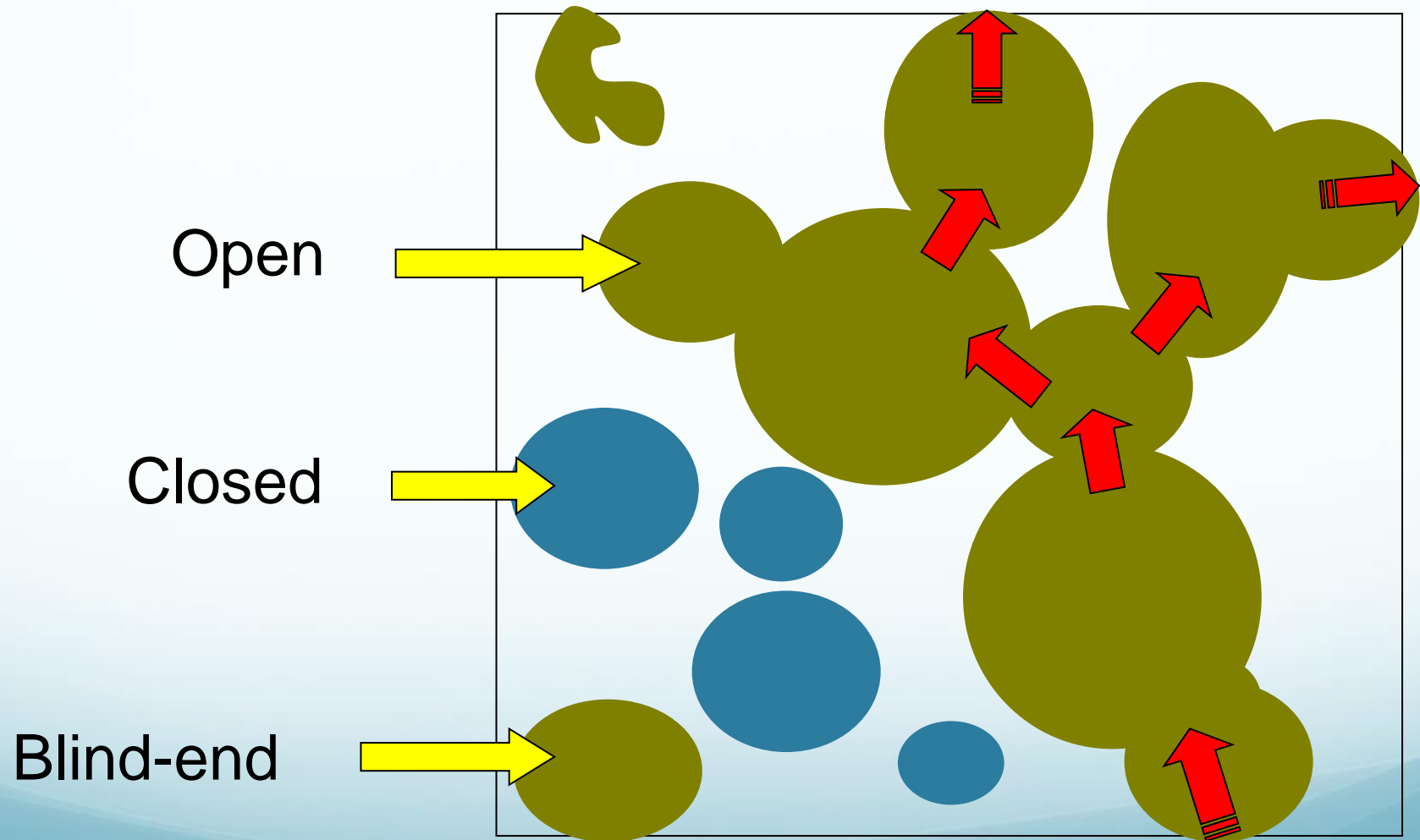




Measuring Porosity (Millimetre to Nanometre scale)

