2 Biological Effects of Electrical Current

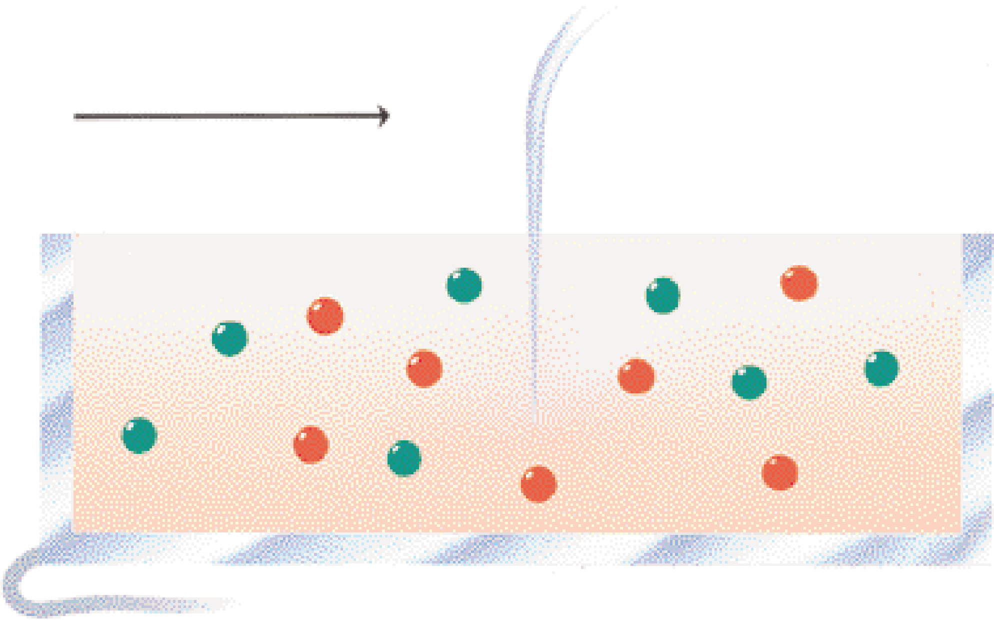

Fig. 2.0.1 A graphical representation of the ions within living tissue prior to the application of electrical current.

In order to understand timedsurgery, it is necessary to understand the effect of an electrical current on living tissue (**Fig. 2.0.1**).
Three types of current can be distinguished: direct current, alternating current and high-frequency alternating current. Only this last is used in timedsurgery.

2.1 **Direct current**

Direct current, which is produced by batteries and dynamos, flows in a single direction and does not change polarity. If a direct current is passed through living tissue, the ions, which are normally distributed uniformly, migrate toward the electrodes (electrolysis).
The "anode" or positive electrode acquires negative ions (e.g. Cl^- and HCO_3^-) while the "cathode" or negative electrode acquires positive ions (e.g. Na^+ and K^+). If the current is applied for sufficient time, the accumulation of ions leads to a chemical lesion due to local acid/base imbalance (**Fig. 2.1.1**).

