Bacteria are among the most ancient forms of life on Earth. Our Earth formed about 4.6 billion years ago. Life is thought to have begun on Earth about 3.8 billion years ago and there is fossil evidence for the existence of bacteria 3.5 billion ago. Bacteria, whose cells do not have nuclei, were the only life forms on Earth for over two billion years as nucleated cells like those of fungi, plants and animals did not evolve until about 1.4 billion years ago.

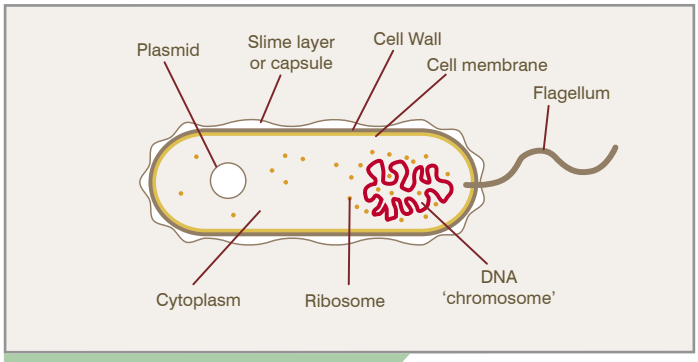


Fig. 1 General structure of a bacterium.

So what are bacteria?

Bacteria are *prokaryotic* organisms meaning they do not have a nucleus or any other membrane-bound *organelles*. Some bacteria are *autotrophic* i.e. they make their own food. These bacteria can either be *photosynthetic* (use light to make food) or *chemosynthetic* (use energy produced in reactions involving sulphur and iron compound and ammonia). Other bacteria are *heterotrophic* i.e. they cannot make their own food. Most bacteria are *saprophytic*, feeding on dead organic matter and acting as decomposers. Some heterotrophic bacteria are *parasites* causing harm to their host organism while others form *symbiotic* relationships with their host.

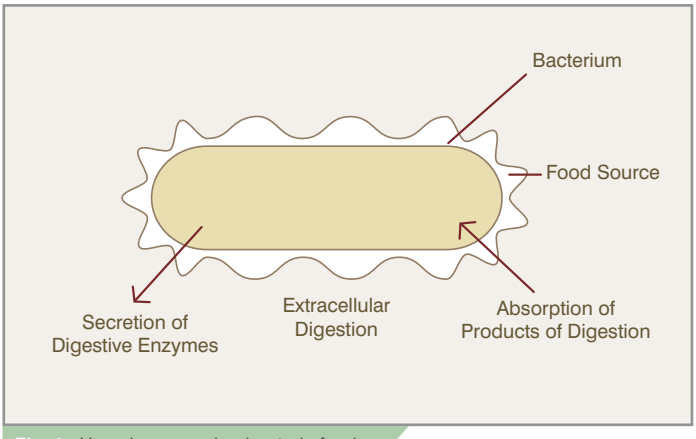


Fig. 2 How decomposing bacteria feed.

Where are bacteria found?

Millions of species of bacteria have successfully evolved since their origin on the planet, exploiting every possible habitat of the biosphere including other living organisms. Our skin and gut are colonised by very different but specialised communities of bacteria, much to their and our advantage. We have evolved in tandem with gut bacteria, resulting in mutual benefit – *mutualism*. However, some of the bacteria naturally found in the human body can have negative effects. Therefore, it is important that the balance of bacteria be maintained to favour the beneficial over that potentially harmful ones.

Our gut bacteria carry out many crucial functions including:

- the breakdown of certain indigestible carbohydrates providing energy
- making vitamins especially B and K
- protection against harmful bacteria by dominating the nutrient resources in the intestine
- acting on pre-*carcinogenic* compounds to decrease carcinogenic activity
- training our immune system to recognise and destroy pathogens

The population of our gut bacteria is kept relatively constant as they receive a consistent stream of nutrients. Their nutrient supply comes from our undigested food. This is similar to alcohol production by *continuous flow processing* in which a culture of yeast in a bioreactor receives a non-stop supply of a nutrient solution and the product is continuously removed at the same rate. This results in a constant population of yeast in a bioreactor.

