Stony Brook University

Cellulose Membrane Technology for Water Purification

A Breakthrough Innovation

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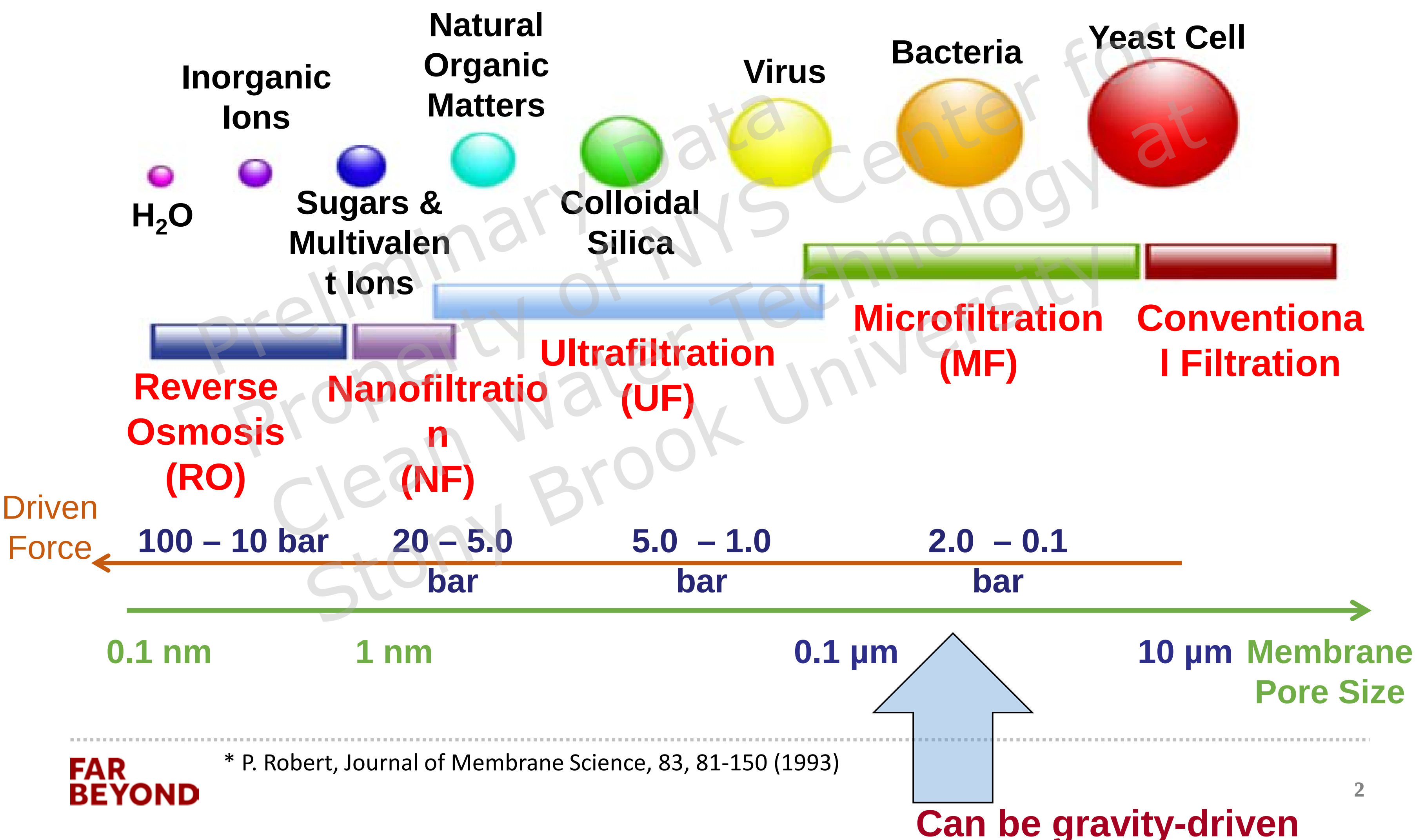
Distinguished Professor
Chemistry Department

