI CHANT
ILLUSTRATED BY IMMY SMITH

This book is dedicated to the students that took part in ‘I’m a Scientist, Get me out of here’ in June 2014, and to Martin Ashby and Craig Hopper, who all inspired me to make ‘Meet the Microbes’ happen.

Without the team at ‘I’m a Scientist, Get me out of here’ and funding from the Wellcome Trust, this book would not have been made possible.

With thanks to Dr. Immy Smith, a talented artist whose enthusiasm and dedication to science outreach made ‘Meet the Microbes’ come to life.

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Naomi Chant, a Senior Development Scientist at Thermo Fisher Scientific UK, develops culture media to grow and identify all sorts of menacing and mischievous microbes. Outside of the laboratory, Naomi loves writing and talking about microbes, especially the marvellous ones. This book is the outcome of Naomi being voted as the winner of the ‘Neodymium Zone’ in ‘I’m a Scientist, Get me out of here’, June 2014, by students aged 12-18 across the UK.

Contents

INTRODUCTION: TO THE MOST DIVERSE LIVING THINGS ON EARTH

There are more microbes than there are animals, insects and plants combined, and they are the most diverse living things on this planet. Microbes have been around for a very long time; they were the first life form that appeared on Earth, long before the evolution of multi-celled organisms including plants and us. You even carry around more microbes in your body than you have of your own cells and they make up 1-3% of your total body mass. Microbes pretty much rule the world, which can be hard to imagine because they're so small that we can't see them without a microscope.

Microbes are incredibly diverse; some are menacing and cause disease, whilst others are marvellous and do lots of beneficial things for us. In this book, you'll learn about the good, the bad and the ugly microbes, from ones that cause an upset tummy to ones that help make snow. With so many to learn about, let's meet Sue Domonas, Anne Thrax and many other weird and wonderful microbes!

CHAPTER ONE

EXPLORING THE INVISIBLE AND WHERE IT ALL BEGAN

With so many microbes in the world, it's of no surprise that there are different weird and wonderful types. Even though we've always been surrounded by billions of them - the good and the bad - we haven't always been aware of their presence because they're so tiny.

In this section, you'll learn about what microbes are exactly, and the very important scientists that discovered them.

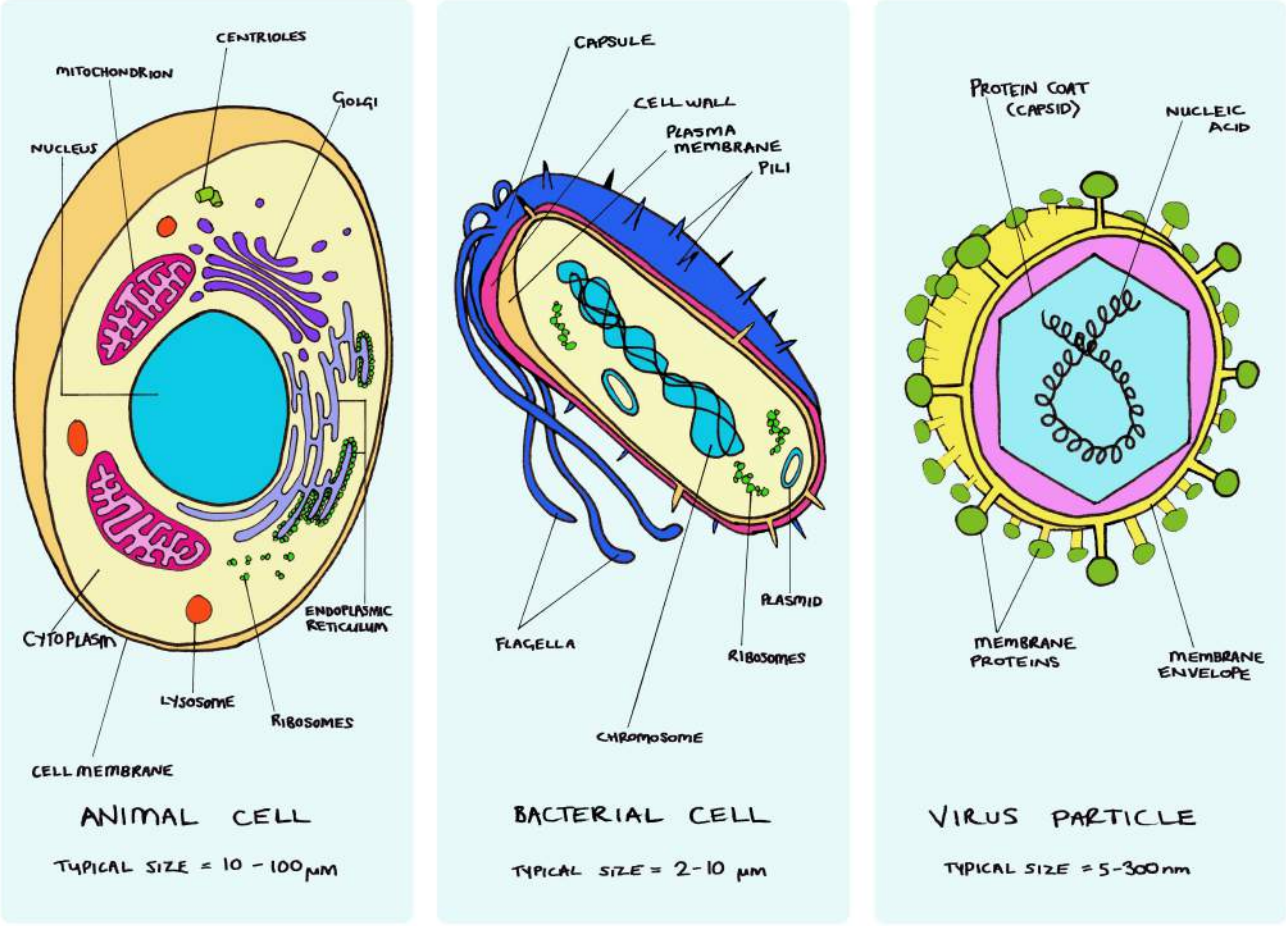
What is a microbe?

A microbe (or microorganism) is the term used to describe tiny single celled living things that include bacteria, fungi and viruses. To give you an idea of how small they are, around 100 average-sized viruses could fit into a bacterial cell and around 10-100 average sized bacterial cells can fit into the width of one of your hairs. And they're absolutely everywhere – you're carrying up to 3000 different types of bacteria on your hand right now!

What are they made of?

Like animal cells, microbes are made of genetic material and proteins but they're much simpler.

The main difference between bacterial and animal cells is their lack of mitochondria (cell structures that carry out respiration) and a nucleus; their DNA is instead a single super-coiled loop floating around in the cell. They can also carry extra loops of DNA called plasmids, which they can transfer to other bacteria. Most bacteria can move around in their environment and they do this using a hair-like tail called a flagellum.



Viruses are the most basic microbes; all they have is genetic material inside a protein coat. They can't live on their own, as they don't have everything they need to replicate and because of this some scientists don't think viruses are living things. To survive, viruses hijack animal or bacterial cells to borrow what they need to reproduce. And they don't even ask!

THE BIRTH OF MICROBIOLOGY

Microbiology is the study of microorganisms and someone who studies them every day is called a microbiologist (which is a very cool job!). Microorganisms were first observed in the 1600s by a scientist called Antonie van Leeuwenhoek, using microscopes he built himself (he made over 600 in his day!).

It was not until the 1800s that microorganisms were proven to be everywhere around us by Louis Pasteur, who is often described as the “Father of Microbiology”.

Before Pasteur, people thought living things could form from lifeless objects, such as maggots spontaneously forming from meat instead of from fly eggs. This absurd theory was called Spontaneous Generation.

Pasteur devised a simple but ingenious experiment to test whether sterile broth could spontaneously generate microbial life. He made flasks containing a sterile broth that had a bendy neck, preventing air from entering. The broth remained unchanged and it was not until he broke the neck off that air, containing microorganisms, was able to contaminate the broth making it murky with microbial growth. This showed that life didn’t spontaneously arise without the introduction of air, which contained microorganisms, proving the Spontaneous Generation theory wrong once and for all. This was the birth of microbiology as we know it.

CHAPTER TWO

GROWING AND IDENTIFYING MICROBES

Being so small makes microbes hard to study and identify. To do this, scientists have to grow them first, so that they can be seen. This enables scientists to identify microbes that make hospital patients ill, study them so we can treat illnesses they cause or make use of them if they're harmless, and identify completely new microbes.

In this section, you'll learn how scientists grow bacteria and how microbes are classified when new ones are discovered. You'll even have a chance to become a scientist yourself by growing some microbes yourself!

Hunting for disease-causing microbes

At the same time as Pasteur, a German scientist called Robert Koch began working with bacteria, proving they caused certain diseases. He did this by growing microbes from diseased animals and infecting healthy animals with these isolated microbes. These healthy animals would develop the same disease, proving the microbe was the cause.

Koch was a fantastic “microbe hunter”; identifying and naming bacteria that caused many diseases. As Koch and Pasteur were both making huge discoveries in microbiology at the same time, with their investigations sometimes overlapping, it’s of no surprise that these two scientists became rivals!

Growing microbes using...jelly!

To study and identify microbes, they have to be grown from a single cell so that they can be seen without a microscope. Koch and others that worked with him developed culture media, which is a nutritious liquid that microbes grow in. This liquid can be made solid using agar that comes from seaweed, giving it the texture of jelly that microbes grow on. Microbiologists most commonly grow bacteria and fungi using agar in round plastic dishes, called Petri dishes.

DID YOU KNOW?

Before agar, scientists used gelatin, which would melt in summer temperatures making it pretty useless at culturing microbes. Agar melts at much higher temperatures and was discovered by Angelina Hesse in the 1880s, who used it in her dessert recipes!

Recipe for growing microbes

Making culture media is a bit like making a cake – ingredients are added to a flask, heated to kill all microbes and cooled before pouring into Petri dishes and allowing the agar to set. Here is a recipe that scientists use to make culture media.

Ingredients

Purified Water
Sugar
Yeast Extract (similar to Marmite)
Blended meat (peptones)
Agar

Steps that scientists follow

1. All components are added to a flask and stirred to dissolve.

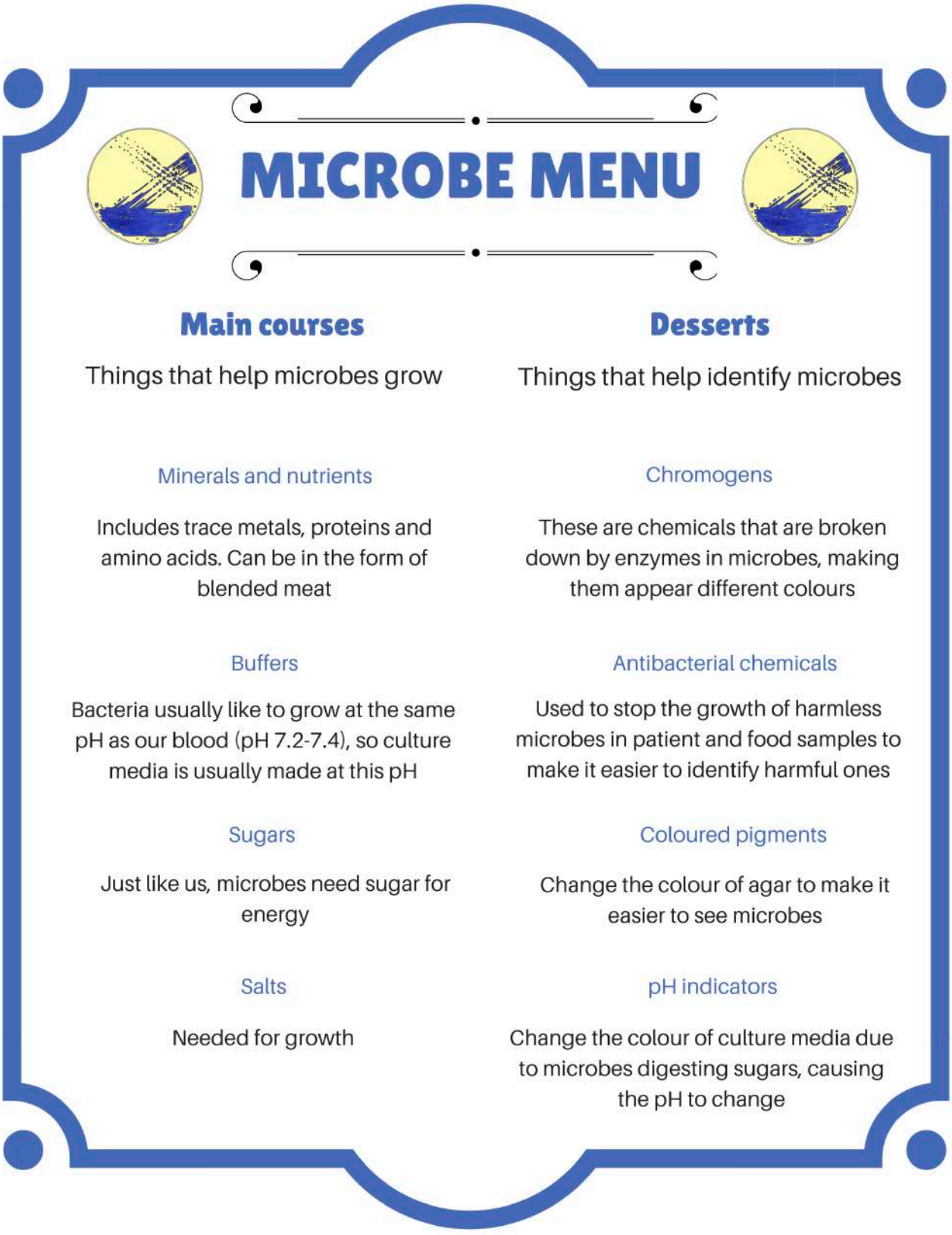
2. The liquid is heated to 121˚C for 15 minutes using steam under pressure to kill all microbes.

3. The liquid is cooled to 50˚C.

4. 20ml is poured into Petri dishes and allowed to set at room temperature. The agar is now ready to grow some microbes!

What's on the menu for microbes?

Isolating microbes that cause disease was no easy task for microbiologists over 100 years ago. In addition to the menacing microbe that was making a patient ill, many harmless microbes would also be found in pus and stool (poo) samples, masking the growth of the one that was the cause of the disease. Today, it's much easier to identify microbes, as scientists make culture media so that it grows specific bacteria and fungi, such as those that cause disease, helping microbiologists identify bacteria straight from patient or food samples. Here's what goes into culture media to feed microbes and also to help identify them:



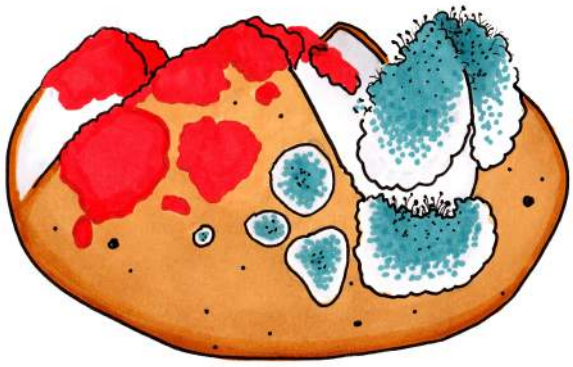
EXPERIMENT 1: CULTURE YOUR OWN BACTERIA!

Before the use of agar, Koch and his fellow microbiologists grew bacteria in less conventional ways. Needing a solid surface to work with bacteria, he noticed that when you boiled a potato and cut it with a hot knife, it would remain sterile if kept in a clean container. However, if left out in the open, raised microbial growth would occur from microbes landing on the potato from the air, multiplying into visible growth.

Although potatoes were able to isolate some microbes, it turned out that many did not grow because it wasn't nutritious enough, so Koch and his colleagues started developing new ways of culturing bacteria, using more refined nutrients solidified with agar. In this experiment you'll get to experience what it was like culturing bacteria in the 1800s!

