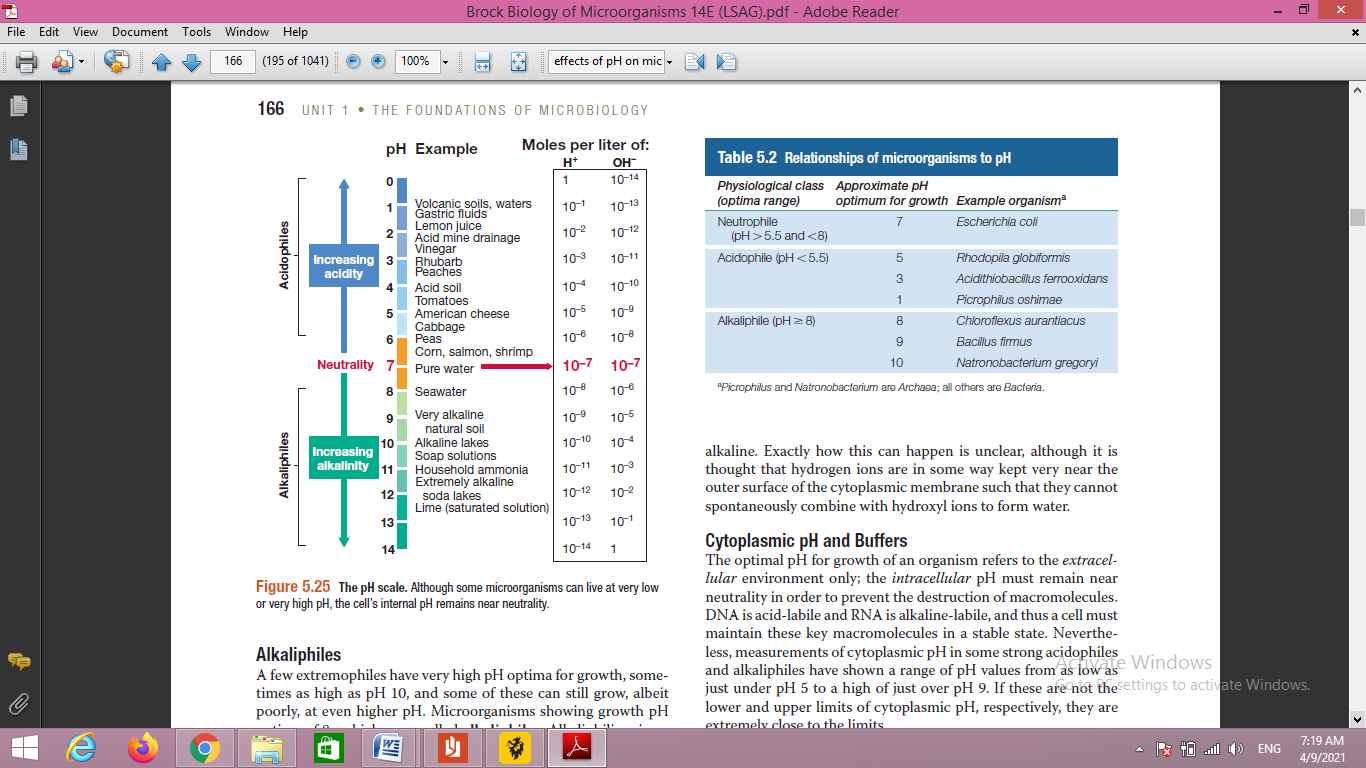
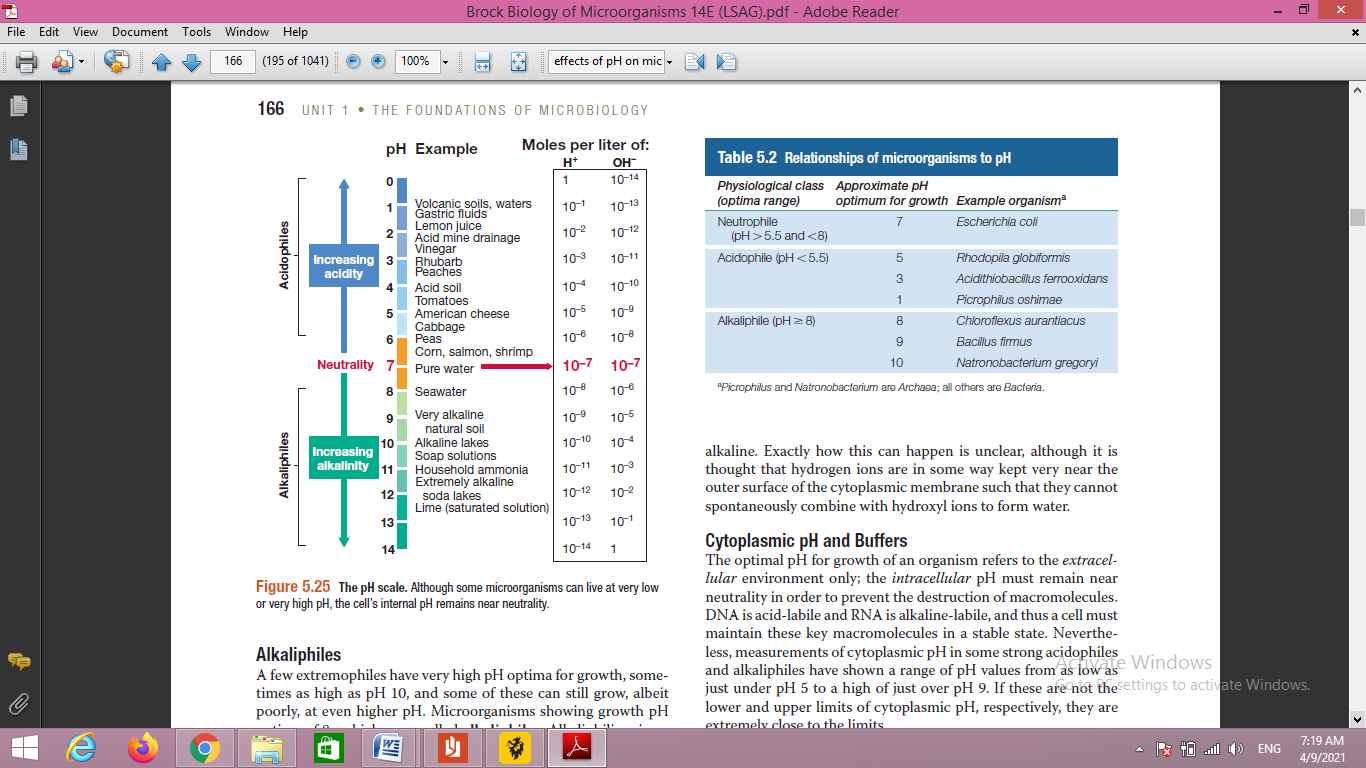
**pH**