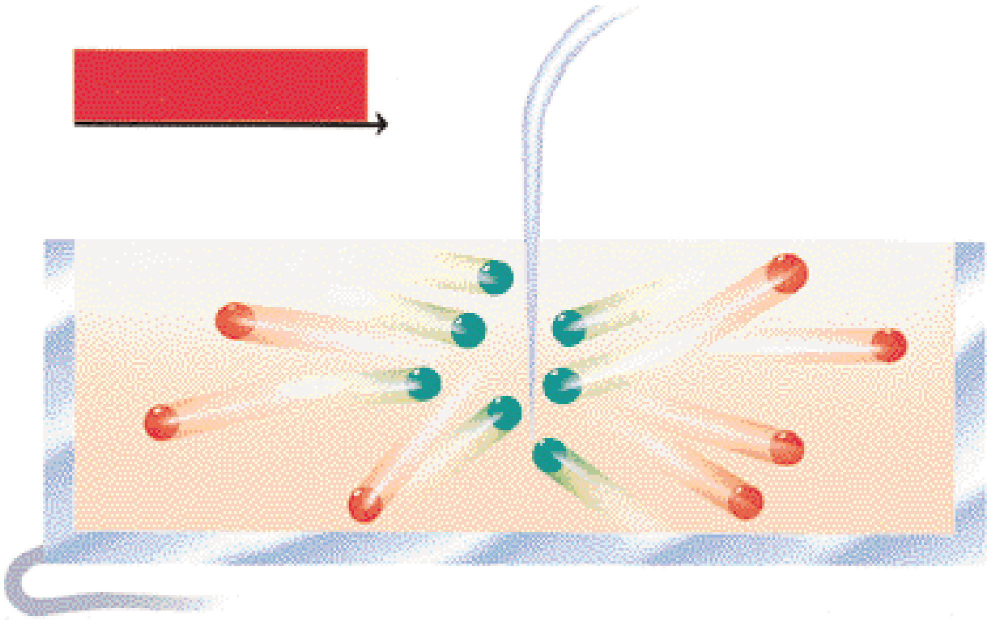

Fig. 2.1.1 With the application of direct current to living tissue, there is a movement of ions towards the electrodes, thus producing local concentrations of acid and base zones. This gives rise to a chemical lesion of the tissue.

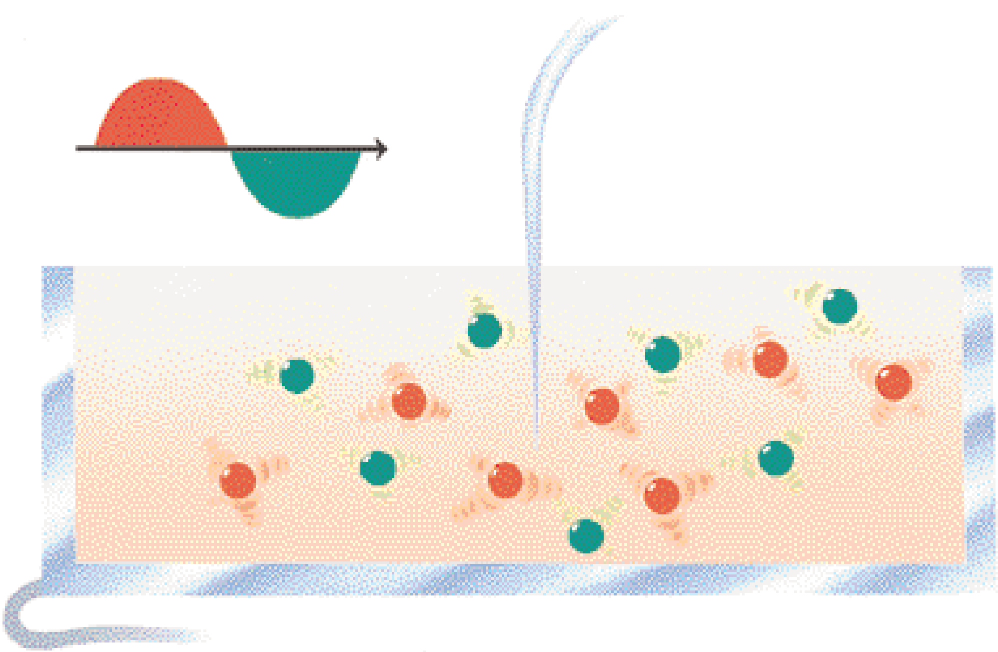

Fig. 2.2.1 A low-frequency alternating current stimulates nerves and muscles but produces no net movement of ions in the tissue and no change in tissue pH.

2.2 **Alternating current**

Alternating current is generated by an alternator and is characterised by cyclical reversal of polarity and direction of current flow. The normal domestic electricity supply is an alternating current which changes direction 50 or 60 times a second (50 - 60 Hz).

If an alternating current is applied to living tissue, the direction of movement of ions in the tissue changes with each change of current direction. If the frequency of the current is high enough, the ions oscillate closely about their original position and there is no net migration of ions and no production of acid and base zones. Low-frequency alternating current is, however, able to stimulate nerves and muscles at relatively low power levels (**Fig. 2.2.1**).