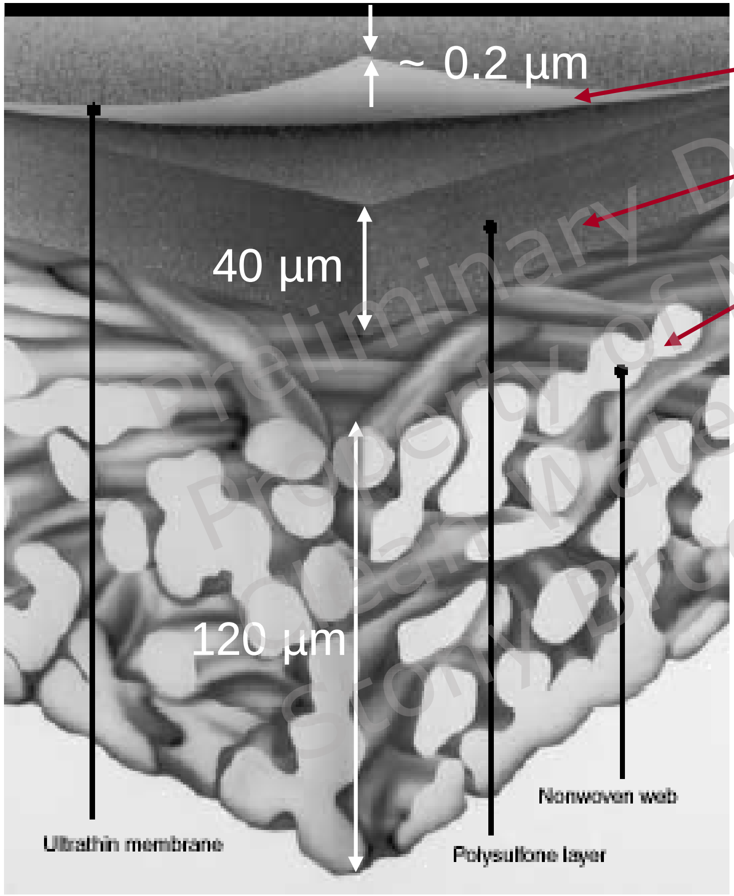
FAR BEYOND

Classification of Membrane Filtration



* P. Robert, Journal of Membrane Science, 83, 81-150 (1993)

Conventional Water Filtration Membranes (since 70's)



