Basics of Membrane Separation/Fractionation

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Dead-End vs Cross-flow Filtration

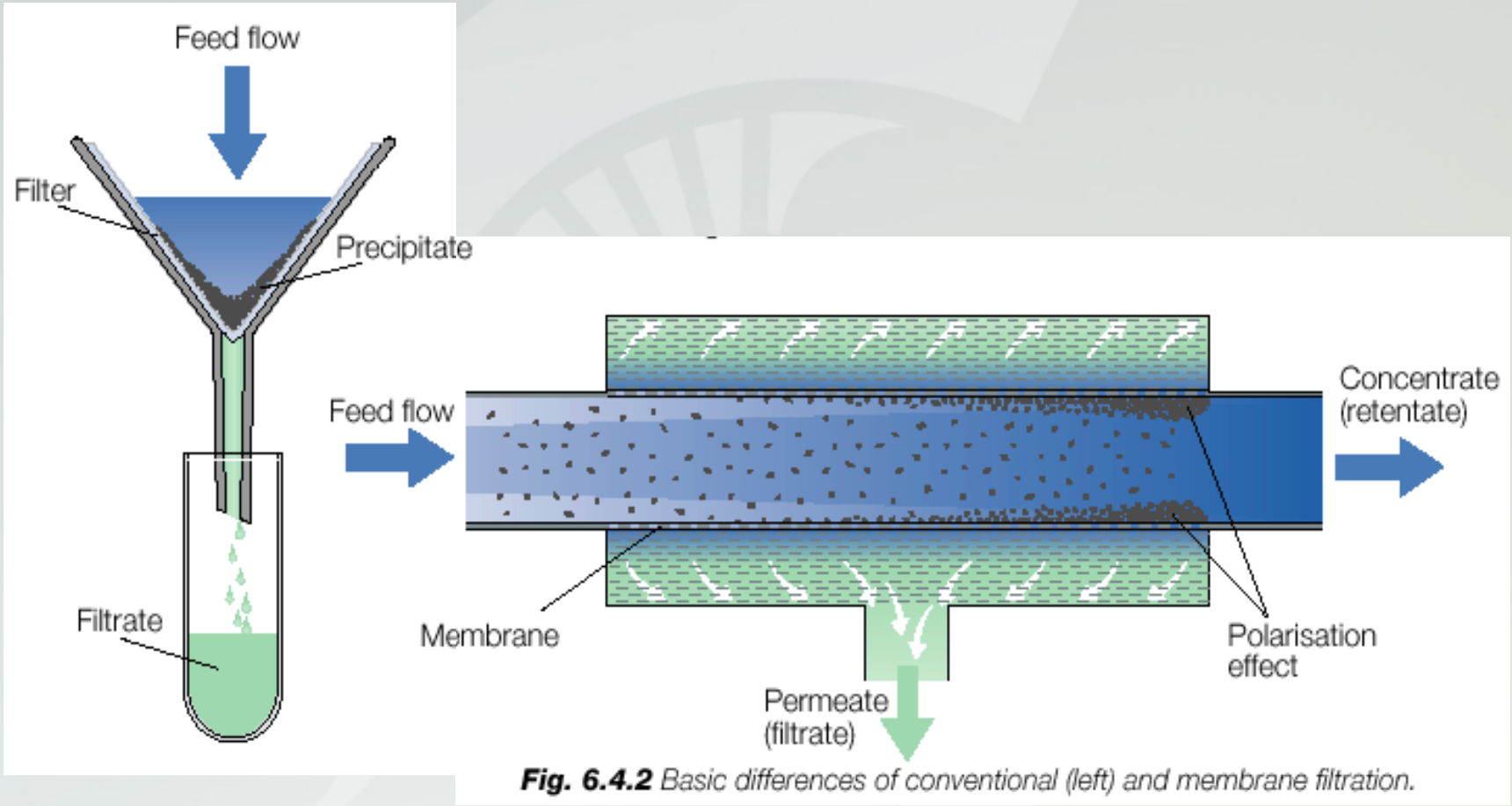
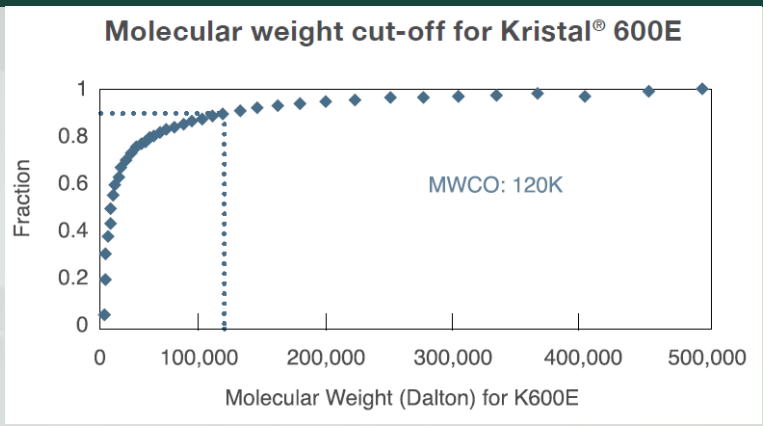


Fig. 6.4.2 *Basic differences of conventional (left) and membrane filtration.*

Hydrostatic Membrane Filtration

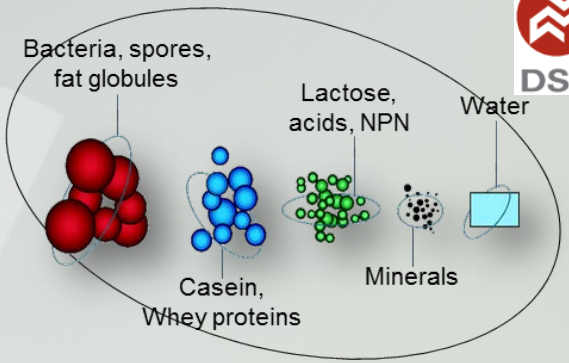
- The removal of water and selected solutes through a semi-permeable membrane
- All are similar:
  - pressure is the driving force
- The amount of pressure and the size of the particles retained differ