Paul Tomlins

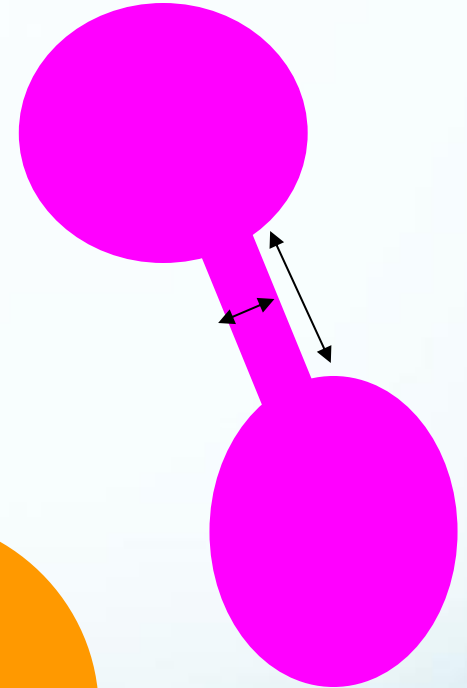
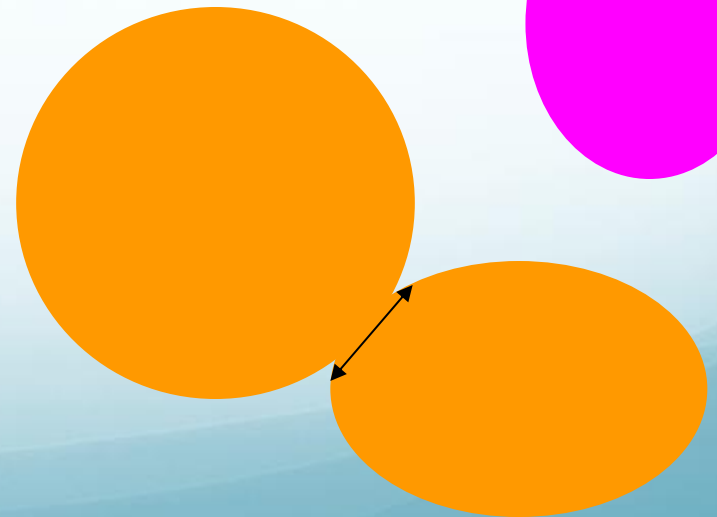
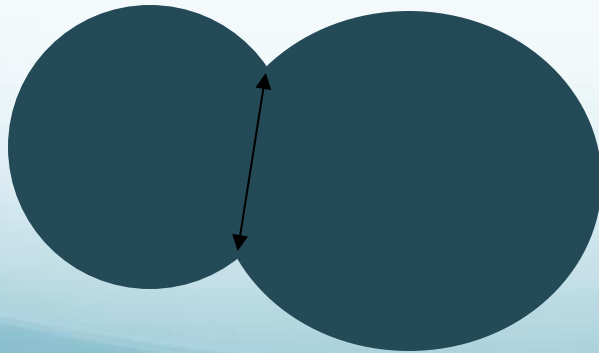
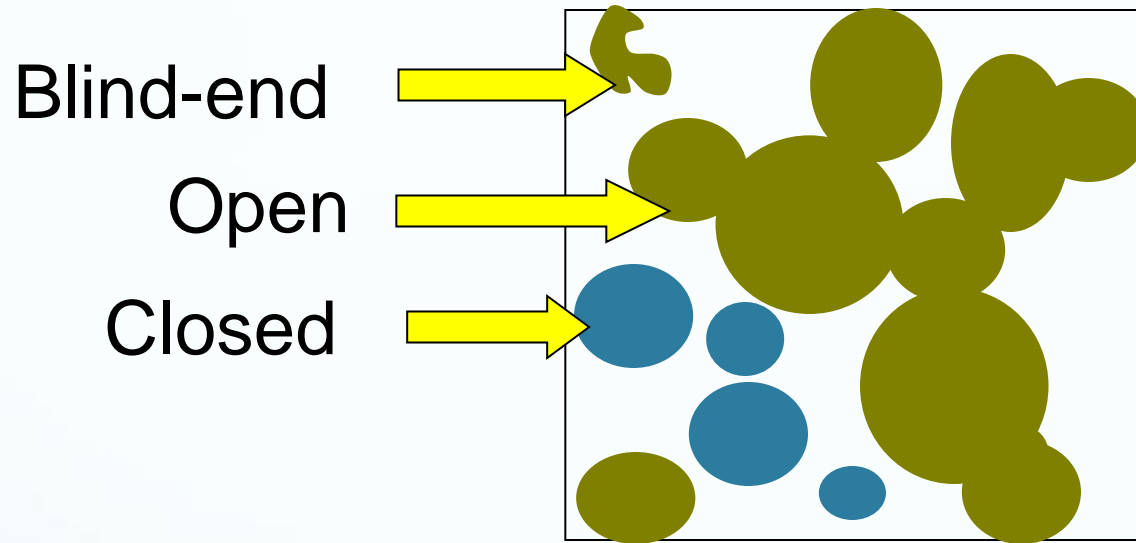
Porosity and pore types



