# Segment Two - A More Detailed Look at Bacteria

This segment looks at bacteria in much more detail.

Sometimes you will see bacteria called germs or, more properly, **Micro-organisms** and **Microbes.** They are everywhere, in soil, water, air, food and all animals. There are very many in the intestines of fish.

## AIMS OF THIS SEGMENT

The main aim of this segment is to help you to achieve Objective - *List the common types of food poisoning bacteria and state how to avoid those conditions which are ideal for their multiplication.*

At the end of this segment you will be able to:

- List the important general features of bacteria.
- List the conditions required for the multiplication of bacteria.
- State how the multiplication of bacteria could be slowed down or stopped.
- List the important types of food poisoning bacteria, their sources and the conditions which help them to develop.
- Recall the effects on the consumer of either the bacteria or the toxins which they produce.
- List the other sources of food poisoning.

## QUESTIONS ABOUT BACTERIA

**Why do we find bacteria everywhere?**
We suppose the best description would be that they are waiting around for a chance to make a living.

A lot of them are pretty much unemployed, but if a job comes along which suits them then they get busy quickly. 'Busy' to them means eating and multiplying, and they are really good at it.

There are thousands of different kinds of bacteria and they specialise in using particular types of foods or living under particular conditions:

- Some will multiply best in the cold.
- Some will multiply best in the heat.
- Some can multiply without oxygen and some can take it or leave it.
- Some will multiply in sea water and so on.

Bacteria will compete with each other for food, space etc. They all wait for conditions which are more suitable to themselves than to other types of bacteria. When this happens they can out-multiply the competition.

**What are the problems?**
This depends on how you look at it. It seems to be quite worrying that we're absolutely surrounded by bacteria, but then most of the time we don't even notice they are there.

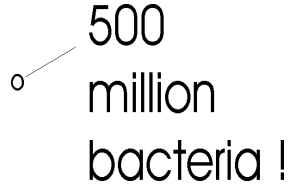
**Most bacteria do us little harm,** in fact they can even be useful. They do cause food spoilage of course, but we have learnt to live with their activities to a great extent.

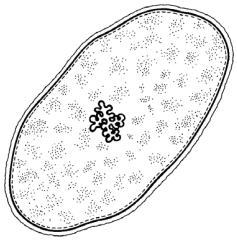
There are a **few** bacteria around that can cause serious problems, if we let them.

**If You're Small You Have To Try Harder**

We've said that bacteria are so small that they are not visible without a microscope.

Each bacterium is a single cell and it takes about 500 million to fill a space the size of a pinhead.



Many bacteria are rod shaped while others are round. Bacteria are surrounded by a rigid cell wall which helps to protect them. The diagram on the right shows the main features of a bacterium.

The outer cell wall of the bacterium protects it. The inside of the bacterium contains the nucleus. Some bacteria have whip-like flagella which help them to move about.

To be poisoned by some types of bacteria can take about one million bacteria per gram of food. The record is held by a batch of imported chocolate bars contaminated with one particular type of *Salmonella*. In this case it only took as few as 100 bacteria per gram to do the damage.

It's quite difficult to get used to sizes and numbers when you think about bacteria. One minute you're impressed because there are 500 million of them, the next minute you realise we're only talking about a pinhead's worth and that doesn't seem like much does it? So why worry?

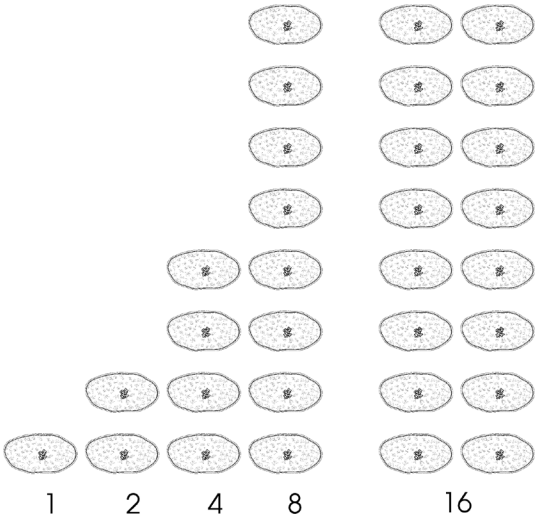
We gave you a clue with the heading - they may be small, but they make up for that by multiplying at amazingly fast rates.

