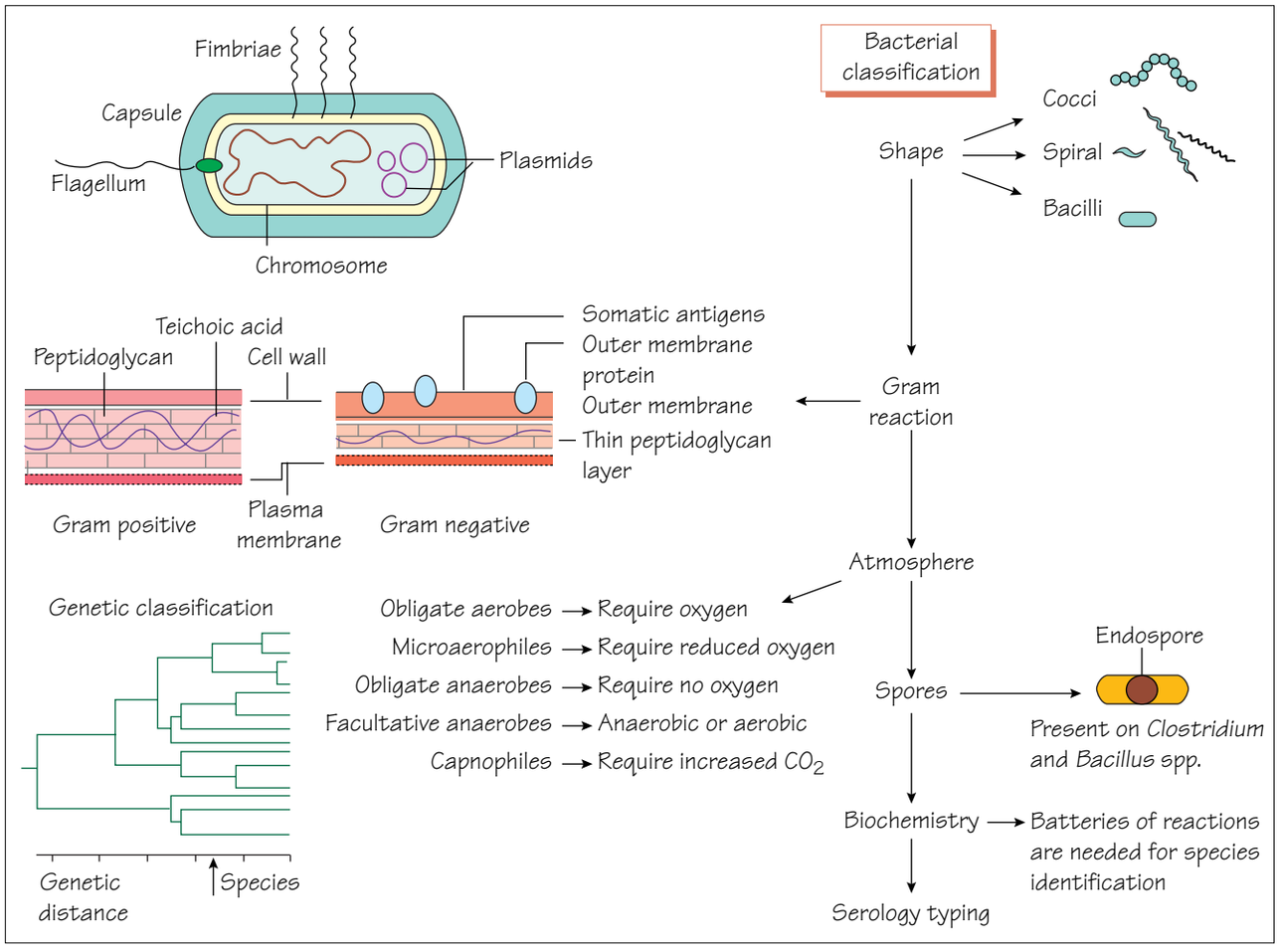
1 Structure and classification of bacteria



Bacterial structural components

The rigid bacterial cell wall maintains its shape and protects the cell from differences in osmotic tension between the cell and the environment. Gram-positive cell walls have a thick peptidoglycan layer and a cell membrane, whereas Gram-negative cell walls have three layers: an inner and outer membrane and a thinner peptidoglycan layer. The mycobacterial cell wall has a high proportion of lipid, including immunoreactive antigens. Bacterial shape is used in classification: cocci are spherical; bacilli are long and thin, with coccobacilli in between; and there are also curved and spiral bacilli with different wavelengths. Important cell structures include the following.

- **Capsule**: a loose polysaccharide structure protecting the cell from phagocytosis and desiccation.
- **Lipopolysaccharide**: protects Gram-negative bacteria from complement-mediated lysis. A potent stimulator of cytokine release.
- **Fimbriae** or **pili**: specialized thin projections that aid adhesion to host cells and colonization. Uropathogenic *Escherichia coli* have specialized fimbriae (P fimbriae) that bind to mannose receptors on ureteric epithelial cells. Fimbrial antigens are often immunogenic but vary between strains so that repeated infections may occur (e.g. *Neisseria gonorrhoeae*).
- **Flagella**: bacterial organs of locomotion, enabling organisms to find sources of nutrition and penetrate host mucus. Flagella can be single or multiple, at one end of the cell (polar) or at many points (peritrichous). In some species (e.g. *Treponema*), the flagella are firmly fixed within the bacterial cell wall.
- **Slime**: polysaccharide material secreted by some bacteria growing in biofilms that protects the organism against immune attack and eradication by antibiotics.
- **Spores**: a metabolically inert form triggered by adverse environmental conditions; adapted for long-term survival, allowing regrowth under suitable conditions.