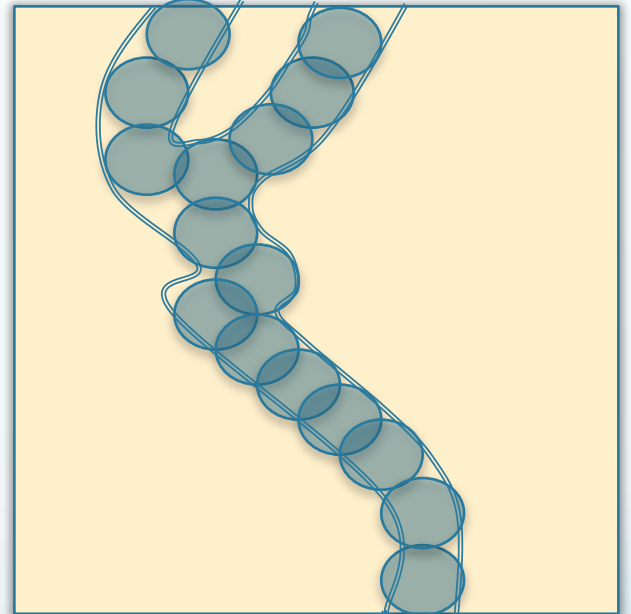
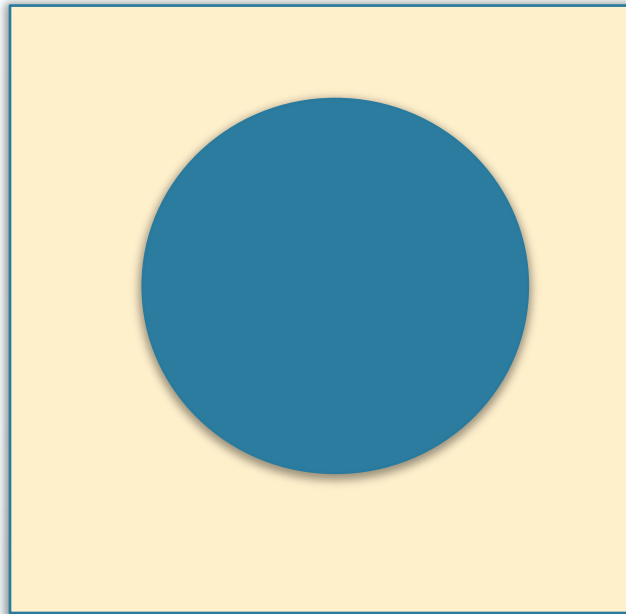
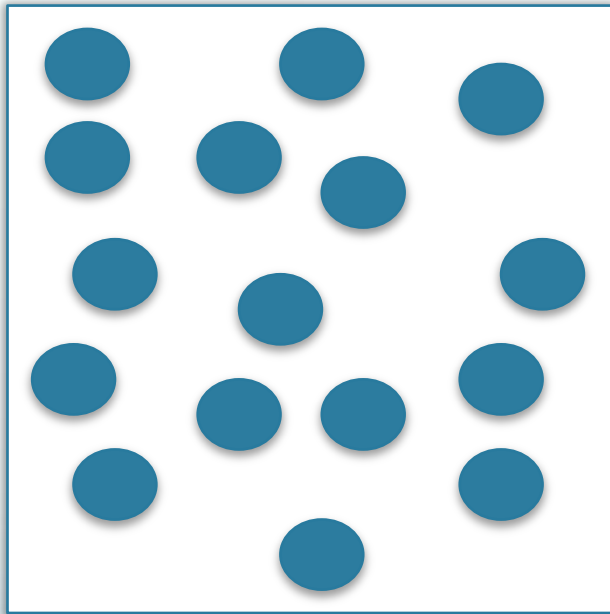
The role of closed/open pores

Open Pores	Closed Pores
Cell ingress	
Nutrient supply/waste removal	
	Mechanical performance Degradation behaviour Gas diffusion

