DOSIMETRY OF INHALED ULTRAFINE PARTICLES

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Abstract: The dosimetry of ultrafine particles is determined by the deposition of the particles in the respiratory system, by the deposition of the particles from the site of deposition, by the translocation of the particles into respiratory tissues and via the circulation into the entire body and, finally, by the dose metric linking particle characteristics and biological responses.
Ultrafine particles are solely deposited in the respiratory tract by diffusion. In the size range 50 - 100 nm deposition occurs soleley in the alveolar region. Smaller particles are also deposited in the bronchial region.
Particles deposited in the bronchial region are rapidly taken up by epithelium (80% of 30 nm particles). Particles deposited in the alveolar region can penetrate into the circulation. The clearance pathways, mucociliary clearance and phagocytosis by macrophages, are of minor importance.
The current understanding of ultrafine particle dosimetry favours the particle surface area as appropriate dose metric. This surface area is the true surface area and not any equivalent used in aerosol physics.
In conclusion, as far as the biological relevance of ultrafine particles is concerned, ultrafine particles have to be considered an aerosol entity different from that of fine particles.

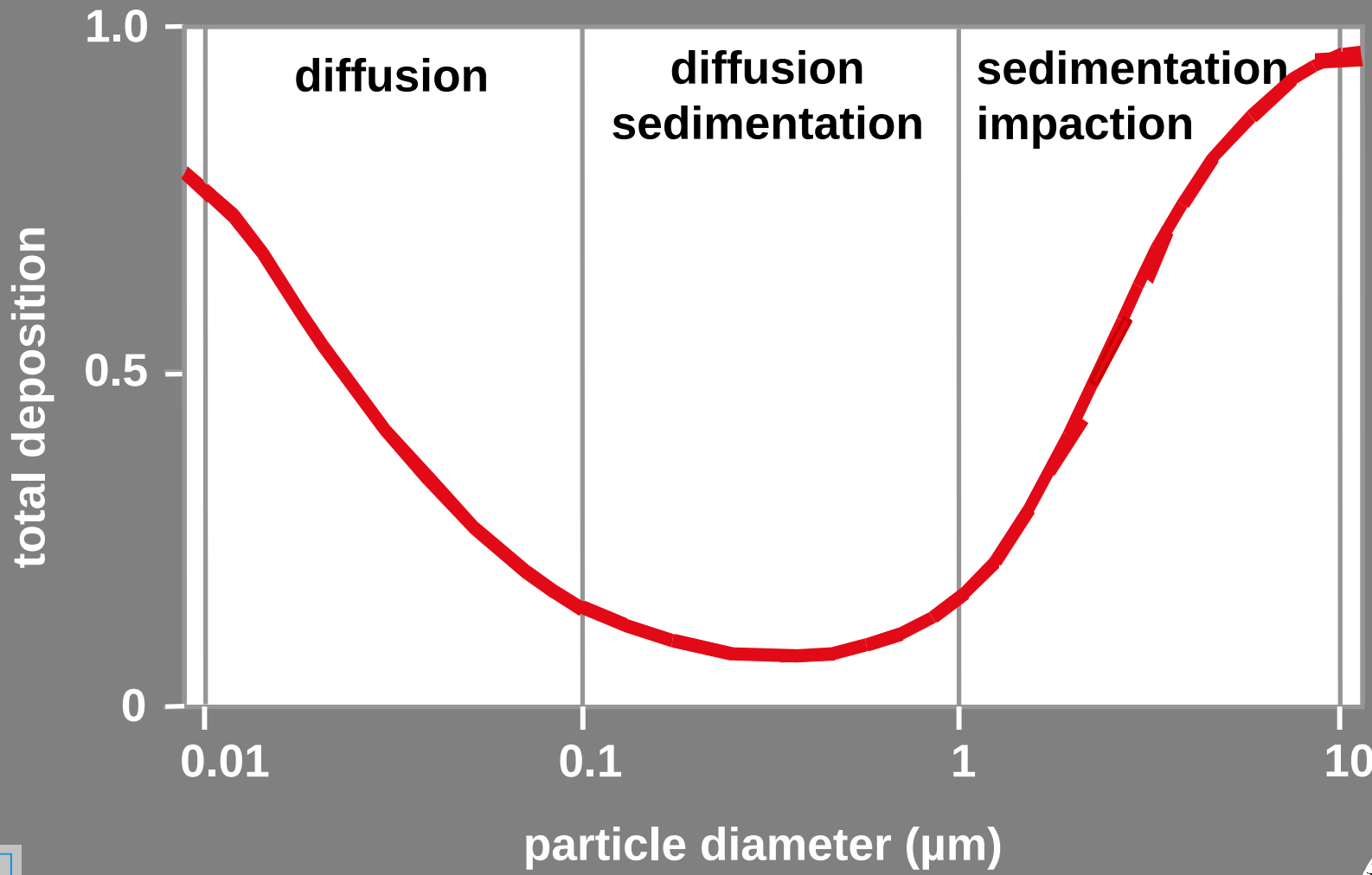
Recent toxicological end epidemiological studies have indicated that the risk associtaed with the inhalation of ambient particles may increase with decreasing particle size. Current studies therefore focus on ultrafine particles, i.e. particles smaller than 100 nm in diameter. When these particles are inhaled they are solely deposited in the respiratory tract by diffusion. Deposition therefore decreases with decreasing particle size and increases with increasing residence time of the particles in the respiratory tract. For oral breathing at rest it increases from 20% for 100 nm particles to 70% for 5 nm particles. The particles are mainly deposited in the alveolar and bronchial region.