Bacteria are prokaryotes, that is they have a single chromosome and lack a nucleus. To pack the chromosome inside the cell the DNA is coiled and supercoiled; a process mediated by the DNA gyrase enzyme system (see Chapter 6). Bacterial

ribosomes differ from eukaryotic ones, making them a target for antibacterial therapy. Bacteria also contain accessory DNA in the form of plasmids. For the role of plasmids in antimicrobial resistance see Chapter 7. They may also code for pathogenicity factors.

Classification of bacteria

The purpose of classification of microorganisms is to define the pathogenic potential. For example, a *Staphylococcus aureus* isolated from blood is more likely to be acting as a pathogen than *Staphylococcus epidermidis* from the same site. Some bacteria have the capacity to spread widely in the community and cause serious disease, for example *Corynebacterium diphtheriae* and *Vibrio cholerae*. Bacteria are identified using a series of physical immunological or molecular characteristics.

- **Gram reaction**: Gram-positive and Gram-negative bacteria respond to different antibiotics. Other bacteria (e.g. mycobacteria) may require special staining techniques.
- **Cell shape** (cocci, bacilli or spirals).
- **Endospore**: presence, shape and position in the bacterial cell (terminal, subterminal or central).
- **Atmospheric preference**: aerobic organisms require oxygen; anaerobic ones require an atmosphere with very little or no oxygen. Organisms that grow in either atmosphere are known as facultative anaerobes. Microaerophiles prefer a reduced oxygen tension; capnophiles prefer increased carbon dioxide.
- **Fastidiousness**: requirement for special media or intracellular growth.
- **Key enzymes**: for example, lack of lactose fermentation helps identify salmonellae, urease helps identify *Helicobacter*.
- **Serological reactions**: interaction of antibodies with surface structures (e.g. subtypes of salmonellae, *Haemophilus*, meningococcus and many others).
- **DNA sequences**: 16S ribosomal DNA sequences are now a key element in classification.

The classification systems used are very effective, but it is important to remember that these are generalizations and that there can be considerable variation in clinical behaviour of different strains of bacteria within a species as well as similarities across species. For example, some strains of *E. coli* may cause similar diseases to *Shigella sonnei*, and toxin-producing *C. diphtheriae* causes different disease from non-toxin producers.

Medically important groups of bacteria

Gram-positive cocci are divided into two main groups: the staphylococci (catalase-positive), for example the major pathogen *Staphylococcus aureus*; and the streptococci (catalase-negative), for example the major pathogens *Streptococcus pyogenes*, an agent of sore throat and rheumatic fever, and *Streptococcus agalactiae*, a cause of neonatal meningitis and pneumonia (see Chapters 14 and 15).

Gram-negative cocci include the pathogenic *Neisseria meningitidis*, an important cause of meningitis and septicaemia, and *N. gonorrhoeae*, the agent of urethritis (gonorrhoea).

Gram-negative coccobacilli include the respiratory pathogens *Haemophilus* and *Bordetella* (see Chapter 20) and zoonotic agents, such as *Brucella* and *Pasteurella* (see Chapter 21).

Gram-positive bacilli are divided into sporing and non-sporing. The sporing are subdivided between those that are aerobic (*Bacillus*: see Chapter 16) and those that are anaerobic (*Clostridium*: see Chapter 18). Pathogens include *Bacillus anthracis* which causes anthrax, and clostridia which cause gas gangrene, tetanus, pseudomembranous colitis and botulism. Non-sporing pathogens include *Listeria* and corynebacteria (see Chapter 16).

Gram-negative bacilli, including the facultative family Enterobacteriaceae, form part of the normal flora of humans and animals and can be found in the environment. They include many pathogenic genera: *Salmonella*, *Shigella*, *Escherichia*, *Proteus* and *Yersinia* (see Chapter 23). *Pseudomonas*, an environmental saprophyte naturally resistant to antibiotics, has become an important hospital pathogen (see Chapter 25). *Legionella* is another environmental species that lives in water but causes human infection if conditions allow (see Chapter 25).

Spiral bacteria include the small gastrointestinal pathogen *Helicobacter* that colonizes the stomach, leading to gastric and duodenal ulcer and gastric cancer, and *Campylobacter* spp. that cause acute diarrhoea (see Chapter 27). The *Borrelia* give rise to relapsing fever (*B. duttoni* and *B. recurrentis*) and to a chronic disease of the skin joints and central nervous system, Lyme disease (*B. burgdorferi*). The *Leptospira* are zoonotic agents causing an acute meningitis syndrome that may be accompanied by renal failure and hepatitis. The *Treponema* include the causative agent of syphilis (*T. pallidum*).

Rickettsia, Chlamydia and ***Mycoplasma***

Of these, only *Mycoplasma* can be isolated on artificial media; the others require isolation in cell culture, or diagnosis by molecular or serological techniques.