RO/NF layer

UF layer

Non-woven MF support

Size exclusion range

RO (Reverse Osmosis): < 1 nm

NF (Nano-Filtration): 1 – 10 nm

UF (Ultra-Filtration): 10 – 100 nm

MF (Micro-Filtration): 0.1 – 50 µm

Aqueous salts: 0.3 – 1.2 nm

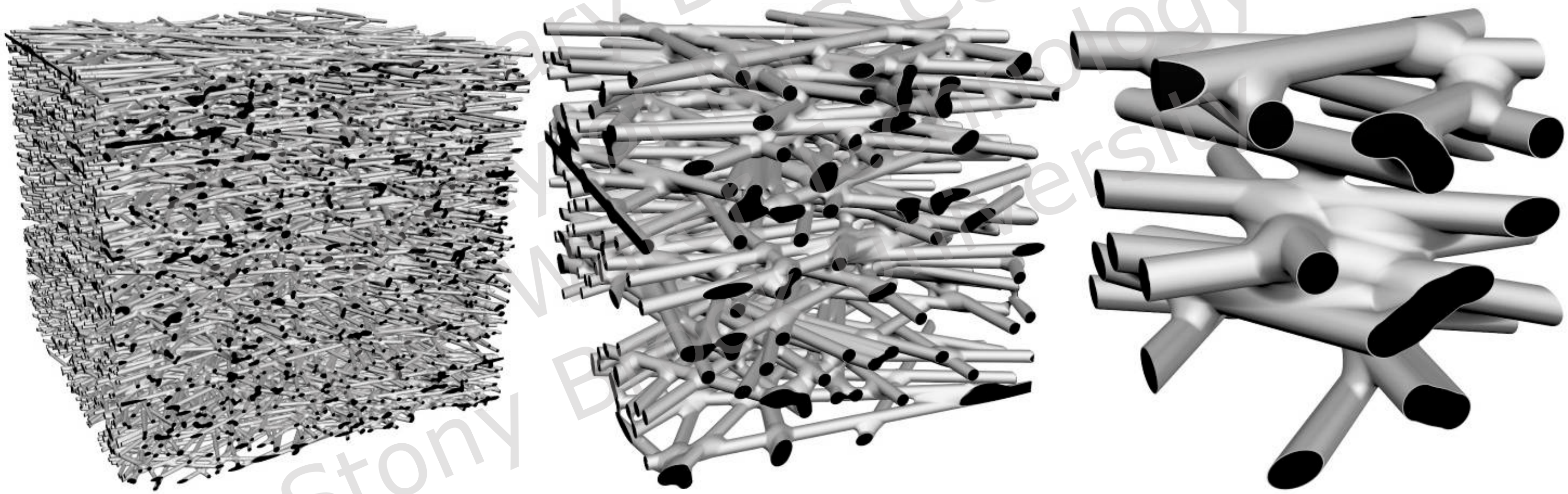
Pesticides, herbicides: 0.7 – 1.2 nm

Virus: 10 – 100 nm

Bacterial: 200 nm – 30 µm

Fiber Diameter and Pore Size in Non-woven Membranes

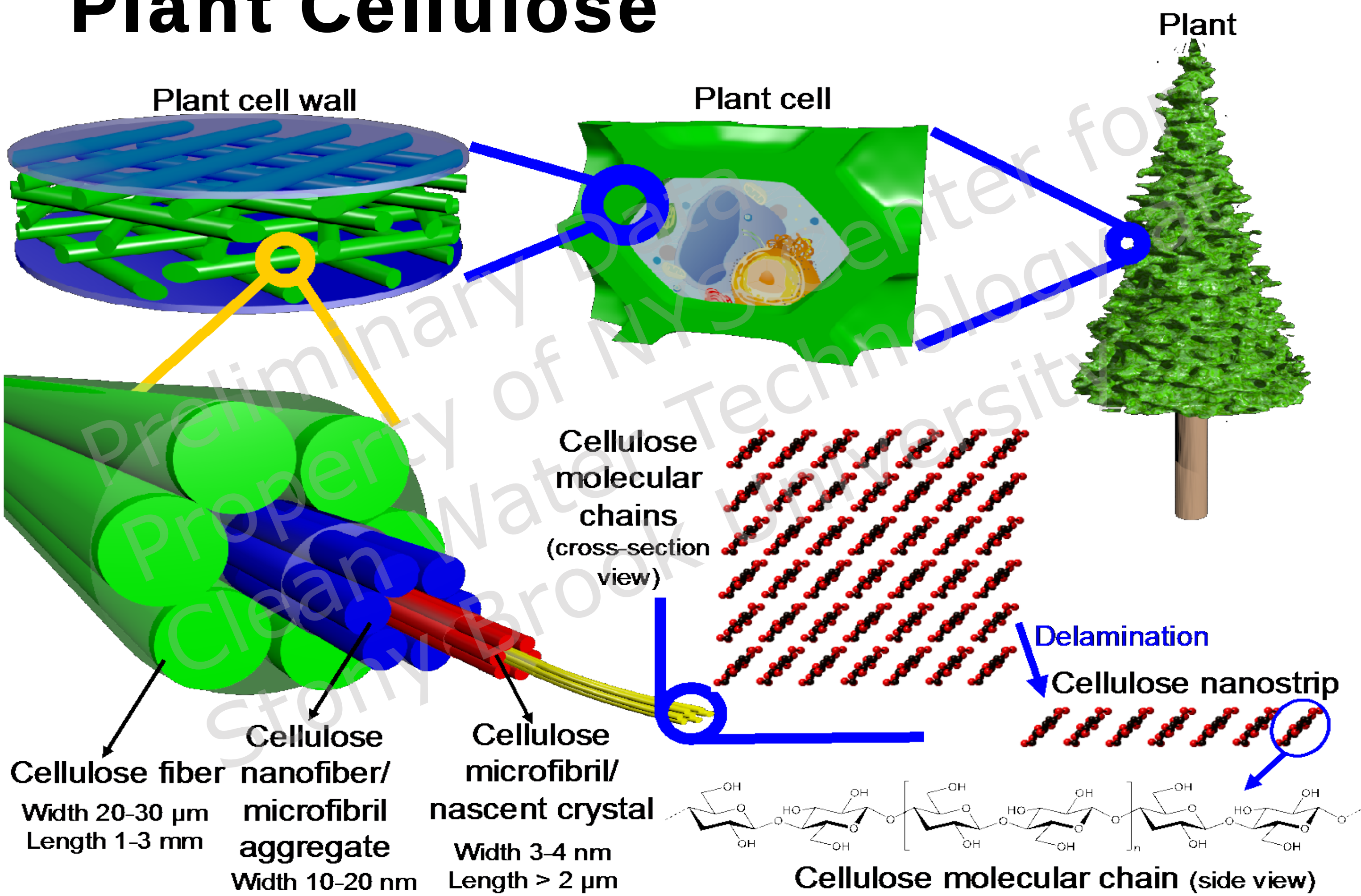
Fiber diameter ratio: 1 : 3 : 10; Porosity: 80 %

