Microbe of the month

Breaking The Chain of Infection

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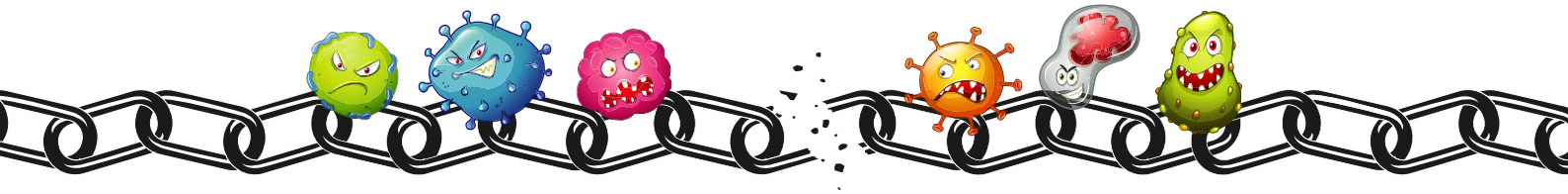
MARCH 2019

Newsletter

Compiled by Helen Loudon, Independent IPC Practitioner



Featured this month:

Back to Basics

ALL ABOUT BACTERIA (Part 1)

There are more bacteria in a gram of stool than there are human beings on the planet (i.e., 7.7 billion), and up to a million per 1cm^2 of wound surface or millilitre of exudate! That's why it is so important to understand how microbes behave and interact with the body's physiology, which in turn helps us with wound assessment, the diagnosis of infection and choosing the most appropriate antibacterial product (if applicable).

Bacteria are not only intelligent, but are an excellent example of successful evolution, surviving and thriving in almost every type of environment, range of temperatures and pH balance – from icy glaciers, to boiling springs and volcanoes, and even outer space!

Most bacteria are not harmful; indeed, they are essential for health. Many play a valuable role – for example, some fix atmospheric nitrogen in soil, making nutrients available to plants, and we have harnessed the activity of some microorganisms to produce everyday foods such as cheese and yoghurt.

This 'Back to Basics' theme will be expanded upon in the months ahead, and the fundamentals of microbiology will be explained in an easy-to-understand format, with insights into commonly-encountered pathogens and their special characteristics, as well as how these impact on clinical practice and antimicrobial therapy.

Fast facts about bacteria

Nuts and bolts' - the size, shape and structure of bacteria (termed *'morphology'*)

In a 1683 letter to The Royal Society of London, Dutchman Anton van Leeuwenhoek described microscopic 'streaks and threads' amongst what he called tiny 'animalcules'. These 'streaks and threads' remained nameless until 1773, when the Danish scientist Otto Frederick Müller christened them 'bacilli'. Bacilli is the plural form of the Latin ***bacillus***, meaning *'little rod'*.

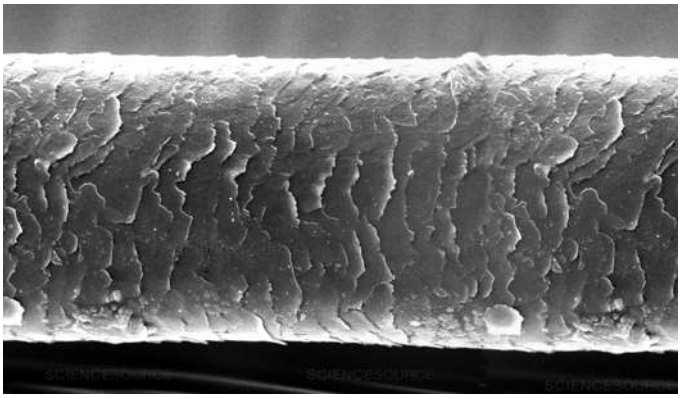
The unit of measurement in bacteriology is the *micron* (also referred to as a micrometre).

The limit of resolution with the unaided eye is about 40 microns - for size comparisons, the diameter of a red blood cell is approximately 5 microns, and a human hair between 60 and 150 microns.

