



**UNIVERSITY OF ROME "LA SAPIENZA"**  
**NANOTECHNOLOGIES ENGINEERING**

# **MEMBRANE APPLICATIONS IN NANOTECHNOLOGY**

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# **MEMBRANE APPLICATIONS IN NANOTECHNOLOGY: INTRODUCTION**

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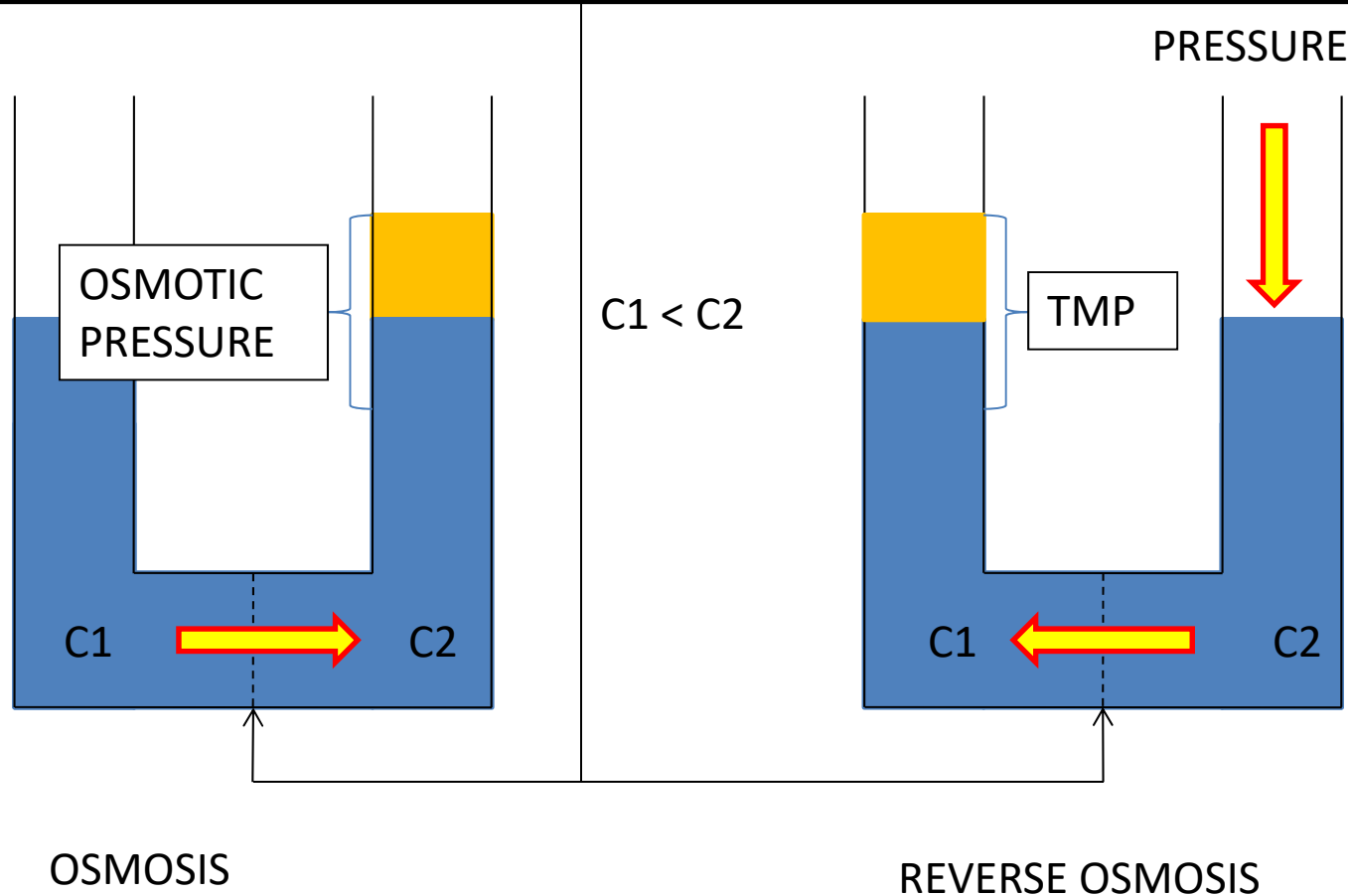
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# Separation by membranes

Membranes are semi-permeable phases which separates other two ones



# Some definitions

- **FEEDSTREAM, CONCENTRATE AND PERMEATE**

*Respectively, the feed stream, the stream exiting the membrane system and the stream crossing the membrane.*

