organism will only grow in the presence of air it is called a strict aerobe, but most organisms can either grow in its presence or its absence and are called facultative anaerobes. A strict anaerobe cannot grow and may even be killed in the presence of oxygen, because some other compound replaces oxygen as the final electron acceptor in these organisms. A fourth group of microaerophilic organisms has also been recognized which grow best in only trace amounts of free oxygen and usually prefer an increased carbon dioxide concentration.

Influence of environmental factors on the growth of bacteria

The rate of growth and metabolic activity of bacteria is the sum of a multitude of enzyme reactions. It follows that those environmental factors that influence enzyme activity will also affect growth rate. Such factors include temperature, pH and osmolarity.

Temperature. Bacteria can survive wide limits of temperature but each organism will exhibit minimum, optimum and maximum growth temperatures and on this basis fall into three broad groups:

- *psychrophiles* – grow best below 20 °C but have a minimum about 0 °C and a maximum of 30 °C. These organisms are responsible for low-temperature spoilage
- *mesophiles* – exhibit a minimum growth temperature of 5–10 °C and a maximum of 45–50 °C. Within this group two populations can be identified: saprophytic mesophiles, with an optimum temperature of 20–30 °C, and parasitic mesophiles with an optimum temperature of 37 °C. The vast majority of pathogenic organisms are in this latter group
- *thermophiles* – can grow at temperatures up to 70–90 °C but have an optimum of 50–55 °C and a minimum of 25–40 °C.

Organisms kept below their minimum growth temperature will not divide but can remain viable. As a result, very low temperatures (–70 °C) are used to preserve cultures of organisms for many years. Temperatures in excess of the maximum growth temperature have a much more injurious effect and this is considered in more detail in Chapter 16.

pH. Most bacteria grow best at around neutrality, in the pH range 6.8–7.6. There are, however, exceptions, such as the acidophilic organism lactobacillus, a contaminant of milk products, which grows best at pHs between 5.4 and 6.6. Yeasts and moulds prefer acid conditions with an optimum pH range of 4–6. The difference in pH optima between fungi and bacteria is used as a basis for the design of media permitting the growth of one group of organisms at the expense of others. Sabouraud medium, for example, has a pH of 5.6 and is a fungal medium, whereas nutrient broth, which is used routinely to cultivate bacteria, has a pH of 7.4. The adverse effect of extremes of pH has for many years been used as a means of preserving foods against microbial attack, for example by pickling in acidic vinegar.

Osmotic pressure. Bacteria tend to be more resistant to extremes of osmotic pressure than other cells owing to the presence of a very rigid cell wall. The concentration of intracellular solutes gives rise to an osmotic pressure equivalent to between 5 and 20 bar, and most bacteria will thrive in a medium containing around 0.75% w/v sodium chloride. Staphylococci have the ability to survive higher than normal salt concentrations. This has enabled the formulation of selective media, such as mannitol salt agar containing 7.5% w/v sodium chloride, which will support the growth of staphylococci but restrict other bacteria. Halophilic organisms can grow at much higher osmotic pressures but these are all saprophytic and are non-pathogenic to humans. High osmotic pressures generated by either sodium chloride or sucrose have for a long time been used as preservatives. Syrup BP contains 66.7% w/w sucrose and is of sufficient osmotic pressure to resist microbial attack. This is used as a basis for many oral pharmaceutical preparations.

Handling and storage of microorganisms

Because microorganisms have such a diversity of nutritional requirements there has arisen a bewildering array of media for the cultivation of bacteria, yeasts and moulds. Media are produced either as liquids or solidified with agar. Agar is an extract of seaweed, which at concentrations of between 1% and 2% sets to form a firm gel below 45 °C. Unlike gelatin, bacteria cannot use agar as a nutrient and so even after growth the gel remains firm. Liquid media are stored routinely in test tubes or flasks, depending upon the volume, both secured with either