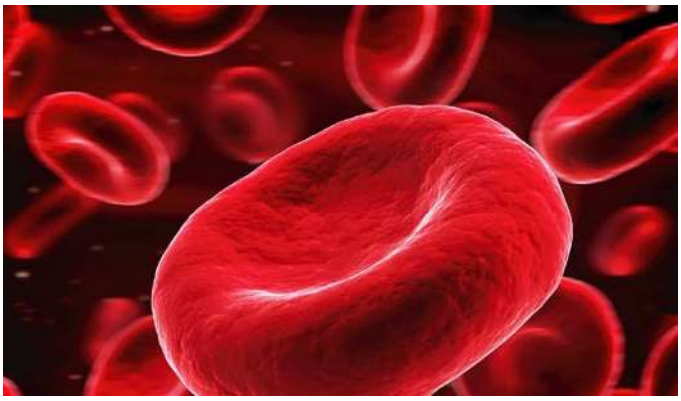
- 1 micron (µ) or micrometre (µm) = one thousandth of a millimetre
- 1 millimicron (mµ) or nanometre (nm) = one thousandth of a micron or one millionth of a millimetre

Bacteria, however, can only be visualized under magnification and generally range in size from 0.3µ to 14µ. Hundreds of thousands of bacteria could fit into the size of the full stop at the end of this sentence.