- **FLUX**

*The value is equal to the flow rate referred to the unity of membrane surface.*

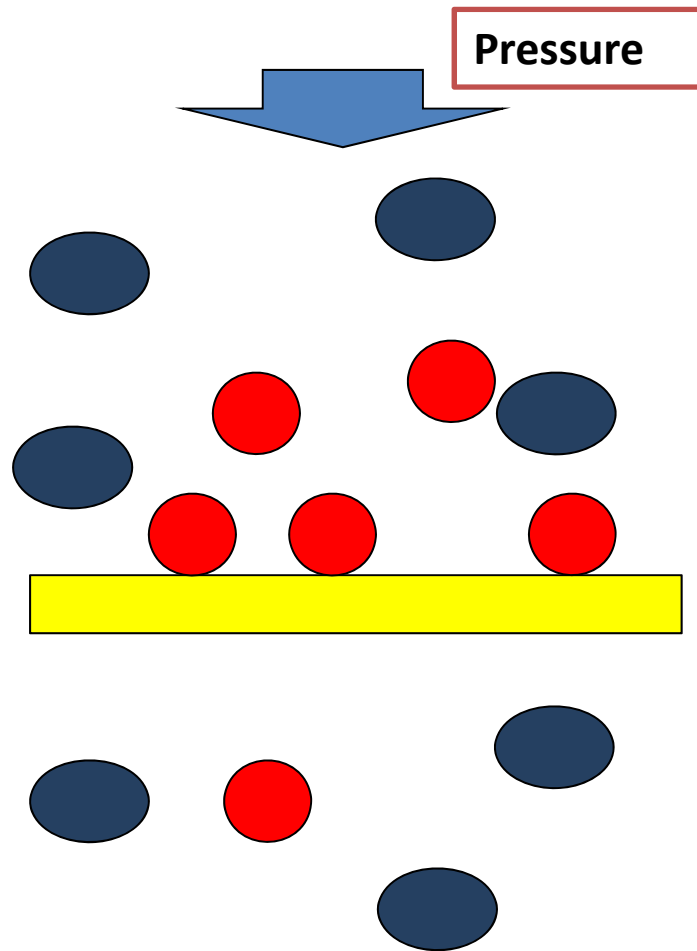
- **REJECTION**

*Generally given as percentage value, it is equal to the quantity of solute NOT crossing the membrane.*

- **RECOVERY**

*Generally given as percentage value, it is the quantity of feed stream having crossed the membrane after the considered operating time.*

