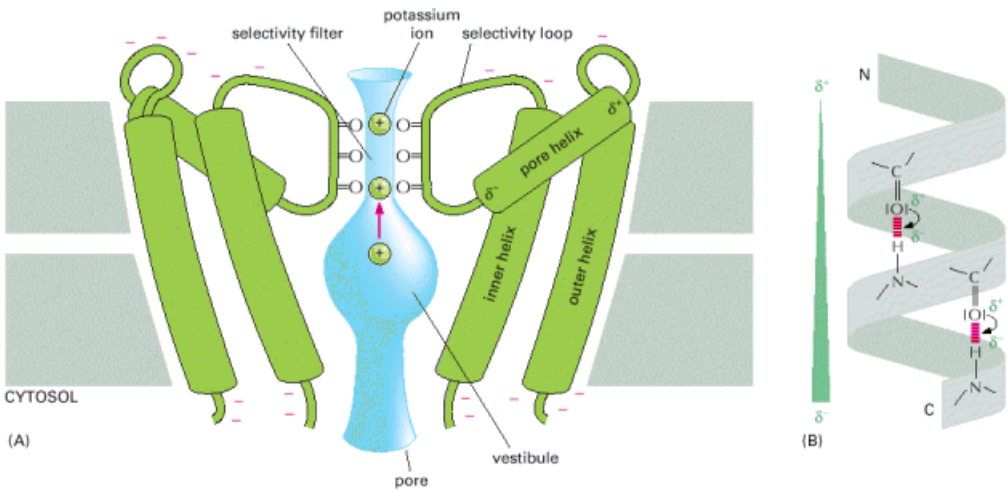
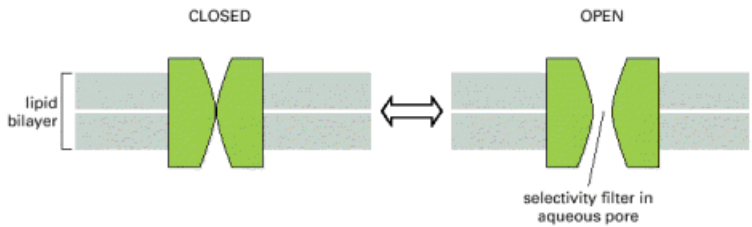
Ιοντικοί δίαυλοι και το δυναμικό της μεμβράνης

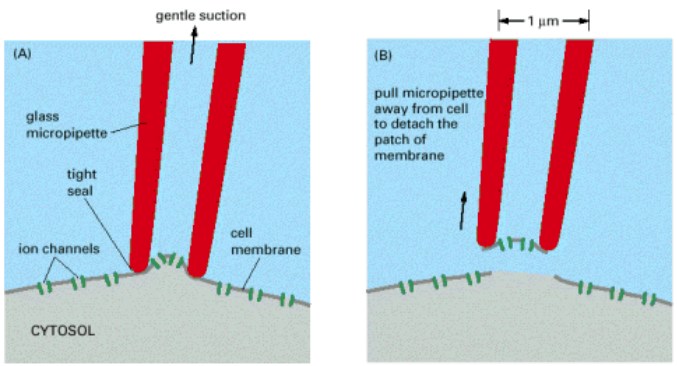
Η δομή ενός βακτηριακού διαύλου K^+

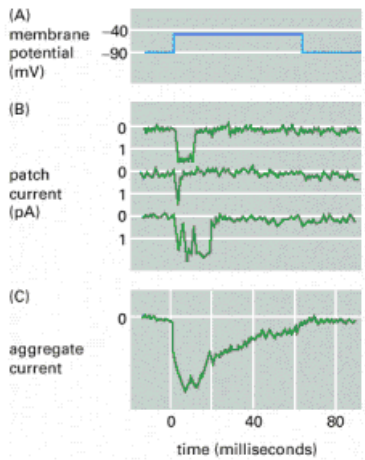


Ένας τυπικός δίαυλος ιόντων μεταπίπτει από κλειστή σε ανοιχτή διαμόρφωση και αντιστρόφως