Clearance of ultrafine particles from the site of deposition is different from that of fine particles (particles in the size range 0.1 – 2 µm). The clearance routes of fine particles, mucociliary transport and phagocytosis by alveolar macrophages, are of minor importance for ultrafine particles, but translocation into epithelium and subsequent penetration into the systemic circulation and potential distribution in the entire body are considerd major clearance pathways. Consequently, the biological relevance of ultrafine particles is different from that of fine particles. The target organ of fine particles is the respiratory tract whereas that of ultrafine particles can potentially be any organ.

So far, the mass of particles deposited in the respiratory tract is considered to be the dose metric for describing the dose-effect relationship of fine particles. However, there is increasing evidence that the appropriate dose metric of ultrafine particles is the surface area of the particles available for particle-cell interactions. This surface area is the true surface area as determined by the BET technique rather than equivalent surface areas used in aerosol physics.

In conclusion, as far as the biological relevance of ultrafine particles is concerned, ultrafine particles have to be considered an aerosol entity different from that of fine particles.

Total Deposition of Particles in the Human Respiratory Tract



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Particle Transport in the Respiratory Tract

	particle diameter	particle density	breathing cycle period	flow rate
diffusion	●		●	
sedimentation	●	●	●	
impaction	●	●		●

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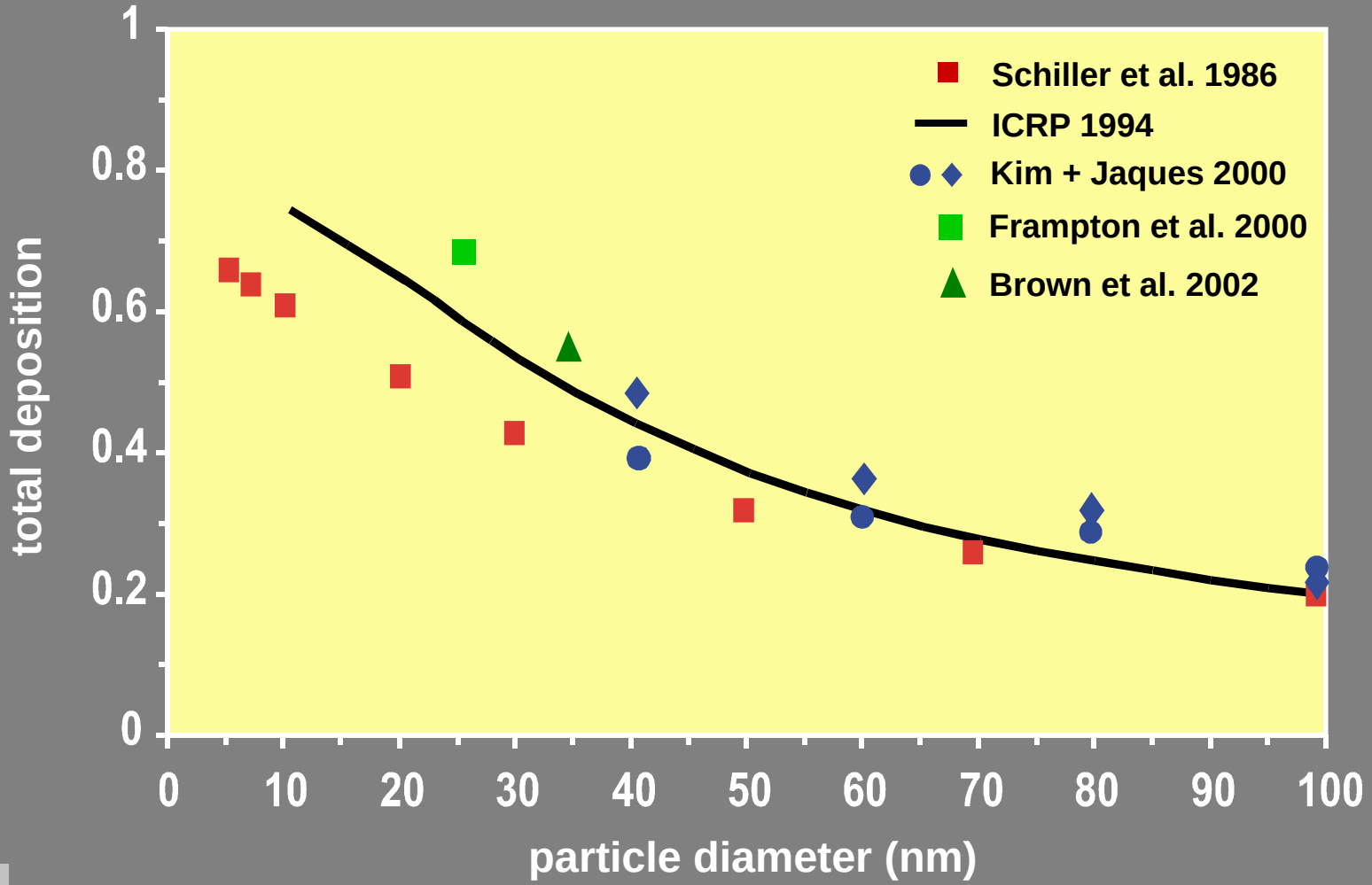
Total Deposition for Oral Breathing of 500 cm^3 Monodisperse Aerosols at 250 $cm^3 s^{-1}$ Flow Rate