We have to explain that:

A single bacterium will 'grow' to a certain size and then split to form two smaller bacteria. This 'splitting' is technically known as **Binary Fission** and it is how bacteria multiply.

These two smaller bacteria, grow to full size and then split into four and then eight and so on.

- The bacteria don't grow much in size but their numbers multiply quickly.



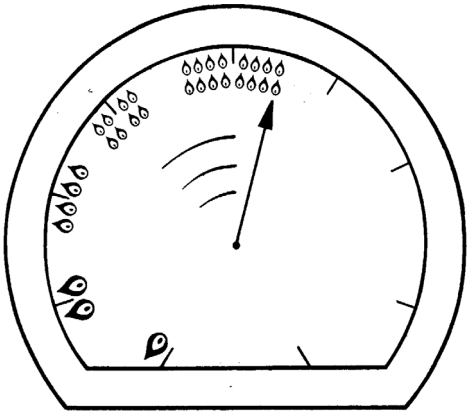

Under ideal conditions it could take 1 hour and 20 minutes to go from 1 to 16 bacteria. This doesn't sound too impressive does it?

Then 32 , 64, 128, 256, 512…….1 million, 2 million, 4 million, 8 million.

**Remember:** Bacteria don't grow so much as multiply. It's the speed with which they multiply that is important to us (and to them).

**How Fast Do They Multiply**



The really impressive thing is how fast multiplication can happen – bacteria can do it as fast as we can write about it! In good conditions **most** bacteria can double their numbers about every 20 mins and some as quickly as every 10 mins. This sounds quick, doesn't it? It is quick, but you also have to remember that every time bacteria multiply, there are twice as many as before to grow and multiply the next time and so on.

If we take a doubling time of 20 minutes we have:

Over 60 times as many bacteria after 2 hours.

Over 4000 times as many in 4 hours.

Over 250,000 times as many in 6 hours.

Over 16 million times as many in 8 hours. All from one individual bacterium in the beginning.

Just try to think of how much ground a man would cover if he took:

One foot with his first step.

Two feet with his second step.

Four feet with his third step.

Eight feet with his fourth step and so on.

His fourteenth stride would be a mile and a half long.

His thirtieth stride would take him to the moon!

**SAQ2**

a. How do bacteria multiply and reproduce?

b. How many bacteria would it take to fill a space the size of a pinhead?

1,000,000

10,000,000

500,000,000

c. If 500 million bacteria could divide every 20 minutes, how many would there be after one hour?

a.

b.

c.

We want you now to think about the following:

Now that you know how fast bacteria can multiply, you are probably pleasantly surprised to realise the world is not completely buried in a thick layer of them.

Write down why you think this might be and then look on the following page.

Did you manage to come up with any ideas?

We haven't given you many clues except that they multiply most quickly under **ideal** conditions.

Their multiplication slows down, or stops, when conditions are not good for them. In fact they start dying off.

So, the short answer is that conditions are rarely ideal for bacteria to multiply quickly - they run out of food, space or poison their environment.

But DO REMEMBER that once a change in conditions favours growth they will multiply at an enormous speed.

## IDEAL CONDITIONS FOR MULTIPLICATION

We've kept on saying 'ideal' conditions for multiplication, and you might have begun to wonder what these are (even though we only want to know the answer so that we can avoid them!).

We mentioned earlier that some types of bacteria can grow on many substances. The same applies to other conditions. (For example, some types multiply well at temperatures that kill other types.) We will just have to talk about the average.

The bacteria that cause poisoning and spoilage like the sort of conditions and foods that we do.

In order to multiply bacteria need:

- **Food**.
- **Water**.
- A suitable **(warm)** temperature.
- **Time** in which to multiply.
- Some bacteria also need oxygen, but not all bacteria.