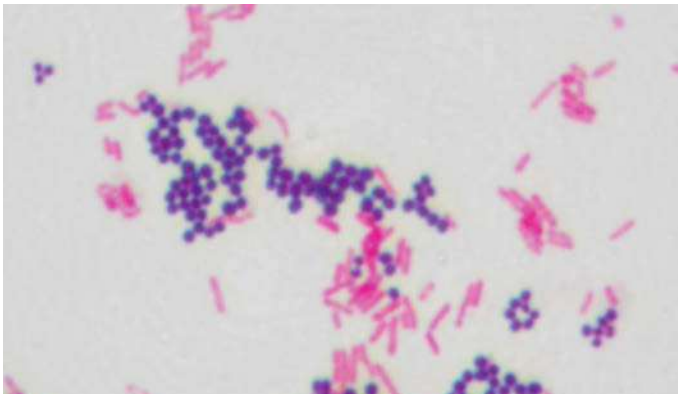
Dust mite: 200µ



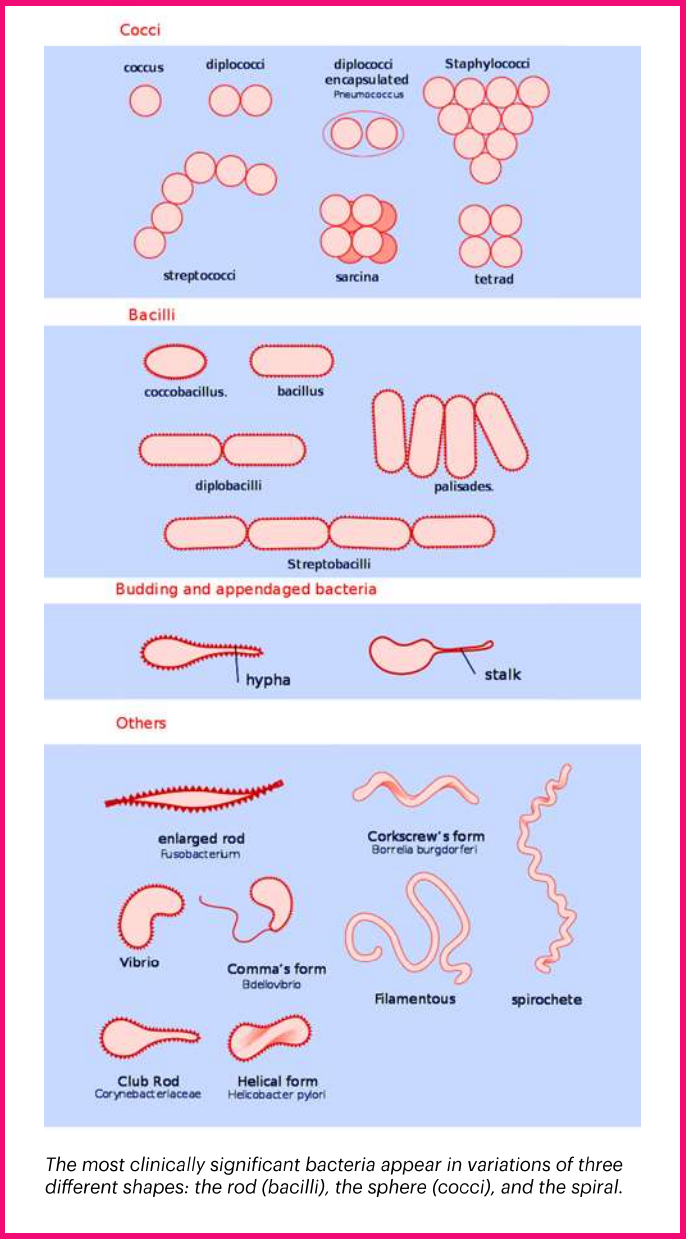
Human hair: 60-150µ



Red blood cell: 5µ



Bacteria: 0.3-5.0µ



The most clinically significant bacteria appear in variations of three different shapes: the rod (bacilli), the sphere (cocci), and the spiral.

The term **morphology** refers to the size and shape of microbes, as well as the physical features that make them distinctive. Bacteria are known as *'prokaryotic'* cells, which means that they are much smaller and less complex than the cells of humans, animals, plants, fungi, parasites and insects (the latter are referred to as *'eukaryotes'*).

Historically, bacteria have been grouped and named primarily according to their morphological, biochemical and metabolic differences. However, evolving molecular methods have also enabled us to classify bacteria according to their immunologic and genetic characteristics – all of which enable the clinician to determine the organism causing a patient's infection.

Bacteria do not have a nucleus – only a single circle of double-stranded DNA, which is not surrounded by a nuclear membrane but which lies in what is called the 'nuclear region' of the cytoplasm.

Unlike animal cells, bacteria have more than one layer protecting their nuclear material and cytoplasm from the external environment.

The outermost layer is the **cell wall**, which determines the shape of the bacterium. It is made of a substance called *'peptidoglycan'* – an intricate, cross-linked structure of carbohydrates and amino acids. **This is an important structural and strategic feature** which differs between Gram-positive and Gram-negative bacteria.

- Clinical relevance? The cell wall plays a role in the efficacy of antiseptics and alcohol-based hand rubs, as well as how antibiotics exert their action – *this will be explained in more detail in the next issue.*

The internal **cell membrane** (the innermost layer in contact with the cytoplasm) carries out most of the functions of the cell – such as transporting nutrients into the cell, making cellular components and generating energy.

Cleverly, the cell membrane is also able to increase its surface area and efficiency by folding upon itself – these folds are called *'mesosomes'*.

Other relevant structures found freely in the cytoplasm are **plasmids** and **ribosomes**.

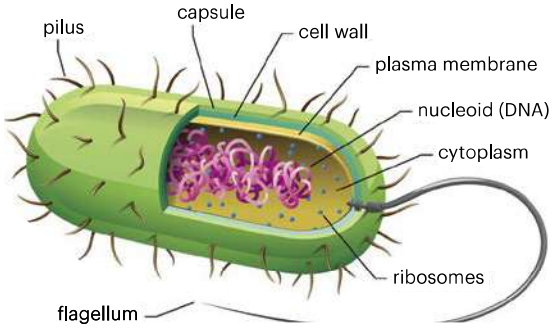
Plasmids comprise of smaller circles of double-stranded DNA and play a role in bacterial cell division (multiplication).

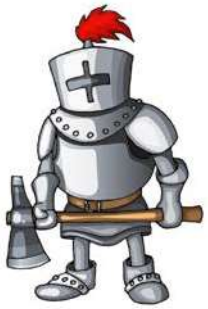
- Clinical relevance? *Certain plasmids carry antibiotic resistance genes and encode enzymes that degrade antibiotics* (e.g., penicillinase) or generate virulence factors – for example, the formation of fimbriae or the production of exotoxins.

Ribosomes are composed of RNA and are involved in the synthesis of bacterial proteins.

- Clinical relevance? This is key to the killing action of certain antibiotics – for example, an antibiotic molecule will attach itself to the ribosomes in the bacterial cell and interfere with their function. With no way to make proteins, the bacteria will die.