Materials

- A couple of potatoes
- Clear plastic containers with a seal tight lid
- Antibacterial spray



Method

1. Cut potato slices so that they are around 5 cm thick and boil for 10 minutes.

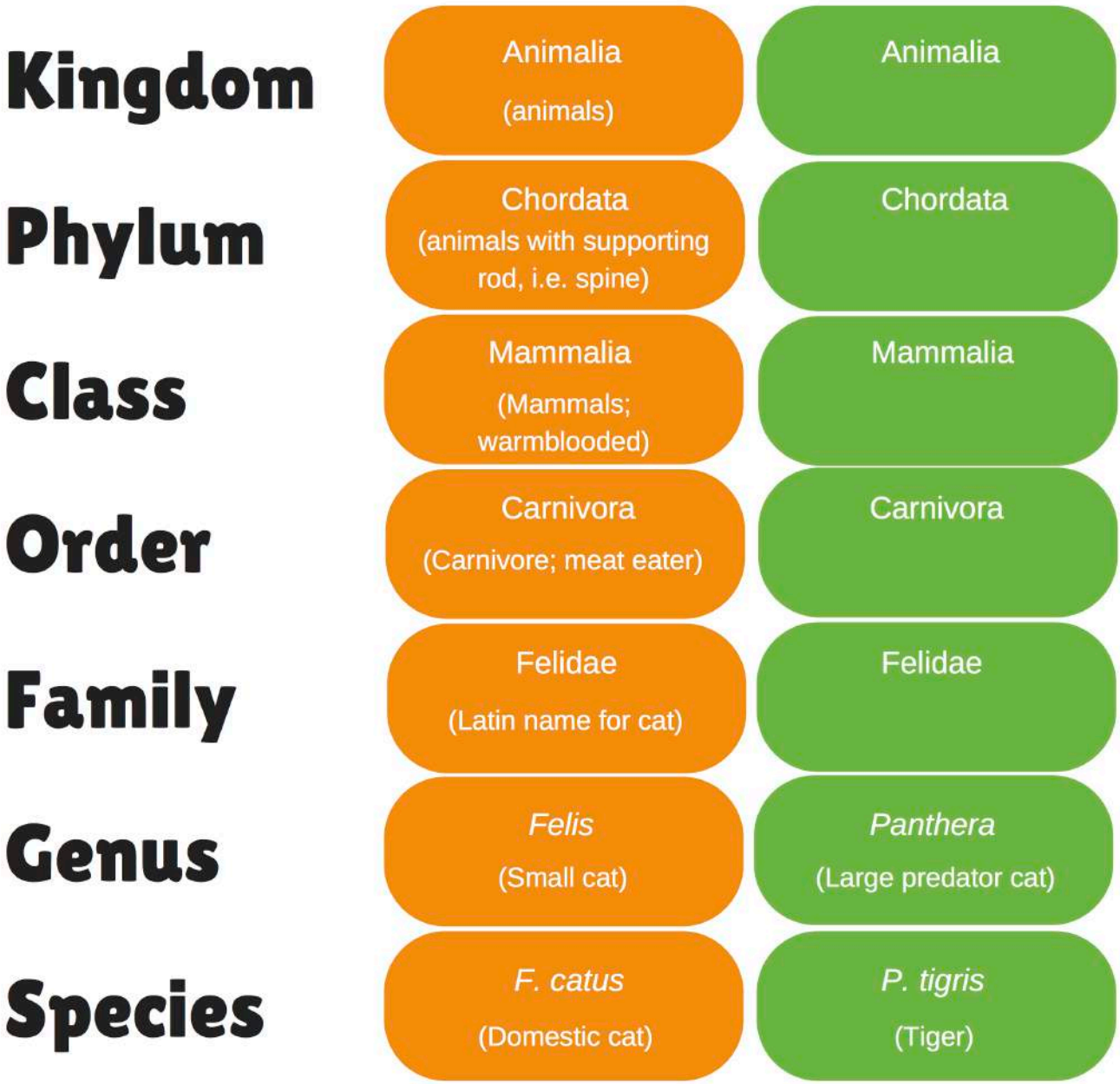
2. Rub two potato slices on a kitchen surface, or on your hands. Spray one with antibacterial spray and put them in a clear disposable container, sealing the lid.

3. Leave for around 5 days, leaving time for the microbes to grow. What do the bacteria or moulds look like? What effect did the antibacterial spray have on growth?

4. Throw your containers straight into a bin without opening the lids.

KEEP POND CLEAN OR FROGGY GETS SICK

Once microbes are identified, they are grouped just like animals and the process of doing this is called classification, or taxonomy. It's important to classify all living organisms so that different species can be identified. All living organisms are grouped in the following order:



This example shows that pet cats and tigers are closely related as they are in the same Family, but because pet cats are a lot smaller and friendlier, they are placed in a different genus.

As you get down the rankings, the more closely related and similar the living organisms are. Microbes are also grouped in the same way; they have different shapes, sizes, diets and some cause disease whilst others help prevent it, which are all factors that aid classification.

DID YOU KNOW?

New bacteria are being found every day – it's estimated we've discovered less than 1% so far!

Microbes in the same genus can be very similar, containing a similar genetic code and may have once been a single species. Over many years, they may have picked up pieces of DNA or their genes may have changed (mutated), which may enable them to cause disease or live in different conditions, altering them enough to be classified as a different species.

A good way to remember the order of classification is by remembering this:

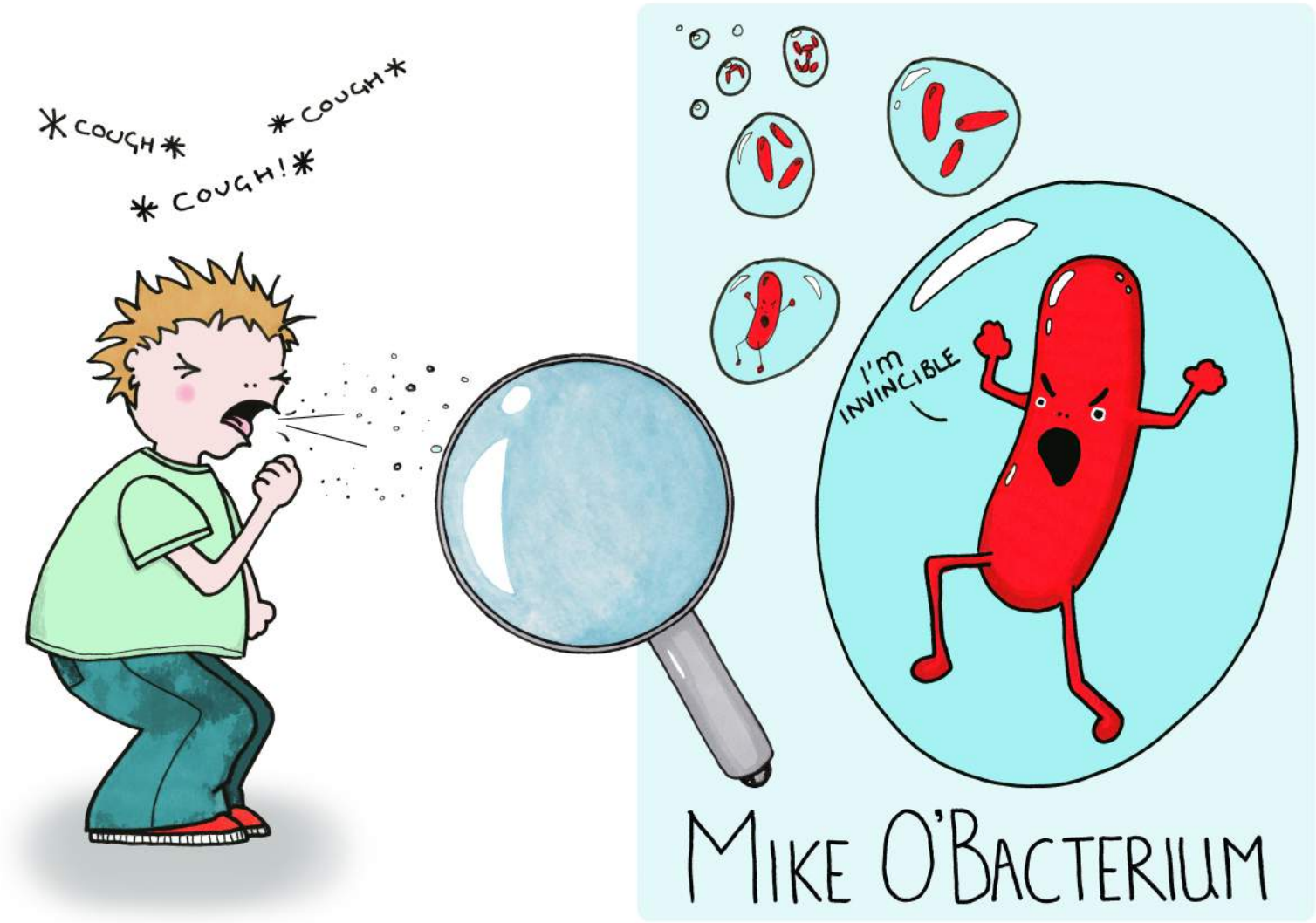
Keep Pond Clean Or Froggy Gets Sick!

CHAPTER THREE

MENACING AND MISCHIEVOUS MICROBES

Of the trillions of microbes that we live with, most are harmless but with so many around it's not surprising that some can make us sick every now and then. Microbes that cause disease are called pathogens and most of us are made poorly by a pathogen at least once a year.

In this section you'll learn about symptoms of diseases caused by menacing and mischievous microbes. You also find out how they are transmitted and how we can prevent these microbes from making us ill.



Hazard Rating

7/10

Death Rate

10%

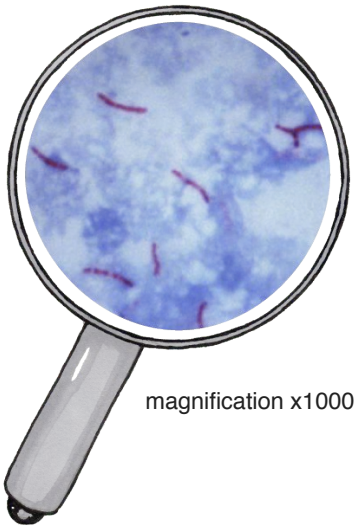
MIKE O'BACTERIUM

Microbe name: *Mycobacterium tuberculosis*

Type of microbe: Bacterium

Where is it found?

In the lungs of people infected



magnification x1000

What does it do?

Causes tuberculosis (TB) in humans, which is a disease that affects the lungs, causing a fever, coughing, weight-loss and tiredness. You can catch it by inhaling sneeze or cough droplets from an infected person and without treatment it can cause death.

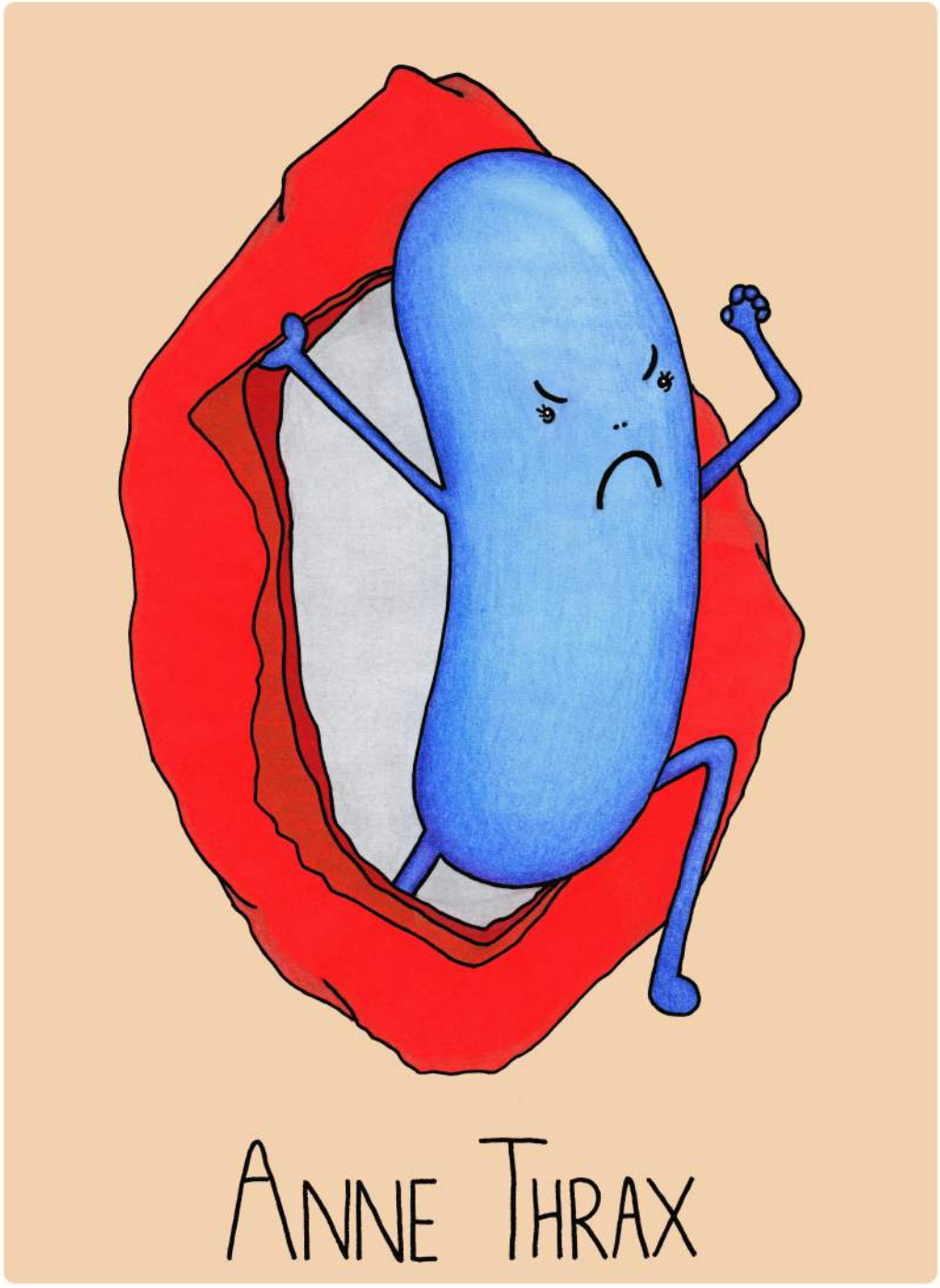
There is a vaccination for tuberculosis, called Bacillus Calmette–Guérin (BCG) which is given to people who are at risk of catching the illness. However, this ancient microbe (it's been around for a very long time) still continues to make millions of people very ill every year and is the leading cause of death by a microbe.

Number of people ill:

More than 8 million each year globally

INTERESTING FACT

Around a third of the world's population carries *M. tuberculosis* in their lungs, but only 10% of these people show symptoms. It also takes a very long time to treat TB with a course of antibiotics - at least 6 months!



Hazard Rating

9/10

Death Rate

90%

ANNE THRAX

Microbe name: *Bacillus anthracis*

Type of microbe: Bacterium

Where is it found?

Soil and in animals such as cows

What does it do?

Causes illness when it enters the body by inhalation, through a cut, or by eating contaminated food; the severity of the illness depends on how it enters. If it enters a cut, an infection of the skin occurs. Cases used to occur in people who handled farm animals that carried this microbe, but thanks to Pasteur who created a vaccine for animals, cases are now very uncommon.

B. anthracis is most deadly if it enters the body through inhalation. When under stress, *B. anthracis* forms a 'spore' by covering itself in a tough, hard coat, which makes it inactive and super resilient. When these spores are inhaled, *B. anthracis* bursts out of this coat and becomes activated, causing severe breathing problems and death if left untreated. Luckily this is extremely rare!