**FOOD + TIME + MOISTURE + WARMTH = IDEAL MULTIPLICATION**

**Food and Oxygen**

Living things survive by producing and using energy. Most organisms get their energy by the reactions of the food they eat with the oxygen in the air they breathe. They may also be able to make use of the dissolved oxygen that is normally present in water.

Food + Oxygen ⟶ Energy + Waste

Food is also used as the building material to make more bacteria.

Food + Energy ⟶ Multiplication in numbers

Some bacteria can multiply without oxygen, in fact oxygen can be poisonous to them. Often it is the bacteria that don't need oxygen that are the most dangerous to us. The bacteria that causes botulism poisoning in canned fish is one example. The heat processing that canned food goes through is enough to destroy the bacteria and the spores that cause this kind of poisoning, so outbreaks of botulism poisoning are rare.

**Vacuum Packing** and **Modified Atmosphere Packing** (MAP) make use of bacteria's need for oxygen and control the multiplication of bacteria by providing either not enough oxygen to support growth, or so much oxygen that it poisons some bacteria. The gas mixture in **MAP** will often include a combination of oxygen, nitrogen and large amounts of carbon dioxide which can also be poisonous to some bacteria.

Vacuum packed smoked mackerel and salmon can cause botulism unless there is enough salt in the fish flesh to stop that bacteria multiplying or it is stored at temperatures close to 0°C. Similar problems can arise with some MAP products which are not cooked before consumption, which is why many of these products are kept refrigerated until eaten.

***What is a suitable food (for bacteria)?***

Almost anything is the short answer. It's very easy for bacteria to live and multiply:

Bacteria **will** be found:

- In a crack on a working food contact surface.
- On a knife.
- On clothing.
- Anywhere there is food, blood etc.

They can easily be transferred from these places onto food being processed and will continue their multiplication there.

**Water**
Most living things are made up of water even though they seem to be solid.

People are over 80% water.

The water does not have to be the liquid water with which you are familiar. The water around and in the cells of food will usually be fine for bacteria to use..

Bacteria can also use the oxygen dissolved in water to help them multiply.

We think you'll have picked up three things that can be done to help hygiene:

- Stop bacteria multiplying as much as possible.
- Avoid transferring any which are around onto food.
- Be quick. Long delays during processing should be avoided.

? Now try and answer these questions.

**SAQ 38**

Write down whether you **agree or disagree** with the following statements and give your reasons for your answers:

a. Bacteria **only** multiply under ideal conditions.

b. Bacteria need **special** foods and conditions before they can multiply

c. Bacteria drown in water

d. Food poisoning bacteria are **naturally** found on food.

e. Food poisoning is caused by bad luck.

**Temperature**

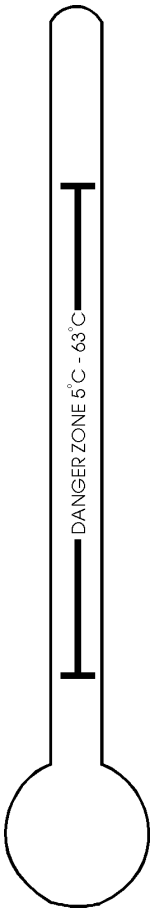
As you already know bacteria need:

**Food**, **Air**, **Water** and enough **Time** in order to multiply.

However, their **speed of multiplication** also depends on **Temperature.**

They multiply slowly when it is too cold.

They multiply very quickly when it is warm enough. In fact they multiply 10 times faster in a warm room than at refrigerator temperatures.




So, if they can double their numbers every 20 minutes when it's warm (20ºC),

it takes 200 minutes to double them in the cold (5ºC).

If you have difficulty understanding this last statement we shall look at it another way:

- In 200 minutes in the cold (5ºC) 100 bacteria double to 200.
- In 200 minutes in the warm (20ºC)100 bacteria become 100,000.

We think you'll find those differences more striking!

Keep bacteria either too cold or too hot so that they cannot multiply and you will keep them out of the **Danger Zone**.

