The 2003 Nobel Prizes and Water

Water in the Human Body

Two of the 2003 Nobel Prizes were linked to the behaviour of water molecules in the human body: the Chemistry Prize, for discoveries regarding movement of water and dissolved ions through channels in the cell membranes, and the Medicine Prize, for diagnostic images by magnetic resonance based on differences in water content in tissues and organs.

Chemistry laureates

Two thirds of the human body is water, a key component of all tissues and organs, rapidly flowing in and out of cells through specific water channels, which allow cells to regulate their volume and internal osmotic pressure.

The 2003 Nobel Prize Laureates for Chemistry, Peter Agre, a professor of biological chemistry at the Johns Hopkins University School of Medicine in Baltimore, USA, and Roderick MacKinnon, a professor of molecular neurobiology and biophysics at the Rockefeller University in New York, have together clarified how water molecules and salt ions move through cellular membranes. Agre discovered the first water channel protein, and MacKinnon the structural basis for ion transport through the channels.

The functioning of membrane channels underlie critical cell functions (neuronal signalling, muscle contraction, cardiac function, water resorption in the kidney, the response to osmotic stress in microorganisms, etc). The cell walls are semipermeable, and perforated by channels, adapted for a specific ion or molecule, allowing nothing else to pass - not even a molecule that is smaller. The water and ion flows make communication between cells possible by transmitting signals from ions that start cascades of chemical reactions governing all bodily funtions.

Such channels are crucial for life and found in all organisms, from bacteria to humans. In plants, water channels are critical for water absorption in the root and for maintaining the water balance throughout the plant. In the human body, there are some 100 billion cells – as many cells as there are stars in a galaxy – such as muscle cells, kidney cells, nerv cells and brain cells. Water channelling in kidney cells makes them extremely efficient recycling plants: by recycling 169 out of the 170 liters of primary urine transported to the kidneys each day, leaving only 1 liter to be lost as urine to evacuate bodily waste products.

The water channels

The key phenomenon discovered by Professor Agre is a protein, Aquaporin, with a particular three-dimensional structure that lines the water channels in cell membranes, existing in different forms in different organs, perfectly adapted to their respective ion flows. There are at least 11 types in the human body and 35 in a single plant.

The ion channels

MacKinnon studied ion flows through channels in cell membranes, fundamental for the electrical signals in living tissue. It is through transport of Na+ and K+ that signals are transmitted from one nerve cell to the next like a relay race, transmitting for instance pain signals to the brain. The rate of these ion flows through cell channels in the brain is unbelievable: fourteen zeroes are needed to write down the number passing in only one minute.

The discovery of ion channel functions provide a firm basis for a molecular understanding of many neurological, muscular and cardiac diseases, opening up new possibilities for drug design.

Medicine laureates

The 2003 Nobel Prize in Physiology or Medicine is also indirectly linked to the behaviour of water molecules in the human body. The Prize was shared by two Laureates, Paul Lauterbur, professor of chemistry, biophysics and computational biology and bioengineering at the University of Illinois, USA, and Peter Manfield of Cambridge University in Nottingham, UK, "for their discoveries concerning magnetic resonance imaging" by which many different dysfunctions and diseases that are reflected in altered behaviour of water in the human cells can be recorded.

Benefitting from hydrogen atom behaviour

The human body has a high water content, and water molecules respond to magnetic fields. Also, different tissues and organs have different water content, and many pathological processes are reflected in altered water content which can be interpreted when registered by the magnetic resonance camera.

The physics behind magnetic resonance phenomena of the human body (recognised with the 1966 award) is that the hydrogen atoms of water molecules act like microscopic compass needles when exposed to a magnetic field. When exposing the human body to a strong magnetic field, the hydrogen atoms respond by standing "at attention" and when adding radio waves, patterns of resonance are generated that can be recorded and interpreted. Small differences in the resonance wave oscillations can be detected and mathematically analysed thanks to a simple relation between the strength of the magnetic field and the frequency of the radio waves causing resonance.

By advanced computer processing, a three-dimensional image can be produced that reflects the chemical structure of the tissue and shows differences in water content and movement of water molecules. Knowing what a healthy organ or tissue should look like, very detailed images of tissues and organs make it possible to detect and document pathological changes like "false notes" in a symphony. ■

Professor Malin Falkenmark, SIWI