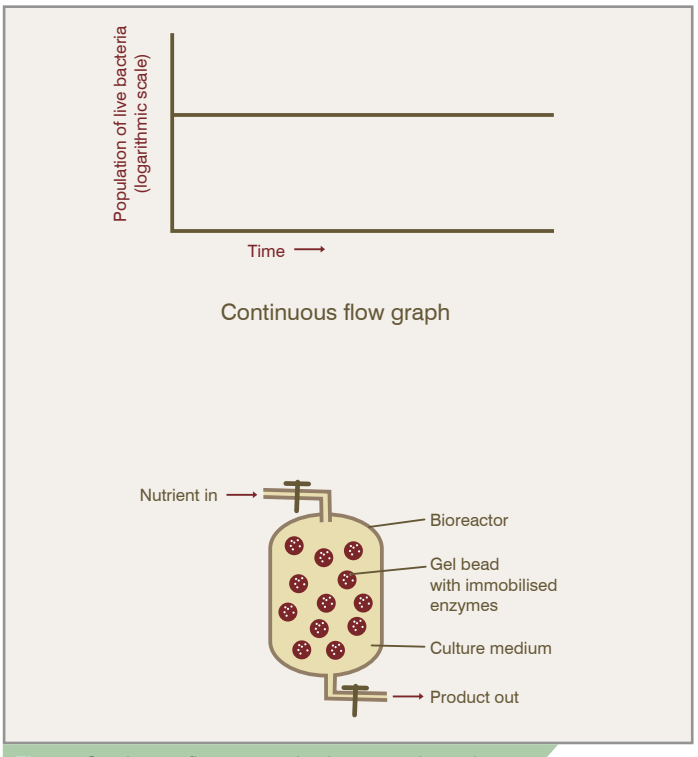


Fig. 3 Continuous flow processing by our gut bacteria

The population of gut bacteria can be altered when we undergo *antibiotic* treatment against *pathogenic* bacteria. When antibiotics are given orally, pathogenic bacteria are killed along with the beneficial gut bacteria. This can often lead to opportunistic infection by pathogenic bacteria resulting in disease, malfunctions of the intestine and *deficiency* of vitamins B and K.

Upon completion of antibiotic treatment, gut bacteria will eventually re-establish their numbers, but this often takes a long time. For this reason, the consumption of probiotic foods is recommended by nutritionists during and after antibiotic treatment to maintain normal digestive function.

What are probiotic foods?

Probiotics foods are specialised foods containing a live culture of 'good bacteria'; the presence of these bacteria in our large intestine is necessary for a healthy gastrointestinal tract.

Probiotic bacteria added to foods can be obtained from human, animal or vegetable sources. The most commonly used strains of bacteria in probiotic foods are the *Lactobacillus* species and *Bifidobacteria* species. These non-pathogenic bacterial strains are also found naturally in the human intestine. The advantage of using these bacteria is that their *metabolic* end-products are acids and can lower the pH of the intestinal contents thereby creating conditions that are less favourable for harmful bacteria.

The *starter bacteria* cultures in yoghurt—*Lactobacillus bulgarius* and *Streptococcus thermophillus*—have been shown to improve lactose digestion in individuals lacking the *enzyme* lactase. For this reason, the starter bacteria are often considered to be probiotic. However, these cultures are not very resistant to the unfavourable conditions of the stomach and small intestine and so do not have many probiotic effects.

How do probiotics work?

First and foremost, the bacteria are resistant to the gastric and pancreatic juices and bile so they reach the colon alive. Once in the intestine, the probiotic bacteria reduce or prevent the growth of pathogenic micro-organisms by competitive inhibition. This competitive inhibition occurs in a number of ways:

- The probiotic bacteria feed on the same nutrients as the pathogenic bacteria, thereby limiting their food supply
- Probiotic bacteria create an unfavourable environment for the harmful bacteria by producing lactic or other organic acids
- The probiotic bacteria produce antibiotic-like substances that kill some other bacteria
- The numbers of harmful bacteria are reduced as the probiotic bacteria secure the best adhesion sites on the intestinal wall.

In addition, probiotics have been shown to have *proteolytic* and *lipolytic* activities which improve the *digestion* and *assimilation* of ingested nutrients. Probiotics have also been shown to possess anti-*mutagenic* properties; for example, Lactobacilli are known to decompose some carcinogens. It is also thought that probiotic organisms interact with the human immune system on many levels including *macrophage phagocytosis*, *cytokine* production and enhancing immunity to bacterial pathogens.

Alimentary Health

Alimentary Health (AH), established in 1999, is a biotechnology company based at University College Cork. AH's mission is to transform the quality of life of patients and consumers through the development of scientifically supported and clinically proven probiotic technologies and products.

AH believes that an understanding of the interactions between human gut flora and the human immune system will lead to the development of a new generation of natural, safe treatments (probiotics or derived from probiotics) for major diseases. AH's focus is on the discovery and development of safe, effective therapeutic products for management of chronic inflammatory conditions including Irritable Bowel Syndrome (IBS), Crohn's Disease, and Ulcerative Colitis (collectively IBD). These conditions affect between 9–12% of the population.