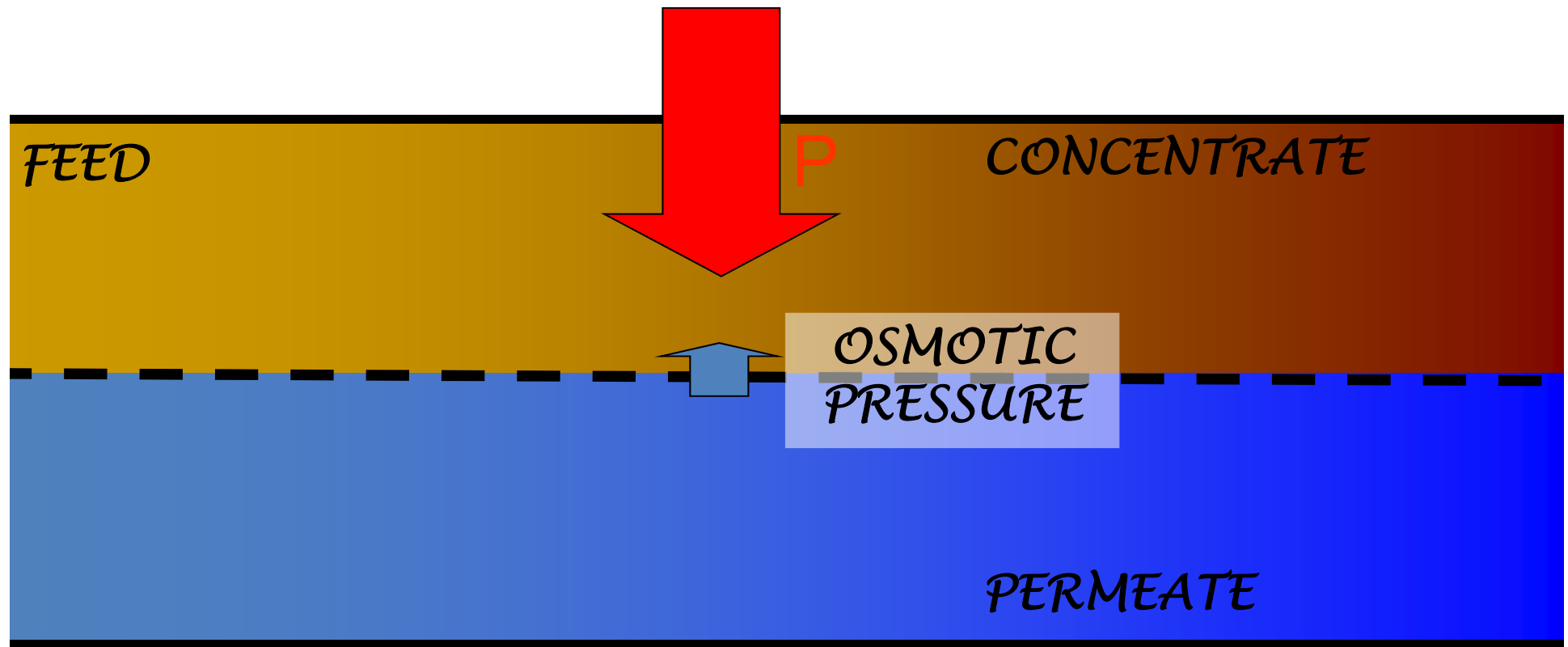
# Operation modes



**DEAD END**

# Operation modes

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**Tangential or Crossflow**

# The most important parameters

- **PRODUCTIVITY** PERMEATE FLUX (PERMEABILITY)

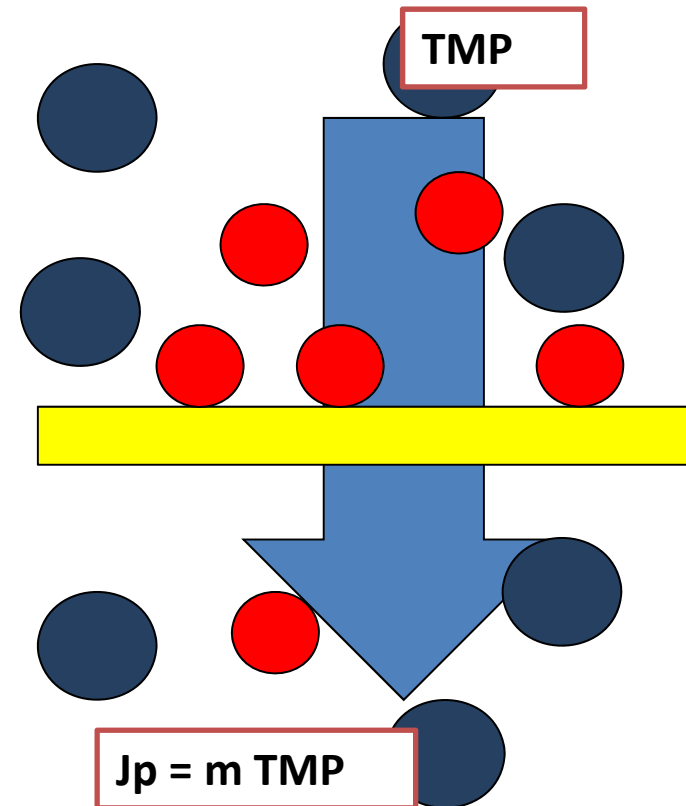
*DEPENDS ON MEMBRANE MATERIAL, MEMBRANE PORE SIZE, MEMBRANE THICKNESS, FEEDSTOCK, SOLUTE CONCENTRATION, OPERATING CONDITIONS, PRETREATMENT.*

- **SELECTIVITY** REJECTION OF SOLUTES

*DEPENDS ON MEMBRANE MATERIAL, MEMBRANE PORE SIZE, FEEDSTOCK, INTERACTION OF SOLUTES, OPERATING CONDITIONS, DONNAN EFFECT.*

