WHY BACTERIA HATE MAGNETS

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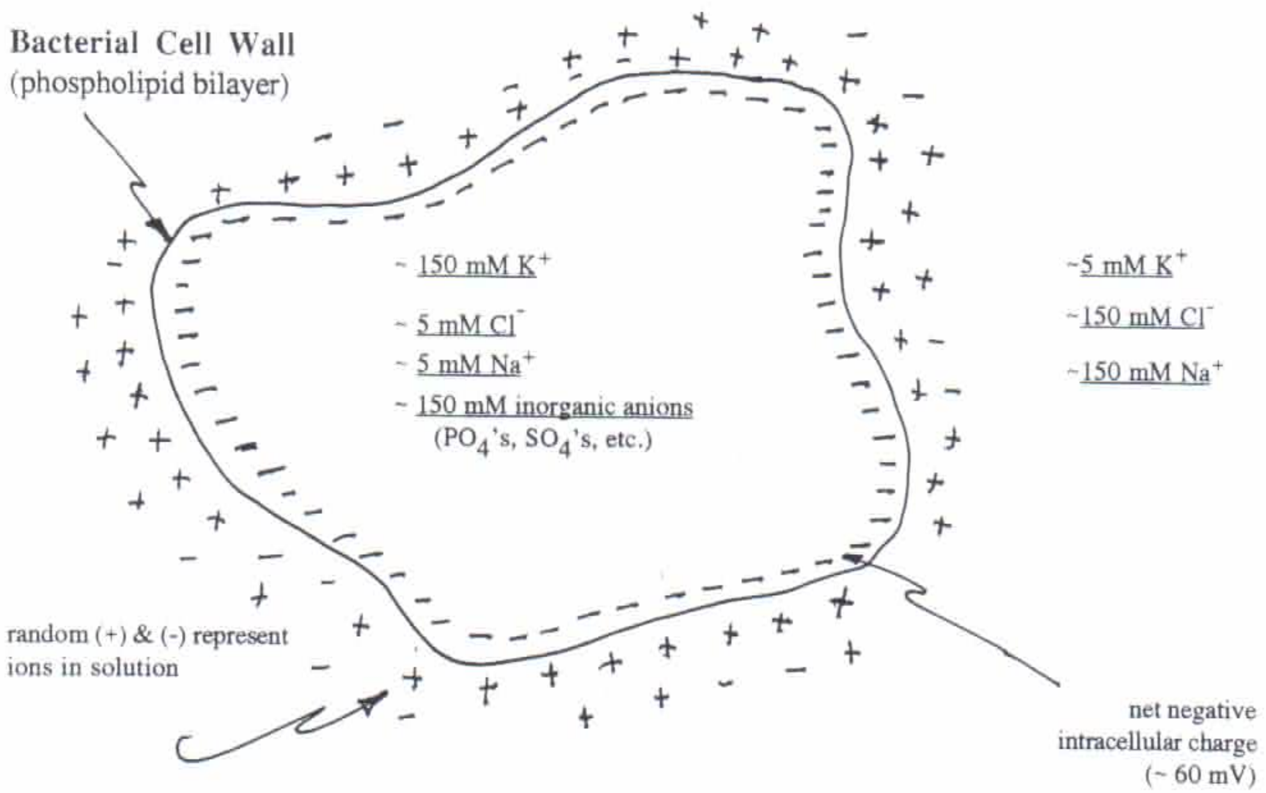
Bacteria are single-celled organisms that are surrounded by phospholipid membranes. The purpose of the membrane is two-fold. First, it physically contains a cell's organelles and other cellular machinery (proteins) that are needed for survival. Second, it maintains a separation between the intracellular and extracellular salt solutions in which the cells exist. A simple diagram is shown below which illustrates the make-up of these salt solutions. Note that the concentration of potassium (K^+) ions is higher inside the cell than outside, and that the opposite is true for sodium (Na^+) and chloride (Cl^-) ions. This separation of ions across the bacterial cell wall is essential, and is maintained by the impermeable phospholipid membrane. If all of the charges (+ and -) on the inside and the outside of the cell are summed (separately), you would find that there is a net negative charge on the membrane's intracellular surface. In other words, the inside of the cell is more negative than the outside of the cell.



Ion Channels and the regulation of cellular pH

As stated earlier, different channel proteins transport different ions across biological membranes. One such ion is the proton, or positively charged hydrogen atom (H^+). The flow of protons through ion channels in bacterial cell membranes is used to control the pH of the intracellular solution. The regulation of cellular pH is crucial for the survival of biological cells. This is true because if the pH is too high of too low, the structural integrity of intracellular proteins is compromised. This, in turn, makes the protein incapable of performing its normal duties, most of which involve catalyzing cellular reactions that are needed to keep the cell alive. The bottom line is that a cell that is unable to control its pH is a dead cell.