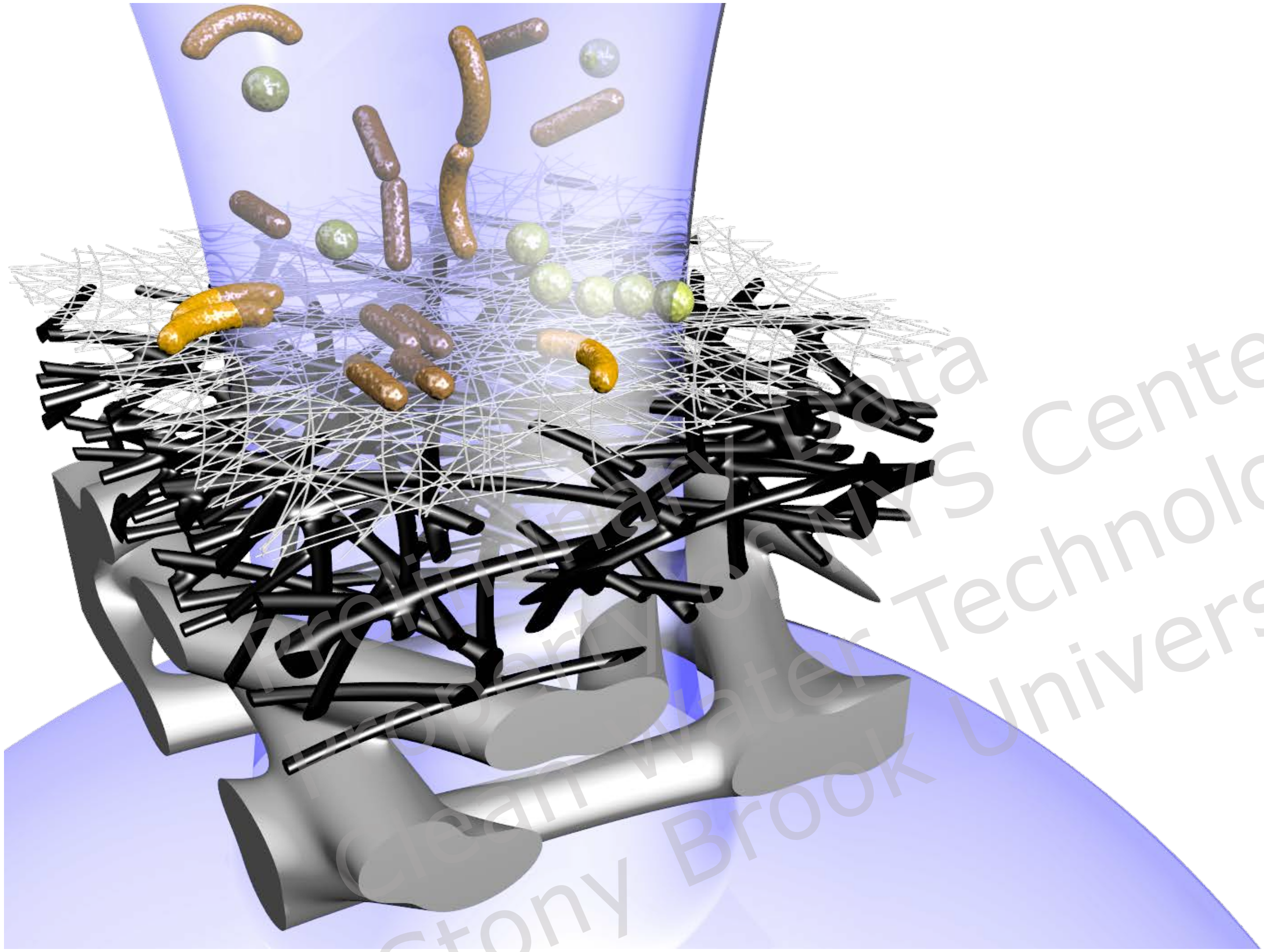


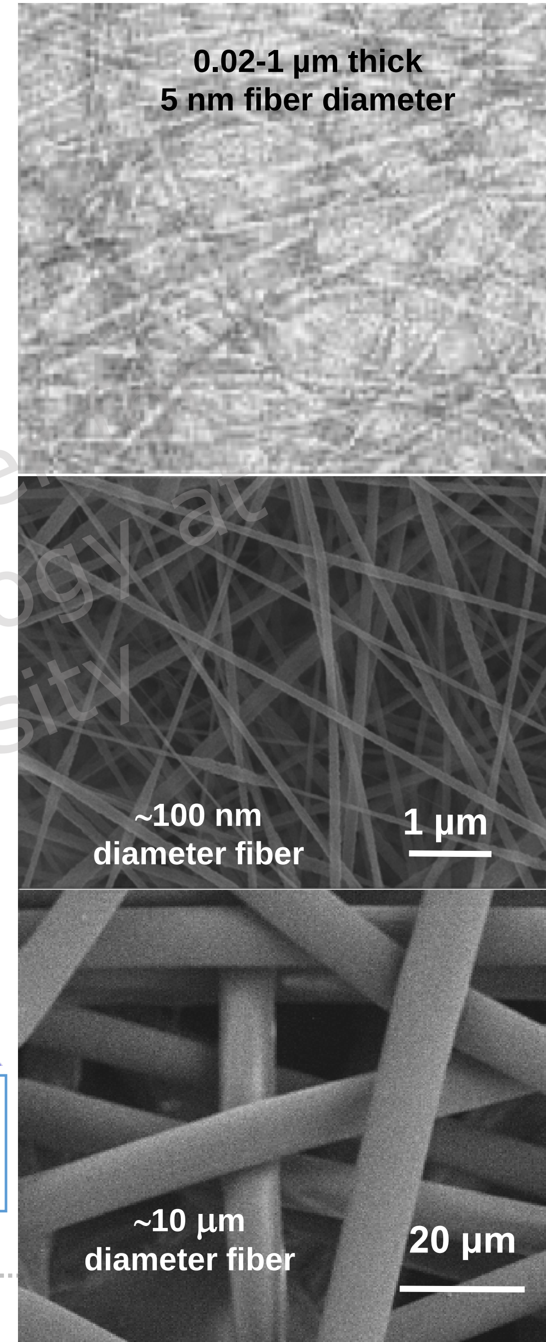
Smaller fiber diameter, smaller effective pore size