Terminology



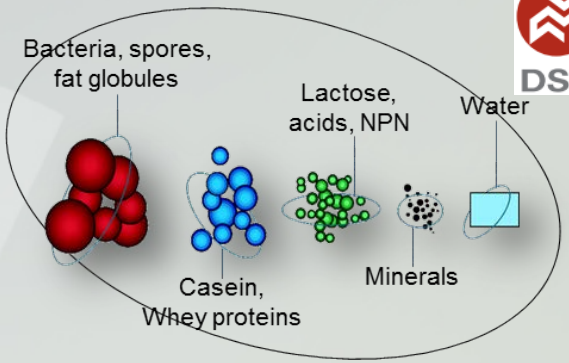
- Molecular weight cut off (MWCO):
  - Used to characterize the membrane
  - Molecular weight of 90% of molecules retained
- Permeate – the portion that goes through the membrane
- Retentate – the portion that is retained by the filter
- Flux – Kg permeate/hour
  - Flow rate of Permeate across the membrane

RO – Reverse Osmosis



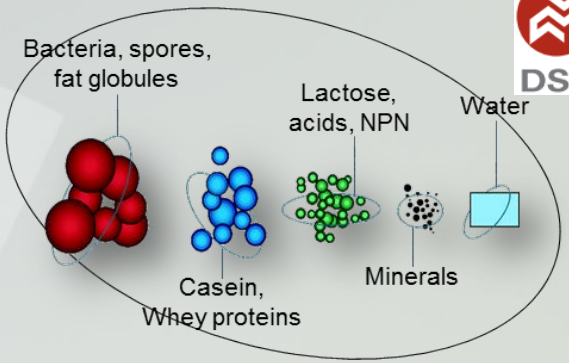
- Used to separate water from low molecular weight solutes
  - i.e. salts, monosaccharides, aroma compounds
- Uses high pressure
  - 4000- 8000 kPa (~550-1200 psi)
- Diffusion through the membrane
  - Not based on pore size.
- Illustration
  - http://www.geafiltration.com/technology/reverse_osmosis.asp

NF - Nanofiltration



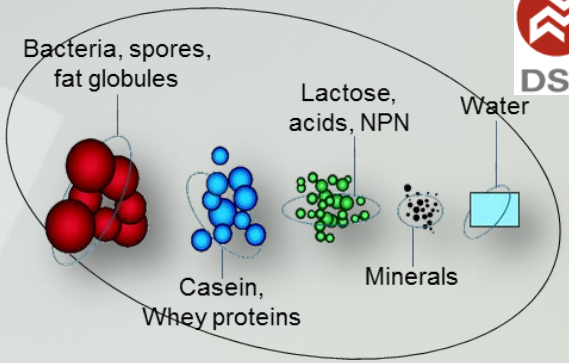
- Used to separate low molecular weight products
  - Mono-, di- and small oligo saccharides
  - Salts from vitamins and carbohydrates
- Mid-range pressures
  - 1500-4000 kPa (~200-600 psi)
- Diffusion through the membrane
  - Primary separation method.
  - Micropores possible.

UF - Ultrafiltration



- Membranes have higher porosity and retain only large molecules
  - i.e. proteins and other colloidal particles
- Operate at lower pressure
  - 50–2000 kPa (10-250 psi)
- Pores allow molecules up to the rejection limit to pass.

MF - Microfiltration



- Membranes have highest porosity and retain large molecules and MO
  - i.e. Bacteria, fats and some proteins
- Uses lowest pressure