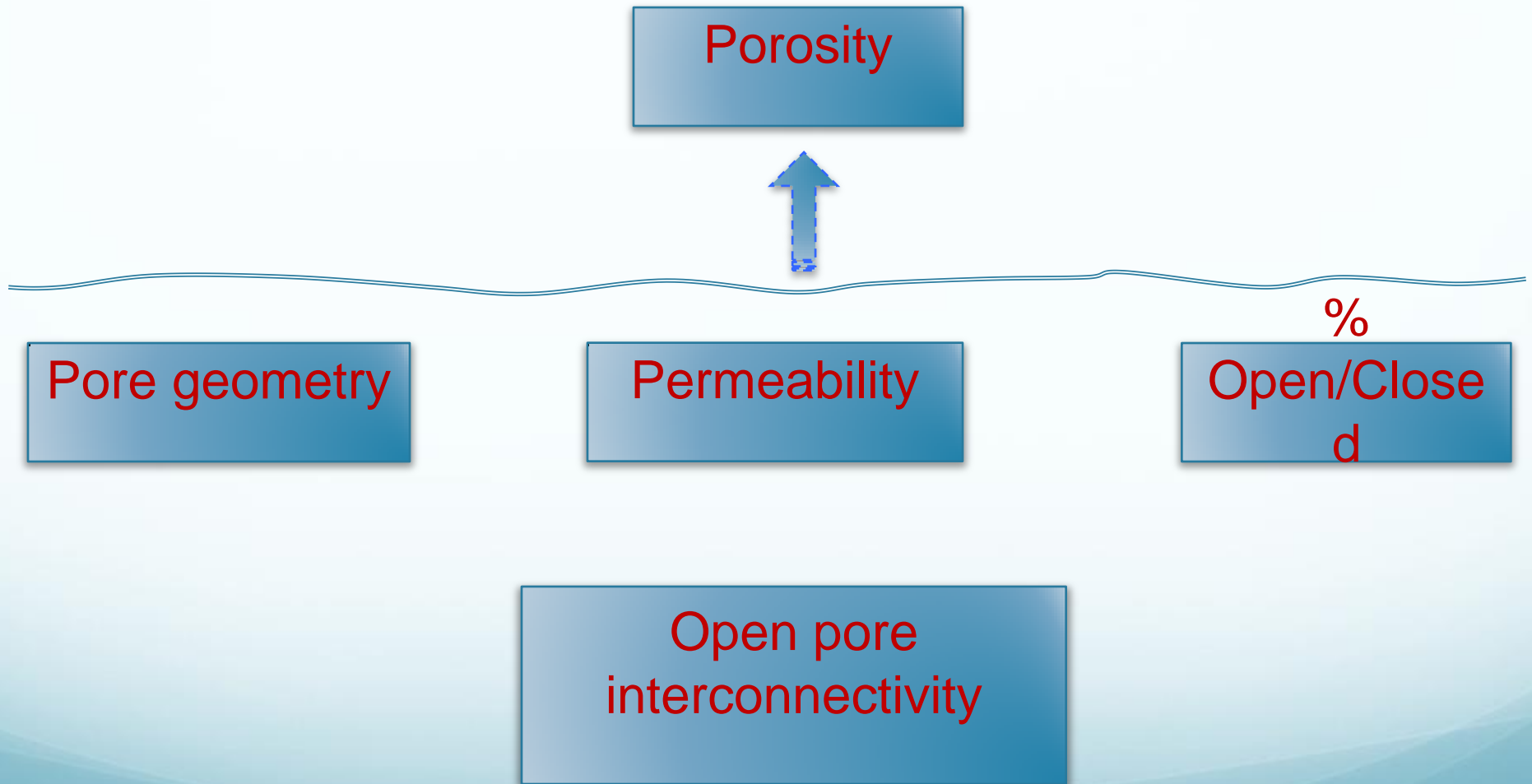
Interconnectivity



Different structures with the same porosity