H. Y. Ma, C. Burger, B. S. Hsiao, B. Chu. J. Mater. Chem., 21(21), 7507 – 7510 (2011)

Hierarchical Structure of Plant Cellulose

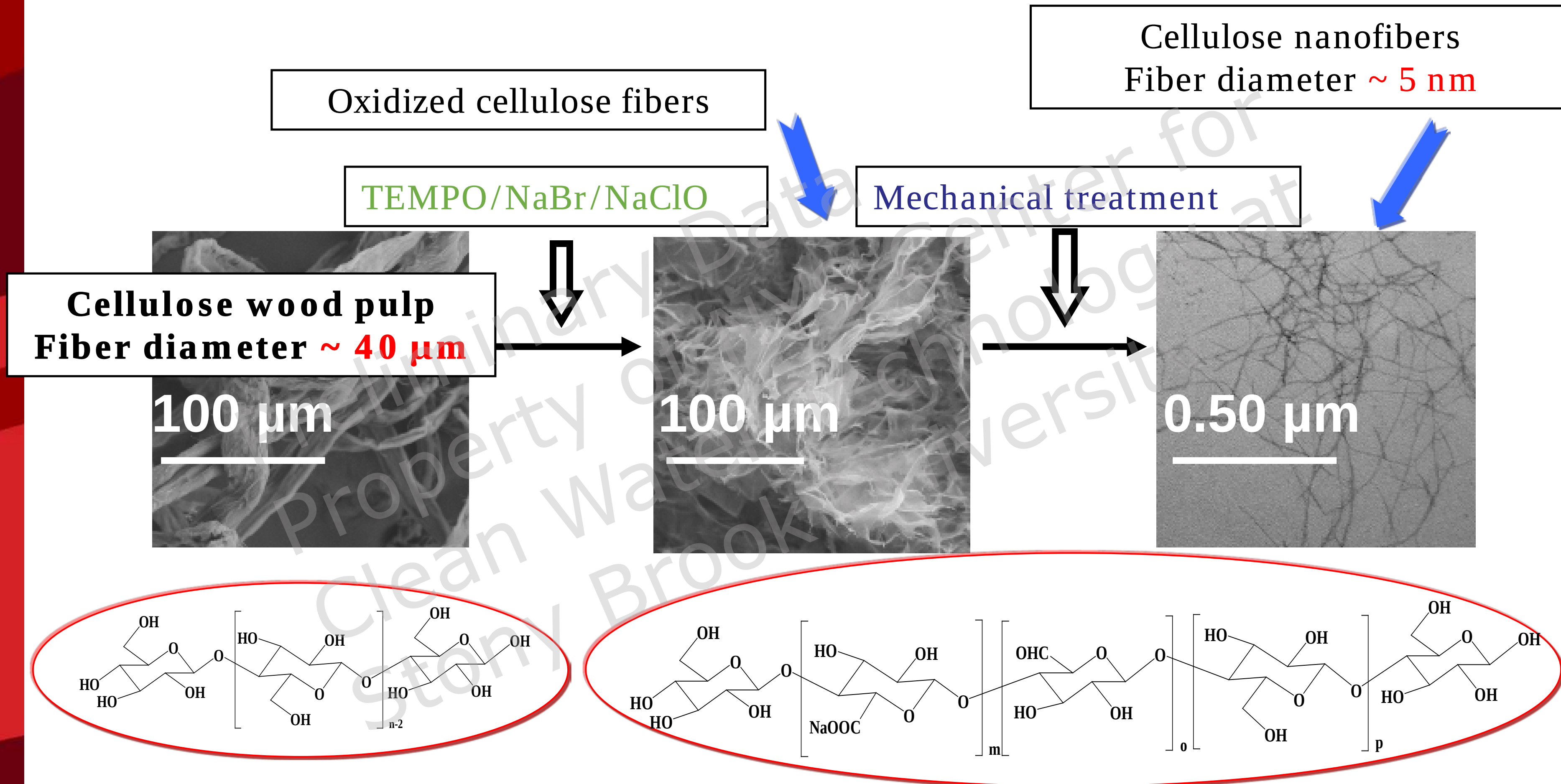






New Concept: Nanofibrous Membranes with Hierarchical Fiber Diameters

Preparation of Cellulose Nanofibers



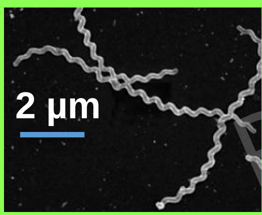
Carboxylate groups (negatively charges and chelation): 0.70 mmol/(g cellulose)

Aldehyde groups (chemical reactivity): 0.25 mmol/(g cellulose)

Hydroxyl groups (chemical reactivity): 2.0 mmol/(g cellulose)

Waterborne Diseases Caused by Bacteria, Viruses and Heavy Metals

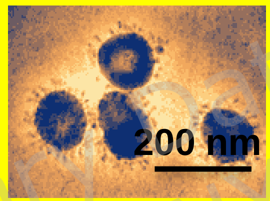
E. Coli
0.5 µm in diameter
2 µm long



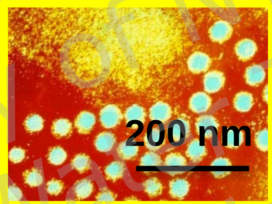
Leptospirosis
0.2 µm in diameter
10~20 µm long