Membrane Processes

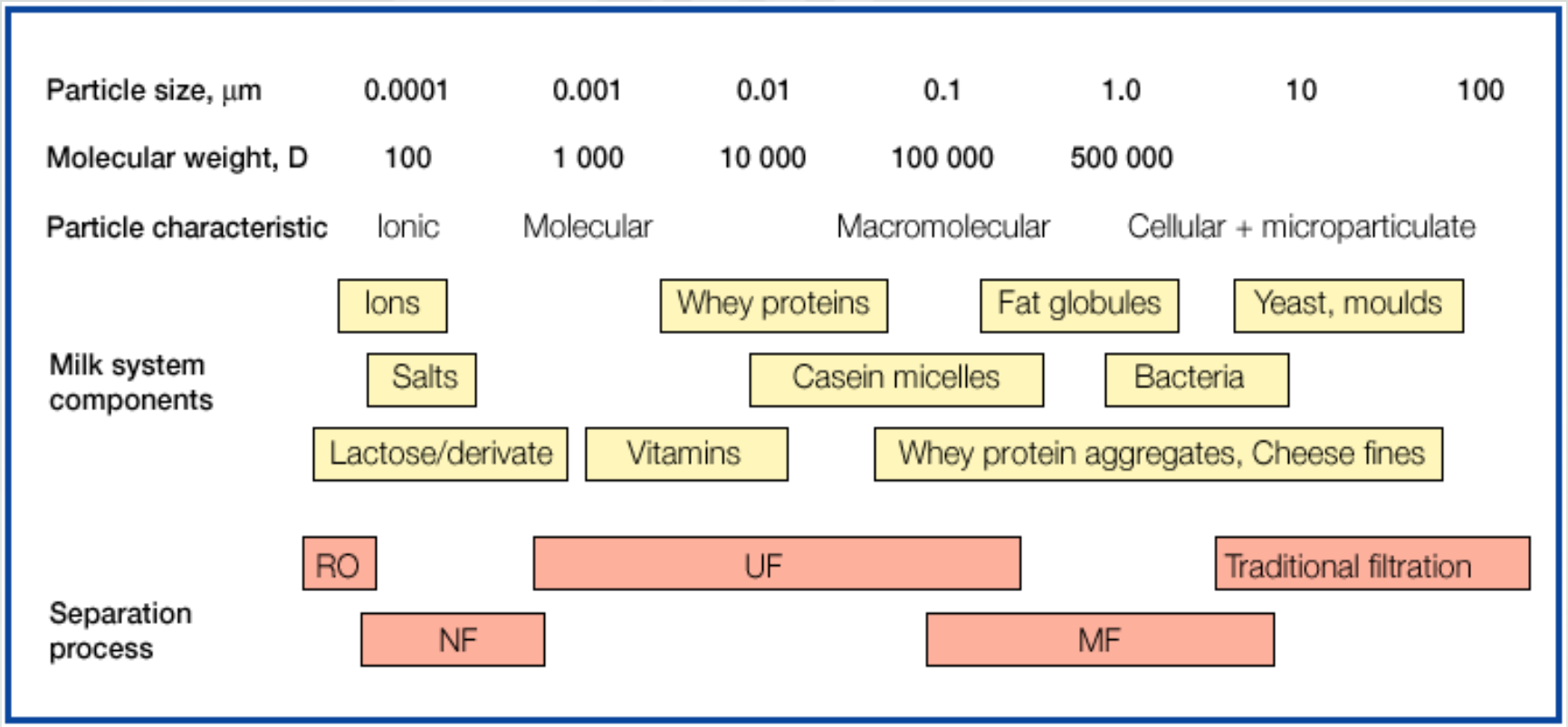


Fig. 6.4.1 *Spectrum of application of membrane separation processes in the dairy industry.*

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Membrane Animations

- Four types – GEA Filtration
  - http://www.geafiltration.com/technology/membrane_filtration_process.asp

