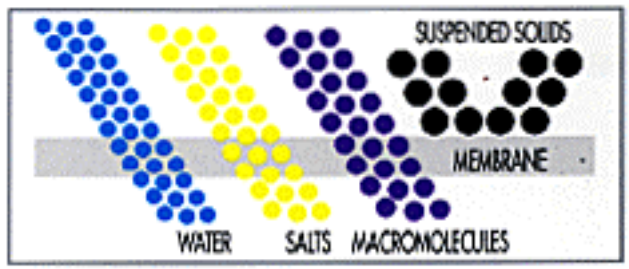
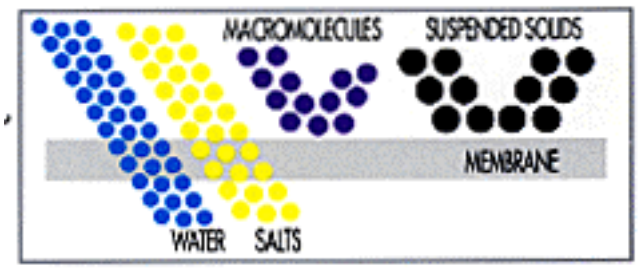
Membrane Separations

- Pressure-driven membrane processes:

- Microfiltration (MF)

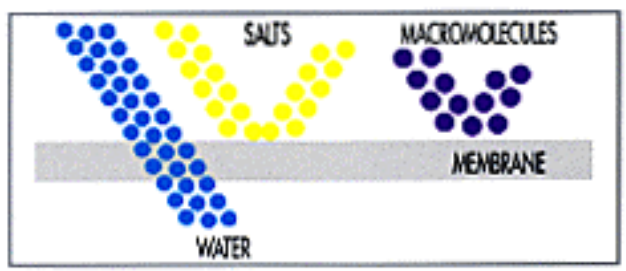


- Ultrafiltration (UF)



- Nanofiltration (NF)

- Reverse Osmosis (RO)



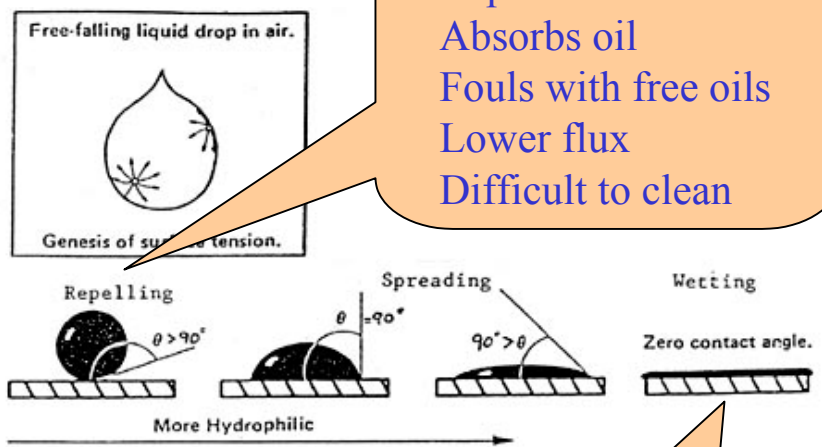
- Microfiltration (MF)

- First commercially developed (≈1930).
- Very popular and used (sharing with RO).
- Pore size between 0.05 and 10 μm (0.45 μm).
- Rejects particles between 0.2 and 10 μm.
- Bacteria, fragmented cells or colloids.
- MW ≥ 300000.
- Driving force: pressure difference.
- Low operation pressure: 0.2 to 3.5 bar.
- Average flux: > 200 L m^{-2} h^{-1}.

Membrane Separations

- Microfiltration (MF)

- Separation given by size exclusion mechanism.
- Flux: Hagen-Poiseuille or Kozeny-Carman
- Hydrophobic membranes.
- Adsorption effects between the membrane surface and the rejected species.
- Important fouling and pore plugging.
- Dead-end filtration and cleaning.



Repels water
Absorbs oil
Fouls with free oils
Lower flux
Difficult to clean

Repels oils
Absorbs water
Not fouled by free oils
Higher flux
Easier to clean

- Microfiltration (MF)

- Polymeric membranes made of a wide variety of polymers or polymers blends:

PTFE, PVDF, PP, PS, CA, CN, CTA, PE, PC, PEST, PI, Nylon ...

CA, CN o CTA are preferred due to their hydrophilicity preventing fouling.

- Also ceramic, basically α-Al_2O_3, because of their easy cleaning, long lifetime and available sterilisation

Membrane Separations

- Microfiltration (MF)

- Applications:
Bioengineering, food industry, wastewater treatment. Examples:

√ High organic loading water treatment.

√ Cutting oil emulsion treatment.

√ Juice, wine or beer clarification.

√ Fermentation product separation.

√ Recovering of precipitaded metals.

Membrane Separations

- Ultrafiltration (UF)

- Microporous membranes (?).
- Pore size between 1 and 50 nm.
- Rejects particles from 15 to 2000 Å.
- Polymers, proteins and colloids.
- Molecular weight from 5000 to $5 \cdot 10^6$ Daltons*.
- Driving force: pressure difference.
- Moderate operating pressure: 1 to 10 bar.
- Average flux: 5-200 L m^{-2} h^{-1}.