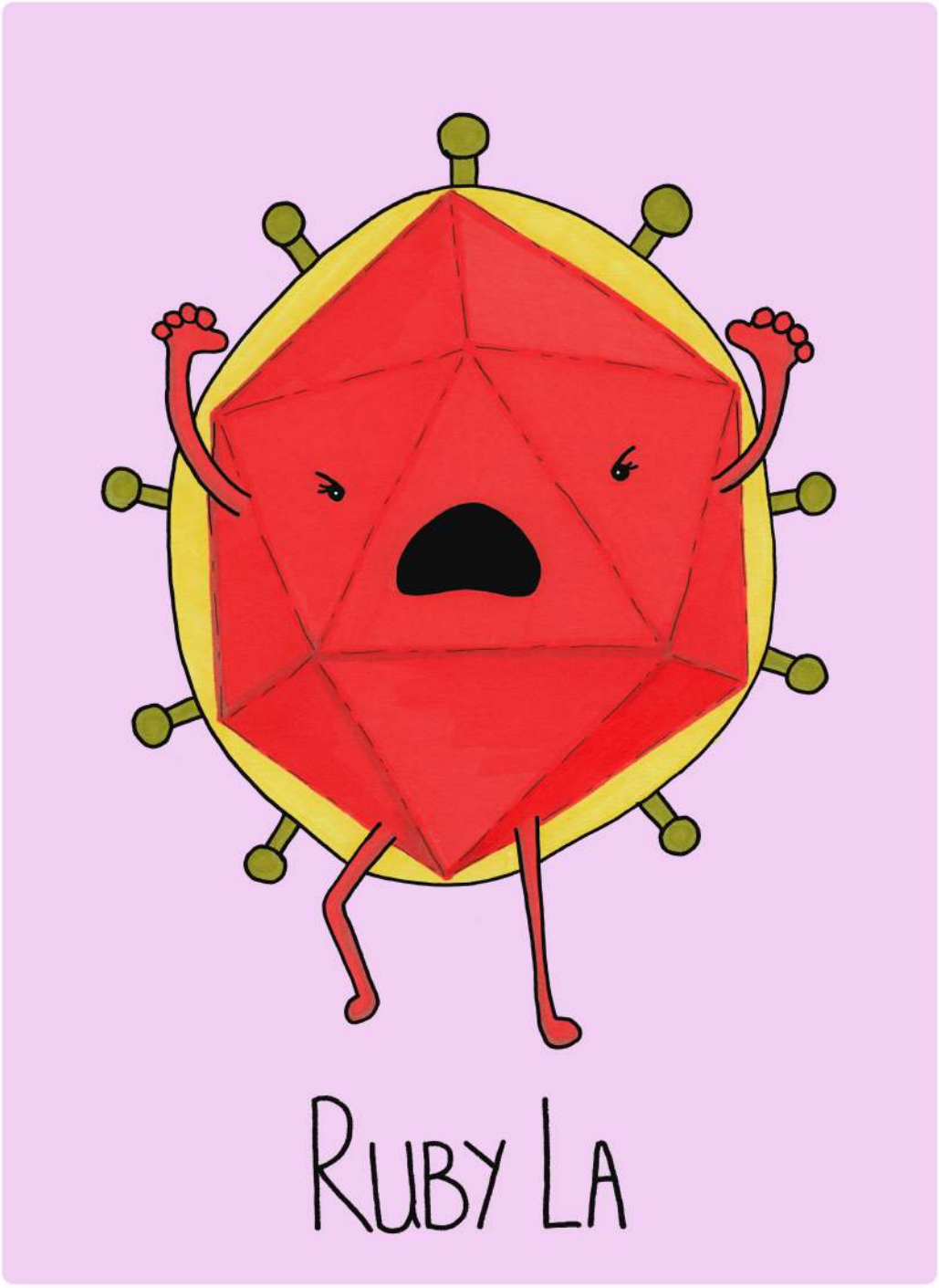
magnification x100

Number of people ill:

Unknown but cases are rare

INTERESTING FACT

Koch and Pasteur worked with *B. anthracis* at the same time; Koch identified it as the cause of anthrax and Pasteur developed the vaccine against it. Both disagreed with each other's methods and this is what sparked their rivalry!



Hazard Rating

5/10

Death Rate

Less than 1%*

*Death rate may higher in unborn children

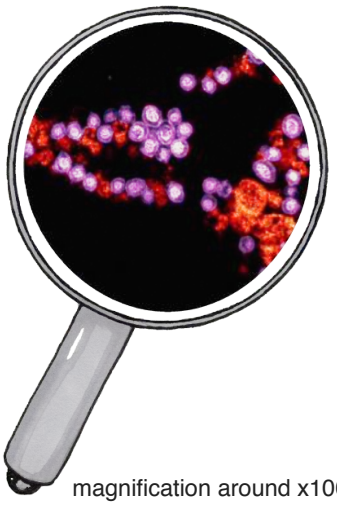
RUBY LA

Microbe name: *Rubivirus* (Rubella virus)

Type of microbe: Virus

Where is it found?

In the lungs of people infected



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What does it do?

Causes rubella, a mild illness in children. It causes flu-like symptoms (fever, chills) and an itchy red rash that lasts a few days. You catch it by inhaling sneeze or cough droplets from people who are infected. Rubella is dangerous to pregnant women as it can have serious effects on the unborn child, causing blindness, deafness, heart disease or even death.

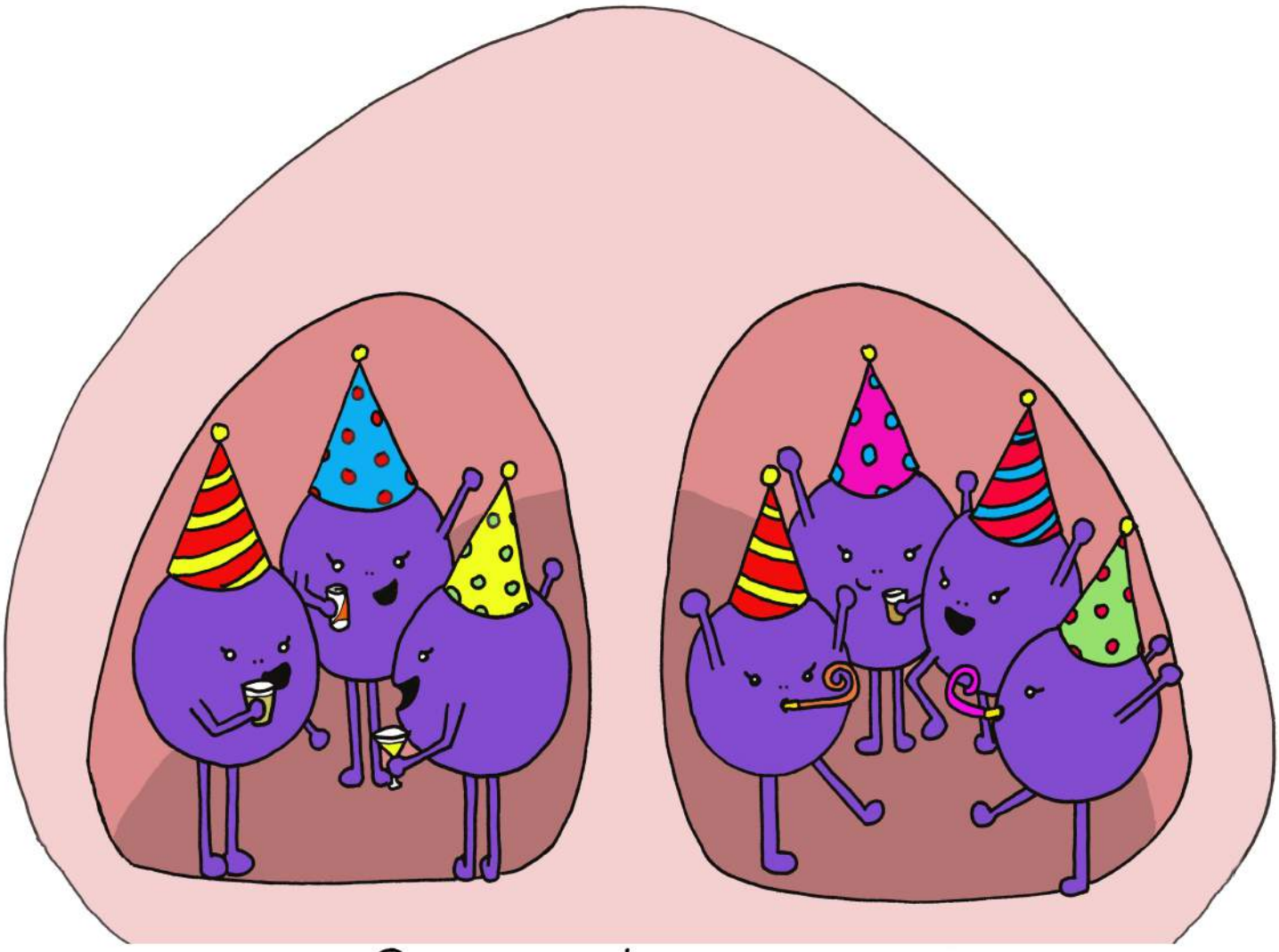
Luckily, cases of rubella aren't very common because it is vaccinated against with the Measles-Mumps-Rubella (MMR) vaccine that you have when you are around one year old.

Number of people ill:

More than 100,000 babies worldwide are born with defects, such as hearing loss and heart problems, due to Rubella infection each year.

INTERESTING FACT

Rubella is also called 'German Measles' as was first noticed by German doctors who described it as a different disease to measles.



Hazard Rating

4
/10

Death Rate

up to **20%**

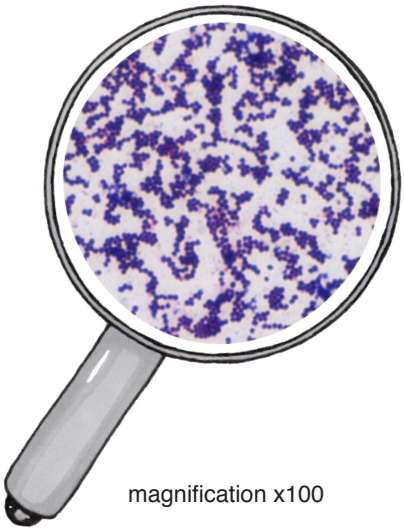
STEPH LE COCCUS

Microbe name: *Staphylococcus aureus*

Type of microbe: Bacterium

Where is it found?

On our skin and inside our nose



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What does it do?

S. aureus lives quite happily on our skin and in our nose without doing any harm. Such microbes are often referred to as 'commensal bacteria'. Although we don't mind this microbe having a party in our nose, it can turn very unpleasant if it enters a cut or sore. When this happens, S. aureus can cause nasty skin infections and if left untreated can cause more serious bloodstream infections that can cause death.

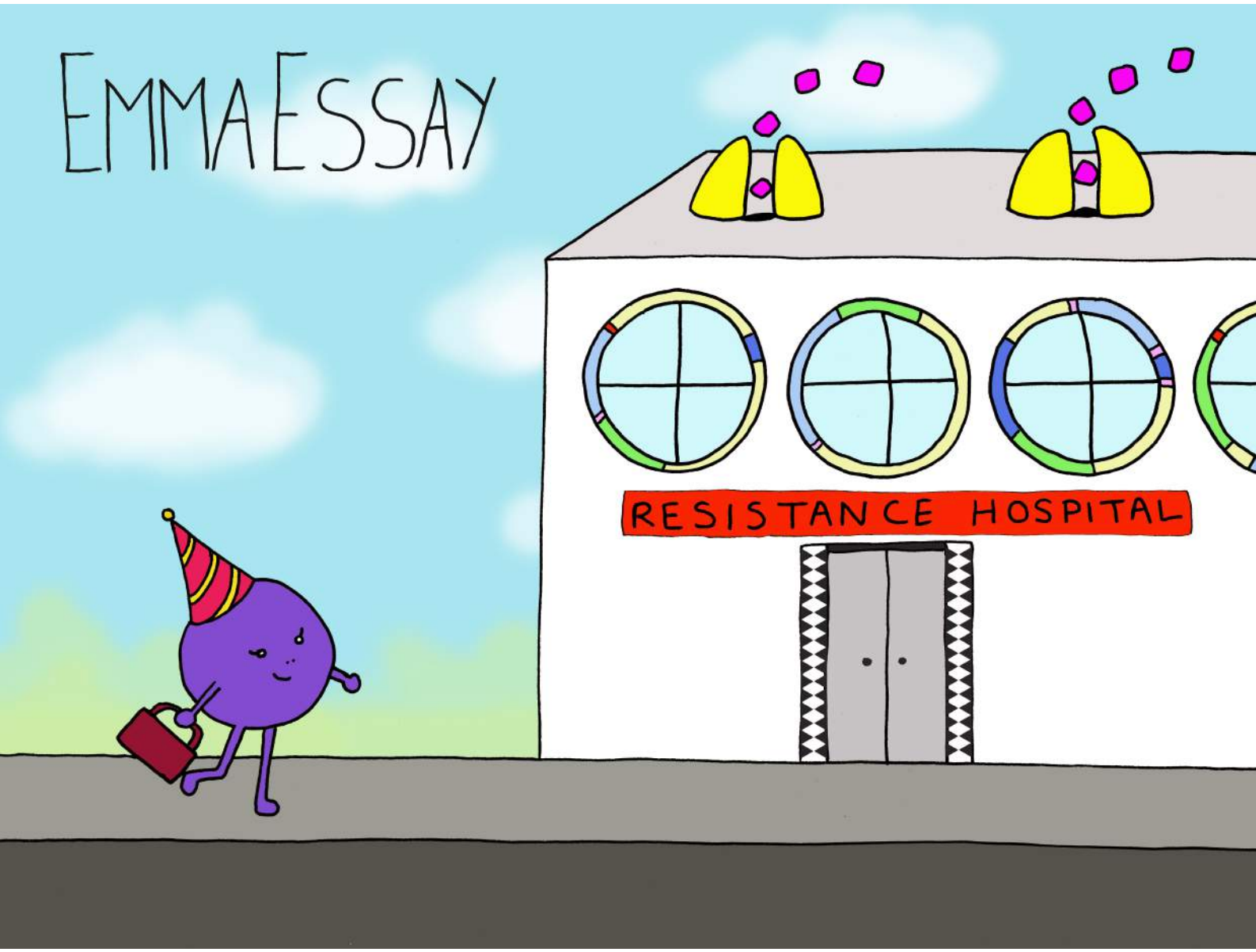
S. aureus can also cause food poisoning. This happens when someone handles food with *S. aureus* on their hands because they haven't washed them. When these foods are then left at room temperature, *S. aureus* multiplies and produces toxins that make you sick - so always wash your hands before making a sandwich!

Number of people ill:

Unknown, as most skin infections and food poisoning cases are not diagnosed or reported.

INTERESTING FACT

1 in 3 people have *S. aureus* living inside their nose!



Hazard Rating

6 /10

Death Rate

up to 45%

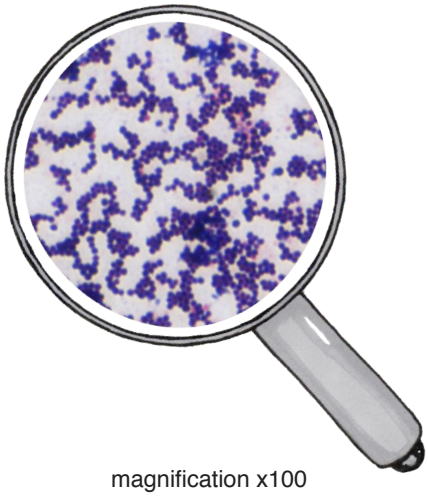
EMMA ESSAY

Microbe name: Methicillin-resistant *Staphylococcus aureus* (MRSA)

Type of microbe: Bacterium

Where is it found?

On our skin and inside our nose



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What does it do?

MRSA is resistant to an antibiotic called methicillin that is used to treat S. aureus infections; it is the same microbe as *S. aureus* but contains DNA that stops methicillin from working. This means it is a lot harder to treat MRSA infections compared to its sister microbe, making it more dangerous.

In hospitals, patients with surgical wounds, catheters and skin cuts made for medical procedures are particularly at risk of MRSA infection, so it's really important to reduce this risk. This is done by making sure hospitals are super clean, and testing all patients and healthcare workers for MRSA, so that they can be treated if they carry it on their skin to prevent it spreading to other patients.

Number of people ill:

More than 90,000 infections in the United States alone each year

INTERESTING FACT

1-3% of the population carries MRSA in their nose. These people are not necessarily ill as MRSA only causes infection if it enters a wound.

VACCINES: PREVENTION IS BETTER THAN CURE!

Jenner - inventor of the 'jab'

Back in 1796, a doctor called Edward Jenner noticed milkmaids who caught a disease called cowpox did not catch the more deadly smallpox, which at the time killed millions each year. To test his theory that cowpox provided immunity to smallpox, he rubbed pus from a cowpox sufferer into a cut in a young boy's arm. A couple of weeks later he carried out the same method, only this time with pus from someone with smallpox. Luckily the young boy didn't get smallpox, proving Jenner's theory right. This was the first vaccination, and the years that followed came vaccinations for many other diseases.

How do vaccines work?