RO and NF

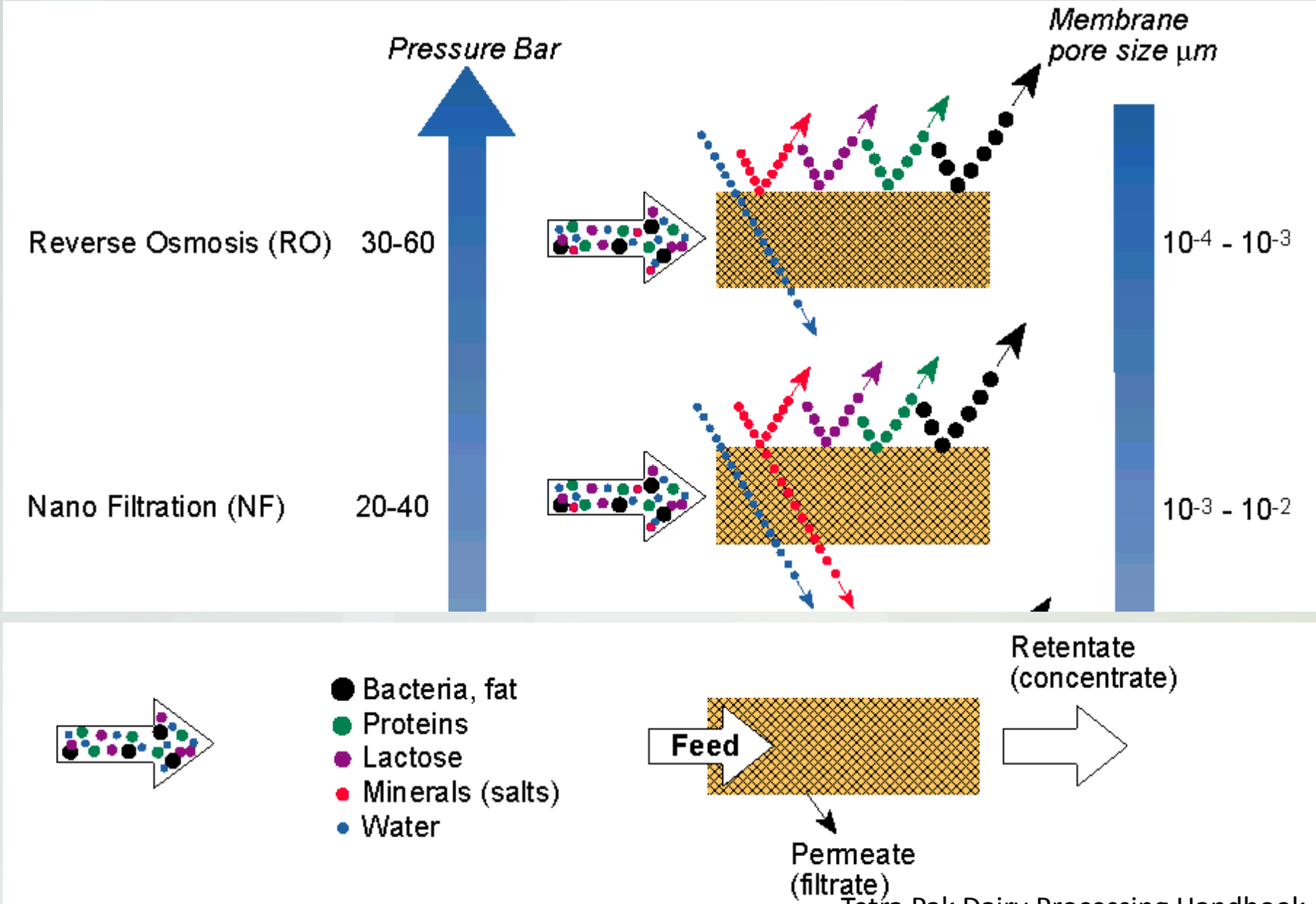

Fig 6.4.3 *Principles of membrane filtration.*

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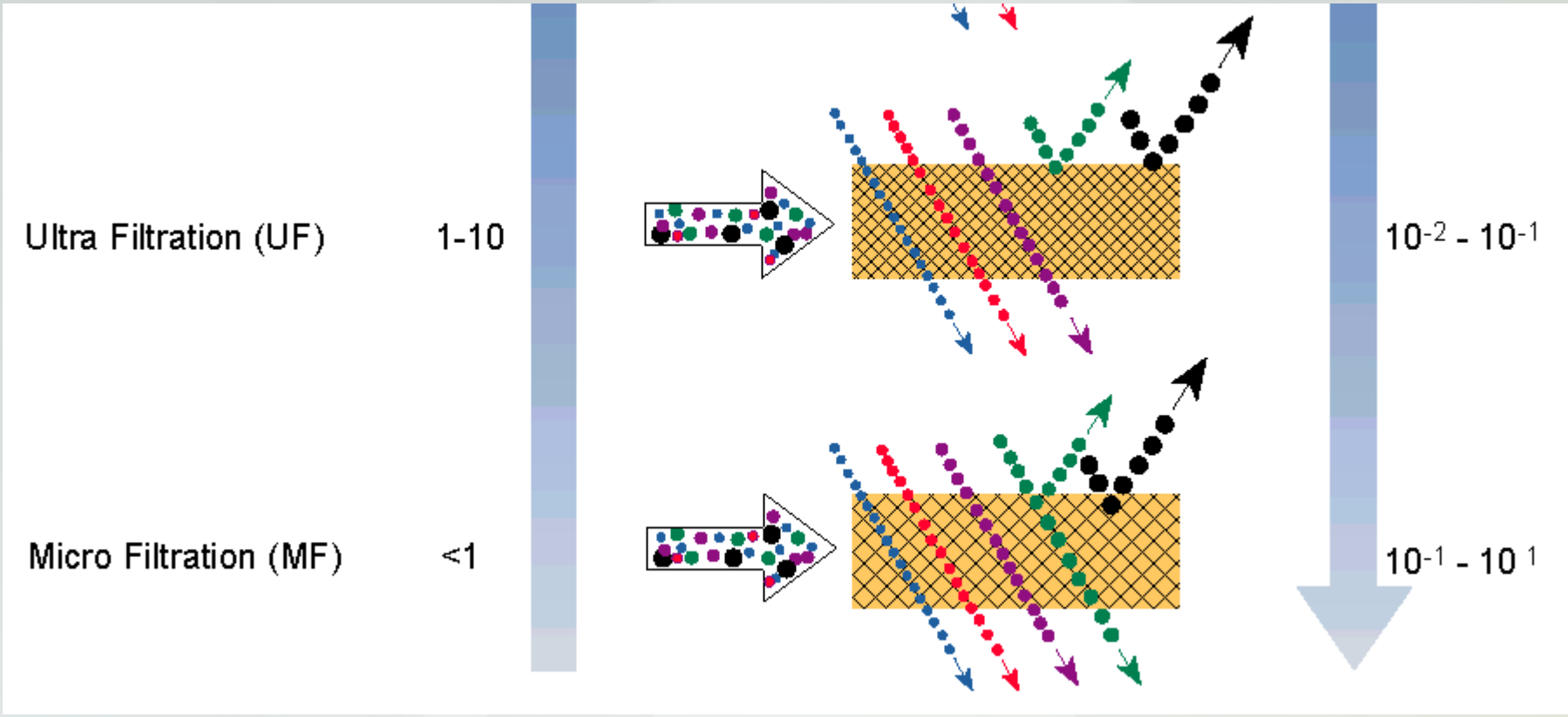
UF and MF