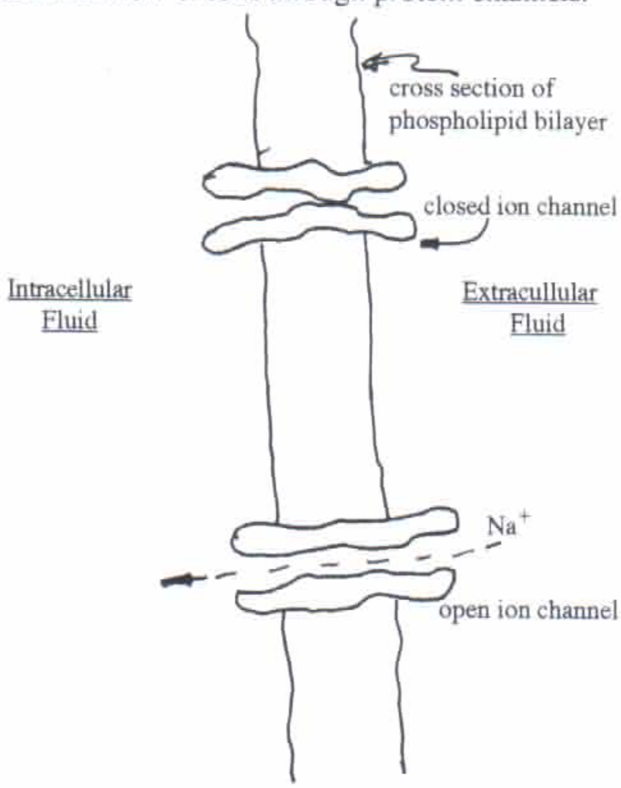
The pH of any solution (including biological ones) is directly related to the concentration of protons, or positively charged hydrogen atoms, in the solution. The higher the concentration of (H^+), the lower the pH, and vice versa. A pH of 7 is neutral, and most cells cannot tolerate having an intracellular pH that is very far from this value. Therefore, bacteria (and other organisms) have developed ways of controlling their pH. This occurs in one of two ways. First, there are intracellular molecules called buffers that bind protons if their concentration gets too high and release protons if their concentrations get too low. The buffer molecules are fine-tuned, however, and are easily saturated. When this happens, (when the concentration of protons gets very high) they can simply be transferred across the cell membrane via ion channels.

The effect of magnets on ion channel behavior

As was discussed earlier, the direction of flow of ions through protein channels is affected by both the electrical and chemical potential that exists across the cell membrane. If bacteria, for example, are placed in an environment where large electrical fields exist, the electrical potential across their cellular membranes will be affected. The presence of a strong magnetic field is a good example of such an environment. The polarized regions of a large magnet will create highly unphysiological electrical potentials in the bacteria's environment. This potential will overwhelm any existing potentials in these very small cells, and they will no longer have control over the movement of ions across their membranes.

The separation of charges across the membrane creates two separate driving forces of the ions. First, because the inside of the cell is more negatively charged than the outside, there is an *electrical* driving force. In this case, if the membrane was punctured, positively charged ions (cations) would be attracted into the cell and negatively charged ions (anions) would be repelled from the the interior of the cell. Second, the separation of charge creates a *chemical* driving force. In this case, ions would want to flow through the puncture down their concentration gradient. For example, both sodium and chloride ions would flow from outside (where they are highly concentrated) to inside the cell (where their concentration is lower). The opposite is true of potassium ions which are more concentrated inside the cell.

Of course, movement of the ions across bacterial membranes does not occur via gaping holes. Rather, it occurs with the aid of proteins that are embedded in the cell membrane. These proteins span the entire membrane, and thus face the extracellular solution on one side of the cell and the intracellular solution on the other. The proteins exist in both "closed" and "open" conformations, and the movement of the ions between these two states is regulated by the bacterial cell. When closed, no ions are allowed through the membrane. When the protein is "open", it forms a small cylindrical hole in the membrane through which ions can pass. Usually, cations and anions flow through different protein channels. Also, some proteins are able to select among different ions of a particular charge. For example, some channels allow sodium but not potassium ions to pass through their pore. The following diagram illustrates the flow of ions through protein channels.



The flow of ions across cell membranes is coupled to many important cellular processes, therefore, bacterial cells become very "sick" when they lose the ability to regulate the ionic currents through protein channels. One of the deadliest scenarios is when the flow of protons is disturbed. In this case, the destruction of the protons' electrochemical gradient equals the destruction of the ability to expel them from the cell. When the hydrogen ion concentration rises, then, the cell cannot release the ions to the environment, and the pH is lowered to a level that is not tolerable. Death ensues.