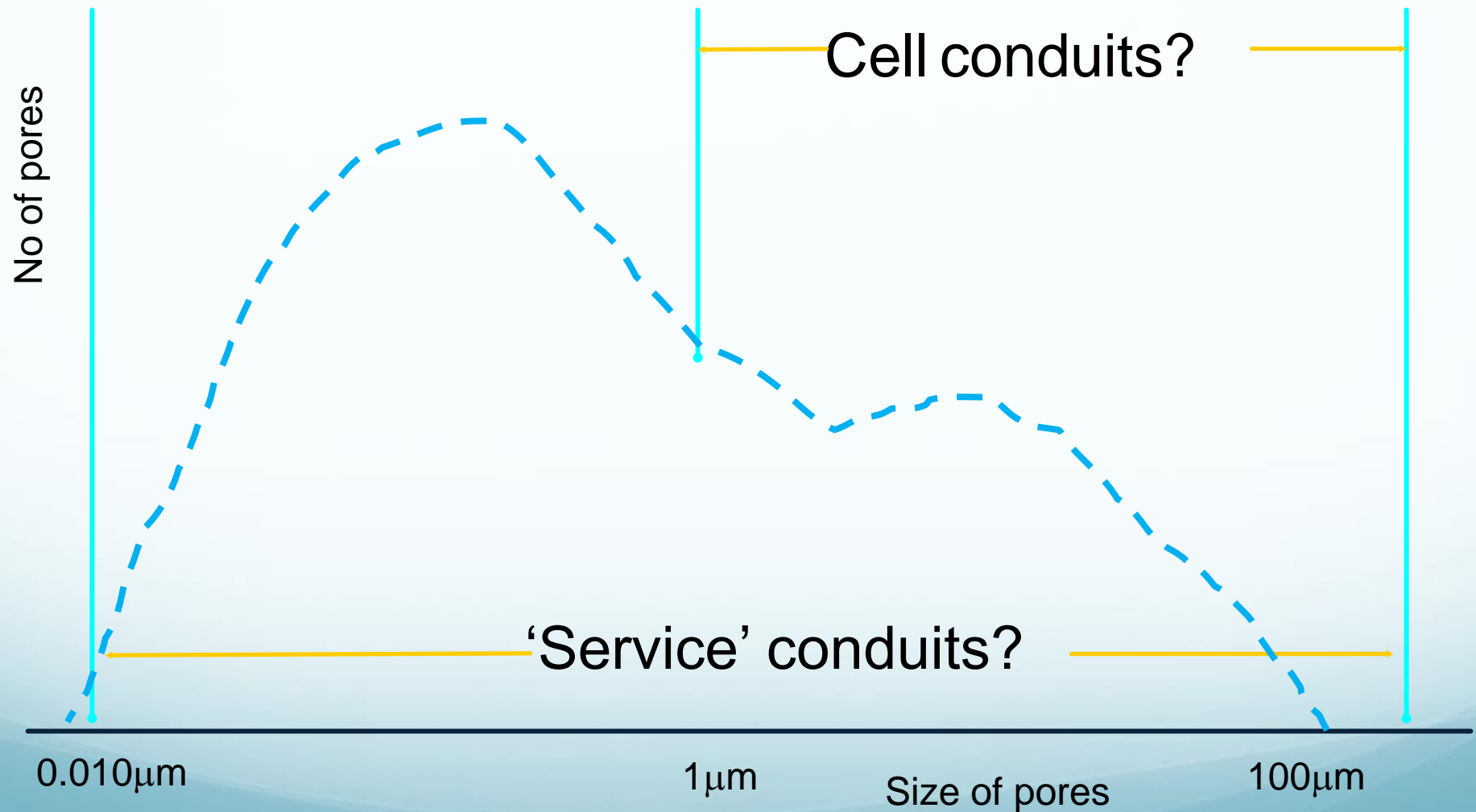
Porosity and scaffold performance



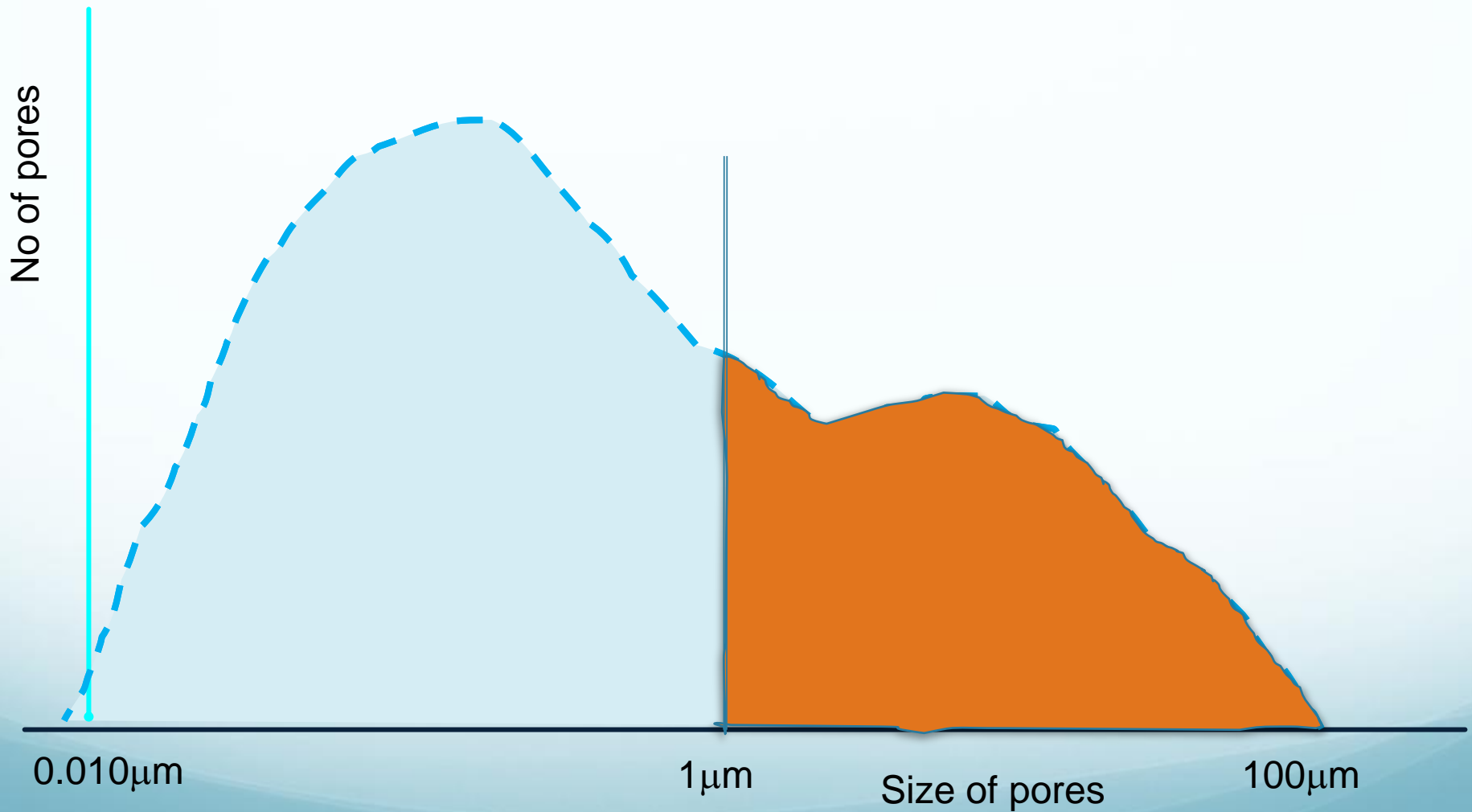
What is porosity?