AH have been working with Procter and Gamble, a major multinational, on commercialisation of a daily probiotic supplement that builds and maintains a natural defence against a range of digestive upsets, such as constipation, diarrhea, abdominal discomfort and bloating. The product (ALIGN) is available in through pharmacies in the US. It contains *Bifidobacterium infantis 35624*, a natural probiotic strain clinically proven to help restore the balance of healthy bacteria in the digestive system. *Bif. infantis 35624* is a proprietary AH technology.

For more information see: www.alimentaryhealth.ie

Enterprise Ireland helps companies such as Alimentary Health to assess their needs and capabilities, formulate a growth plan and access a range of financial and other resources needed to execute that plan.

For more information see: **www.enterprise-ireland.com**

Why are most probiotics found as dairy foods?

Probiotic bacteria have been associated with dairy foods for centuries; in the past people would drink sour milk to treat gastrointestinal ailments. Today dairy products are chosen as the delivery medium for probiotic bacteria for several reasons:

- dairy foods can protect the probiotic bacteria in the acidic environment of the stomach and small intestine and increase their chance of survival.
- dairy products are generally refrigerated and this in turn ensures stability of the probiotic bacteria.
- the benefits of probiotic bacteria combine with the health benefits of dairy foods making them a good 'all round package.'

ENTERPRISE IRELAND

Probiotics – Taking the Strain

Syllabus Reference

Leaving Certificate

3.1.3
Bacterial cells: basic structure (including plasmid DNA), three main types
Reproduction
Nutrition
Factors affecting growth
Understanding of the term "pathogenic"
Definition and role of "antibiotics"

H.3.1.9
Prokaryotic nature of bacteria

H. 3.1.10
Growth curves of micro-organisms

3.3.4.
Two functions of symbiotic bacteria in the digestive tract

Junior Certificate Science

Section 1C8
Investigation of examples of micro-organisms such as bacteria, fungi and viruses
Biotechnology in industry and medicine

Learning Outcomes

On completing this section, the student will be able to:

- Appreciate that bacteria were the only life form on Earth for two billion years
- Recall that bacteria are prokaryotes – their cells do not have a nucleus
- Define the following nutritional terms: autotrophic, photosynthetic, chemosynthetic, heterotrophic, saprophytic and parasitic
- Explain the difference between symbiosis and mutualism
- Understand how the population of our gut bacteria is kept constant
- Explain how the early use of antibiotics led to our discovery of 'good gut bacteria'
- Explain why the starter bacteria for yoghurt production are not suitable for probiotics
- List the characteristics of suitable probiotic bacteria
- List the advantages of dairy foods to act a delivery medium for probiotic bacteria

General Learning Points

- Life began on Earth about three thousand eight hundred million years ago
- Bacteria were the only type of living organisms for about 2 billion years
- Bacteria are the only organisms whose cells do not have a membrane-bound nucleus
- We have beneficial mutualistic bacteria on our skin and in our gut
- Our mutualistic gut bacteria feed on the food we do not absorb
- It is our regular feeding habit that maintains a good colony of gut bacteria
- Destruction of our gut bacteria by antibiotics leads to health problems
- Probiotics are used to rapidly re-establish a big population our good gut bacteria
- The usual starter cultures used in yoghurt production are not strongly probiotic
- Probiotic yoghurts and other foods also contain live culture of particularly beneficial bacteria that normally live in the large intestine
- Probiotic bacteria prevent pathogenic bacteria colonising the gut
- Our friendly gut bacteria improve our nutrient supply, reduce our risk of cancer, and aid our immune system
- Dairy foods are particularly suitable to successfully deliver probiotic bacteria

Student Activity

- Review the mandatory practical activity at Junior Certificate – the investigation of the presence of micro-organisms in soil.
- Review the mandatory practical activity at Leaving Certificate – investigate the growth of leaf yeast using agar plates and controls.
- Growing bacteria at home outside the laboratory without proper supervision poses dangers to yourself and others. There are many interesting variations on the experiments carried out in the school laboratory but it is advisable that these should not be carried out at home.
- Microscopic examination of prepared slides of bacteria and compare the magnification needed to view these as against plant and animal cells.

True/False Questions

(a) Bacteria are eukaryotic organisms. **T F**

(b) All bacteria are heterotrophic. **T F**

(c) The relationship with our good gut bacteria is known as mutualism. **T F**

(d) Our gut bacteria feed on the food we did not digest and/or absorb. **T F**

(e) Antibiotic treatment does not harm our gut bacteria. **T F**

(f) Probiotics are special food with a culture of dead bacteria. **T F**

(g) Probiotic bacteria are resistant to digestive juices. **T F**

(h) Probiotic bacteria protect against cancer of the large intestine. **T F**

(i) Probiotic bacteria inhibit our immune system. **T F**

(j) Dairy products are not suitable to deliver probiotic bacteria. **T F**

Check your answers to these questions on www.sta.ie

Examination Questions

Leaving Certificate Biology, 2005 Higher Level

Q15 (b)

(i) Draw and label a diagram to show the basic structure of a typical bacterial cell.

