

History of Polymer Membranes

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The genesis of membrane science traces back to the pioneering studies in the 18th century, marking the inception of our understanding of osmosis. Abbe J.A. Nollet, in 1748, observed the preferential passage of ethanol through a pig's bladder when in contact with a water-ethanol mixture, laying the groundwork for comprehending semipermeable membrane phenomena.

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Further contributions in the 19th century by Dutorchet, Mitchell, Graham, Matteucci, and Cima expanded this realm of knowledge. Mitchell noticed deflation in rubber balloons filled with hydrogen gas, hypothesizing gas diffusion through the balloon wall. Graham later quantitatively measured gas permeation through rubber films. Additionally, Fick developed the first synthetic membrane using nitrocellulose, laying a pivotal foundation for osmosis studies by Pfeffer and elucidating diffusion as concentration-dependent.

By the early 20th century, Bechhold's pioneering work allowed the production of synthetic membranes by impregnating filter paper with nitrocellulose, introducing the term "ultrafiltration." Nitrocellulose membranes were vital in Zsigmondy's studies as ultrafilters, leading to their production by Sartorius GmbH in 1937.

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The significant breakthrough of the first successful hemodialyzer in the mid-20th century propelled membrane application in biomedicine. Advances in polymer chemistry facilitated a myriad of synthetic polymers for tailored membrane production, characterized by specific transport properties and robust mechanical and thermal stability.

A monumental stride in membrane technology unfolded with the creation of the reverse osmosis membrane from cellulose acetate by Loeb and Sourirajan. This defect-free, high-flux membrane proved instrumental in seawater desalination.

Later, interfacial-polymerized composite membranes surpassed cellulose acetate's capabilities, leading to the dominance of synthetic polymers like polyamides, polysulfone, and polyacrylonitrile in reverse osmosis membranes.

These membranes, initially developed as flat sheets and spiral-wound modules, expanded to self-supporting hollow fiber membranes with Du Pont's asymmetric hollow fiber membranes becoming pivotal in brackish and seawater desalination.

Electrodialysis emerged as a practical reality with Ionics Inc.'s reliable ion-exchange membranes, initially applied for brackish water desalination. This method expanded into new domains with the advent of bipolar membranes for acid-base recovery.

Gas separation, pioneered by Monsanto Inc., evolved from hydrogen recovery to diverse applications such as CO₂ removal from natural gas or organic vapor recovery.

Each milestone in membrane science and technology has significantly reshaped industries, enabling critical applications across water treatment, biomedicine, and gas separation, fostering a continuous quest for innovation and advancement.