Basic structure (morphology) of a bacterial cell



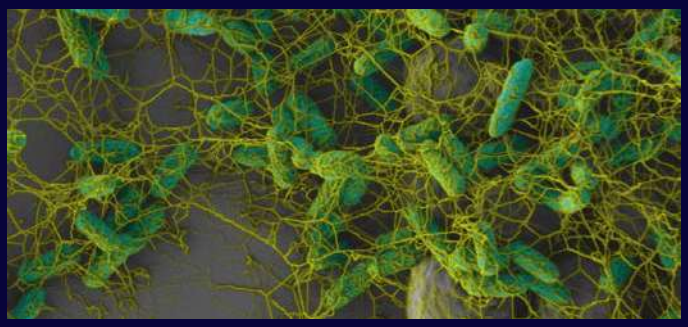


Staying ahead of the pack – CELL STRUCTURES AS WEAPONS OF VIRULENCE

Cell capsules and slime layers: Many bacteria secrete a gelatinous layer of polysaccharides and proteins called the *'glycocalyx'* (meaning 'sweet coat').

This layer may be thick and tightly bound to the cell, in which case it is known as a 'capsule'. When thinner and less tightly bound, it is referred to as a *'slime layer'*. It acts as a protective buffer between the bacterial cell and its external environment, as well as preventing nutrients from flowing away.

- Clinical relevance? Slime layers and cell capsules are key elements in the formation of **biofilms and the disease process**. *They enable bacteria to be more virulent (harmful) because macrophages and neutrophils are unable to phagocytose them.*



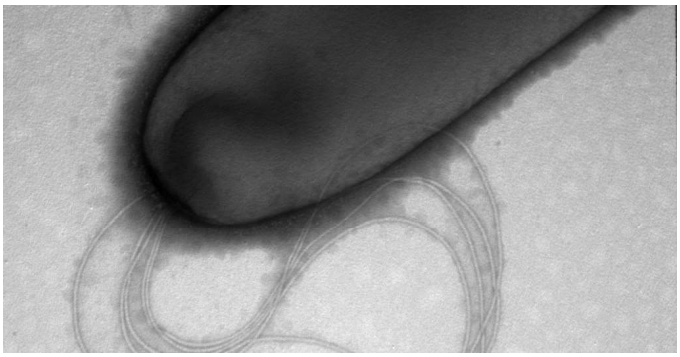
Electron microscope image of Gram-negative rods and cocci embedded in biofilm

Think of **biofilm** as a 'mechanical scaffold' around bacteria. Often described as a complex matrix of carbohydrates and proteins, biofilm encompasses a *multitude of bacterial colonies*, providing a medium for bacterial communication (*'quorum sensing'*), nutrition and multiplication – a 'biological bunker' shielding the bacteria from the action of antibodies, neutrophils and antimicrobial agents.

- Clinical relevance? Biofilm allows bacteria to bind to prosthetic devices and protects them from attack from antibiotics and the immune system. *Staphylococcus epidermidis* and *Staphylococcus aureus* are prolific biofilm producers – they often form a biofilm on intravascular catheters, which disperses bacteria into the bloodstream to cause bacteraemia and potentially-lethal catheter-related sepsis. These biofilms are very difficult for antibiotics to penetrate. The most effective way to cure an infection involving a prosthetic device is to remove the device.

Flagellae: These are hollow, *hair-like* structures that protrude from the surface of the cell and are often much longer than the cell itself. The number and arrangement of flagellae (singular *'flagellum'*) varies according to the species and not all bacteria have them.

- Clinical relevance? Flagellae act like a *propeller*, enabling the bacterium to move towards nutrients or away from phagocytic white blood cells and antimicrobial agents. Some bacteria are known to travel up to 2000 times their own length in an hour!

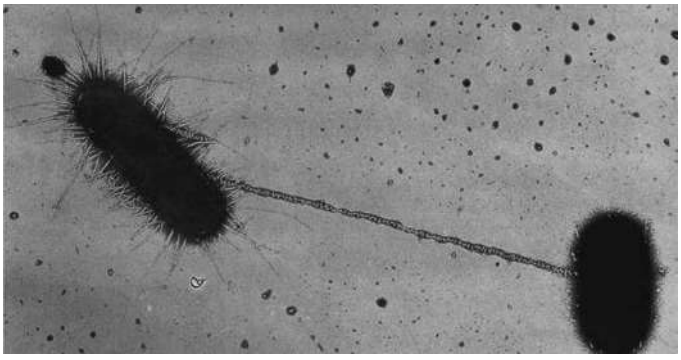


An electron micrograph illustrating the **flagellae** on the opportunistic pathogen Pseudomonas aeruginosa, which causes wound, bloodstream, urinary and respiratory infections

Fimbriae or pili: These are similar to flagellae, but are much thinner and shorter. They are present on many Gram-negative bacteria and enable the organism to adhere to specific host cells.