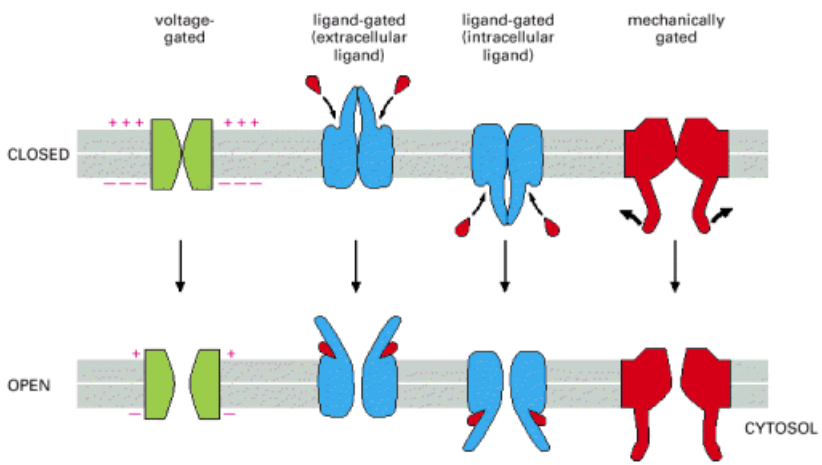


Καταγραφή καθήλωσης δυναμικού

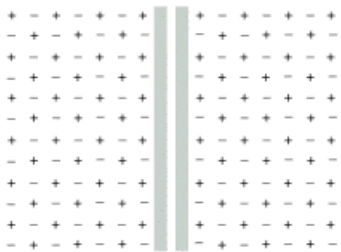




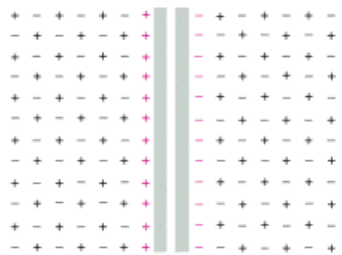
Ελεγχόμενοι ιοντικοί δίαυλοι



Η κατανομή των ιόντων δημιουργεί το δυναμικό της μεμβράνης

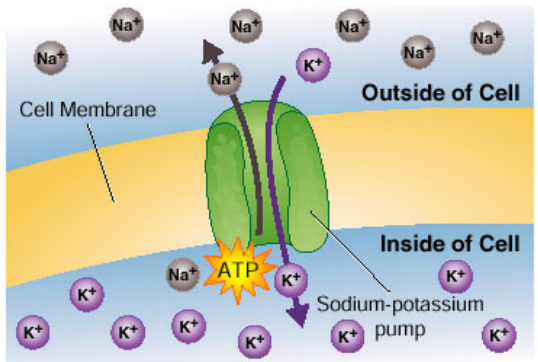


exact balance of charges on each side of the membrane; membrane potential = 0

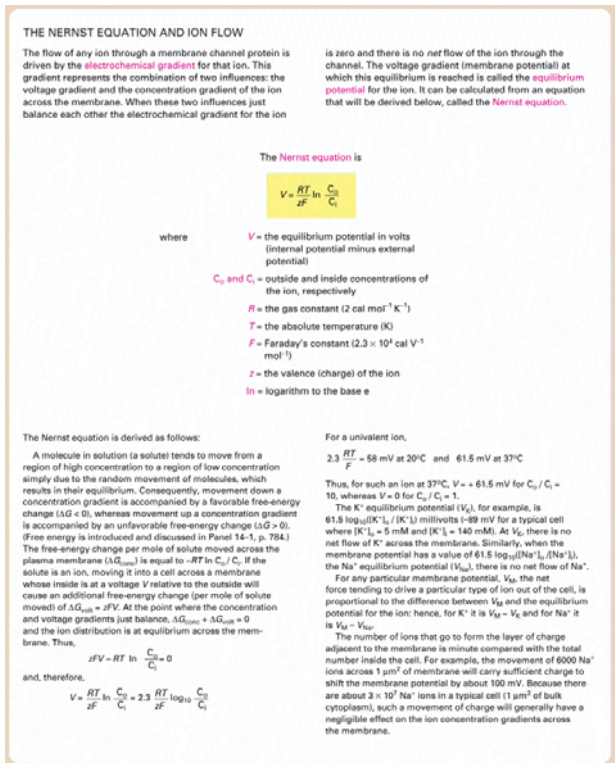


a few of the positive ions *(red)* cross the membrane from right to left, leaving their negative counterions *(red)* behind; this sets up a nonzero membrane potential

Ο ρόλος του K^+ στη δημιουργία του δυναμικού της μεμβράνης



Η εξίσωση του Nernst



THE NERNST EQUATION AND ION FLOW

The flow of any ion through a membrane channel protein is driven by the electrochemical gradient for that ion. This gradient represents the combination of two influences: the voltage gradient and the concentration gradient of the ion across the membrane. When these two influences just balance each other the electrochemical gradient for the ion is zero and there is no *net* flow of the ion through the channel. The voltage gradient (membrane potential) at which this equilibrium is reached is called the equilibrium potential for the ion. It can be calculated from an equation that will be derived below, called the Nernst equation.

