Donnan Equilibrium

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Introduction

- The **Gibbs–Donnan effect** (also known as the **Donnan effect**, **Donnan law**, **Donnan equilibrium**, or **Gibbs–Donnan equilibrium**) is a name for the behavior of charged particles near a semi-permeable membrane that sometimes fail to distribute evenly across the two sides of the membrane.
- The usual cause is the presence of a different charged substance that is unable to pass through the membrane and thus creates an uneven electrical charge.
- For example, the large anionic proteins in blood plasma are not permeable to capillary walls.
- Because small cations are attracted, but are not bound to the proteins, small anions will cross capillary walls away from the anionic proteins more readily than small cations.
- Some ionic species can pass through the barrier while others cannot.
- The solutions may be gels or colloids as well as solutions of electrolytes, and as such the phase boundary between gels, or a gel and a liquid, can also act as a selective barrier.
- The electric potential arising between two such solutions is called the Donnan potential.
- The effect is named after the physicist Josiah Willard Gibbs and the chemist Frederick G. Donnan.

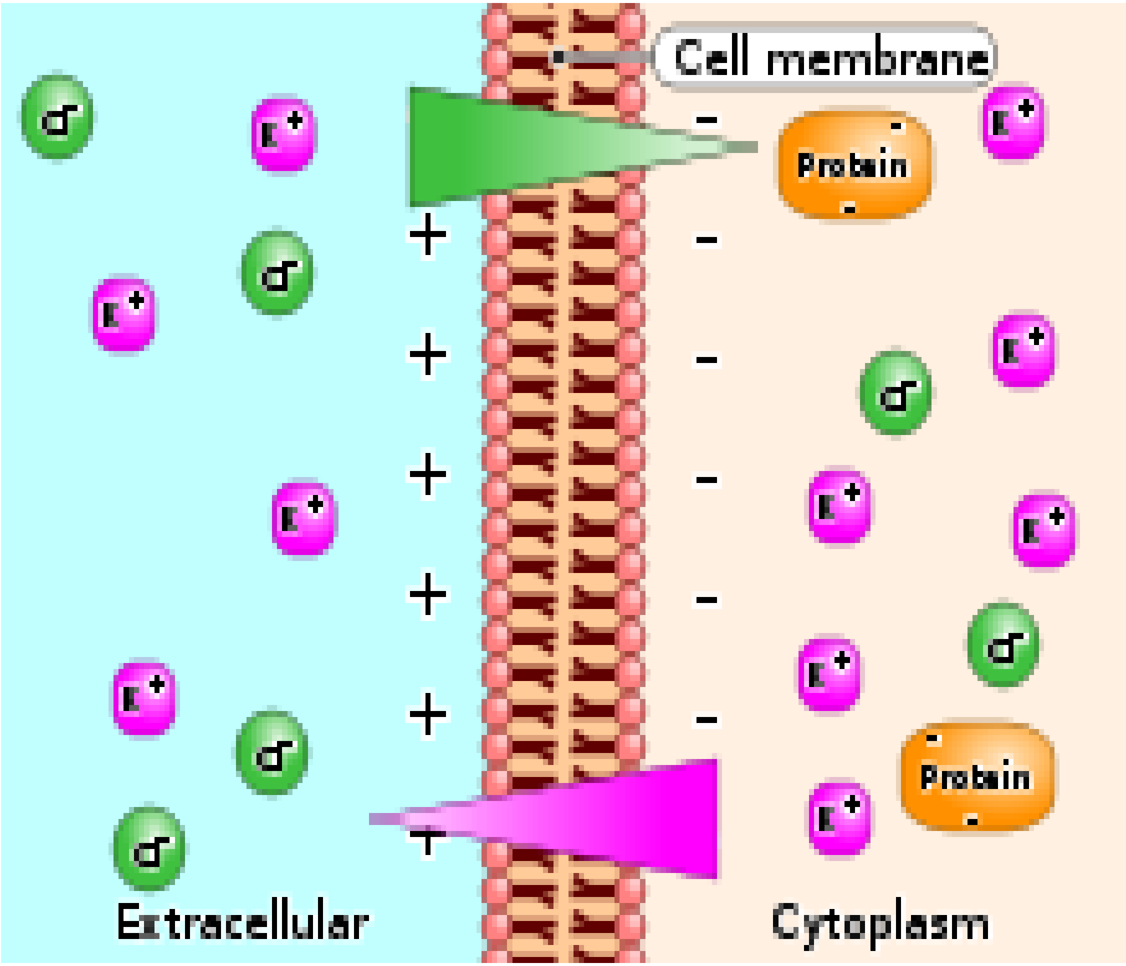
Example

- The presence of a charged impermeant ion (for example, a protein) on one side of a membrane will result in an asymmetric distribution of permeant charged ions.
- The Gibbs–Donnan equation at equilibrium states (assuming permeant ions are Na^+ and Cl^-):

$$[Na^+_{Side\ 1}] \times [Cl^-_{Side\ 1}] = [Na^+_{Side\ 2}] \times [Cl^-_{Side\ 2}]$$

Start	Equilibrium
Side 1: 9 Na^+, 9 Cl^-	Side 1: 6 Na^+, 6 Cl^-
Side 2: 9 Na^+, 9 Protein	Side 2: 12 Na^+, 3 Cl^-, 9 Protein

Donnan equilibrium across a cell membrane (schematic)



Osmoregulation of the Periplasmic Space

- In gram-negative bacteria there is a compartment between the cytoplasmic membrane and the peptidoglycan cell wall, known as the periplasm or periplasmic space, which houses a number of hydrolases for macromolecular nutrients, binding proteins for metabolites, and receptors for chemotactic signals.
- The periplasmic space occupies approximately 20 to 40% of the total volume of *E. coli* and *S. typhil/iriuln*, and it is maintained as a separate compartment during steady-state growth at all conditions of osmolarity.
- Because solutes of 500 Da can readily diffuse into the periplasmic space through porin proteins located in the outer membrane, there are unique problems in the maintenance of the osmotic potential of the periplasm.

... **Osmoregulation of the Periplasmic Space**

Membrane-Derived Oligosaccharides

- The periplasmic space of enteric bacteria contains large quantities of highly anionic polysaccharides, known as membrane-derived oligosaccharides, which are too large to diffuse through the porin proteins.
- In *E. coli*, these molecules consist of 6 to 12 glucose units which are held together by α-1,2 or α-1,6 linkages, and they carry sn-1-phosphoglycerol, phosphoethanolamine, and O-succinyl side chains.
- Their average molecular mass is about 2,300 Da, and their average charge is -5 .
- *Agrobacterirmn tumefaciens* contain high-molecular mass α-1,2 glucans, which probably function to maintain the turgor pressure of the periplasm of these organisms.
- **The presence of these anionic polymers in the periplasm gives rise to an electric potential across the outer membrane.**
- **This potential, known as the Donnan potential, results in the accumulation of cations at a higher concentration in the periplasm than in the medium, resulting in hydrostatic pressure in the periplasmic space .**
- The **synthesis of the membrane-derived oligosaccharides was subject to osmotic regulation so that they are synthesized maximally in media of low osmolarity and increasing osmolarity results in a reduction in their synthesis.**