- Clinical relevance? The pili (singular *'pilus'*) of the bacterium *Escherichia coli* (E. coli – commonly responsible for urinary tract infections) anchor the bacteria to the epithelial cells of the bladder.

  Fimbriae also provide a highly-specialised function as sex pili. '**Sex pili**' join two bacteria together (not necessarily the same species) through a bridge-like connection, enabling the transfer of genetic material – this is termed **bacterial conjugation** and *is an important mechanism for how bacteria acquire and disseminate antibiotic resistance.*



Electron microscope image depicting multiple fimbriae on an E. coli, as well as a single sex pilus extending to another bacterium, enabling the exchange of genetic material

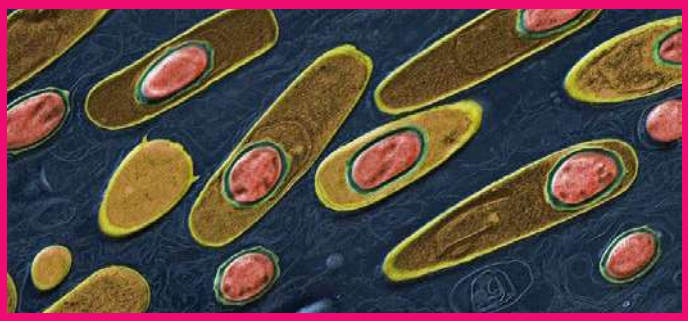
Toxins: Many bacteria produce toxins, enzymes and pigments, and these play an important role in pathogenicity (the ability of an organism to cause infection). Bacterial toxins are categorised into two types:

Exotoxins are proteins that are released by living Gram-positive and Gram-negative bacteria as part of their normal growth and metabolism. Exotoxins evoke an immune and inflammatory response and may cause a variety of disease symptoms, from diarrhoea to paralysis.

- Clinical relevance? Toxoid vaccines are made with inactivated exotoxins whose toxicity have been suppressed either by chemical or heat treatment, while the exotoxin's immunogenic properties are maintained. Therefore, vaccination stimulates an immune response and immunological memory is formed against the molecular markers of the toxoid without resulting in toxin-induced illness. Well-known vaccine examples include diphtheria and tetanus toxoids.

Endotoxins, on the other hand, are poisonous lipopolysaccharide complexes which are released from the cell wall when Gram-negative bacteria die and disintegrate.

- Clinical relevance? Endotoxins can cause a wide spectrum of non-specific pathophysiological reactions, such as fever, changes in white blood cell counts, disseminated intravascular coagulation (DIC), hypotension, toxic shock and death.



Electron microscope image depicting Anthrax spores (pink centres)

Spores: Spore-forming bacteria surround themselves with durable coats of protein that allow them to survive in hostile environmental conditions.

- Clinical relevance? As spores, *bacteria can remain dormant for years, highly-resistant to external stressors such as chemicals, extreme heat, radiation and dehydration*. Common examples include *Anthrax bacillus, Mycobacterium TB* (tuberculosis) and the *Clostridium* species (tetanus, gas gangrene, botulism and antibiotic-associated diarrhoea). When environmental conditions improve, the spore germinates and the bacterial cell inside starts to multiply again. Hence the importance of thorough environmental cleaning.

Lessons learned for infection prevention and control

- Bacteria are everywhere!
- An understanding of bacterial structure and virulence mechanisms are essential for wound assessment, the selection of antiseptics and antibiotic stewardship.
- Bacterial evolution is a constant process driven by natural selection, and environmental and antimicrobial practices.
- When they fall on hard times, some bacteria are able to turn themselves into spores and hibernate for months or years.
- Toxin-based vaccines and antibiotics are bacteria's gift to humanity.

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Your comments or suggestions for future topics?

References:

1. Alcamo, I.E. 2001. Fundamentals of Microbiology. Jones and Bartlett: Boston, Toronto, London, Singapore. **2.** Gladwin, M. Trattler, W. Mahan, C. 2014 6th Ed. Microbiology made ridiculously simple. MedMaster Inc. **3.** Todar, K. On Line Textbook of Bacteriology. http://textbookofbacteriology.net/ **4.** Wilson, J. 2000. Clinical microbiology – an introduction for healthcare professionals. Baillière Tindall: Edinburgh.