- **LONGEVITY** WORN-OUT, FOULING

*DEPENDS ON MEMBRANE MATERIAL, FEEDSTOCK, SOLUTE CONCENTRATION, OPERATING CONDITIONS, PRETREATMENT.*



# Rigorous membrane equations

- **OSMOTIC PRESSURE**

$$\pi = R T V^{-1} \ln a = n R T c$$

- **TRANSMEMBRANE PRESSURE**

$$\text{TMP} = \Delta P - \Delta \pi = P_{\text{op}} - \pi_f$$

- **MEMBRANE RESISTANCE**

$$R_m = D \delta^{-1} dc/dx$$

- **TOTAL MEMBRANE RESISTANCE**

$$R_{\text{tot}} = J_p (R_m + R_p + R_a + R_{f,\text{rev}} + R_{f,\text{irrev}})$$

- **REJECTION**

$$R(x) = 1 - (c_{x,p} / c_{x,f})$$



# Rigorous membrane equations

- **SOLVENT FLUX**

$$J_w = k_w \text{ TMP}$$

- **SOLUTE FLUX**

$$J_s = k_s \Delta c = J_w c_p$$

$\pi$ : Osmotic pressure

$n$ : number of ions

$P_{op}$ : Operating pressure

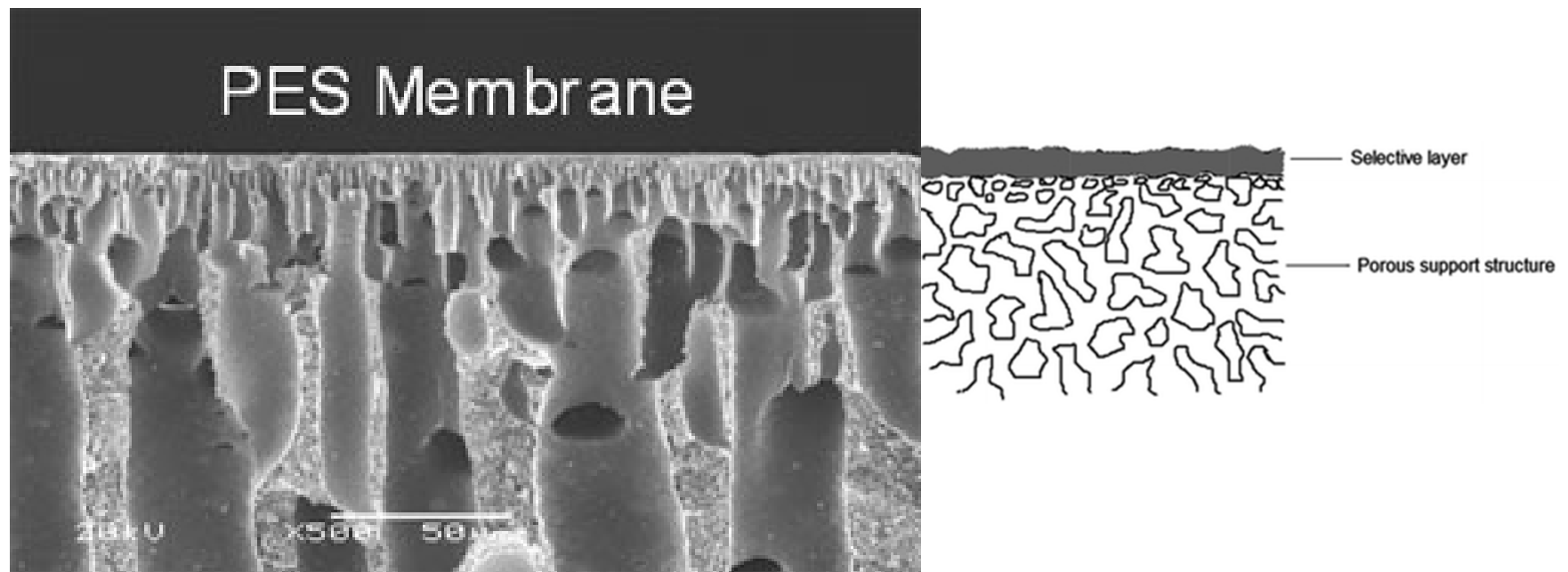
$D$ : diffusivity

$\delta$ : Membrane thickness

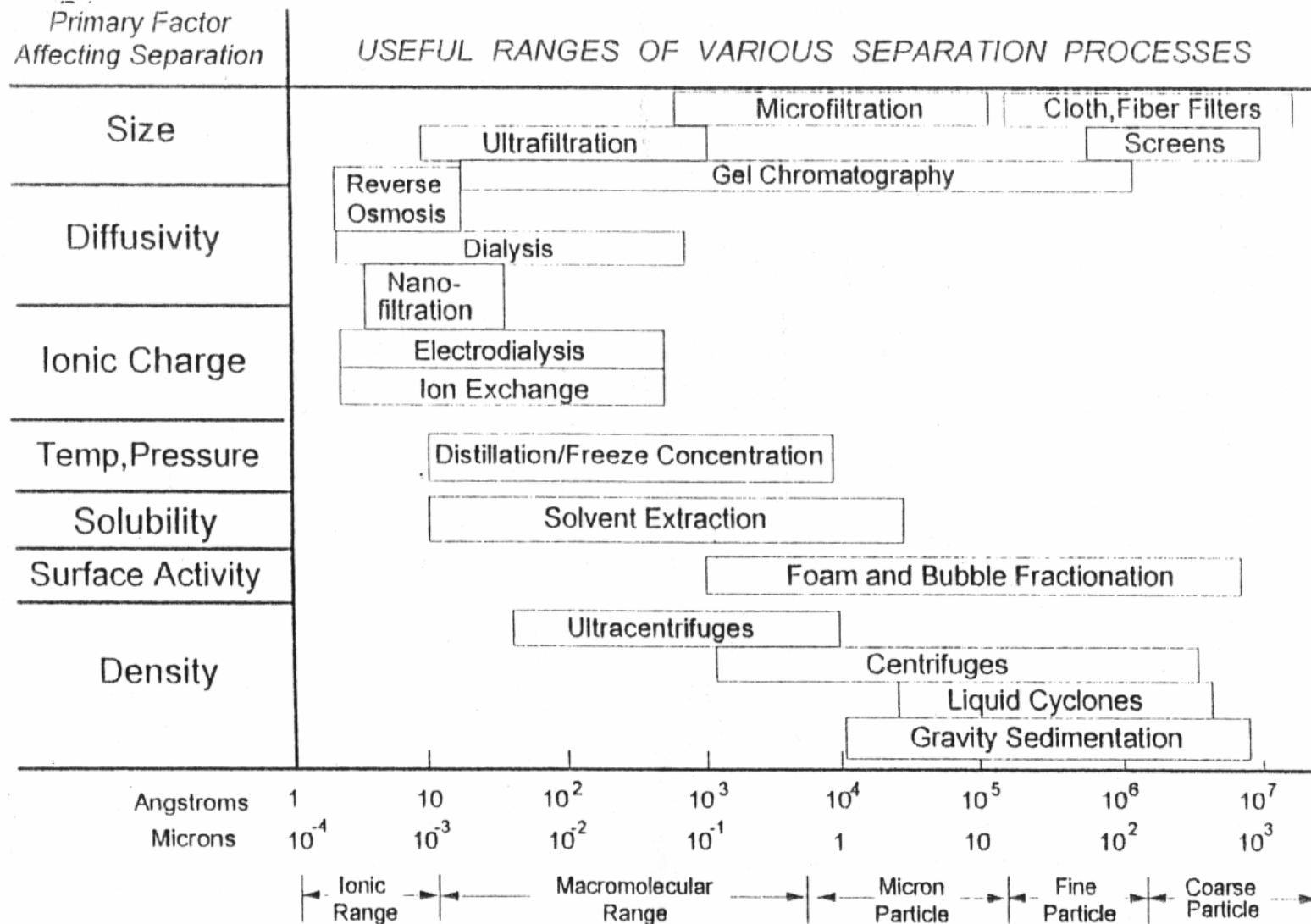
$R_m, R_p, R_a, R_{f,rev}, R_{f,irrev}$ : Resistance of membrane, polarization layer, aging, reversible and irreversible fouling, respectively.