Most bacteria have sizes over 0.2 µm

Filtered by Size Exclusion



SARS
100 nm
pI = 4.5



Hepatitis A
20-30 nm
pI = 3～4

Most viruses have pI ＜7, with negative charges at pH = 7

Adsorbed by Charge Interactions

As (III), (V)
in pesticide and burning coal

Cr (VI)
in dye and paint

Most heavy metal ions have charges and can be interacted via chelating agents

Adsorbed by Charge Interactions & Chelating Agents

http://www.hyfluxmembranes.com/
http://en.wikipedia.org/wiki/

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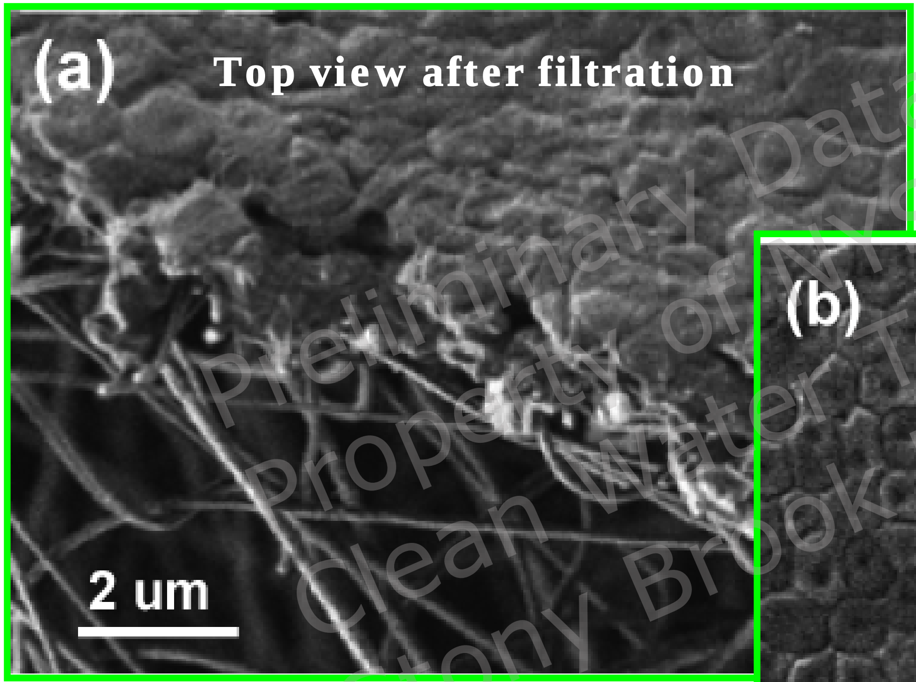
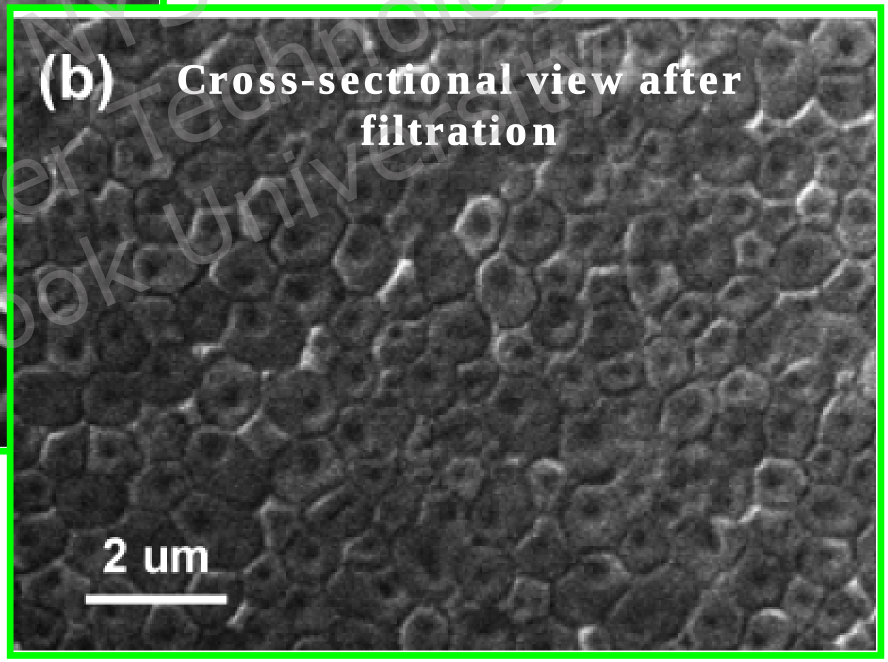
Cellulose Nanofibers MF Membrane for Removal of E. Coli by Size Exclusion

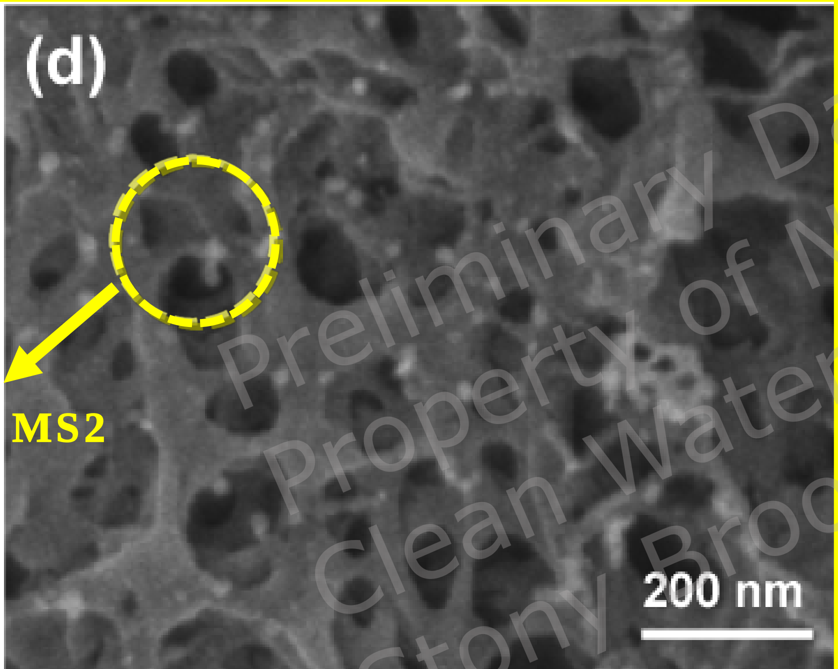
The surface of the membrane was covered by E. Coli particles, whereas the retention ratio was 99.9999 %.