Like temperature pH also has major effect on the growth of microorganisms.

**Effects of pH on Microbial Growth**

Acidity or alkalinity of a solution is expressed by its **pH** on a logarithmic scale in which neutrality is pH 7 (Figure 5.25). pH values less than 7 are *acidic* and those greater than 7 are *alkaline*. In analogy to a temperature range, every microorganism has a pH range, typically about 2–3 pH units, within which growth is possible. Also, each organism shows a well-defined pH optimum,where growth occurs best.

Most natural environments have a pH between 3 and 9, and organisms with pH growth optima in this range are most common. Terms used to describe organisms that grow best in particular pH ranges are shown in Table 5.2.



**Acidophiles**

Organisms that grow optimally at a pH value in the range termed *circumneutral* (pH 5.5 to 7.9) are called **neutrophiles** (Table 5.2).

By contrast, organisms that grow best below pH 5.5 are called **acidophiles**.

There are different classes of acidophiles, some growing best at moderately acidic pH and others at very low pH. Many fungi and bacteria grow best at pH 5 or even below, while a more restricted number grow best below pH 3.

An even more restricted group grow best below pH 2 and those with pH optima below 1 are extremely rare. Most acidophiles cannot grow at pH 7 and many cannot grow at pH values more than two units above their optimum.

A critical factor governing acidophily is the stability of the cytoplasmic membrane. When the pH is raised to neutrality, the cytoplasmic membranes of strongly acidophilic bacteria are destroyed and the cells lyse. This indicates that these organisms are not just acid-*tolerant* but that high concentrations of protons are actually *required* for cytoplasmic membrane stability.

Alkaliphiles

A few extremophiles have very high pH optima for growth, sometimesas high as pH 10, and some of these can still grow, albeit poorly, at even higher pH. Microorganisms showing growth pH optima of 8 or higher are called **alkaliphiles**.

Alkaliphilic microorganisms are typically found in highly alkaline habitats, such as soda lakes and high-carbonate soils. The most well-studied alkaliphilic prokaryotes are certain *Bacillus* species, such as *Bacillus* *firmus*. This organism is alkaliphilic, but has an unusually broad range for growth, from pH 7.5 to 11.

Some extremely alkaliphilic bacteria are also halophilic (salt-loving), and most of these are

*Archaea*. Some phototrophic purple bacteria are also strongly alkaliphilic. Certain alkaliphiles

have industrial uses because they produce hydrolytic exoenzymes, such as proteases and lipases. Exoenzymes are those that are excreted from the cell, and in the case of alkaliphiles, their exoenzymes must function well at alkaline pH. These enzymes are produced commercially on a large scale and added as supplements to laundry detergents to remove protein and fat stains from clothing.

How a cell might generate a proton motive force when the external surface of its cytoplasmic membrane is so alkaline. One strategy for circumventing this problem in *B. firmus* is the use of sodium (Na+) rather than H+ to fuel transport reactions and motility; that is, a sodium motive instead of a proton motive force. Remarkably, however, a proton motive force is coupled to ATP synthesis in *B. firmus*, even though the external membrane surface is highly alkaline. Exactly how this can happen is unclear, although it is thought that hydrogen ions are in some way kept very near the outer surface of the cytoplasmic membrane such that they cannot spontaneously combine with hydroxyl ions to form water.

**Buffers**

To prevent major shifts in pH during microbial growth in batch cultures, *buffers* are commonly added to culture media along with the nutrients required for growth. However, any given buffer works over only a relatively narrow pH range. Hence, different buffers are used for different pH classes of microorganism. Near neutral pH, potassium phosphate (KH2PO4) or sodium bicarbonate (NaHCO3) is often employed.