The Danger Zone is from 5ºC to 63ºC. This is the temperature range that

most food poisoning bacteria like the best. If food is kept below 5ºC then bacteria don't multiply too quickly. Above 63ºC most food poisoning bacteria don't multiply at all.

**Killing Bacteria**

Many people may think that food hygiene is just about killing bacteria. There is much more to food hygiene than this, but being able to kill bacteria is very important.

There are various ways of killing bacteria. We can kill them with disinfectants, sanitisers and sterilisers. We can kill them with high temperatures or irradiation.

What will **not kill** bacteria are low temperatures such as freezing, that only stops them multiplying and doing more harm.

In a freezer, most bacteria will stop multiplying, **but they will not die**.

We will look at some of the ways of killing bacteria here and in **segment Five.**

**Heat Treatment**

As you have seen bacteria usually prefer it warm and not cold, but make them too hot and they will die!

This is the idea behind cooking, thorough reheating, and keeping food hot (above 63ºC) until eaten. Heat foods above 82ºC for a few minutes and you will kill off most food poisoning bacteria. This is why hot water (in dish washers for example) can sterilise or disinfect plates and cutlery.

Heat treatment is not a universal cure though, not unless we heat food well above 82ºC. There is a problem with the spores produced by some bacteria because **spores can survive the high temperature** conditions that would kill most bacteria.

Spores have tough, heat resistant coats which will allow them to lie around, resting for a long time while conditions are too harsh. When conditions improve the coat splits and new bacteria emerge to multiply. Spores can often **survive**[1] **drying, disinfection, freezing** and **heat**, so even efficient cleaning cannot remove all of them. Freezing food will not destroy them, and even cooking may leave some to survive and cause problems later.

Spores need to be heated to higher temperatures and for longer times than bacteria, before they are killed. Canned foods are heated to a high enough temperature and for long enough to kill off these spores. That is why canned food lasts so long.

Even though there is no oxygen, or food, or water, the spores may wait a long time for the right conditions to come before producing more bacteria[1].

**Fish Preservation**

What ways do we use to preserve fish before eating?

a. Freezing and icing (reduces temperature, bacteria cannot multiply well)

b. Drying and salting (reduces water content, bacteria cannot multiply at all)

c. Canning (sterilises food through heat treatment, bacteria all killed off).

You may have used different words to describe these. Each way of preserving fish depends on making it harder for the bacteria to multiply or survive.

Heating methods aim to kill off most or all of the bacteria and the spores.

The canning process heats the food to a high temperature for a long time to kill off the bacteria and spores in the food product which is in a sealed container (e.g. canned mackerel, pilchards, etc.). The sealed container prevents recontamination until the can is opened.

**Cooking or hot smoking**

Raising the temperature **above 74ºC** to cook the food will kill off most food poisoning bacteria (but will not destroy any spores).

**Freezing, salting**, and **pickling** of fish products in vinegar all slow down bacterial multiplication and prolong shelf life, but do not destroy all the bacteria and spores.

**Irradiation** is another method used to preserve fish and fish products. It is very rarely used in the UK except when sterile food is required, for example in some high care wards in hospitals. The radiation will kill bacteria, parasites and pests (e.g. in spices) but has little effect on spores and will not destroy toxins.

**Avoiding trouble.** We've talked so much about the multiplication of bacteria you might have got the idea we were keen to grow them!

The reason we explained it in this way was so that you will understand what conditions to avoid to keep them from multiplying.

So let's summarise a few points:

- Don't provide them with food.
- Don't provide them with warmth.
- Keep their numbers down as much as possible.
- Thorough washing of the fish removes about 90% of the bacteria on the skin of the fish.
- Don't provide them with time to multiply.
- Don't transfer bacteria from one thing to another accidentally, from your hands to tools, cutting boards, food etc. and back again.
-

We'll talk more about this later but remember that **cold, clean** and **quick** go a long way to solving the problems caused by bacteria.

## COPING WITH THE COMPETITION

We hope you've got a picture in your mind of the many types of bacteria waiting around for chances to multiply.