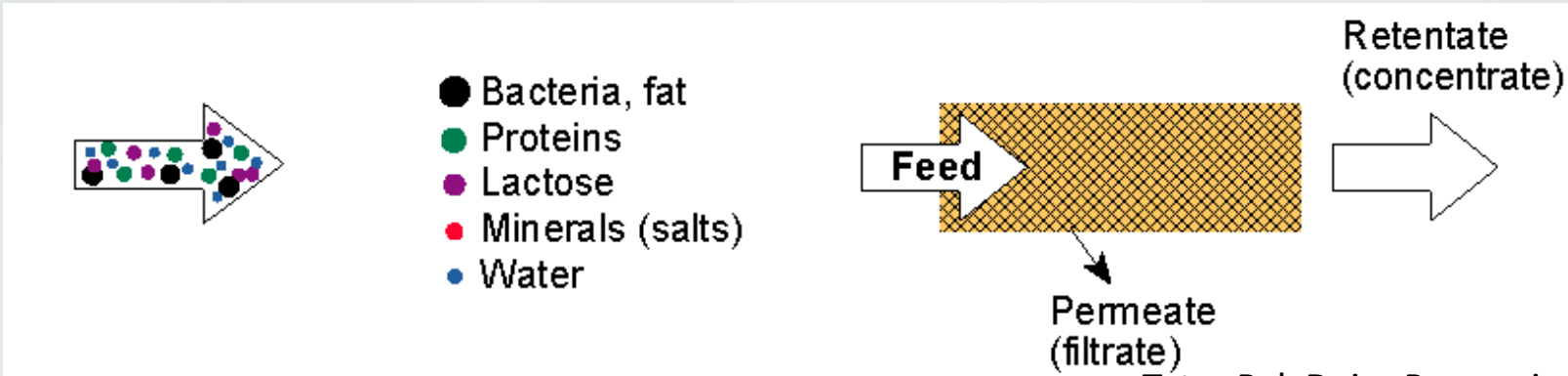


Fig 6.4.3 *Principles of membrane filtration.*

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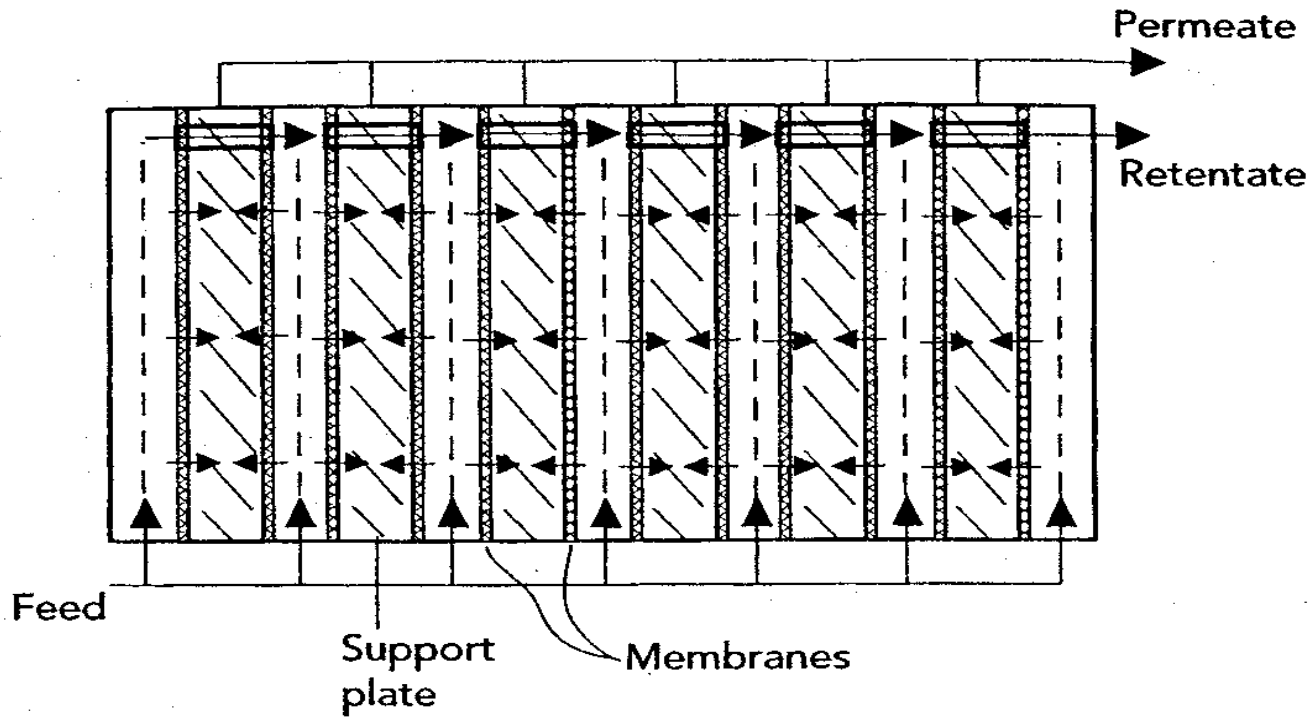
Membrane Characteristics

- Capable of being cleaned and sanitized
  - Heat, pH and chemical (Cl^-) resistance
- RO and NF
  - Should have high water permeability
  - R_{fi} close to 1
- UF and MF
  - Retain a micro-porous structure during
    Manufacture, operation, mechanical and thermal stress

Types of membranes

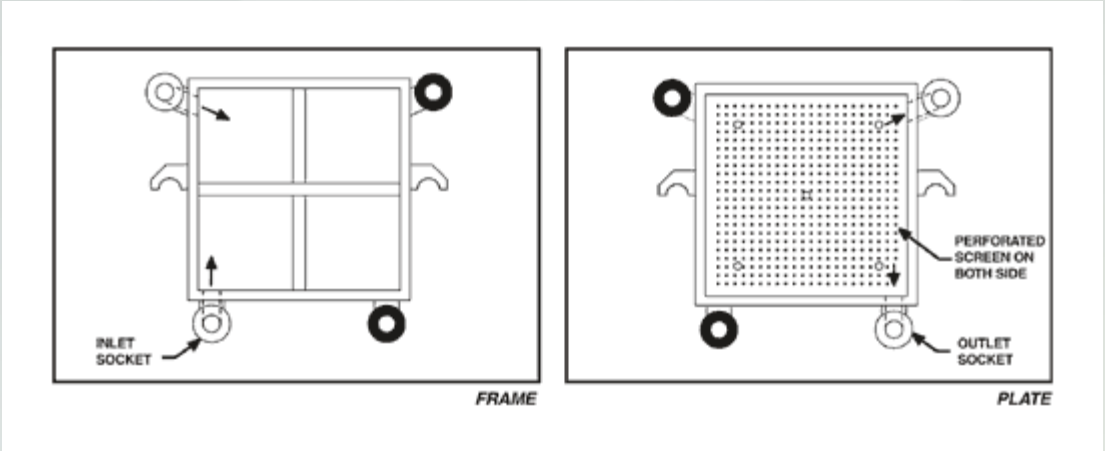
- Cellulose Acetate
  - Original material – limited use
- Polymer
  - Very common today
- Composite (ceramic) or Stainless Steel
  - Made from porous carbon, zirconium oxide or alumina or sintered SS
  - Robust but expensive

Membrane Design: Plate and frame

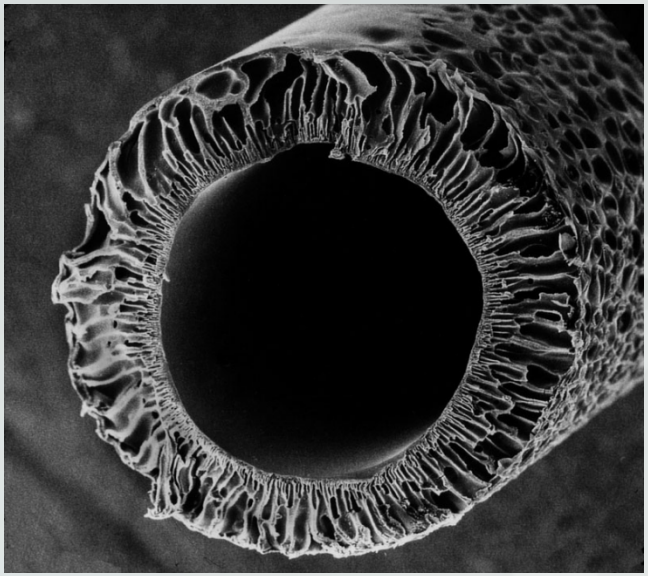


7.17 figure Plate and frame membrane arrangement.