(ii) Other than being prokaryotic, state two ways in which a typical bacterial cell differs from a typical human cell (e.g. cell from cheek lining).

(iii) Describe how some bacteria respond in order to survive when environmental conditions become unfavourable.

(iv) What is meant when a bacterium is described as pathogenic?

(v) What are antibiotics? Use your knowledge of the Theory of Natural Selection to explain the possible danger involved in the misuse of antibiotic.

Leaving Certificate Biology, 2007 Ordinary Level

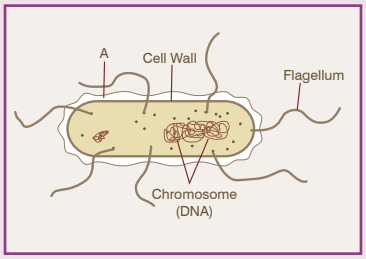
Q13 (a)

The diagram shows a typical bacterial cell.

(i) Some bacteria have a layer outside the cell wall (labelled A in diagram)

Name this layer and state its function

(ii) Name a structure, other than A, which is not found in all bacteria.



Q13 (b)

The table below shows ways in which bacteria obtain their food. Study the table and then answer the questions that follow.

Autotrophic	Heterotrophic
Photosynthetic	Parasitic
Chemosynthetic	Saprophytic

(i) Distinguish between autotrophic and heterotrophic nutrition.
(ii) What is saprophytic nutrition?
(iii) Why are saprophytic bacteria important in nature?
(iv) Briefly explain chemosynthesis.
(v) What term is used for the organism from which a parasite obtains food?
(vi) Give examples of two harmful bacteria.

Junior Certificate Science, 2006 Ordinary Level

Q3 (c)

(i) In ecology micro-organisms play a major role in recycling nutrients. Name one decomposer from the habitat you have studied.
(ii) Micro-organisms are used widely in biotechnology. Give one use of biotechnology in industry.
(iii) Micro-organisms can be found growing in a variety of locations. Describe how the presence of micro-organisms in a sample of soil might be investigated. Include diagrams of any equipment that might be used.

For further examples of past papers check www.sta.ie

Did You Know?

A typical bacterial cell is about a trillionth the size of a drop of water and about 1,000 times smaller than the average human cell.

Some bacteria live in solid rock nearly 3 kilometres below the surface where the temperature is about 75˚C.

Much less than 1% of the different types of bacteria cause disease – the vast majority of bacteria are harmless and many are beneficial.

In good growth conditions bacteria reproduce rapidly by simple cell division – dividing in two every 20 minutes. In 8 hours just 1 bacterium could give rise to 16 million bacteria all genetically identical to each other and to the original.

Florey, Chain and Heatley were very lucky that they tested the penicillin toxicity on mice in the laboratory before human trials. If they had tested penicillin on guinea pigs there would have been a great delay in the use of penicillin as the guinea pigs would have died – the penicillin kills their 'good gut bacteria' leading to rapid colonisation of the guinea pigs' large intestine by other bacteria leading to blood poisoning.

Biographical Notes

Antonie van Leeuwenhoek (1632–1723)

Dutch draper Antonie van Leeuwenhoek was, in 1683, the first to observe bacteria when he used a single lens microscope that he designed to examine material from his mouth. He called them 'animalcules' (little animals) as in his day living things were classified either as plants or animals.

Karl von Naügeli (1817–1891)

Karl von Naügeli, a Swiss botanist, in 1857 suggested that these 'animalcules' be placed in a class of their own in the plant kingdom. He considered them to be plants because their cells had walls that looked similar to the walls of plant cells.

Louis Pasteur (1822–1895)

Louis Pasteur, French chemist and microbiologist, showed that sour wine was caused by bacteria contaminating the alcoholic fermentation process carried out by yeast. Pasteur suggest a heat treatment, now known as pasteurisation, whereby the fermenting grape juice is heated gently to about 49˚C to kill the bacteria but not the yeast.

Read more about other famous scientists on www.sta.ie

Revise The Terms

Can you recall the meaning of the following terms?

Prokaryotic, autotrophic, organelles, photosynthetic, chemosynthetic, heterotrophic, saprophytic, parasites, symbiotic, mutualism, carcinogenic, continuous flow food processing, antibiotic, pathogenic, deficiency, metabolic, enzyme, proteolytic, lipolytic, digestion, assimilation, mutagenic, macrophage, phagocytosis, cytokine, starter bacteria

Check the Glossary of Terms for this lesson at www.sta.ie