They are all in competition with one another. Sometimes the type of food available or other conditions suit the multiplication of one type, and sometimes another type.

Fish muscle usually contains no bacteria, so if it's cut with a knife or is in contact with an infected surface after cutting, the food poisoning bacteria may be the first arrivals.

If competing bacteria are killed off (for example, by **cooking)** the first bacteria to get back to the food have a head start – will they be spoilage bacteria or poisoning bacteria?

It's what we call the 'ploughed field' effect.

It's exactly like weeds in the garden! It's very hard for them to get a foothold if the ground is already well covered by other plants.

But if a field is ploughed than whatever seeds are applied can get a head

start. It's similar with bacteria, which is one reason for taking extra care with cooked food.

## FOOD POISONING BACTERIA

There are two main types of poisoning bacteria and a few special cases that we want you to know about.

### 1. Bacteria which cause poisoning by multiplying inside people

Quite a few types of bacteria are in this group, but the main one is ***Salmonella*.** (Perhaps you've heard of it before on TV, or in the newspapers, in reports of food poisoning outbreaks.) They multiply on food which has been contaminated after cooking.

They multiply on foods where the cooking has not been long enough to kill them all.

These bacteria are usually found in the gut of animals such as **chickens**, **seagulls**, dogs and people! The bacteria are spread through the careless handling of contaminated and uncontaminated food.

Hand washing is essential when handling a different food, in particular before moving from uncooked to cooked food.

Food poisoning takes about a day to develop.

It usually involves serious vomiting and diarrhoea.

Vomiting and diarrhoea are the body's way of trying to get rid of the poisoning bacteria, but the loss of water and salt can be dangerous to some people. Salty drinks can be taken to put water and salt back into the body, and the health visitor or doctor should be seen if you are worried.

Salmonella poisoning can be avoided by:

- Clean handling – no contact with contaminated objects such as hands, clothes, knives, pests etc.:
- Keeping cooked and uncooked foods apart.
- Thorough cooking and reheating.

***Listeria*** is another food borne illness which may be found in a variety of food products including soft cheeses and cold smoked salmon. *Listeria* is particularly important because it multiplies at temperatures just above 0°C and will even multiply in some lightly salted products. A large number of deaths have been caused by *Listeria* mostly outside of the UK.

***Campylobacter enteritis*** is a bacterium that causes a range of symptoms including headache, nausea, fever and diarrhoea. It is often transmitted by animals and in food (chicken), and may contaminate the water supply. It multiplies well at body temperature and the illness may persist for up to seven days. It is one of the commonest causes of bacterial diarrhoea.

**Group Two - Bacteria which poison by producing a toxin (poison)**

The main type of bacteria in this group is ***Staphylococcus aureus***. These bacteria are commonly found in the human nose, on our skin and often in septic cuts. They are often found on badly cleaned equipment. They multiply on food and as they multiply they produce a toxin that poisons the person who eats the food. The longer the time they have to multiply, the more toxins are produced.

Poisoning takes just a few hours to develop once the food is eaten.

Another Group Two Bacteria is Clostridium. ***Clostridium perfringens*** causes problems with stews, gravies and joints of meat that have been contaminated. It cannot multiply where there is oxygen but can survive fairly high temperatures by forming spores (it will multiply quickly between 15°C and 50°C) and produces a toxin which causes the food poisoning. Bad cooking practice is the main cause, e.g. stews that are cooked at too low a temperature and held within the danger zone until served. The toxin isn't destroyed by high temperatures, so once produced even thorough cooking will not remove the toxin.

***Clostridium botulinum*****,** which causes botulism poisoning, cannot multiply where there is oxygen. It is an uncommon, but often fatal food poisoning bacteria, and is usually only found in canned and vacuum packed products. Cooking will easily destroy the bacteria and toxin causing this kind of food poisoning but not any spores it has produced, so food products that are eaten without cooking pose the highest risk. Outbreaks in recent years have been rare, a case in 1979 involved four persons poisoned by contaminated canned salmon. Two died.