Membrane Design: Plate and frame

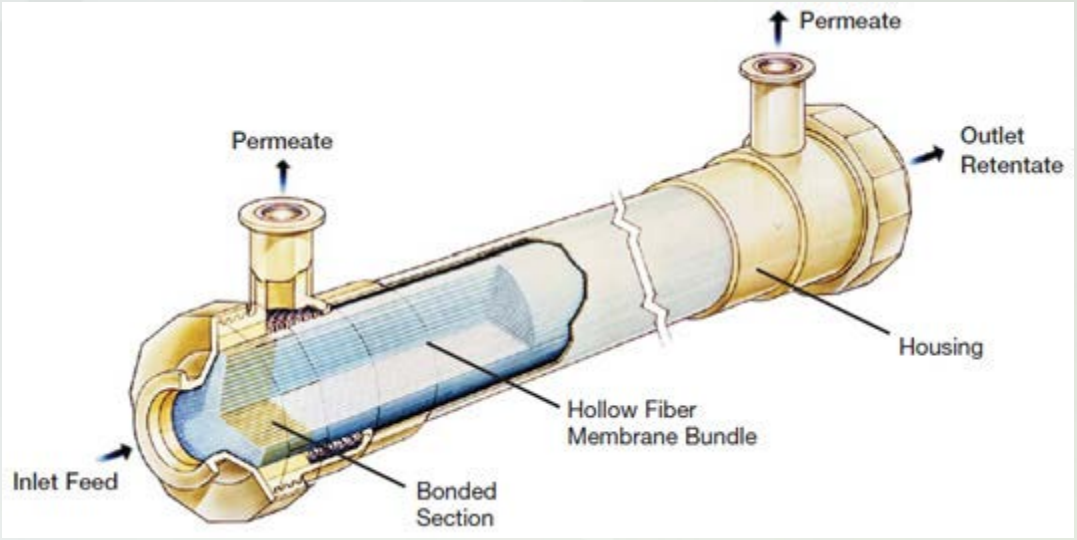


Membrane Design: Hollow Fiber



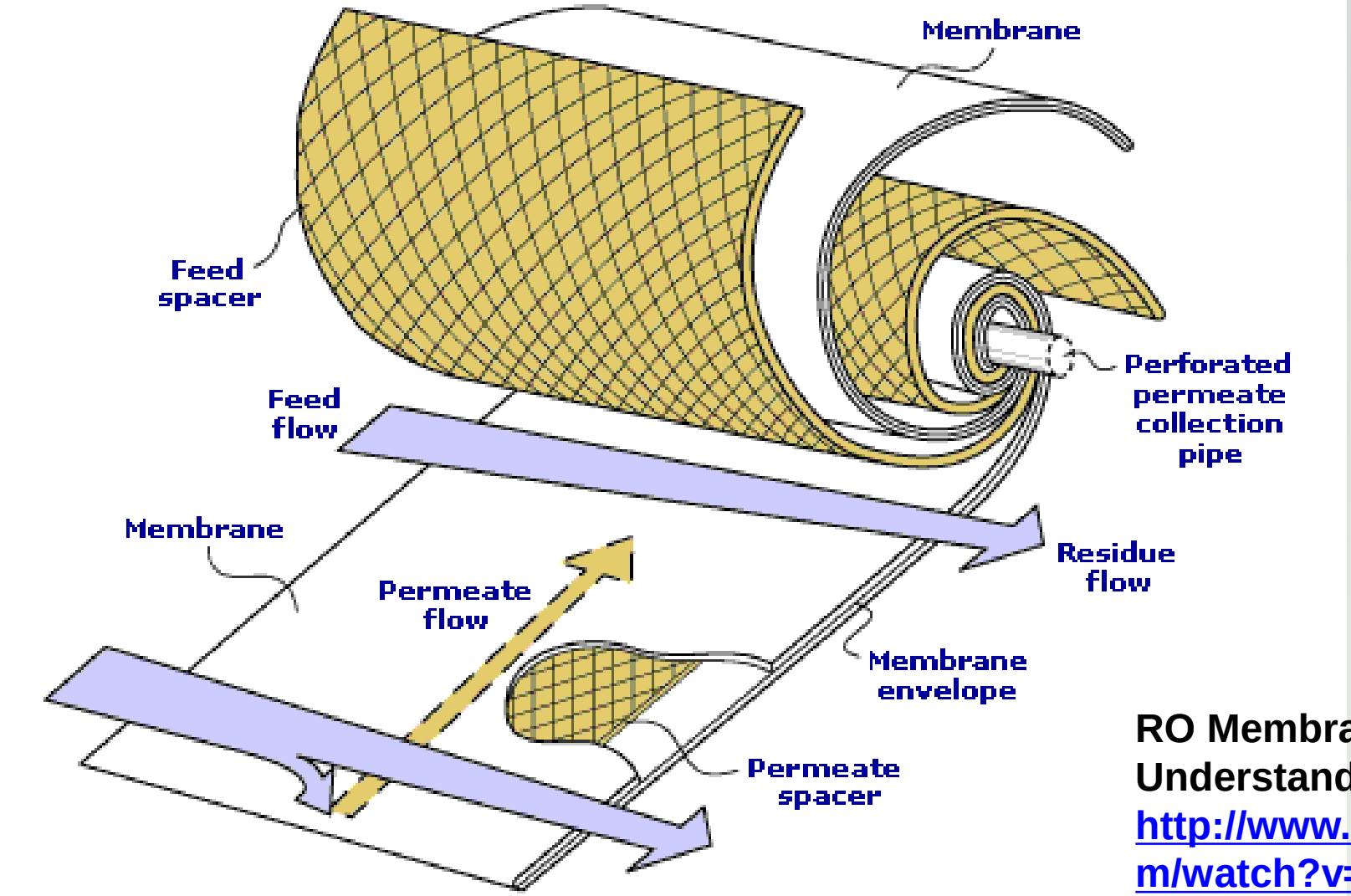
http://www.igb.fraunhofer.de/en/press-media/archive/1997/a-filter-for-fresh-air-and-drinking-water.html

http://www.ultraguardfilters.com/technology/techspecs.html



http://www.pall.com/main/graphic-arts/recommended-products-for-crossflow-filtration.page

