Alkali and Alkaline earth metals

Sodium, Potassium, Magnesium and Calcium are four of the most important constituents of living systems (sodium being the principal extracellular and potassium the major intracellular monovalent cations). Alkaline and Alkaline earth metal cations also participate in the stabilization of cell membrane, enzyme, polynucleotide (DNA, RNA) conformations via electrostatic interactions and Osmotic effects. Nucleic acids are polyanions and as such, require, counter ions to neutralize partially or completely the negative charged phosphate groups, so that electrostatic repulsions do not overwhelm other stabilizing effects. This charge neutralization requirement is generally accomplished by cation such as Na^{+}, K^{+} and Mg^{2+}. The binding of alkali and alkaline earth metal cations to ligands is generally weak and thus often requires elaborate molecular constructions.

Calcium

The presence and central role of calcium in mammalian bones and other mineralized tissues were recognized soon after its discovery as element by Davy in1808. Calcium is used in various processes. No metal other than calcium is used in such large extent. Today it is widely recognized that Ca^{2+} ions are central to a complex intracellular messenger system that is mediating a wide range of biological process such as bone formation, muscle contraction, blood clotting, Secretion and as a co-factor for stabilization of various protein and ion transport.

Several extracellular enzymes have one or more Ca^{2+} ions as integral parts of their structure. In few of them the Ca^{2+} ion is bound at or near the active cleft, and appears necessary for maintaining the catalytic activity (phospholipase A2, α-amylase, nucleases).

Magnesium

Magnesium is a biologically essential element with the average human adult requiring almost 0.5 g/day. Because it appears in chlorophyll, leafy green vegetables are an excellent source of Mg^{2+}. The typical adult contains about 25 g Mg^{2+}, with about 65% in the bones and 35% distributed widely and serving as a polynucliec acid stabilizer and enzyme activator. Virtually all enzymes with phosphate cofactors including ATP require Mg^{2+} for their function. Mg^{2+} also helps maintain the conformation of nucleic acids such as RNA and the stability of the ribosome. Until recently a Mg^{2+} deficiency was thought rare in humans. However, recent animal studies suggest that low- Mg^{2+} diets may be widespread and liked to diabetes and high blood pressure. Deficiency of Mg causes convulsions and excess causes anaesthetic feeling, treated using chelate agents.

Sodium & Potassium

Sodium is a vital element. The human diet must contain a sensible amount of sodium. The sodium cation is the main extracellular (outside cells) cation in animals and is important for nerve function in animals. Potassium salts are essential for both animals and plants. The potassium cation (K^+) is the major cation in intracellular (inside cells) fluids (sodium is the main extracellular cation). It is essential for nerve and heart function. A normal diet containing reasonable amounts of vegetables contains all the potassium necessary.