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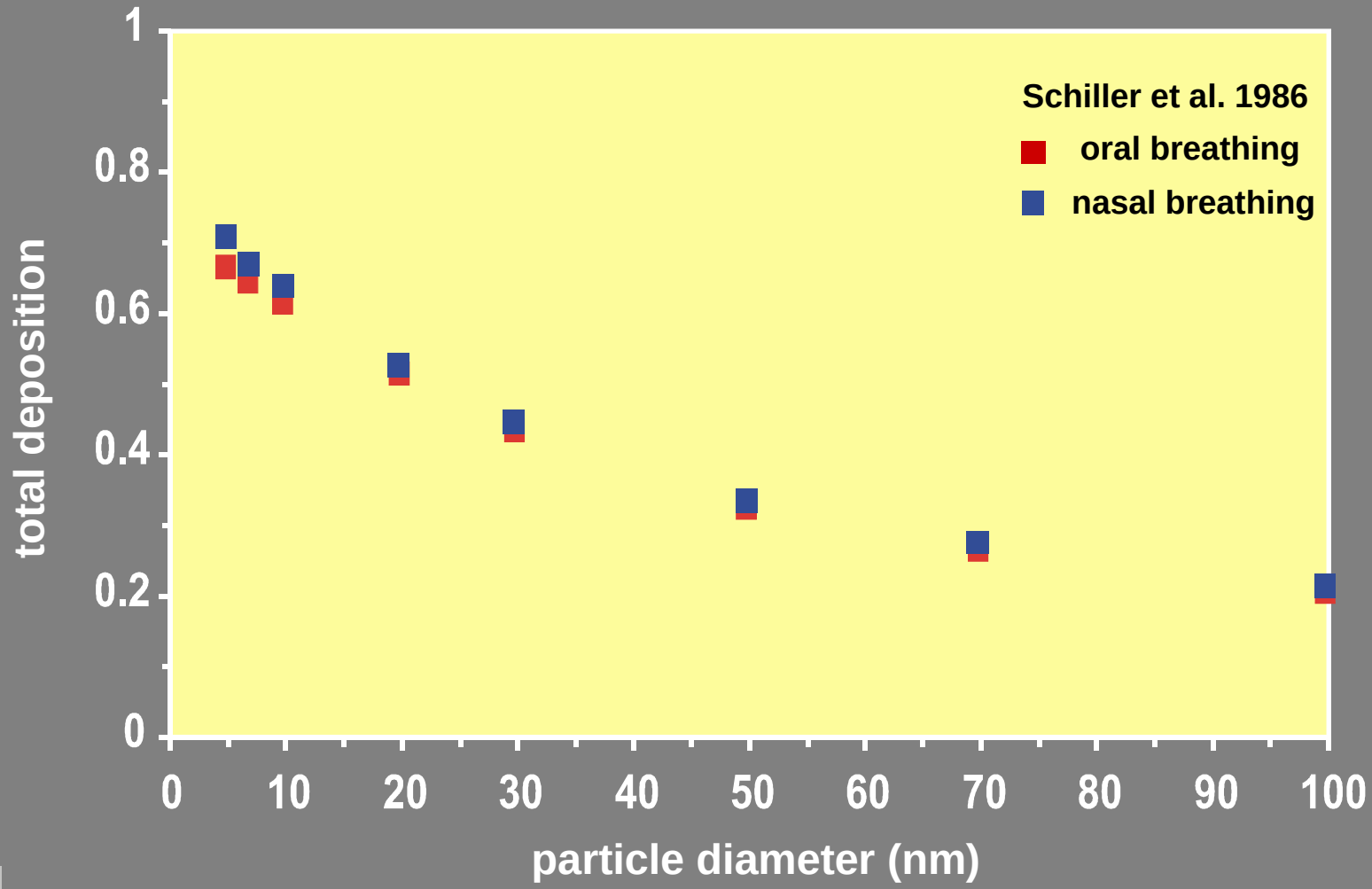
Total Deposition for Oral and Nasal Breathing of 500 cm^3 Monodisperse Aerosols at 250 cm^3s^{-1} Flow Rate