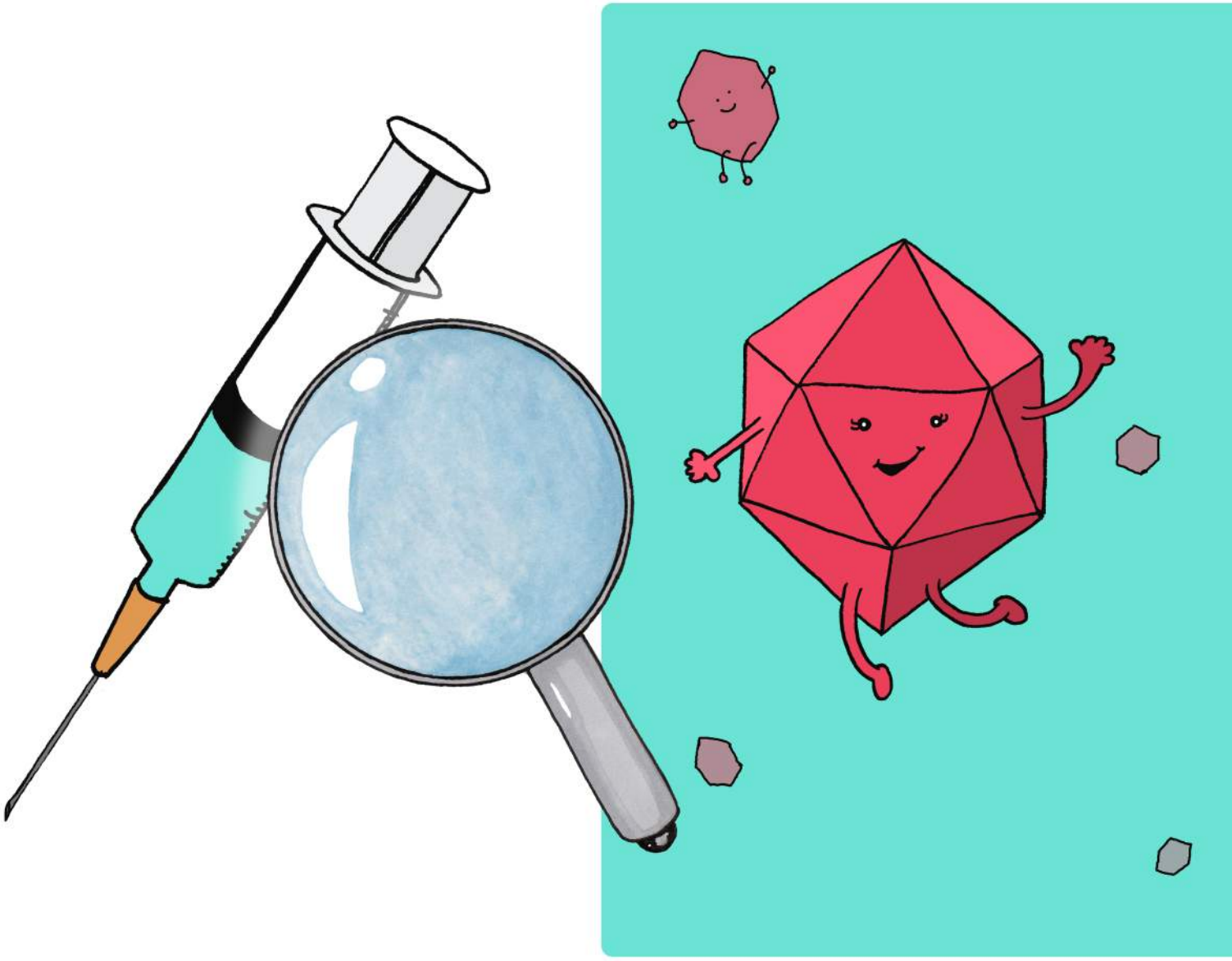
Vaccines work by improving our immunity to microbes, including bacteria and viruses. They do this by mimicking a harmful microbe, which doesn't make you sick but stimulates your immune system. In Jenner's case, cowpox looked like smallpox to the young boy's immune system, providing him with immunity to the deadly virus.

Brilliant B cells

Immunity provided by vaccines is down to the stimulation of antibody production. Antibodies are proteins produced by immune cells called B cells, that destroy microbes. They do this by coating them so they can't enter our cells and by recruiting other immune cells that directly kill the microbe.

If it's the first time the microbe has entered our body, it takes a while for B cells to produce antibodies, which can sometimes mean life or death. Luckily, B cells have fantastic memories - they remember microbes that have previously invaded. The next time the microbe comes along, B cells produce antibodies faster so you don't get ill.

Vaccines give B cells memories, so that they work much more effectively when the real dangerous microbe invades your body.



Luckily, modern day methods for vaccination have advanced and do not involve injecting people with pus today. There are now 3 main ways in which vaccines are made:

- The microbe to be vaccinated against is killed by heat. They cannot reproduce but still stimulate an immune response.

- A less harmful version of the microbe is made which doesn't make you ill.

- Only parts of the microbe are included in the vaccine, which do not contain everything they need to reproduce so they don't cause illness.

DID YOU KNOW?

Above all, the best way to prevent infection from a menacing microbe is by washing your hands with soap and water for 20 seconds.

Vaccines are used to protect against all types of microbes but there are still many to be developed. For some microbes, such as viruses that cause flu, vaccines are hard to develop because the virus changes so much each year by altering their genetic material - as soon as a vaccine is developed, the virus would have changed so that our antibodies no longer recognise it.

Luckily, for infections caused by bacteria that we don't have vaccines for we have antibiotics that can treat them.

ANTIBIOTICS: MAGIC MOLECULES THAT BEAT MENACING MICROBES

Antibiotics are chemicals that are used to treat infections caused by bacteria but not viruses; they work by stopping them from reproducing or by destroying them directly by acting on their cell walls, causing them to burst.

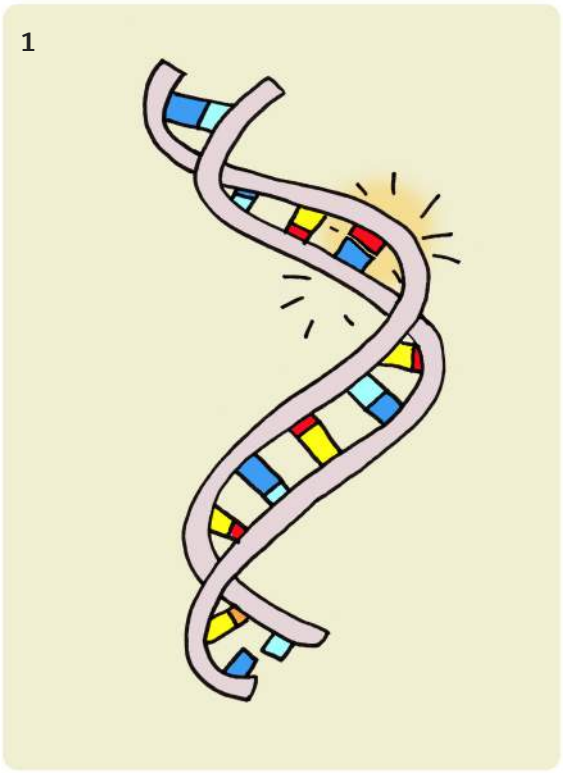
Antibiotic Resistance

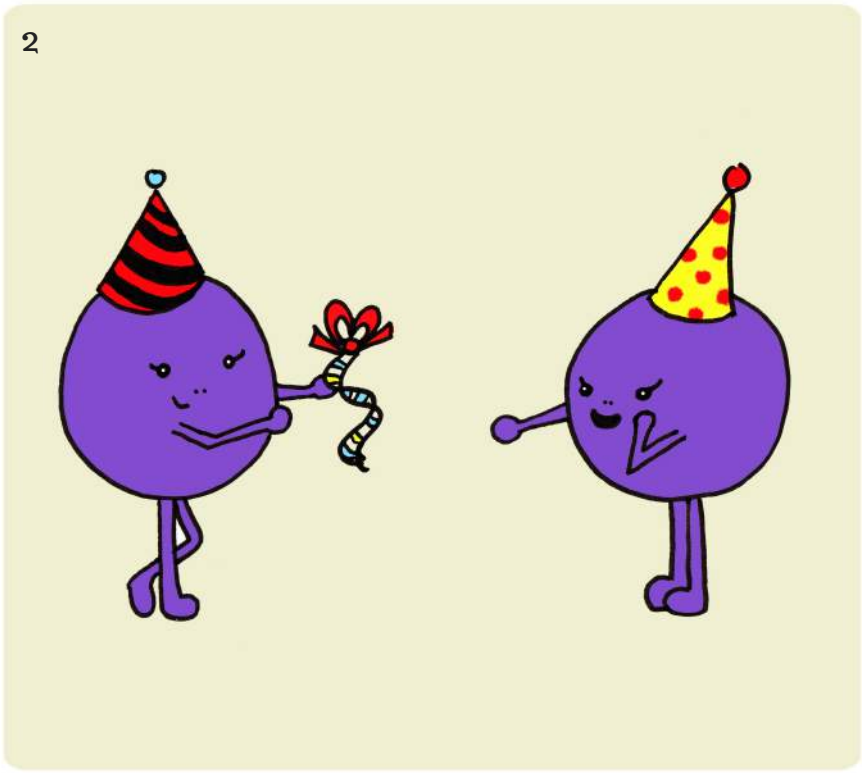
When bacteria are not affected by an antibiotic, they are resistant. This can happen when antibiotics are used too much or not properly, for example, not finishing a course of antibiotics. Without antibiotics, people would die from infections that have been easily treated for many years and this is why antibiotic resistance is such a huge threat to human health.

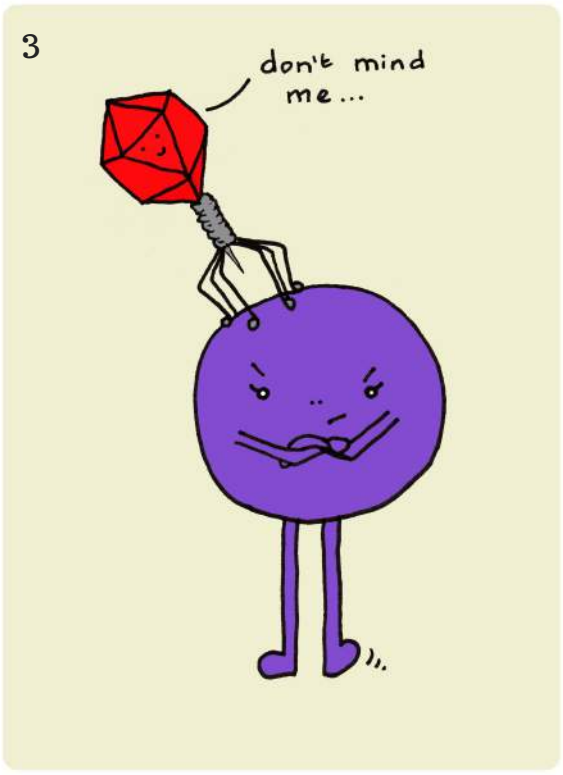
Bacteria fighting back

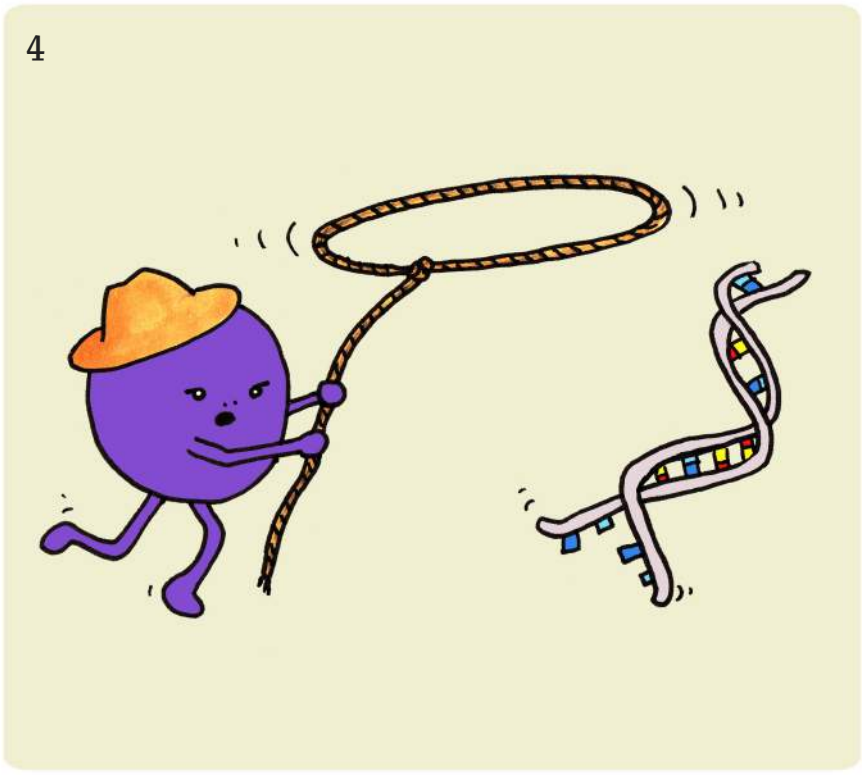
Bacteria may be naturally resistant to antibiotics because of their structure (such as having a cell wall that is difficult to get through), whilst others can become resistant to antibiotics that were once effective. In a population of bacteria, only one may develop resistance, which then reproduces, creating more resistant bacteria. Eventually, all the susceptible bacteria die, whilst the resistant ones grow and spread. This is an example of natural selection. Resistance happens when bacteria change their DNA, which protects them against the antibiotic. They're very good at doing this and have several mechanisms:

1. Their genes can change randomly (called a mutation)
2. Different bacteria can join and pass DNA to each other
3. They get pieces of DNA passed from viruses that only infect bacteria
4. They can take up pieces of DNA floating around









Can we beat bacteria?

Not all bacteria are bad, but the ones that are will always evolve to outsmart our ways of killing them. To beat antibiotic resistance, scientists need to find new antibiotics and ways of killing bacteria, health workers need to keep hospitals super clean, doctors need to prescribe antibiotics responsibly, and we need to take them properly. If we don't all work together we won't beat bacteria, and if we do it's not going to be easy - we'll always be racing against bacteria to stay ahead of the game; they're one clever bunch!

EXPERIMENT 2:

IT'S AN EPIDEMIC!

When a microbe suddenly causes disease in a lot of people in a specific location, it's called an epidemic. An epidemic is usually caused by immunity of the population falling below a threshold limit (i.e. not enough people getting vaccinated), mutations in microbes allowing them to infect people more efficiently, or because microbes are transmitted from their natural host (such as the Ebola virus in bats) to humans. When people infected don't catch their microbes in a tissue when they sneeze or keep their hands microbe-free, an epidemic can occur. This experiment shows how easily an epidemic can happen!

Materials

- Hand lotion
- Glitter
- Around 5-10 people - grab your friends for this one!

DID YOU KNOW?

When an epidemic spreads to more than one country it's called a pandemic, and when a disease is always present it's called an endemic.

Method

1. Get one person to be the "virus" in this experiment, and the rest of you close your eyes and stick out your hands in front of you.

2. The "virus" puts a dollop of hand lotion in the hands of everyone with their eyes closed and sprinkles some glitter ("viruses") in the lotion of one person's hands.

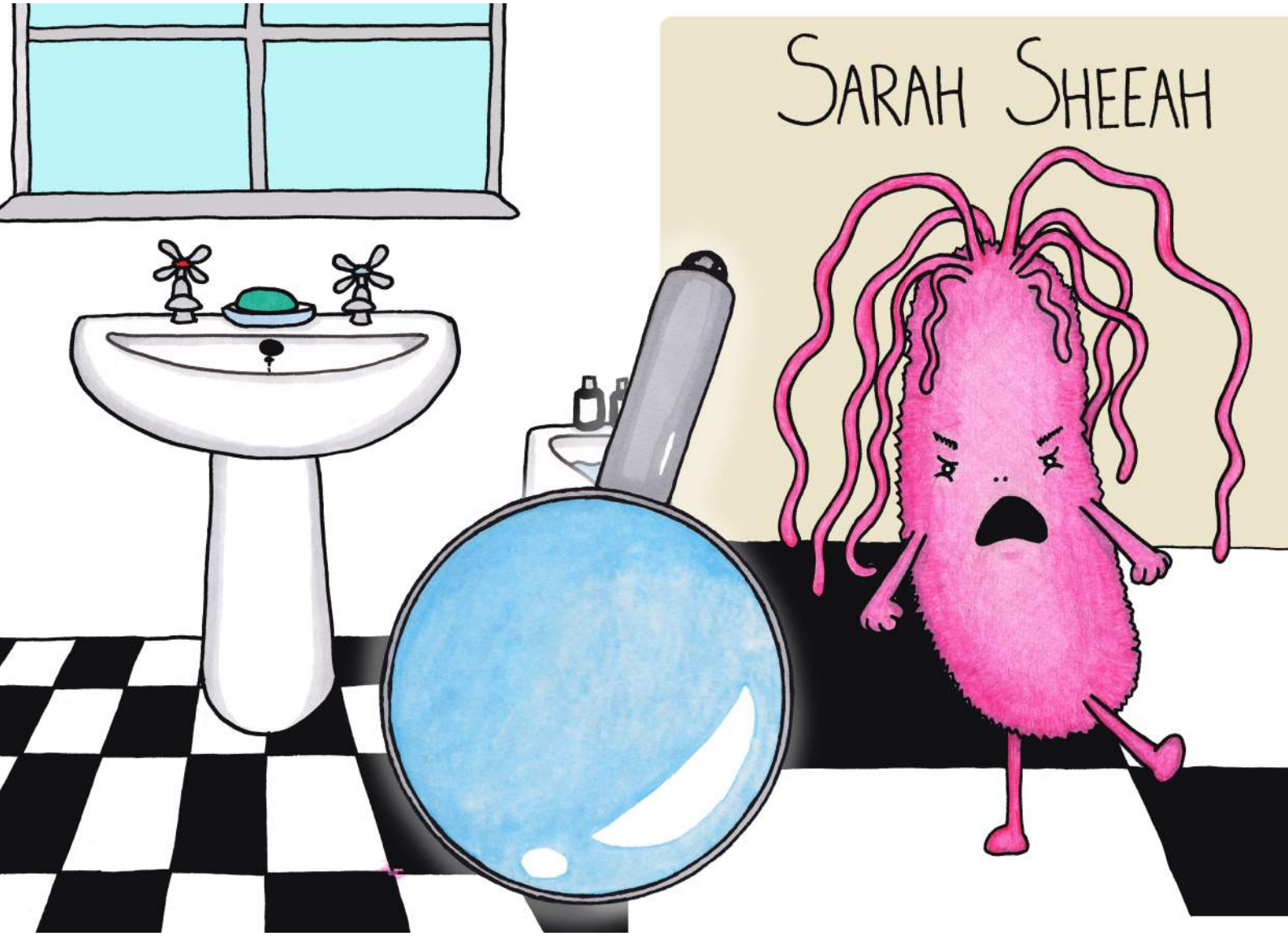
3. Rub your hands together - keeping your eyes closed!