A. Sato, R. Wang, H. Y. Ma, B. S. Hsiao, B. Chu, J. Electron Microsc., 60, 201-209 (2011)

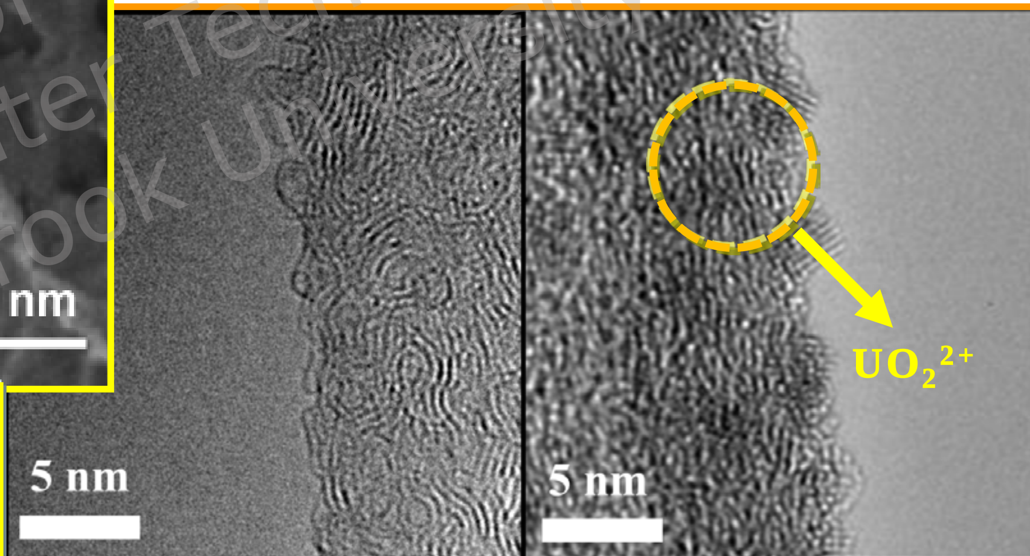
Cellulose Nanofibers MF Membrane for Removal of Virus and Toxic Metal by Adsorption



The adsorption capacity of CN based MF membrane for MS2 was 99%, i.e., ~10X better than the adsorption capacity of commercially available GS9035 for MS2 which was 90%.

The adsorption capacity of UCN for UO_2^{2+} was 167 mg/g;

The adsorption capacity of commercially available activated carbon for UO_2^{2+} was 57 mg/g.



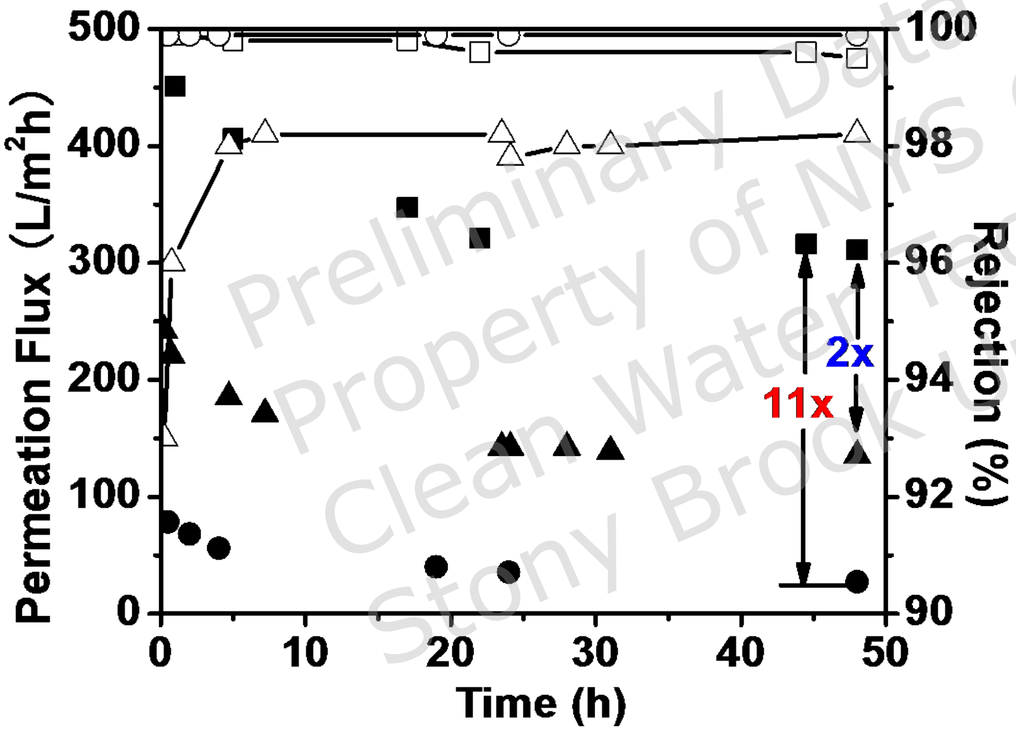
H. Y. Ma, B. S. Hsiao, B. Chu, ACS Macro Lett., 1, 213-216 (2012)