2.3 **High-frequency current**

High-frequencey alternating current may be produced by several types of oscillator. Spark-gap coil and capacitor circuits were the first to be used, followed shortly afterwards by the first vacuum tube oscillators; more recently, solid-state electrosurgery machines were developed. The typical frequency used in electrosurgery is of the order of 500 KHz. At this frequency the changes in direction of current flow are so rapid (500,000 times a second) that heat is generated in the tissue (**Fig. 2.3.1**). As the threshold for nerve and muscle stimulation increases with frequency, at lower frequencies muscular fibrillation may occur, producing an unpleasant sensation of electric stock in the unanaesthetised patient. This can also occur if a spark

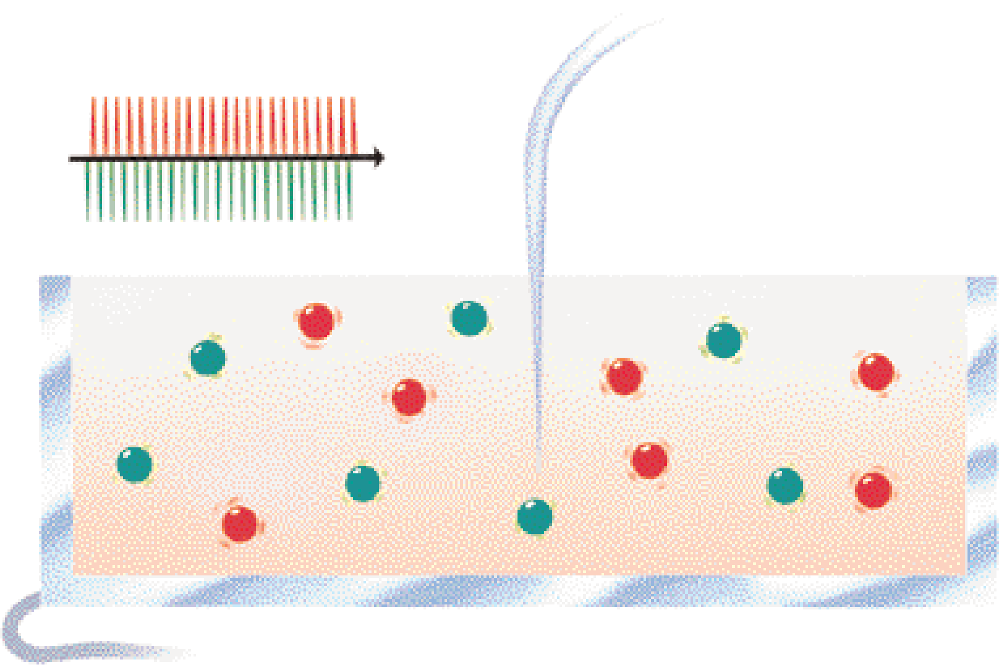

Fig. 2.3.1 With the application of high-frequency alternating current, the oscillation of ions is so rapid that the only effect is the generation of heat.

forms between the electrode and the tissue, in which case the high frequency current may be partially split into lower frequency components or even direct current. To minimise these untoward effects, it is desidable to use frequencies above 800 KHz. At this frequency, the changes in direction of current flow are 800,000 a second.

2.4 **Interference caused by high-frequency current**

High-frequency current can propagate through mechanisms other than the movement of ions, or charged particles, through materials normally considered to be insulators, for example rubber, plastics and air. Indeed, the transmission of radio waves is possible because of these phenomena. For this reason electrosurgical generators may interfere with local radio and television reception as well as with monitoring equipment attached to the patient (e.g. electrocardiographs and implanted pacemakers).

Although the frequency used in timedsurgery is selected to minimise such interference, it is impossible to prevent it totally. Interference is not produced by the generator itself, but by the emission of high-frequency current.

Very high frequencies (> 2 MHz) are not used in timedsurgery because it is very difficult to contain the current within a cable and electrical dispersion tends to occur through many routes, leading to the generation of heat over a wide area. This property can be utilised to advantage; for example, when operating on parenchymatous organs (e.g. liver) a series of coagulations can be produced intentionatly in the general area of an incision.

With very high-frequency currents, dispersion through the air is also influenced by atmospheric conditions; such high frequencies are therefore unsuitable for use in timedsurgery, which requires a perfectly constant energy transfer to the patient at all times.

High frequencies are also used to induce hyperthermia with ferromagnetic implants.