4. Open your eyes and shake hands with one other person, trying not to look at your hands.

5. Now shake hands with someone else in the group.

6. Who has "viruses" on their hands? Notice how quickly microbes can spread? Note down who shook hands and in what order. Can you work out who may have started the epidemic?

What do you think would happen if you washed your hands in between handshakes? How do you think this relates to a real epidemic?



Hazard Rating

3 /10

Death Rate

up to **25%**

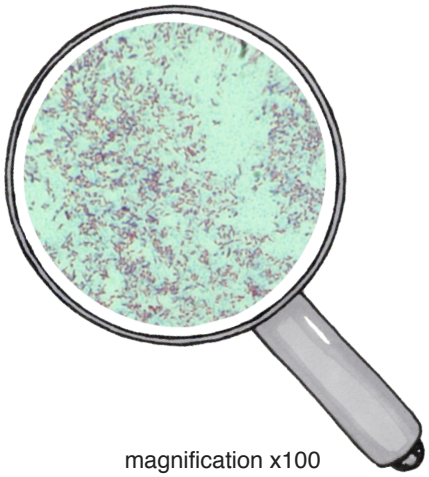
SARAH SHEEAH

Microbe name: *Serratia marcescans*

Type of microbe: Bacterium

Where is it found?

On our skin and in our environment.



magnification x100

What does it do?

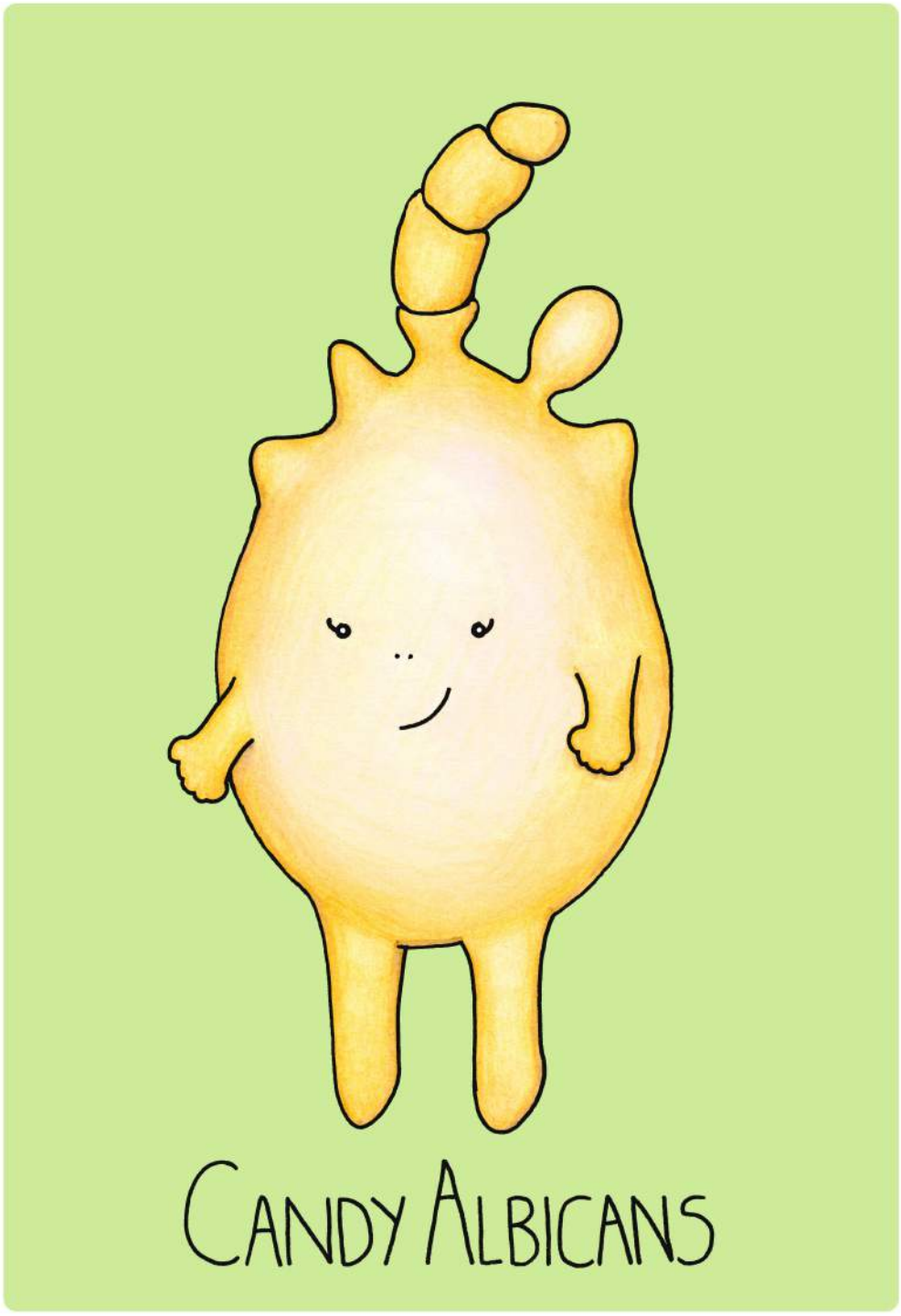
This microbe produces a pigment that makes it red and it enjoys hanging out in damp conditions, such as your bathroom. When you see pink stains around bathroom tiles, it's likely to be this microbe!*S. marcescans* is usually harmless, but takes advantage of hospital patients and people that have a weak immune system, causing illness when it enters through hospital equipment and wounds. It can cause infections in the urinary system, lungs and eyes, and can be deadly if it enters the bloodstream.

Number of people ill:

Causes 800 - 900 blood-stream infections each year in the United Kingdom.

INTERESTING FACT

S. marcescans can grow on starchy foods such as bread and its red appearance was thought to be the blood of Christ when it appeared in Church during medieval times.



Hazard Rating

3 /10

Death Rate

up to 70%

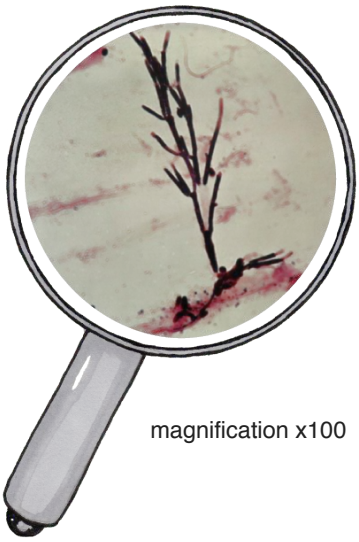
CANDY ALBICANS

Microbe name: *Candida albicans*

Type of microbe: Fungus

Where is it found?

In our mouth and gut



magnification x100

What does it do?

C. albicans usually lives on us without causing any harm and up to 80% of the population have this microbe living in their mouth and gut. However, *C. albicans* growth has to be kept in check, as when it overgrows it can it can cause 'thrush' in the mouth or genital region, which causes irritation.

It can be particularly dangerous in people with a weak immune system, as it can cause bloodstream infections that can be fatal if not treated.

Number of people ill:

Worldwide, *C. albicans* causes more than 400,000 bloodstream infections.

INTERESTING FACT

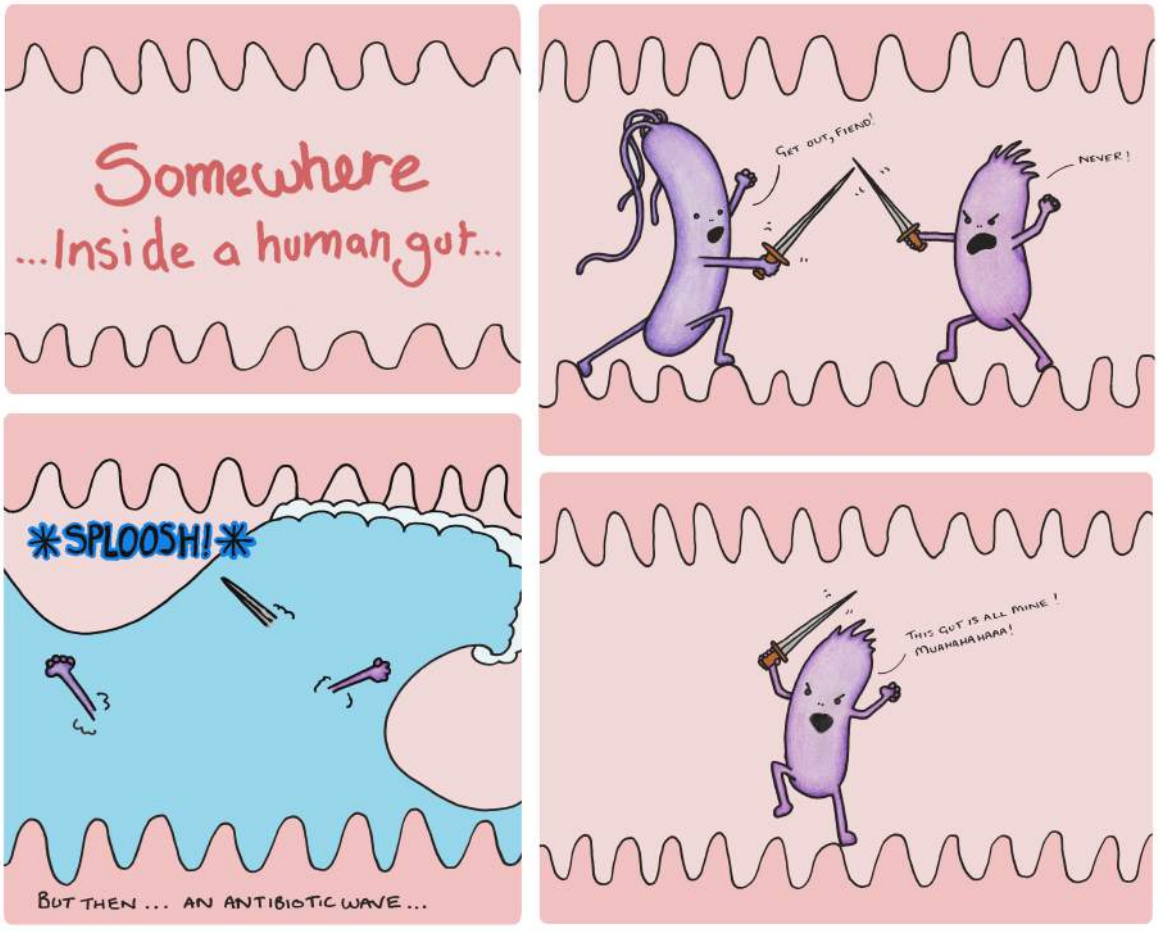
C. albicans is pretty clever and by reacting to our bodies' environments, it can change from a harmless, single celled microbe into an invasive yeast that produces hyphae, which are long filaments that look like Candy's hair. It's the hyphae that penetrate our body surfaces causing irritation.

OPPORTUNISTIC MICROBES: TAKING ADVANTAGE WHEN BARRIERS ARE DOWN

C. *albicans* and *S. marcescans* are examples of pesky opportunistic pathogens – microbes that take advantage of certain situations. Opportunistic microbes live in our environment, on our skin and in our gut without causing any harm, but if our body environment changes, these microbes can overgrow and cause disease. So what can cause this to happen?

1. Our immune system weakens. This can happen with certain diseases or as we get older.

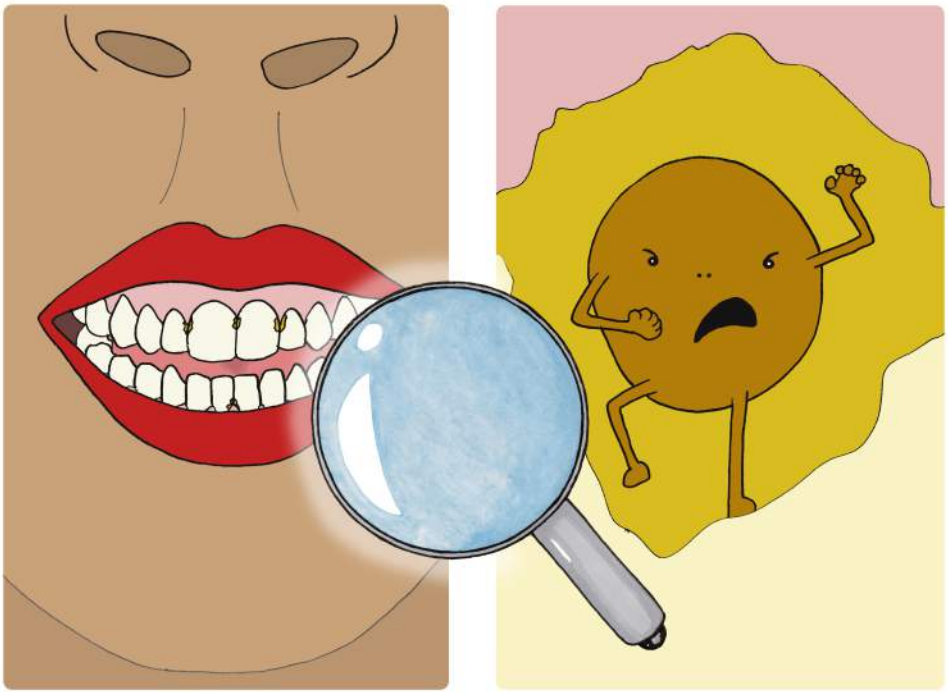
2. Our gut microbes change, reducing the amount of “good” bacteria that usually prevent the growth of harmful microbes. This can happen when antibiotics are used to treat infections, which can kill our good microbes, too.



EXPERIMENT 3: WHAT'S GROWING ON YOUR TEETH?

When we eat, we also feed our microbial habitants, including those that live on our teeth. It's the hundreds of microbes in our mouth, living on our teeth, which are responsible for tooth decay. These pesky microbes live in communities covered in a slimy substance that is otherwise known as a biofilm, or dental plaque.

When we eat sugary foods, these microbes turn sugar into acid that weakens our teeth by destroying minerals, causing tooth decay and cavities. This experiment will reveal why brushing your teeth is so important!