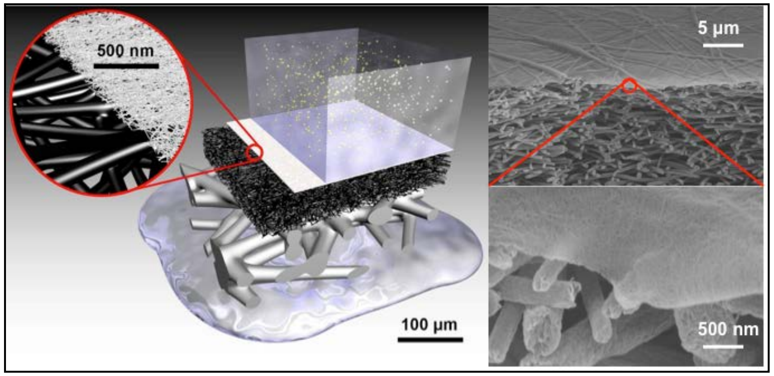
Liquidity CORPORATION

www.liquico.com

Nanofibrous UF Membranes

- Permeation flux of nanofibrous UF membrane can be 10 X higher than conventional UF membranes (at the same rejection ratio) - due to higher porosity (80%) of non-wovens
- Cellulose nanofibers barrier layer is anti-fouling and more chemical resistant



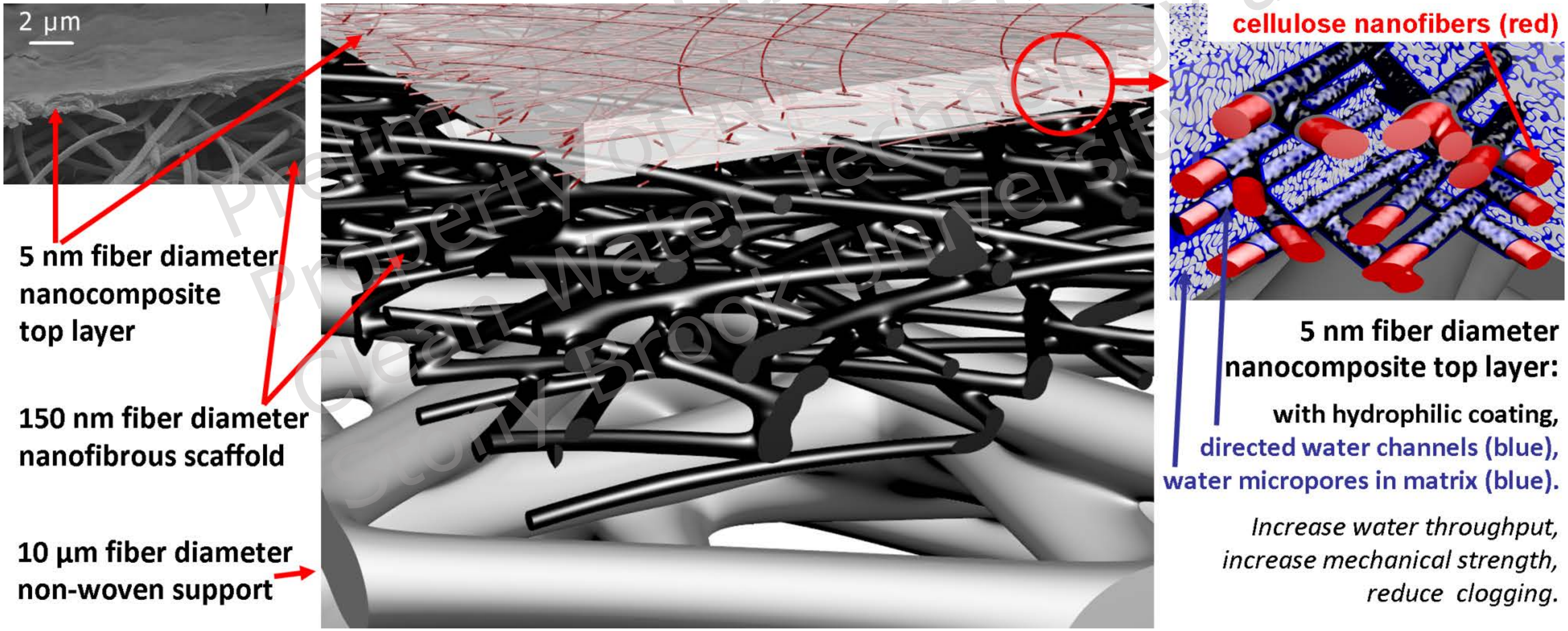


H. Ma, et al., Journal of Materials, 20(22), 4692-4704 (2010)

Nanofibrous NF/RO Membranes

The nanocomposite barrier layer (cellulose nanofibers + polyamide matrix)

- is stronger than the conventional barrier layer
- introduces "directed water channels" to increase the flux by 2-5 X for RO desalination



H. Ma, C. Burger, B.S. Hsiao B. Chu, ACS Macro Letters, 1(6), 723-726 (2012)

Sources of Cellulose in Nature

- Higher plants (fibers, parenchyma etc.)
- Seaweeds (Valonia, etc.)
- Animals (Tunicates, Salpae etc.)
- Bacteria (Acetobacter, etc.)
- Fungi (Saprolegnia, etc.)
- Amoebae (Dictyostelium, etc.)

Our Goal

Sustainable membrane fabrication (MF, UF, NF RO, and MBR) using nanocelluloses from diverse biomass sources to treat a wide range of water problems.