This type of poisoning cannot be stopped by recooking the food. The toxin is not affected by heat once it is made. It can only be avoided by:

- Clean handling.
- Keeping raw and cooked foods separate.

***Bacillus cereus*** usually causes food poisoning by producing a toxin in foods such as cooked rice. The spores of this bacterium can survive cooking and will produce a toxin once they are eaten resulting in severe vomiting shortly after eating. This bacteria can also multiply in the intestine and will produce stomach pain and diarrhoea.

*Salmonella* and *Campylobacter* bacteria are the most common causes of food poisoning, with *Clostridium* and *Staphylococcus* bacteria responsible for most of the rest.

**Shiga toxin-producing Escherichia coli (0157), sometimes known as STEC** is a very serious bacteria that can be fatal by causing kidney failure, particularly in children. More information here.

It originates in the gut of animals and is associated with undercooked meat and contaminated vegetables. A 2024 outbreak was traced to contaminated salad ingredients is prepacked sandwiches. At the time of writing 122 people ended up in hospital.

## SPECIAL CASES OF POISONING IN FISH

### Shellfish

Shellfish can contain poisoning bacteria, viruses, or toxins when they are caught.

Some food poisoning is caused by poisonous plants contaminating the product. An example of this is paralytic shellfish poisoning which occasionally occurs in some British shellfish, and is caused by the toxin produced by small algae.

This is a seasonal problem for which there are clear control measures in place. It's not something that you would be expected to know too much about at this level.

**Scombrotoxin** is a toxin produced in mackerel and other oily fish which have been stored at about or above 5°C for a number of hours, it can cause an allergic reaction in people.

The toxin is not destroyed by cooking.

As an example, there were 75 persons poisoned in this way in 1979 - mostly from mackerel, but also from tuna, sardines and pilchards. This type of poisoning is largely due to poor quality control and storing fish at too high a temperature. Symptoms can include sweating, flushing, rash etc.

**Norovirus** is a common cause of gastroenteritis.
The virus originates in the gut and sewage contaminated water and commonly involves foods which are eaten raw such as shellfish and salads.
The virus can be spread from person to person through coughing and sneezing.

Before completing this segment, you should attempt the following four SAQs.

**SAQ4**

Write down four ways of preventing bacteria from multiplying to large numbers.

**SAQ16**

What are the two main differences between poisoning due to bacteria that poison by multiplying in the body after eating food and bacteria which produce a toxin in the food before it is eaten? (You'll probably need to look back and work this one out.)

i.

ii.

**? SAQ26**

Above what storage temperature does mackerel develop Scombrotoxin?

**? SAQ30**

What are the main effects of bacteria on fish (as far as people are concerned)?

**SUMMARY**

Now that you've read this segment, you'll know a lot more about how bacteria are linked with hygiene. You'll now realise why it is so important to stop bacteria, especially the food poisoning kinds, from getting near fish. You've learnt that there are bacteria **everywhere** and, given the conditions they like, they multiply **very fast.** A few bacteria can produce huge numbers of bacteria in a very short time.

Bacteria like to have:

- Some food (most aren't fussy about the kind and will eat what we do).
- Some water.
- Some oxygen.
- A nice warm temperature.

If they get these conditions they really start to multiply and multiply and multiply.

Now that you know what bacteria like, you can try to make sure that they

don't get these conditions.

Keep them very cold, or too hot (out of danger zone, 5°C to 63°C).

Don't spread them around.

You now know the main bacterial causes of food poisoning:

- Salmonella.
- Campylobacter.
- Staphylococcus (toxin).
- Clostridium perfringens (toxin).
- Clostridium botulinum (toxin, causing botulism poisoning).
- E.coli 0157
- Bacteria and other contaminants in some shell fish.
- Norovirus – not actually a bacterium, but a virus.

In the rest of this module we'll be looking at ways of stopping these from getting near or multiplying on fish.

Other types of poisoning are caused by contamination with chemicals such as pesticides and cleaning materials.

You have now completed segment two and achieved Objective 2