Materials

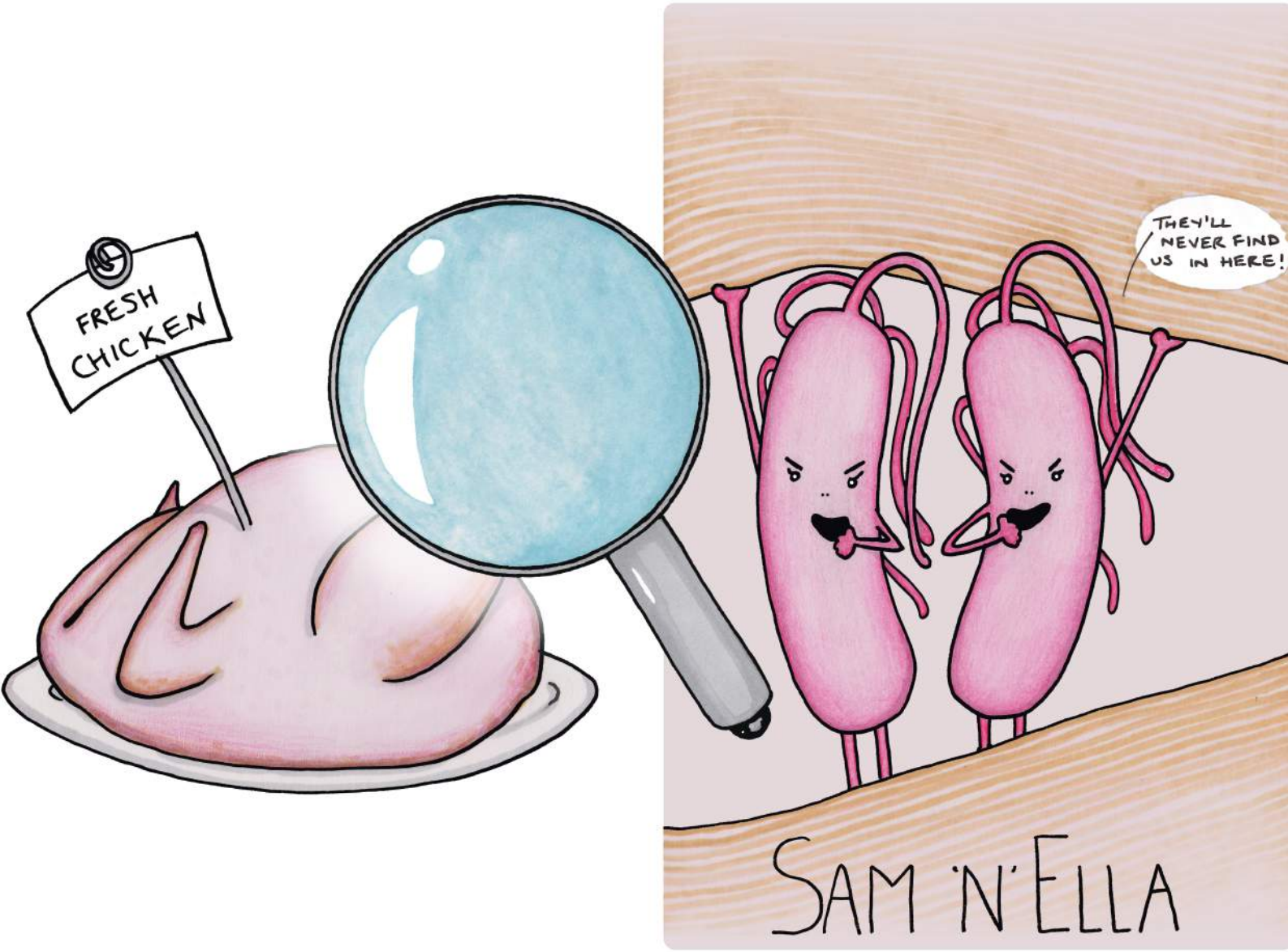
- Toothbrush
- Toothpaste
- Plaque disclosing tablets (available from health stores)

Method

1. Follow the instructions given for the discolouration tablets. Notice any staining on your teeth? This is dental plaque. If you don't notice any stains, then your teeth are plaque-free and you should keep up the good work!

2. Brush your teeth to get rid of the bacteria and plaque. Brushing with fluoride toothpaste replaces lost minerals in our teeth, thereby strengthening them and also preventing the buildup of microbes.

Make sure you brush those pearly whites twice a day to keep the bad microbes away!



Hazard Rating

5 /10

Death Rate

1%

SAM 'N' ELLA

Microbe name: *Salmonella enteritidis*

Type of microbe: Bacterium

Where is it found?

In the gut of animals such as chickens. It can also be present on eggshells and vegetables that have been in contact with animal poo.

magnification around x20000

What does it do?

Causes food poisoning when food contaminated with *Salmonella* is eaten. This happens when food hasn't been handled or cooked properly, such as not cooking chicken for long enough. Once food contaminated with *Salmonella* is eaten, they multiply and cause symptoms that include diarrhoea, stomach cramps and vomiting.

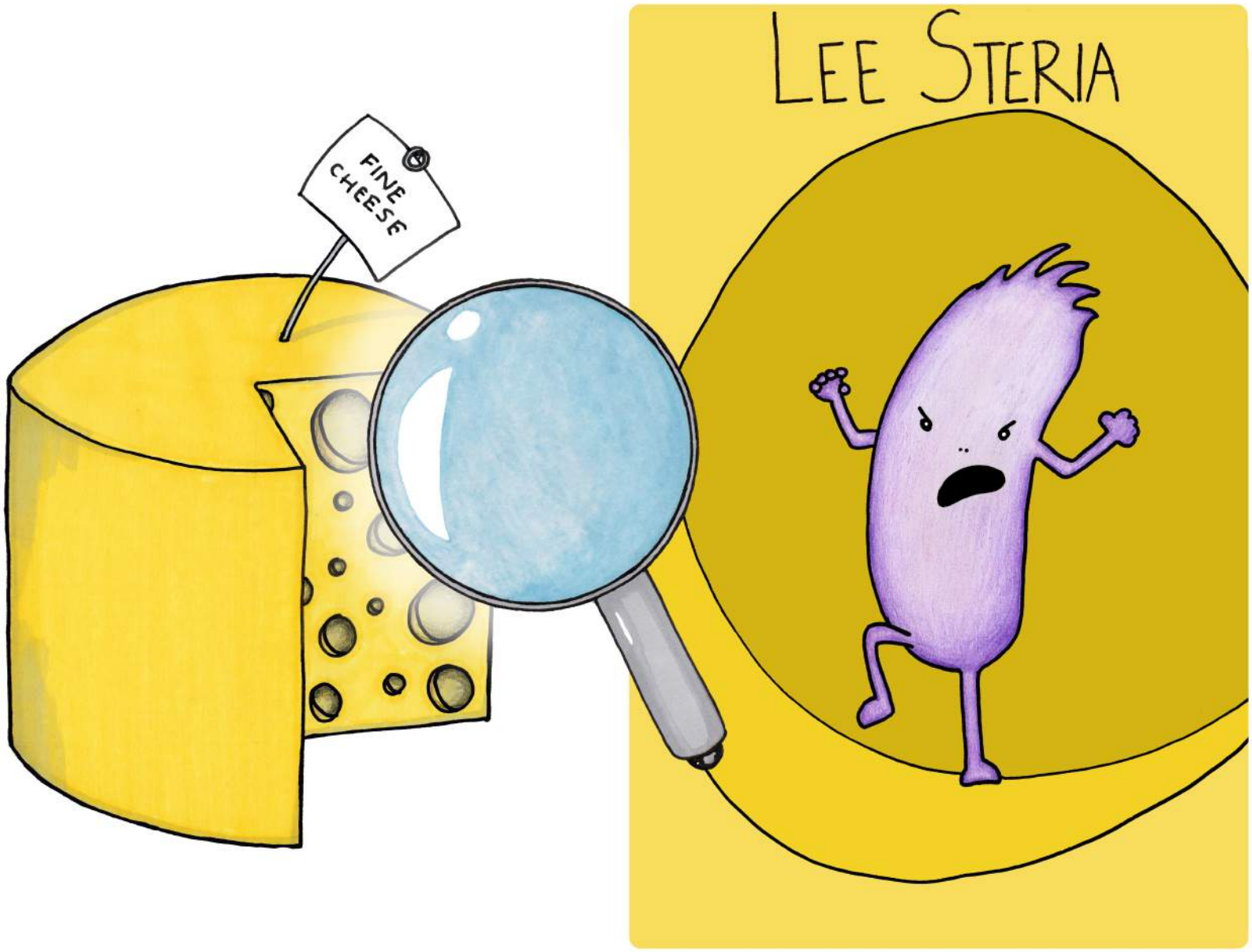
A more unlikely source of becoming ill from *Salmonella* is by handling turtles as reptiles also carry this microbe on their skin and outer shells. So make sure you wash your hands after stroking a pet snake!

Number of people ill:

Estimated to be >90 million globally

INTERESTING FACT

Salmonella was named after its discoverer, an American scientist called Daniel Elmer Salmon. Many scientists have named microbes after themselves!



Hazard Rating

6/10

Death Rate

20%

LEE STERIA

Microbe name: *Listeria monocytogenes*

Type of microbe: Bacterium

Where is it found?

In the environment and the gut of many animals.

magnification x100

What does it do?

Causes food poisoning when food contaminated with *L. monocytogenes* is eaten. Although healthy people rarely become ill, if they do symptoms include vomiting, diarrhea and fever. In people with a weak immune system, such as the elderly, *L. monocytogenes* infection can be life threatening if it gets into the bloodstream and it is especially dangerous to pregnant women as it can cause infant death.

Listeria levels are usually higher in foods that have been made with milk that hasn't been heat-treated in a process called pasteurisation. This is why expecting mothers are advised to not eat soft cheese that is sometimes made with unpasteurised milk.

Number of people ill:

Around 1500 cases in the United States alone each year

DID YOU KNOW?

Louis Pasteur invented the process of heating and rapidly cooling liquids to kill bacteria, which is called pasteurisation. It's still used today to prolong the shelf life of foods.

INTERESTING FACT

L. monocytogenes is very tough and can even grow at refrigeration temperatures, so it's important that chilled foods are kept cold and eaten by their 'use-by' date.

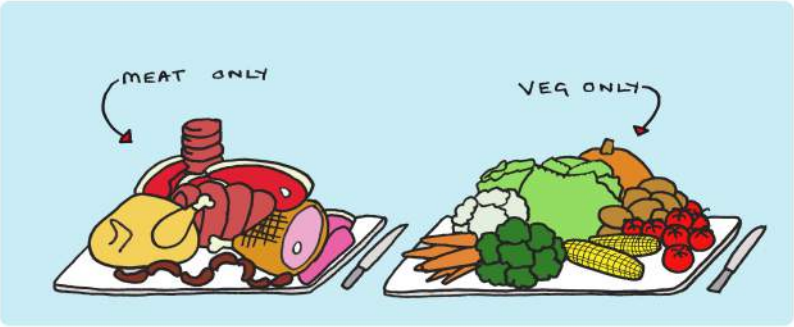
HOW MICROBES LURKING IN FOOD CAN MAKE YOU SICK

Food poisoning is caused when we ingest food or water that contains certain microbes. These microbes cause symptoms such as vomiting, diarrhoea and fever.

Some microbes, such as *Salmonella*, are present in the gut of animals including humans. Meat, eggs and even vegetables that have been in contact with manure in fields are foods that pose a risk. Other microbes are present everywhere in our environment (such as *Listeria*), making it harder to control in foods that don't require cooking, so it's very important that microbiologists test these foods before they get to the supermarket shelves.

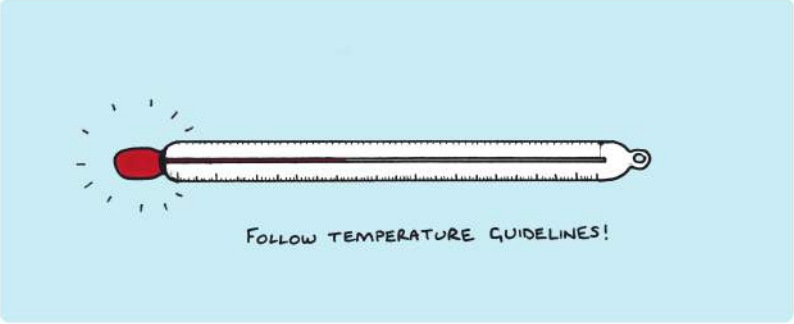
Food poisoning can be caused by under-cooking food, but in many cases it's caused by cross-contamination, which is the transfer of microbes from raw food to cooked food – such as using a knife to cut vegetables that has been used on raw meat. It can also be caused by touching raw food then handling cooked food, and by washing raw meat causing bacteria to spread via splashed water.

Food poisoning can be easily prevented



1. Keep raw and cooked food separate.

2. Wash hands after handling raw food.

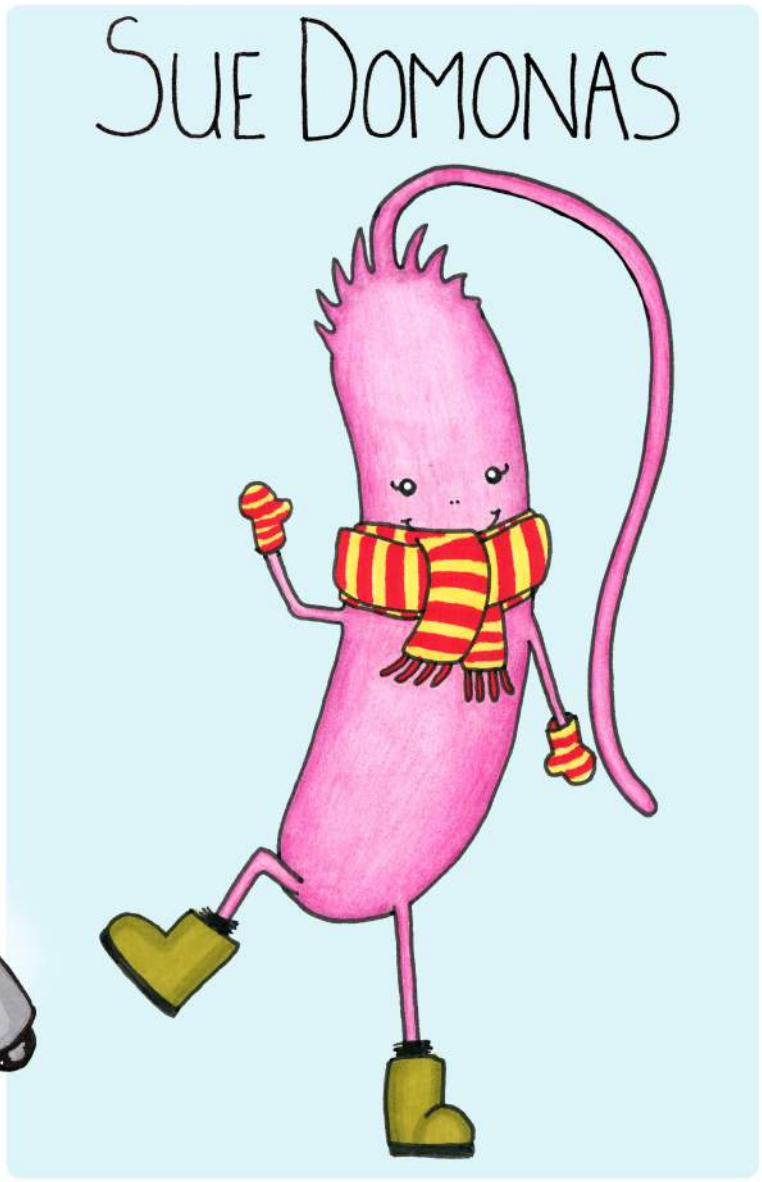


3. Cook food thoroughly according to the instructions on the packaging and store foods at the correct temperature.

CHAPTER FOUR

MAGNIFICENT AND MARVELLOUS MICROBES

Most microbes that live inside us and in our environment do us no harm. In fact, many microbes are essential for keeping us healthy, clearing up environmental waste and for the production of useful things such as food. In this section you'll learn about magnificent and marvellous microbes that do all sorts of great things – from stopping menacing microbes from making us ill to making snow.



Hazard Rating

0/10

Death Rate

0%

SUE DOMONAS

Microbe name: *Pseudomonas syringiae*

Type of microbe: Bacterium

Where is it found?

In snow and rain droplets

magnification x100

What does it do?

It helps form snow, so we can build snowmen! It does this by binding to water in our atmosphere and making it freeze at a warmer temperature. Although this is fun for us, it's not so fun for plants that can suffer from frost damage because of this microbe. *P. syringiae* destroys crops every year – so farmers are not so fond of this cool microbe.

There are a lot of different *Pseudomonas* species and not all are as nice to humans as *P. syringiae*; *Pseudomonas aeruginosa* is a close relative that most commonly causes infections in hospital patients.