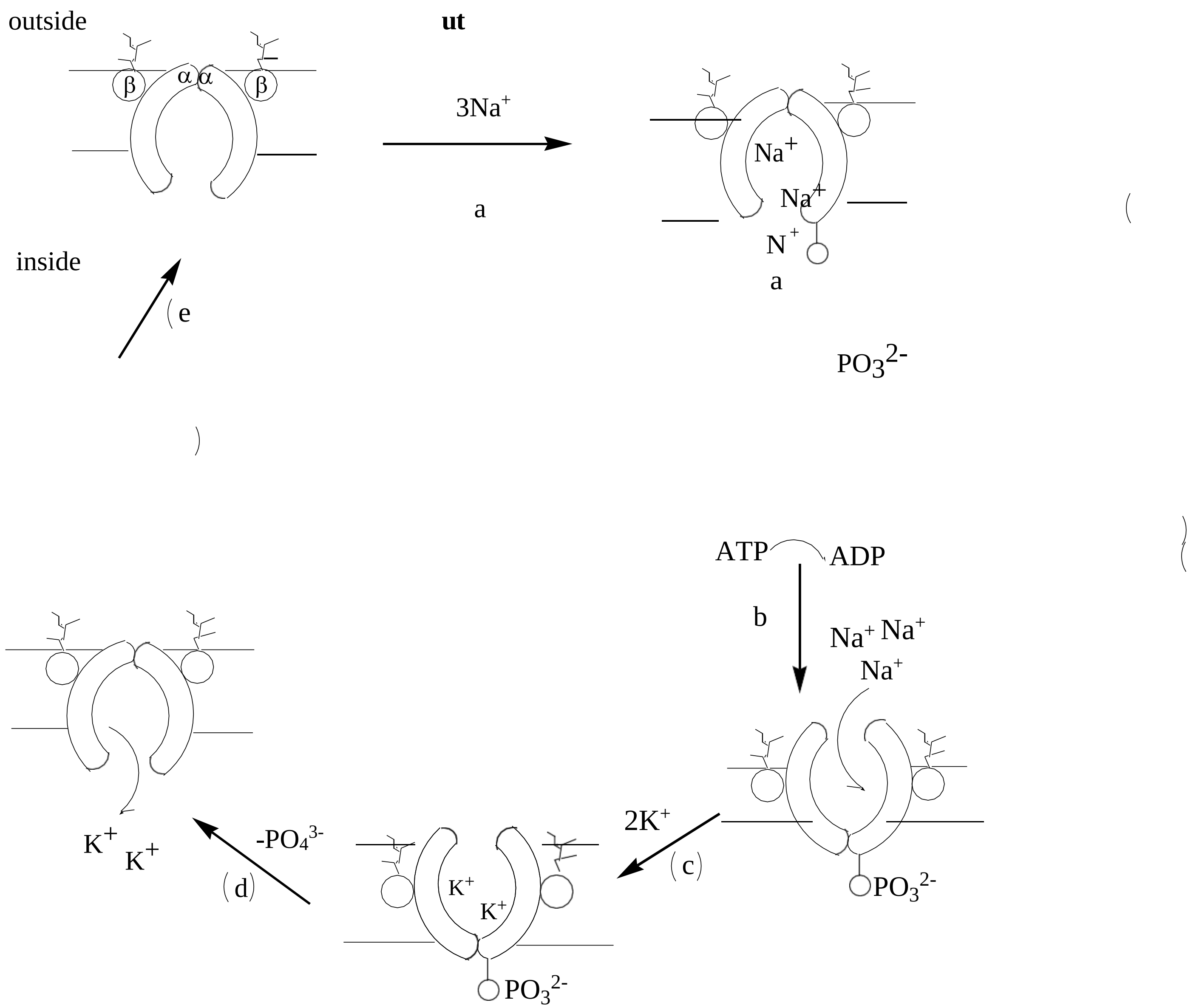
Sodium-Potassium Pump

In order to maintain the cell potential, cells must keep a low concentration of sodium ions and high levels of potassium ions within the cell (intracellular). Outside cells (extracellular), there are high concentrations of sodium and low concentrations of potassium, so diffusion occurs through ion channels in the plasma membrane. In order to keep the appropriate concentrations, the sodium-potassium pump pumps sodium out and potassium in through active transport.

The ionic transport conducted by sodium pump creates both an electrical and chemical gradient across the plasma membrane. Enzyme, Na^+-K^+ ATPase is the major component of the Na^+-K^+ pump, which is essential in creating membrane potential. This intrinsic membrane protein consists of two components; a 100KD catalytic subunit and a 45KD associated glycoprotein, organized in to a $\alpha_2\beta_2$ tetramer.

Mechanism

$$3Na^+_{in} + 2K^+_{out} + ATP + H_2O \leftrightarrow 3Na^+_{out} + 2K^+_{in} + ADP + P_i$$



First of all the Na^+-K^+ pump bound with ATP binds 3 intracellular NaP^{+P} ions (step a). This starts phosphorylation of an Asp residue leading to a conformational change, which weakens NaP^{+} ^{P}binding and moves NaP^{+} ^{P}out of the cell (step b). A conformational change in the pump exposes the NaP^{+} ^{P}ions to the outside, where they are released. ATP is hydrolyzed during this process with the release of ADP. Now in the changed conformational state pump binds 2 extracellular KP^{+P} ions (step c). Potassium binding leads to dephosphroylation and return to original conformation (step d). In this conformation ATP binds and the pump reorients to release KP^{+P} ions inside the cell (step e). The pump is ready to go again.