Spiral Wound



RO Membrane Element Understanding.wmv
http://www.youtube.com/watch?v=-jJywQvnVnc

Vaporsep Membrane Technology and Research http://www.mtrinc.com/faq.html

Spiral Wound Cartridge

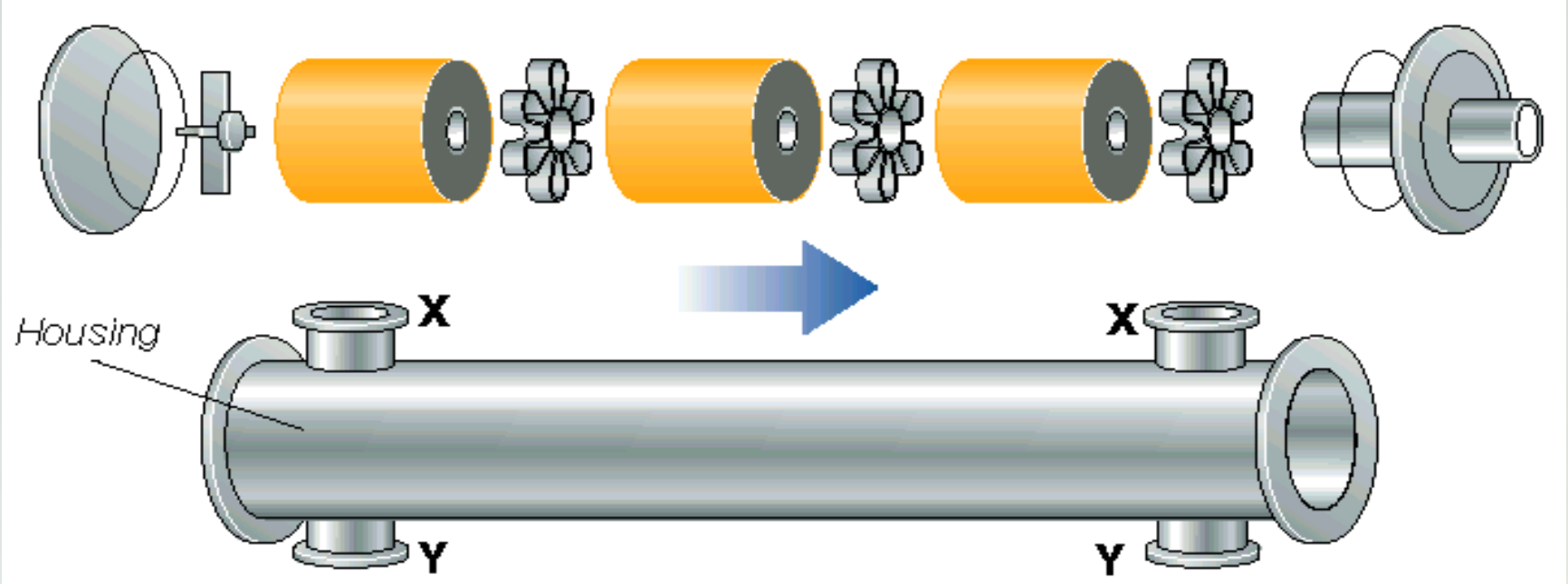


Fig. 6.4.13 *Spiral-wound module assembly. Either or both of the pairs of connecting branches (X and Y) can be used for stackable housing, specially used in UF concepts.*

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Tubular

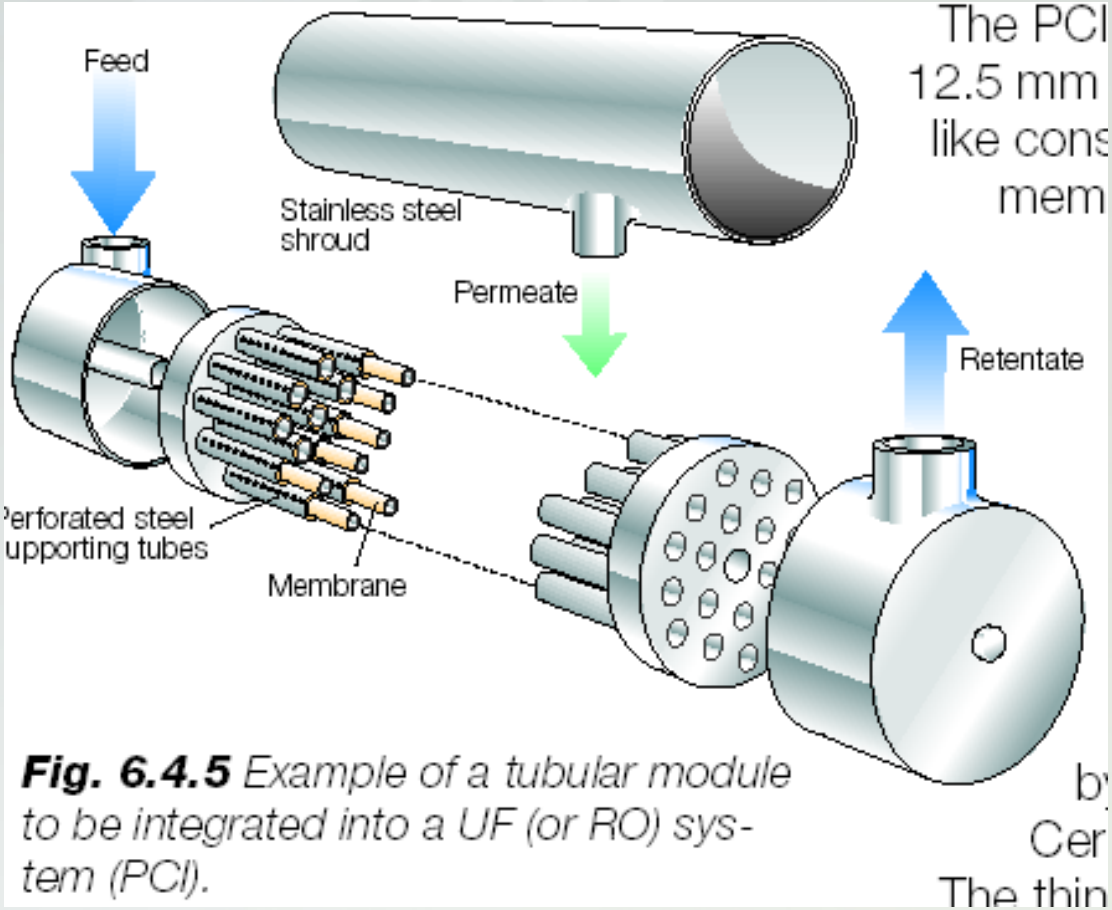

Fig. 6.4.5 *Example of a tubular module to be integrated into a UF (or RO) system (PCI).*