Number of people ill:

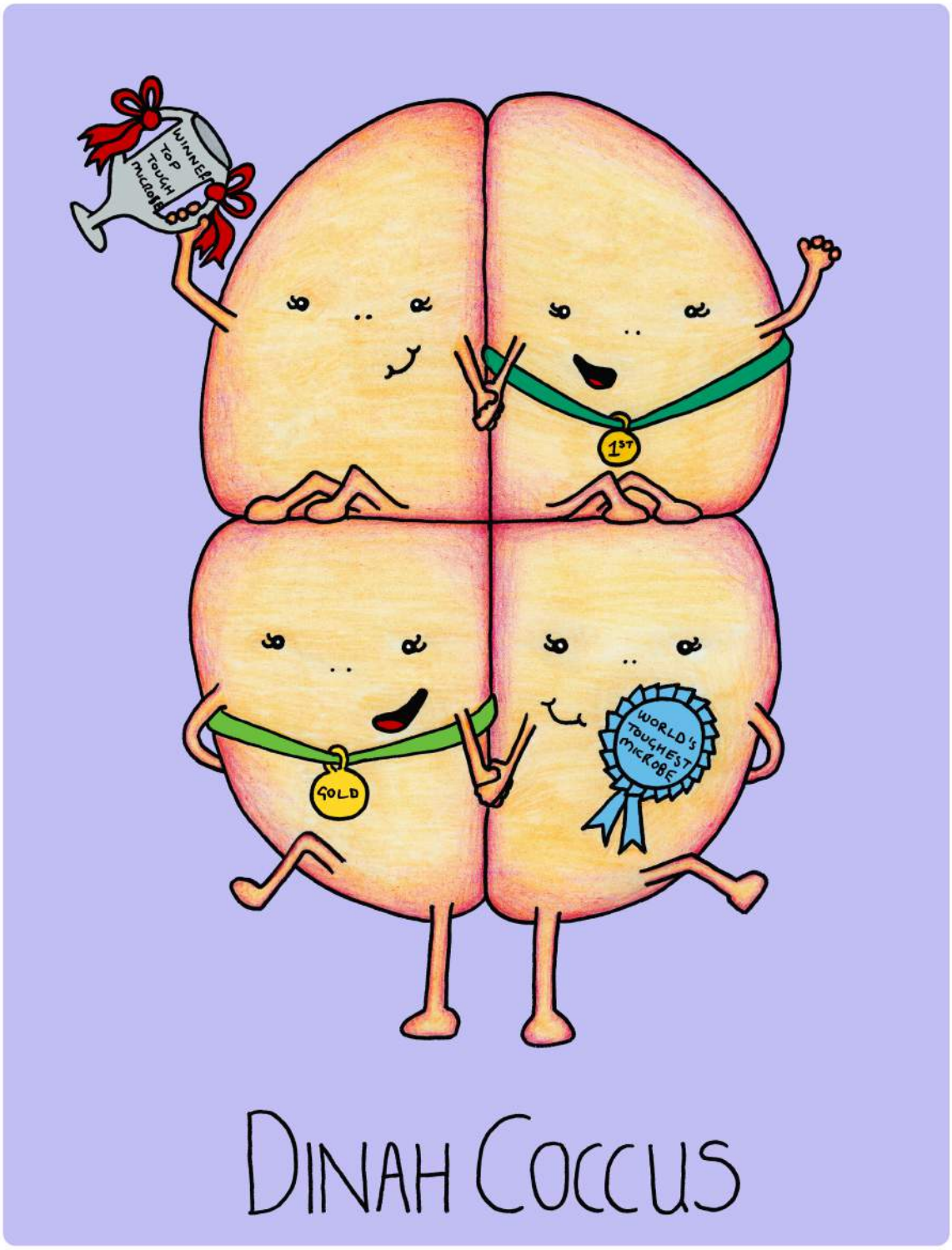
None.

DID YOU KNOW?

Bacteria communicate with each other using chemicals they release. By communicating they change their behaviour – some can even glow in the dark!

INTERESTING FACT

Some ski resorts add dead *P. syringae* to their snowmaking machines so snow can be produced at warmer temperatures!



Hazard Rating

0/10

Death Rate

0%

DINAH COCCUS

Microbe name: *Deinococcus radiodurans*

Type of microbe: Bacterium

Where is it found?

Everywhere in our environment, including soil and even radioactive waste sites!

What does it do?

Enjoys being the toughest microbe around; *D. radiodurans* is so tough that it can grow in Earth's harshest environments including deserts and Antarctica. This is one super strong microbe that can survive extreme cold and tremendously high levels of radiation – 3,000 times the amount that would kill us. The reason it's able to withstand such conditions lies in its ability to repair itself when it becomes damaged. Such properties have made scientists very interested in this bacterium, and they are genetically modifying *D. radiodurans* so that it can clear up radioactive waste.

It's of no surprise that the durable Dinah has been named the World's toughest bacterium by the Guinness World Records!

Number of people ill:

None

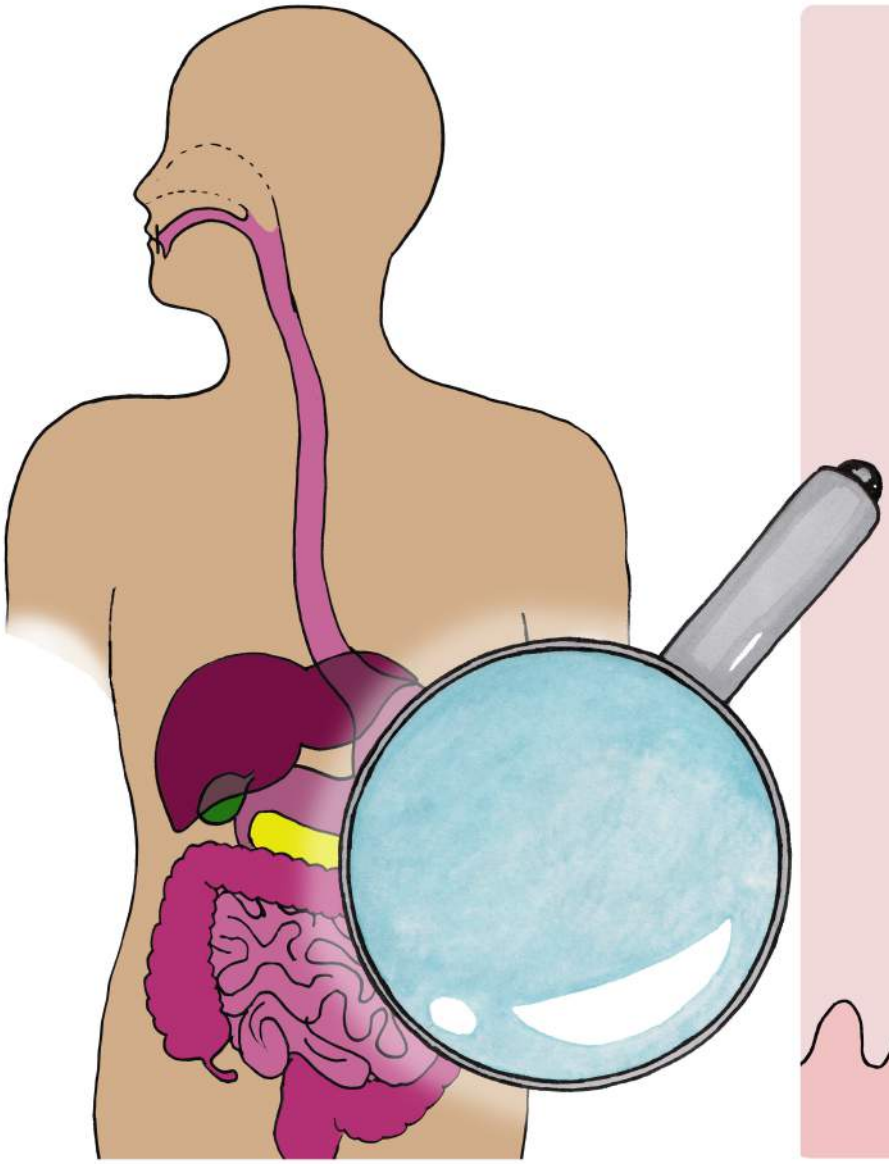
magnification x100

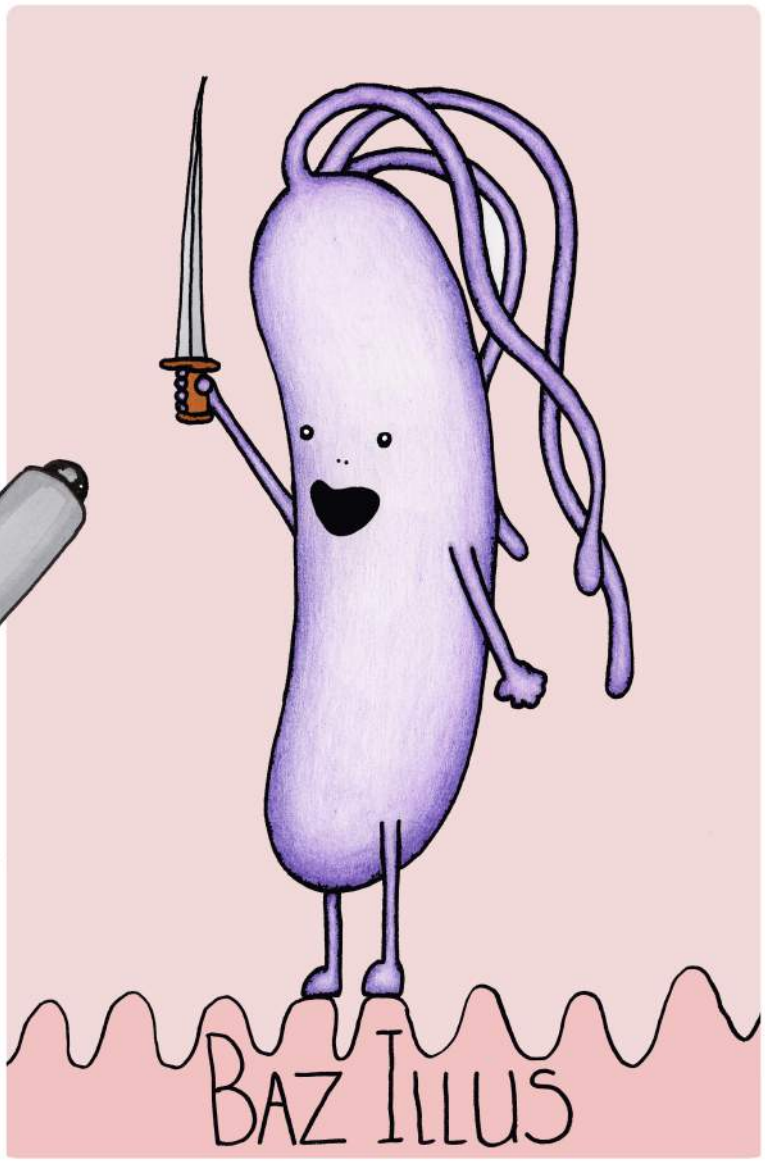
DID YOU KNOW?

D. radiodurans is called an 'extremophile' because it lives in extreme environments. Bacteria that can grow at extremely hot temperatures (over 100°C) are called 'thermophiles' and those that grow at very cold temperatures (as cold as -15°C) and are called 'psychrophiles'.

INTERESTING FACT

This resilient microbe could withstand the intense radiation that's on Mars, and some scientists believe it could have even come from this planet, being delivered to Earth on a meteorite!





Hazard Rating

0/10

Death Rate

0%

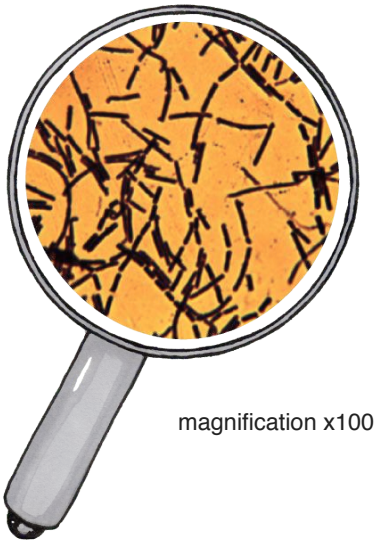
BAZ ILLUS

Microbe name: *Bacillus subtilis*

Type of microbe: Bacterium

Where is it found?

In soil and in our gut



magnification x100

What does it do?

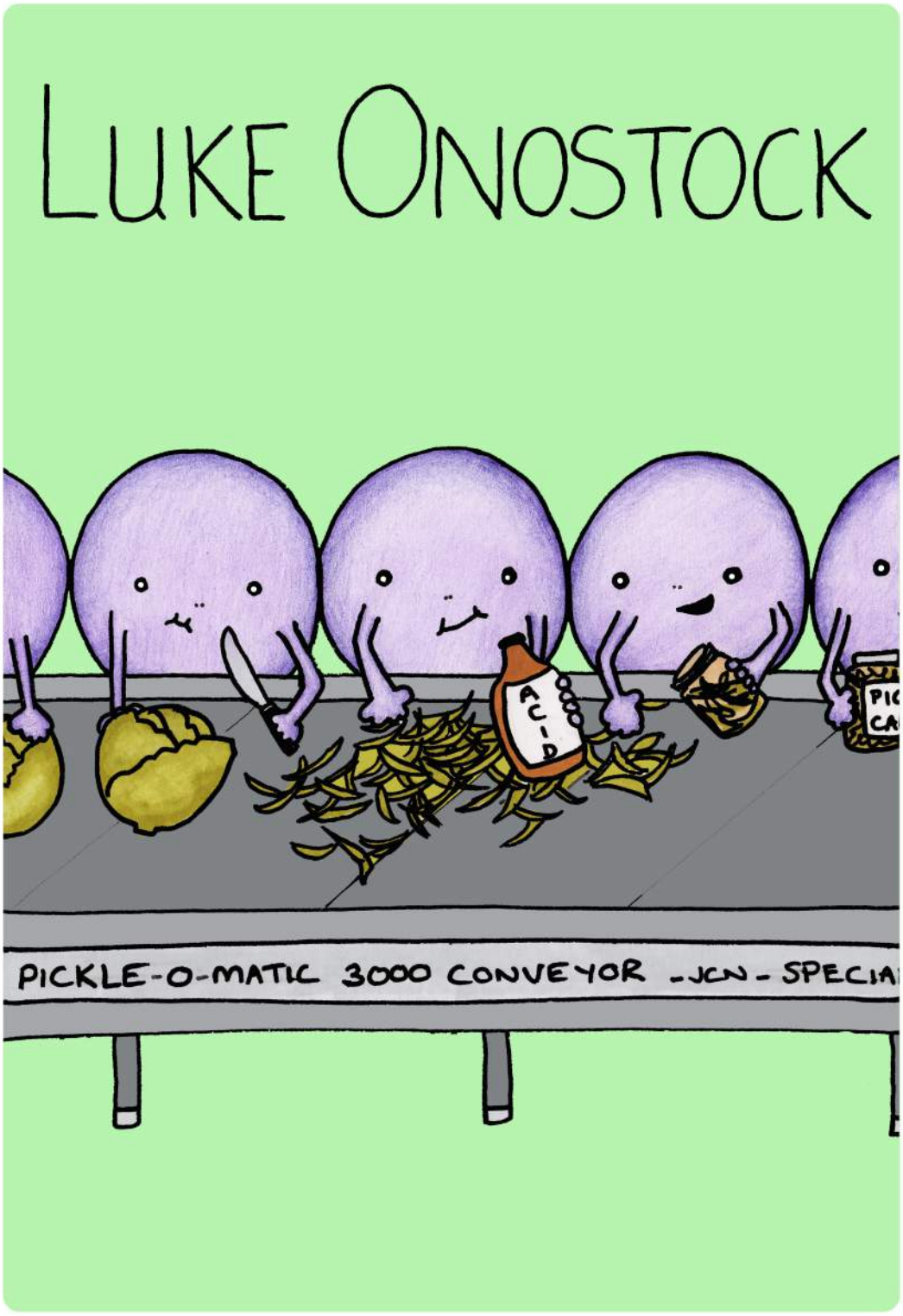
B.subtilis is a close relative of *B. anthracis*, but couldn't be more different because it's a much friendlier microbe. *B. subtilis* lives in our gut without causing any harm, along with a trillion other microbes. Not only are these microbes harmless, they're also very important for our health, helping us break down food, boosting our immune system and fighting off bad microbes that can cause illness.