* 1 Dalton ≡ $1.66 \cdot 10^{-24}$ g

Membrane Separations

- Ultrafiltration (UF)

- Characteristic parameter: *Molecular Weight Cut-Off*

MWCO is the minimum MW the rejection being of 90%*.

Relation between MWCO and the pore size for UF membranes.

	Pore Diameter		
MWCO (Daltons)	**µm**	**nm**	**Å**
1000000	0.1	100	1000
500000	0.02	20	200
100000	0.01	10	100
50000	0.04	4	40
10000	0.0025	2.5	25
5000	0.0015	1.5	15

* To design, the membrane MWCO must be taken about the half of lower MW species to be retained.

- Ultrafiltration (UF)

- Polymeric membranes made of a wide variety of polymers or polymer blends:

CA, PS, PES, PAN, PVDF, PI

CA: low fouling, high flux.
PS: chemically stable.
PES: available sterilisation.
PI: solvent resistant, only tubular.

- Also ceramics, mainly made of α and γ-Al_2O_3.

Easy cleaning, long lifetime and available sterilisation.

Membrane Separations

- Ultrafiltration (UF)

- Separation mostly given by size exclusion.

- In low pore size membrane, some solution-diffusion phenomena are present (typical for RO).

- Performance affected by pressure, temperature, stirring, concentration and ionic environment.

- Significant fouling and pore plugging.

- Cross-flow filtration and cleaning.

- Any configuration.

Membrane Separations

- Ultrafiltration (UF)

- Applications:

Food industry, wastewater treatment. Also potentially useful paper pulping or textile industry. Some Examples:

√ COD reduction in wastewater.

√ Treatment of cutting-oil emulsion.

√ Metal finishing water treatment.

√ Treatment of black-liquor from paper pulping.

√ Protein recovery from blood plasma.

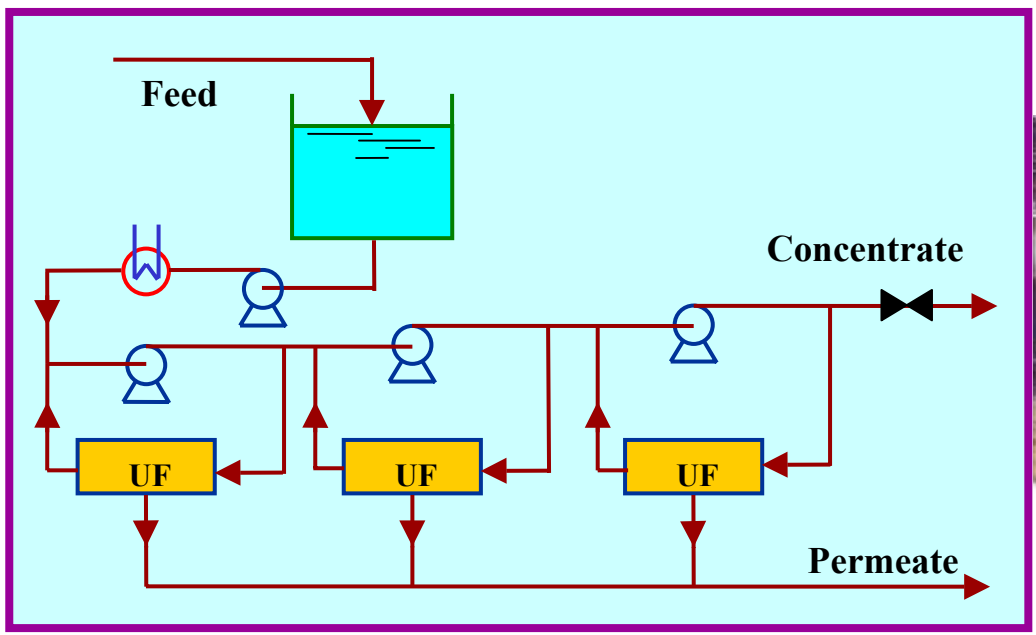
√ Egg white concentration.

√ Serum recovery from milk.

Membrane Separations

- Ultrafiltration (UF)

- Serum recovery from cheese production. The cheese production is a biochemical process followed by precipitation (of the solid cheese). The remaining solution contains, in addition to the water, the most of the initial lactose, proteins, vitamines and minerals.



Continuous UF process for recovering of lactoserum.

- Nanofiltration (NF)

- Separation range between UF and RO.
- Typical pore size of 2 nm.
- Separation mainly due to electrostatic interaction and also by size exclusion.
- Rejects neutral molecules (MW > 200 g/mol) by size exclusion and multivalent salts by electrical charge.
- Driving force: pressure difference.
- Moderate pressure: 15 bar.
- Average flux: 20-80 L m^{-2} h^{-1}.

- Nanofiltration (NF)

- Polymer membranes (CA, PA, PVA):

- Spiral-wound modules.

- Applications: Water pretreatment, food industry, metal recovery.

  √ Color removal and humic acids (precursor of trihalometanes) elimination in drinking water.

  √ Water softening (removal divalent ions).

- Potentially, it is useful when UF does not offer sufficient rejection and RO is not economically viable.

- Nanofiltration (NF)

- In 1996, 150 plants all over the world where producing drinking water by means of NF, with an overall capacity of 600000 m^3/day.

(compare with the 3000000 m^3/day capacity of the working plants based on RO)

- As instance, in Florida (USA) is the only technology selected for making drinking water.