The Nernst equation is

$$V = \frac{RT}{zF} \ln \frac{C_o}{C_i}$$

where

V = the equilibrium potential in volts (internal potential minus external potential)

C_o and C_i = outside and inside concentrations of the ion, respectively

R = the gas constant (2 cal mol^{-1} K^{-1})

T = the absolute temperature (K)

F = Faraday's constant (2.3×10^4 cal V^{-1} mol^{-1})

z = the valence (charge) of the ion

ln = logarithm to the base e

The Nernst equation is derived as follows:

A molecule in solution (a solute) tends to move from a region of high concentration to a region of low concentration simply due to the random movement of molecules, which results in their equilibrium. Consequently, movement down a concentration gradient is accompanied by a favorable free-energy change ($\Delta G < 0$), whereas movement up a concentration gradient is accompanied by an unfavorable free-energy change ($\Delta G > 0$). (Free energy is introduced and discussed in Panel 14–1, p. 784.) The free-energy change per mole of solute moved across the plasma membrane (ΔG_{conc}) is equal to $-RT \ln C_o / C_i$. If the solute is an ion, moving it into a cell across a membrane whose inside is at a voltage V relative to the outside will cause an additional free-energy change (per mole of solute moved) of $\Delta G_{volt} = zFV$. At the point where the concentration and voltage gradients just balance, $\Delta G_{conc} + \Delta G_{volt} = 0$ and the ion distribution is at equilibrium across the membrane. Thus,

$$zFV - RT \ln \frac{C_o}{C_i} = 0$$

and, therefore,

$$V = \frac{RT}{zF} \ln \frac{C_o}{C_i} = 2.3 \frac{RT}{zF} \log_{10} \frac{C_o}{C_i}$$

For a univalent ion,

$$2.3 \frac{RT}{F} = 58 \text{ mV at } 20^\circ\text{C} \quad \text{and} \quad 61.5 \text{ mV at } 37^\circ\text{C}$$

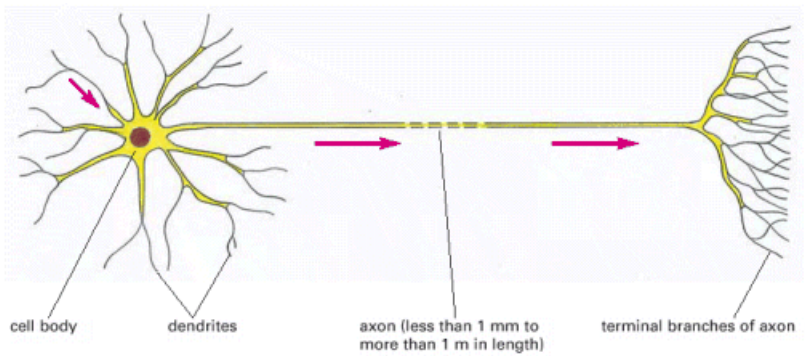
Thus, for such an ion at 37°C, $V = +61.5$ mV for $C_o / C_i = 10$, whereas $V = 0$ for $C_o / C_i = 1$.

The K^+ equilibrium potential (V_K), for example, is 61.5 $\log_{10}([K^+]_o / [K^+]_i)$ millivolts (−89 mV for a typical cell where $[K^+]_o = 5$ mM and $[K^+]_i = 140$ mM). At V_K there is no net flow of K^+ across the membrane. Similarly, when the membrane potential has a value of 61.5 $\log_{10}([Na^+]_o / [Na^+]_i)$, the Na^+ equilibrium potential (V_{Na}), there is no net flow of Na^+.

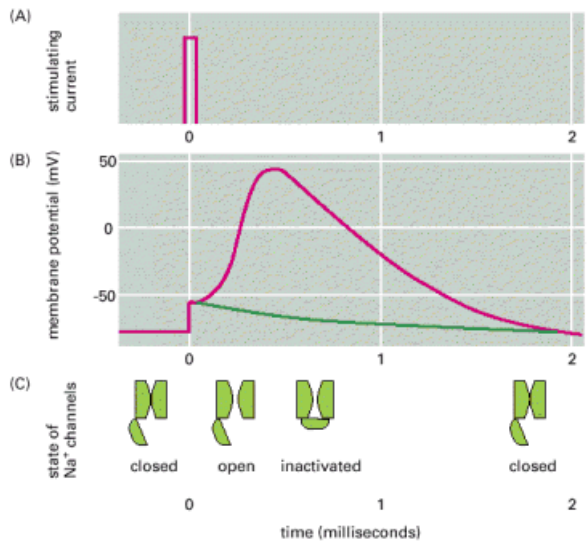
For any particular membrane potential, V_m, the net force tending to drive a particular type of ion out of the cell, is proportional to the difference between V_m and the equilibrium potential for the ion: hence, for K^+ it is $V_M - V_K$ and for Na^+ it is $V_M - V_{Na}$.