Number of people ill:

None

INTERESTING FACT

B. subtilis can also convert nuclear waste and explosives into harmless compounds!



Hazard Rating

0/10

Death Rate

0%

LUKE ONOSTOCK

Microbe name: *Leuconostoc mesenteroides*

Type of microbe: Bacterium

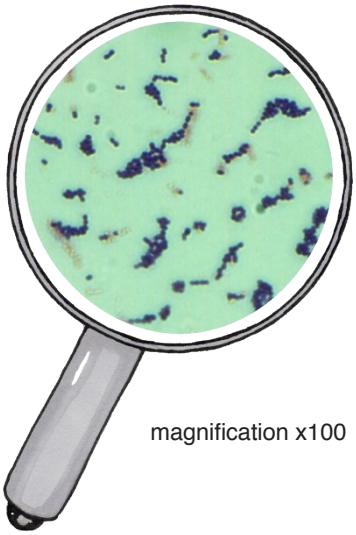
Where is it found?

In food, including vegetables and milk, and also in our gut.

What does it do?

L. mesenteroides is a very useful microbe that pickles vegetables, including cucumbers and cabbage. It does this during a process called fermentation. This is the process by which microbes create energy from sugars in the absence of oxygen, producing waste products that help make food.

L. mesenteroides digests sugars in the vegetables, producing lactic acid as a waste product. This acid gives pickled vegetables that sour taste and also prevents the growth of microbes that cause food to go off, prolonging the shelf life.



magnification x100

Number of people ill:

Extremely rare

DID YOU KNOW?

You may have noticed many of the microbes you've met are pink or purple. Bacteria have different cell wall structures, which can be stained pink or purple in a staining process called the 'Gram Stain' and this helps microbiologists identify them.

INTERESTING FACT

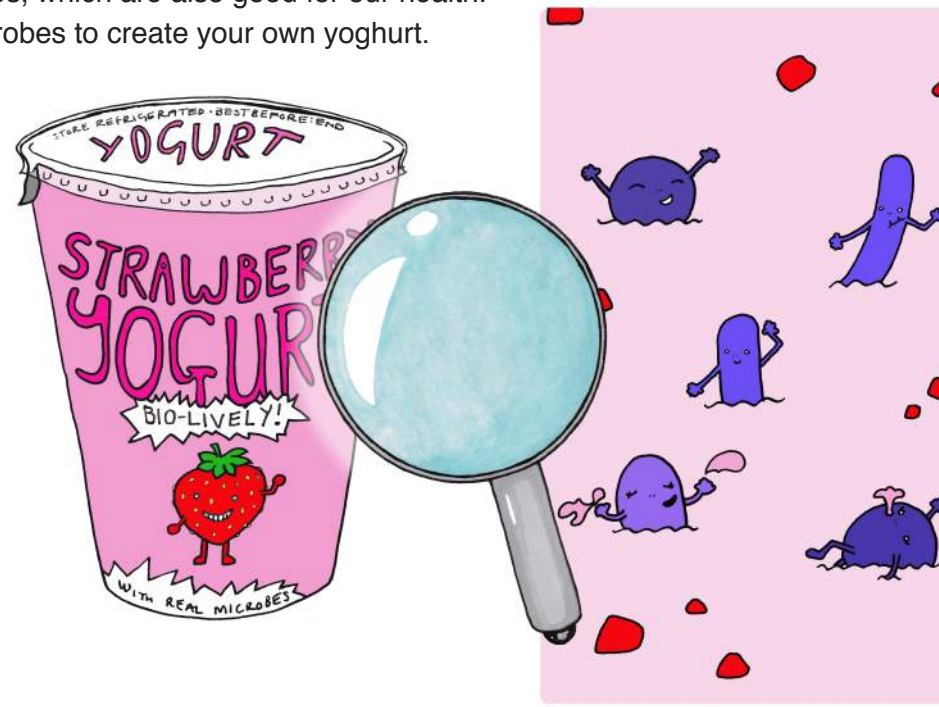
L. mesenteroides is responsible for making Sauerkraut, a pickled cabbage that's popular in German cuisine.

EXPERIMENT 4: MICROBIAL FOOD–MAKING YOGHURT

Microbes are essential in the production of food and we actually eat food everyday that they help produce, including bread, cheese and yoghurt. Yoghurt is made by two microbes called *Lactobacillus bulgaricus* and *Streptococcus thermophilus* which change the texture and taste of milk during fermentation. In milk, these microbes use the sugar lactose for energy, creating lactic acid as a waste product. It's the lactic acid that lowers the pH, changing milk proteins that give yoghurt that thicker texture. By lowering the pH, microbes that cause food to go off don't grow which is why it keeps in the fridge for a few days. Many types of yoghurt on the supermarket shelves will contain these helpful microbes, which are also good for our health.
In this experiment you will use these microbes to create your own yoghurt.

Materials

- 1 pint of pasteurised or UHT milk
- Around 500ml of 'Live' yoghurt (may be labelled probiotic)
- Fruit puree (optional)
- Thermos flask x 2 or heavy ceramic saucepan
- Food thermometer
- Containers to store yoghurt



Method

1. Heat pasteurised milk to 85 degrees Celsius and allow to cool to 46 degrees. This will kill most unwanted microbes and is a nice temperature that your starter culture microbes will love. If using UHT milk, just heat to 46 degrees.

2. Add around 3 tablespoons of your live yoghurt to the milk and pour into a Thermos flask or heavy ceramic saucepan.

3. Leave for around 8 hours or until you like it - the longer you leave it, the sourer it will be due to the buildup of lactic acid. Add fruit puree to give it some more flavour and store in the fridge for a maximum of 5 days.

MICROBES AT WORK – MAKING US FOOD AND KEEPING US HEALTHY

We all have lots of microbes living on our skin, in our mouth and in our gut. Our intestines contain over 100 trillion of them – we have 10 times more microbial cells in our bodies than we have of our own cells making us more microbial than we are human. From the day we are born, microbes start living inside us and we all have a unique population of microbes - called our microbiota - that are crucial for our health. Our microbiota is as unique as our fingerprints!

With this many microbes inside us it's of no wonder that they do a LOT for us, including:

1. Helping us digest food and absorb nutrients.

2. Fight off bad microbes. They do this by competing for space in our gut making it hard for bad microbes to reproduce and also by producing substances that kill them.

3. They enhance our immune system so it's more effective at fighting off bad microbes.

4. They produce substances that help keep our gut cells healthy.

DID YOU KNOW?

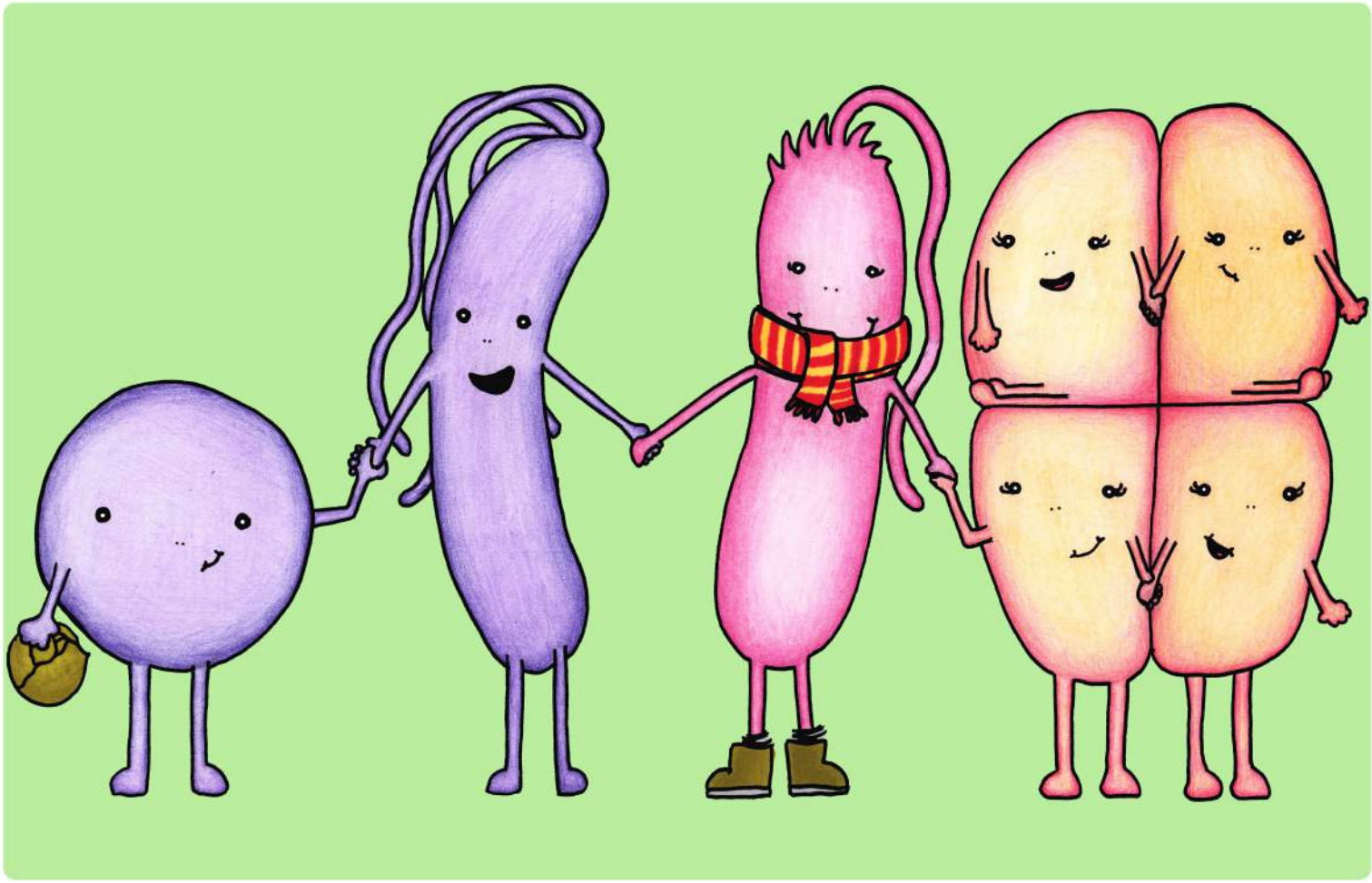
The microbes in an average sized-adult weigh around 1 kg, which is about the same as a bag of sugar!

These "good" microbes are also called 'probiotics' and are often included in yoghurts and available as dietary supplements. Eating foods containing probiotic bacteria is thought to have beneficial health effects by boosting the amount of good microbes in our gut. Availability of such products in supermarkets began with the founder of 'Yakult', Minoru Shirota, who isolated a good bacterium from his own poo and started selling it in a yoghurt drink, which is now sold in over 30 countries!

They also produce lots of important things

Microbes need energy sources just like we do and what they prefer to eat varies between different microbes. What they digest helps us tremendously; microbes help turn food waste into compost, clear up oil spills and hazardous waste, and break down our own food in our gut, which saves us from doing all the work!

The waste products produced by microbes can also be very helpful, especially in food production. Yeast can turn sugar into carbon dioxide and alcohol, which can be used to make wine, beer and bread. Waste products can also include antibiotics - yes, microbes make antibiotics to kill other bacteria that compete for food. You can't get more useful than that!

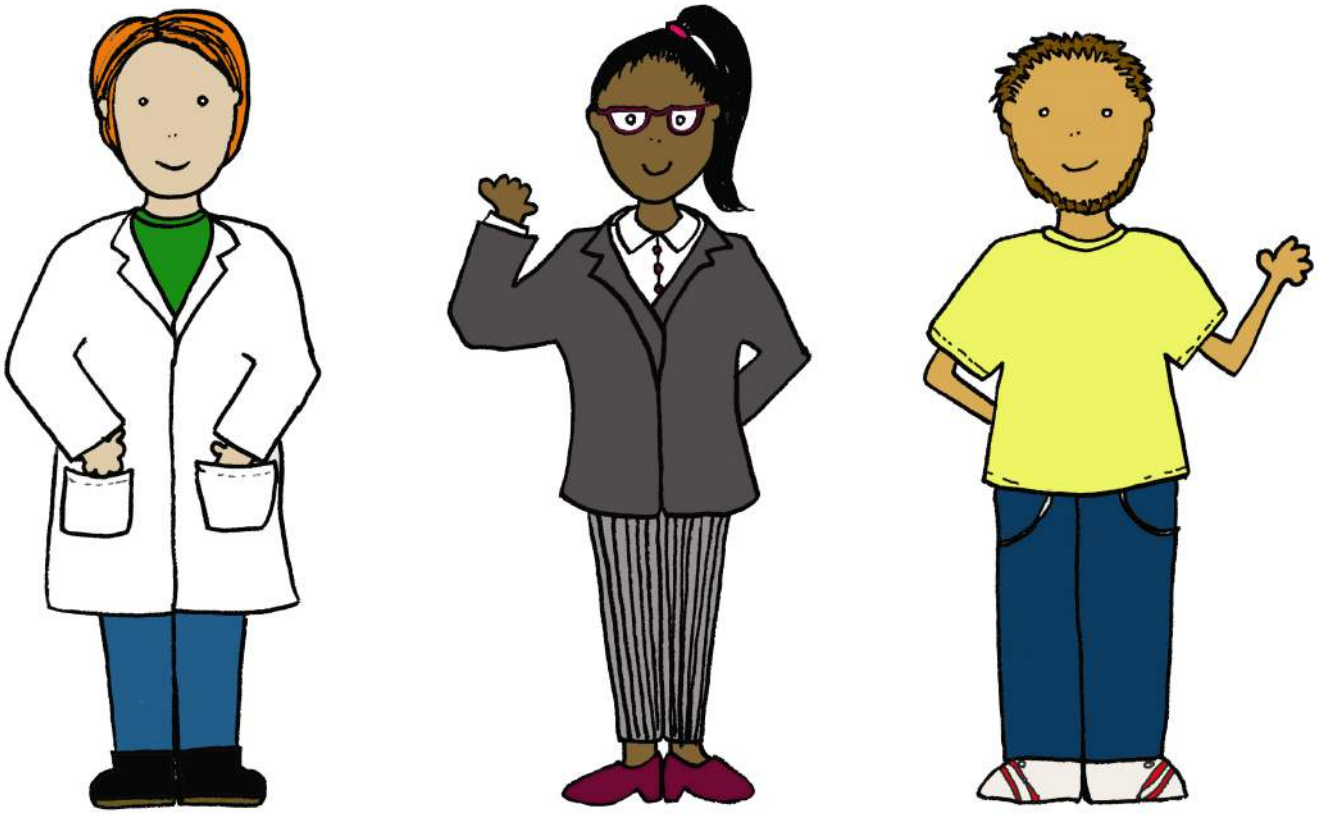


Microbes are everywhere - in the air, in our food and inside us. Although some can cause disease, most are very useful and we couldn't live without them. Next time you have an upset stomach, eat yoghurt or brush your teeth, think about how your everyday life is affected by microbes now that you've met them.

CHAPTER FIVE

MEET THE MICROBIOLOGISTS

You've met the microbes, now meet the microbiologists! The job roles that microbiologists have are as diverse as microbes themselves and do not necessarily involve working in a laboratory. Here are just a few job roles that microbiologists do.



OUTSIDE THE LAB

Science communication

Not all scientists enjoy carrying out experiments and instead prefer to talk about science instead. The communication of science to the public is very important, and job roles in science communication can include teaching, journalism, working in television and organising events such as science fairs.

Sales and Marketing

Scientists working in laboratories need products to carry out experiments, such as culture media to grow bacteria, and that's where sales and marketing comes in. These people have more customer-facing roles and their jobs involve solving problems customers are having, advertising products and making appointments to sell products.

Patent Attorney

When scientists invent something new, they can protect their invention using exclusive rights called a patent, so that it can't be copied and used to make money by someone else. Patent attorneys give advice and enforce patents to protect the ideas of scientists. They usually work in scientific companies or with the government and are people with qualifications in science and have had extra training in legal skills.

INSIDE THE LAB

Healthcare microbiologist

These scientists work in hospitals, identifying what microbes are making patients ill using culture media or DNA analysis. Once they know what menacing microbe is the cause of an infection they can advise doctors on what treatments should be used to make the patient better.

Epidemiologist

An epidemiologist is someone who monitors disease spread in the population. If there's an outbreak, such as the West Africa Ebola epidemic, they have to find how it started and how it spreads.

Food Microbiologist

These are the scientists that test food for harmful microbes and also research and develop ways to eliminate them before they get to the supermarket shelves. Food manufacturers, scientific companies and universities employ food microbiologists, and they ensure the food you eat is safe so you don't get sick.

Environmental Microbiologist

Microbes play a very important role in our environment, where they clean up waste and maintain healthy ecosystems. These scientists study the interaction of microbes with our environment, such as their effect on pollution. These scientists research some really cool stuff, such as using bacteria to clean up hazardous waste (such as *D. radiodurans*), or even produce fuel for cars.

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