- 80 definitions in ASTM terminology (some duplicates!!)
- Holes in a solid, not necessarily connected. (Standard: E7)
- That portion of a membrane filter volume which is open to fluid flow, also known as void volume. (D6161 Standard: D1129)
- Percentage of the total volume of a material occupied by both open and closed pores. ([D02.F0] C709 Standard: D4175)

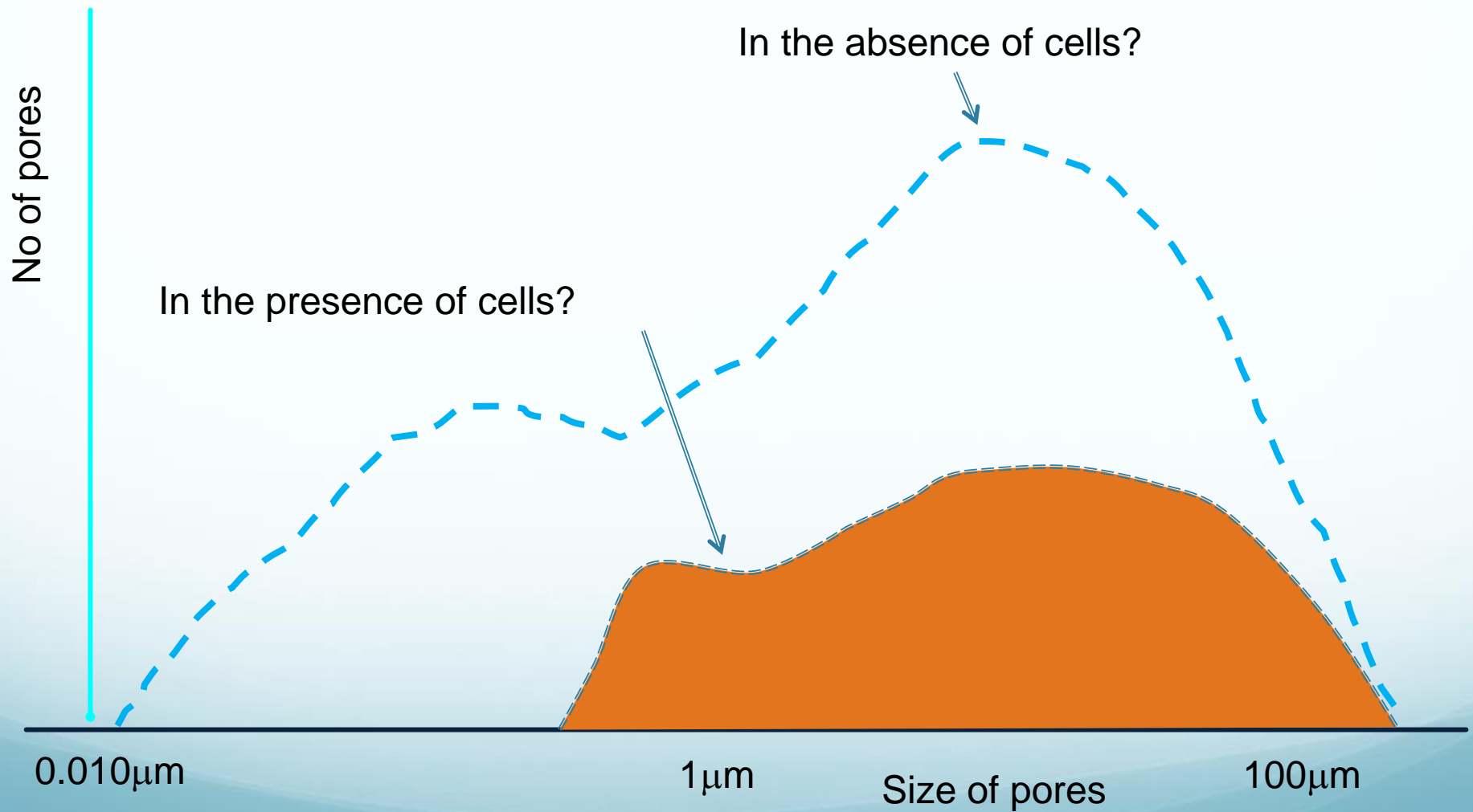
Porosity and length scale



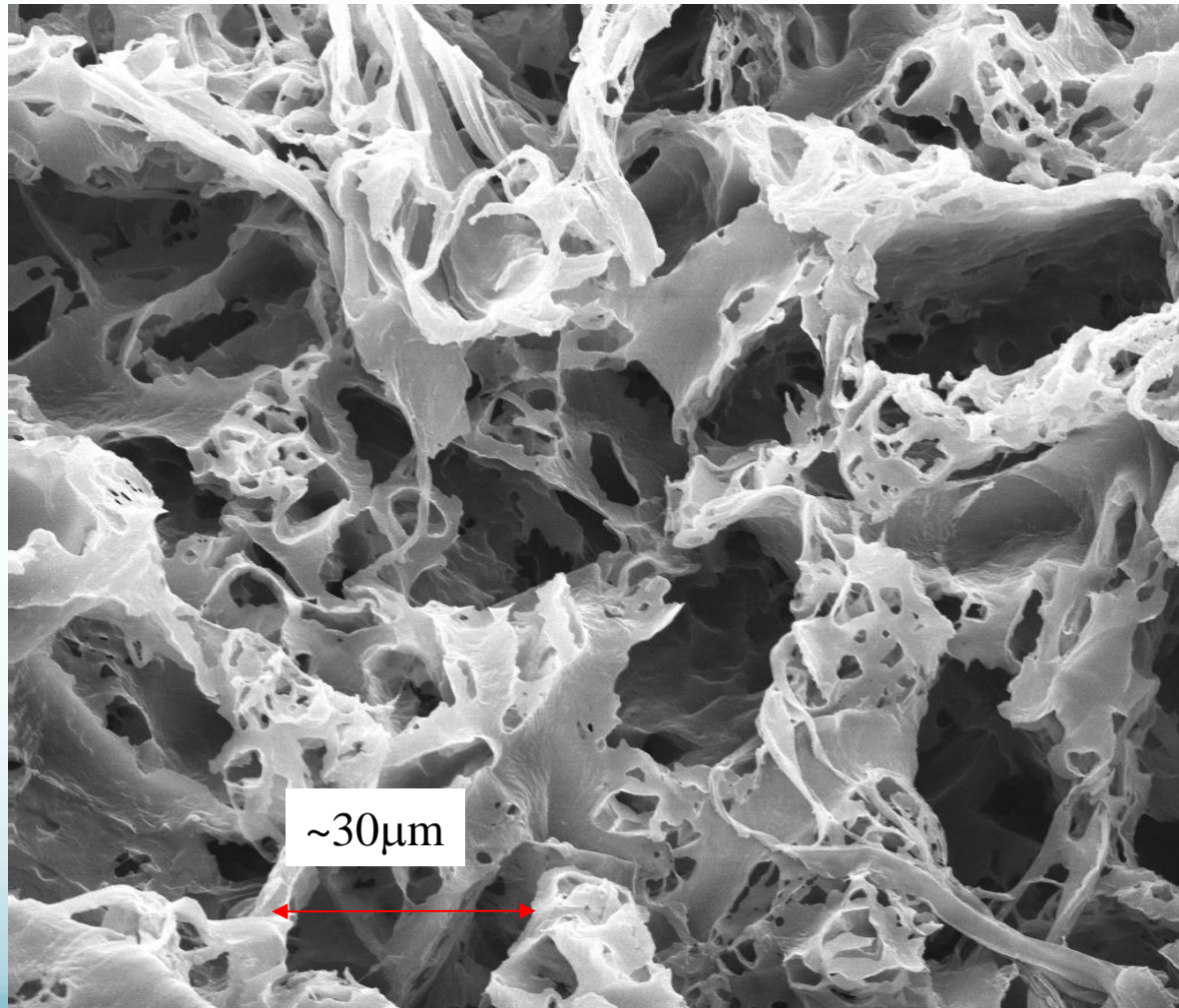
Porosity linked to resolution of technique



Porosity in a cell-seeded scaffold?