The number of ions that go to form the layer of charge adjacent to the membrane is minute compared with the total number inside the cell. For example, the movement of 6000 Na^+ ions across 1 μm^2 of membrane will carry sufficient charge to shift the membrane potential by about 100 mV. Because there are about 3×10^7 Na^+ ions in a typical cell (1 μm^3 of bulk cytoplasm), such a movement of charge will generally have a negligible effect on the ion concentration gradients across the membrane.

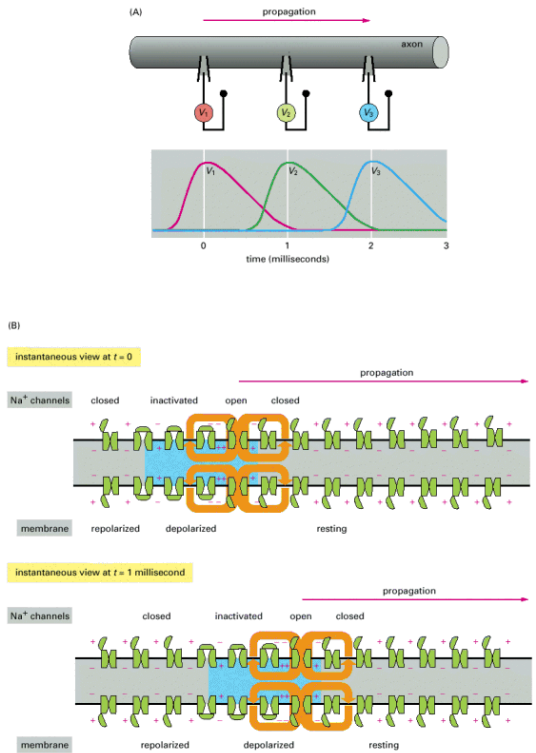
Νευρώνες


cell body
dendrites
axon (less than 1 mm to more than 1 m in length)
terminal branches of axon

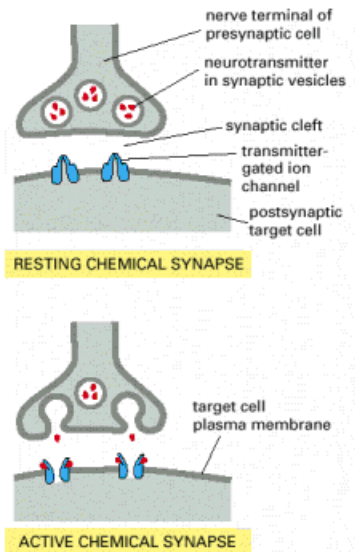
Ένα δυναμικό ενέργειας



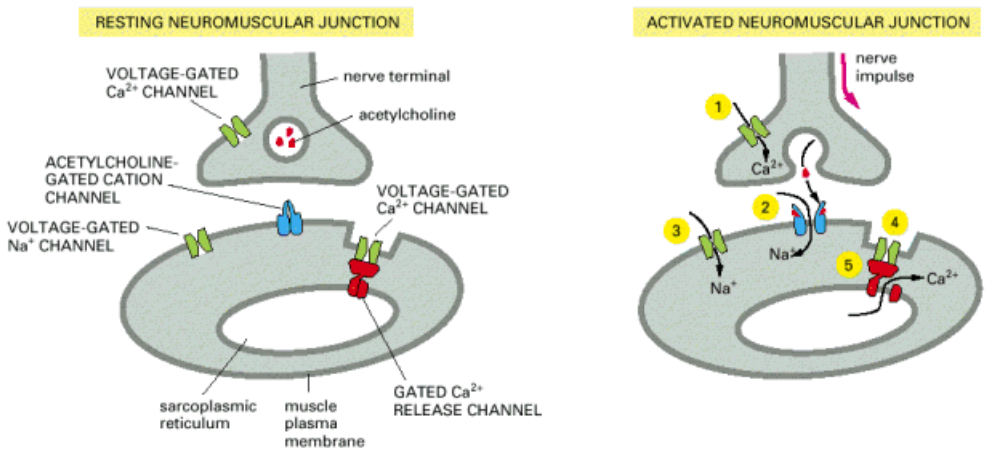
Μετάδοση ενός δυναμικού ενέργειας κατά μήκος ενός άξονα