# Asymmetric membranes

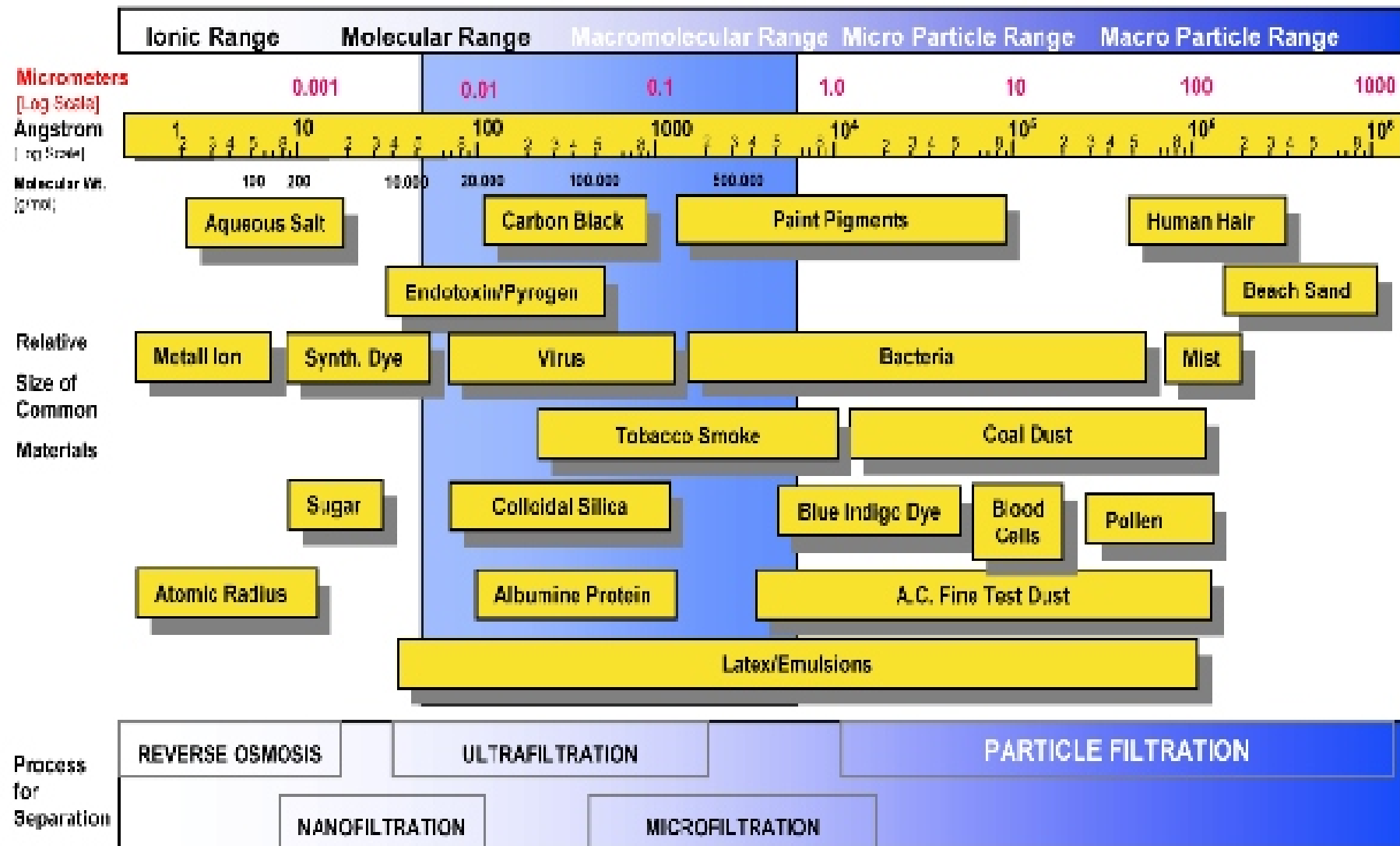
- MEMBRANE FLUX IS INCREASED IF MEMBRANE THICKNESS IS REDUCED, SELECTIVITY AND LONGEVITY REMAIN UNAFFECTED, BUT MEMBRANE MUST RESIST HIGH PRESSURE VALUES  
→ ASYMMETRIC MEMBRANES



# Membrane technologies summary



# Liquid-Liquid separation



# Other membrane technologies

Dialysis	symmetric microporous membrane, 0.01 – 1 $\mu\text{m}$ pore radius	concentration gradient	diffusion in convection-free layer	separation of salts and microsolute from macromolecular solutions
Electrodialysis	cation- and anion-exchange membranes	electrical potential gradient	electrical charge of particle and size	desalting of ionic solutions
Gas separation	asymmetric homogeneous polymer membrane	hydrostatic pressure and concentration gradients	solubility, diffusion	separation of gas mixtures
Pervaporation	asymmetric homogeneous polymer membrane	vapor pressure gradient	solubility, diffusion	separation of azeotropic mixtures
Facilitated and coupled transport	liquid membrane with carrier	concentration gradient	solution and diffusion in liquid membrane	selective removal of ions, gas separation
Membrane distillation	symmetric hydrophobic porous membrane	vapor pressure gradient	vapor pressure differences	desalination of aqueous solutions