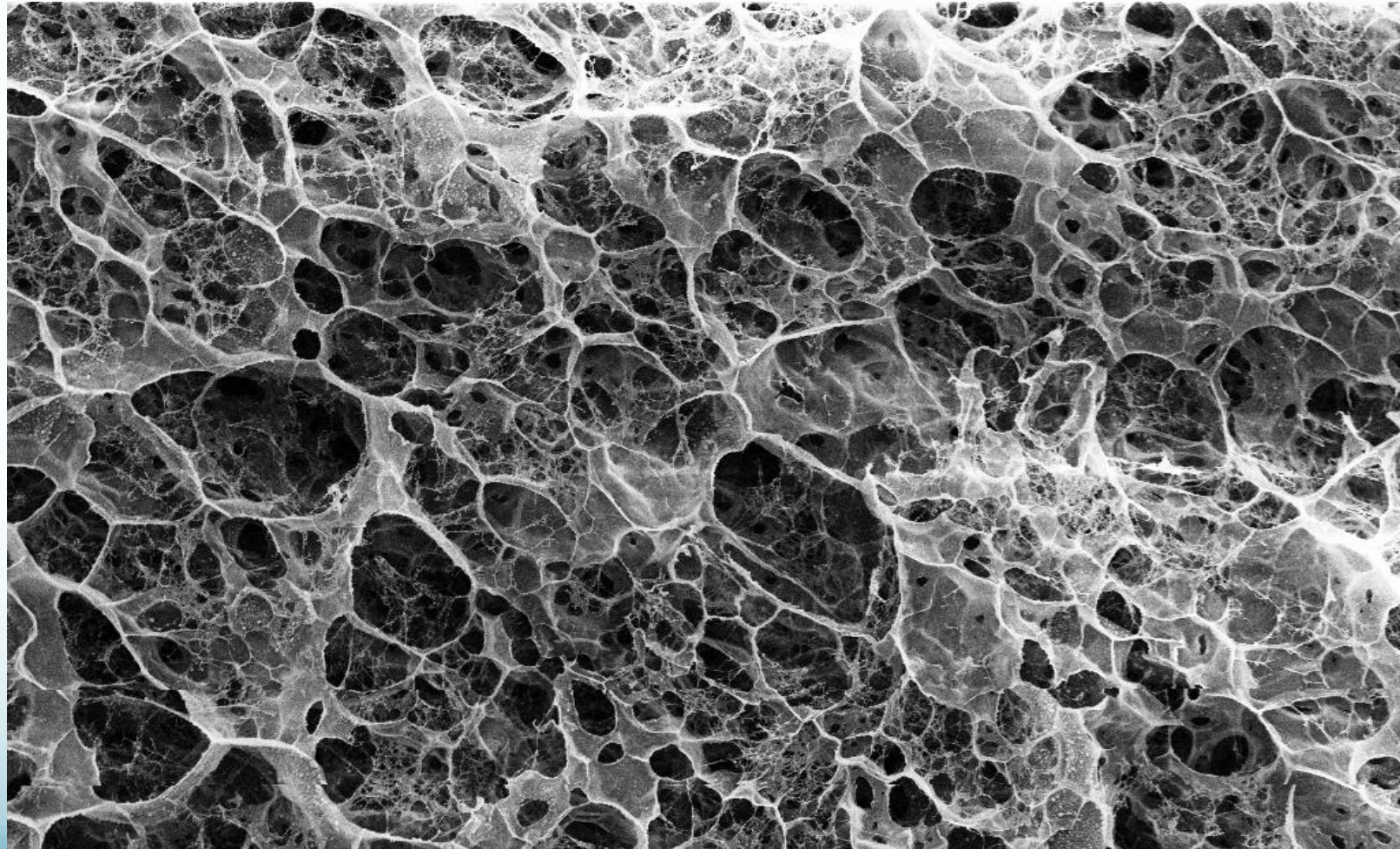
Links with pore volume?



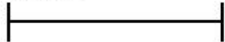
Techniques for obtaining a porosity value

	Closed Pores	Open Pores
Mercury Porosimetry		✓
Density Measurements - Archimedean Buoyancy - Helium Pycnometry	(✓) (✓)	✓ ✓
Gas Flow Porometry		✓
Permeability		✓
Image Analysis - SEM - Optical - X-ray Micro-CT	(✓) (✓) (✓)	(✓) (✓) (✓)

Fibrin Gel (slush nitrogen/freeze dryer)



10µm



EHT = 5.00 kV

WD = 9 mm

Signal A = SE2

Photo No. = 3862

Date :16 Apr 2009

Time :16:31:01



How is porosity reported?

- As a percentage e.g 42.2%, often with no standard deviation and coupled with an average pore diameter e.g. 161.5 μm .
- “in which the pores are so open that it is difficult to distinguish what can be considered a pore from what is actually a pore window” Renghini et al (J. Eur. Cer. Soc. 33 (2013) 1553)
- “....the total pores content assessed by micro_CT analysis is lower than that evaluated by weight-volume measurements ...” Renghini et al (J. Eur. Cer. Soc. 33 (2013) 1553)

Question

- What needs to be done to improve the practical use of a measured porosity?

Enhancing the value of the metric

- Identify one or more preferred methods that can be used for >95% of scaffolds
- Encourage investigators to report open and closed porosity where possible
- Encourage investigators to report range of length scales over which porosity has been determined
- Encourage reporting of pore size distributions (and volumes?)
- Evaluate the role that sub-micrometre pores have on scaffold performance

Thank you for your attention