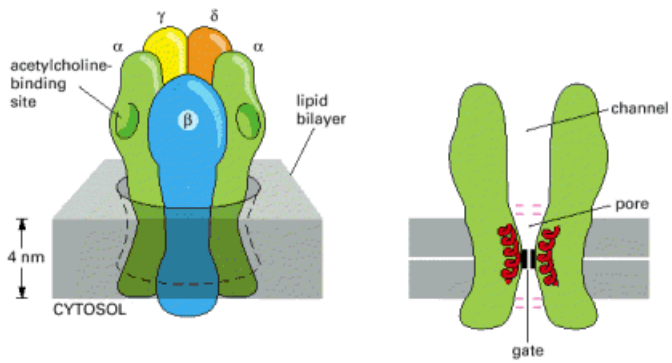
Μια χημική σύναψη



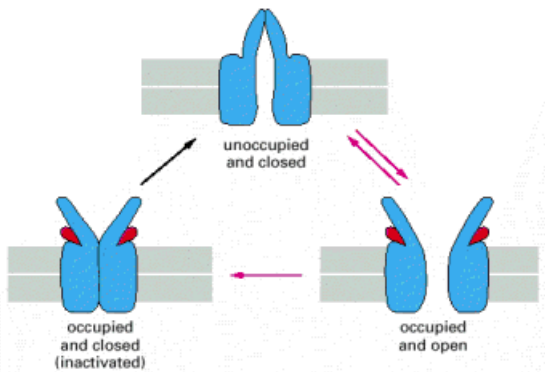
Ιοντικοί δίαυλοι στη νευρομυϊκή συμβολή



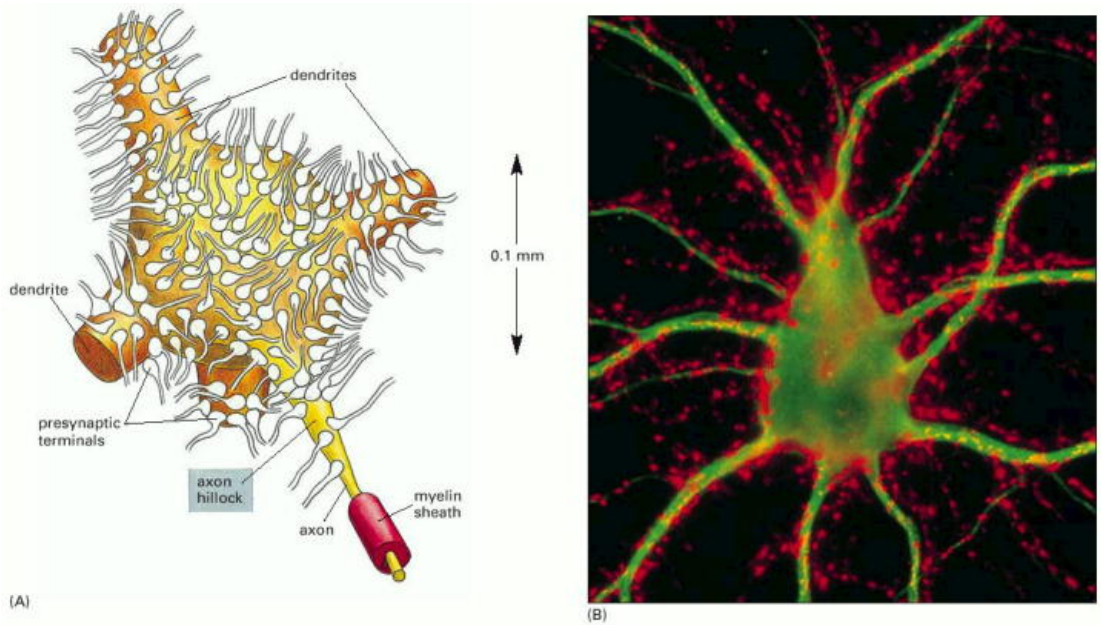
Μοντέλο για τη δομή του υποδοχέα της ακετυλοχολίνης



Ο υποδοχέας της ακετυλοχολίνης



Συνάψεις στο κυτταρικό σώμα και στους δενδρίτες ενός κινητικού νευρώνα της σπονδυλικής στήλης



Το καλαμάρι αποκαλύπτει τα μυστικά της μεμβρανικής διαγερσιμότητας