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Batch Operation

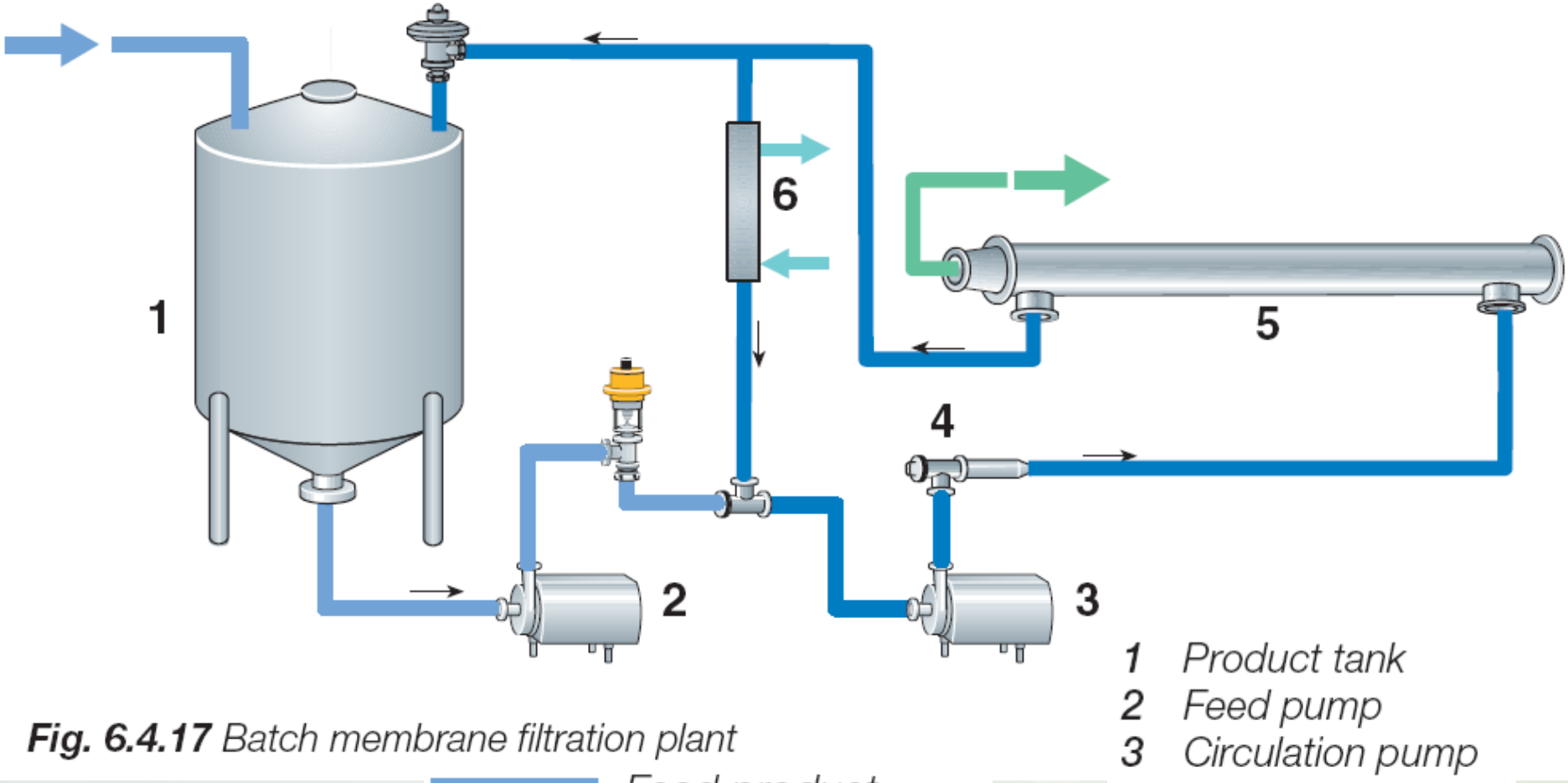

Fig. 6.4.17 *Batch membrane filtration plant*

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Batch Operation

Cross-flow Filtration Animation:
https://www.youtube.com/watch?v=9_rGkmDZhdo&list=PL2ERr8gClnU2lJxtTLfDdJt2Vscewiz52&index=14

Continuous Membrane System

http://www.spx.com/en/images/full20_20474APV_Membrane_Nanofiltration_NF.jpg

Membrane Cleaning Methods

- 2:25 – Backwash
  - **Rinse**
- 3:25 – Backwash with Chemical Enhancement
  - **Cleaning**
- 4:45 – Integrity Testing

Norit X-Flow Membrane Filtration Technology - XIGA™
http://www.youtube.com/watch?v=MEfFq_SJ0Pk
You Tube

Effects on food

- Concentration without heat
  - Retention of functional properties of proteins
  - Retention on sensory characteristics
  - Retention of nutritional quality

Table 6.2 — Loss of nutrients during membrane concentration of milk

Nutrient	Loss (%)	
	Reverse osmosis	Ultrafiltration
Protein	0	5
Fat	0	0
Carbohydrate	0	43
Energy	0	13
Thiamin	0	38
Riboflavin	0	39
Nicotinic acid	8	41
Vitamin B_6	3	36
Vitamin B_{12}	0	2
Vitamin C	—	87
Folic acid	0	5
Pantothenic acid	0	32
Biotin	0	37

From Glover (1971).

Websites of Interest for Membrane Separations.

- Hollow Fiber
  - http://www.hyfluxmembranes.com/pdf/brochures/Kristal.pdf
- Water Treatment
  - http://www.lenntech.com/membrane-technology.htm
- PCI
  - http://www.pcimembranes.pl/
- GEA
  - http://www.geafiltration.com/technology/technology.asp
- DSS – A Tetra Pak Company
  - http://www.dss.eu/Technology/technology.html