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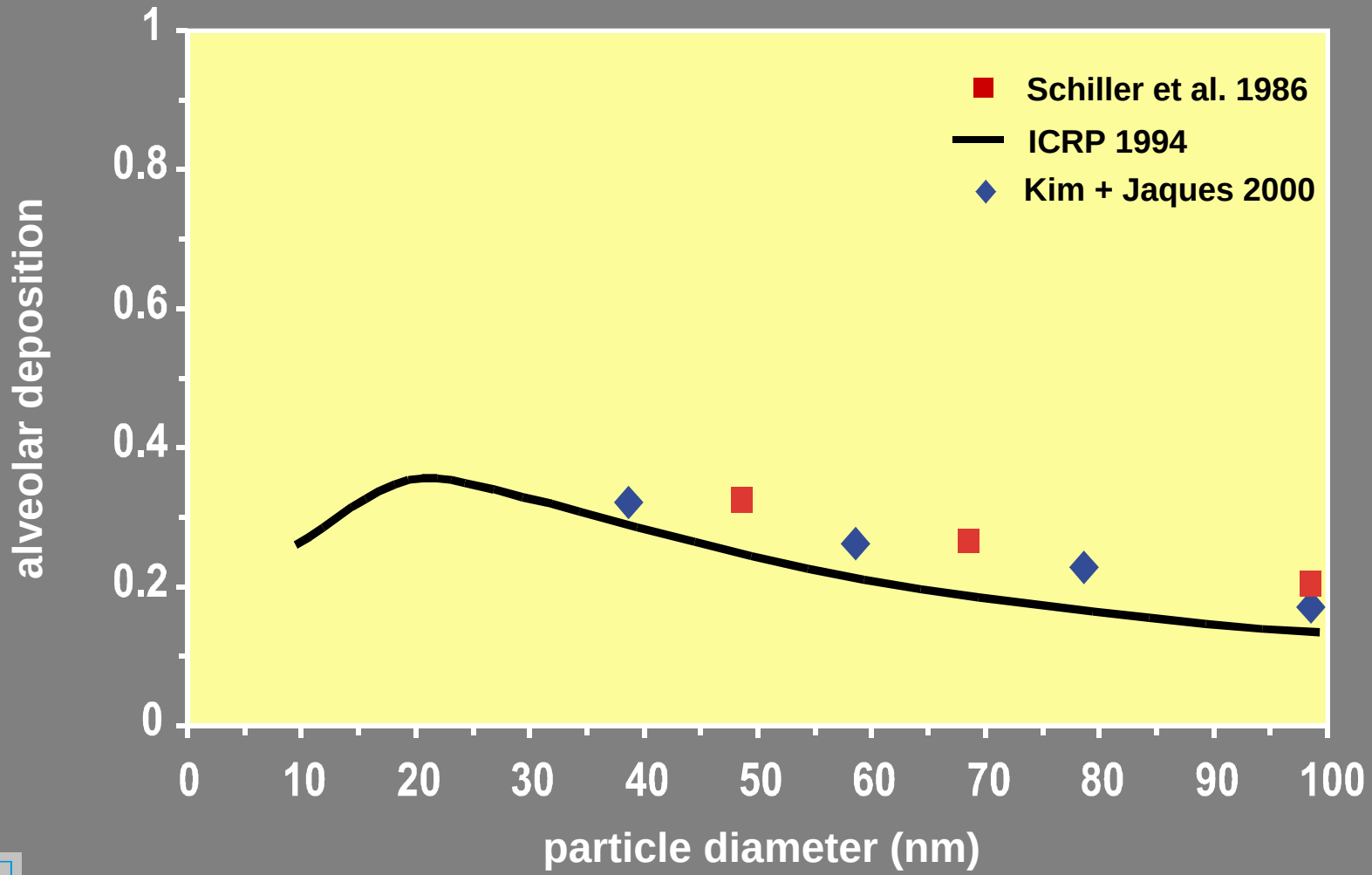
Alveolar Deposition for Oral Breathing of 500 cm^3 Monodisperse Aerosols at 250 $cm^3 s^{-1}$ Flow Rate



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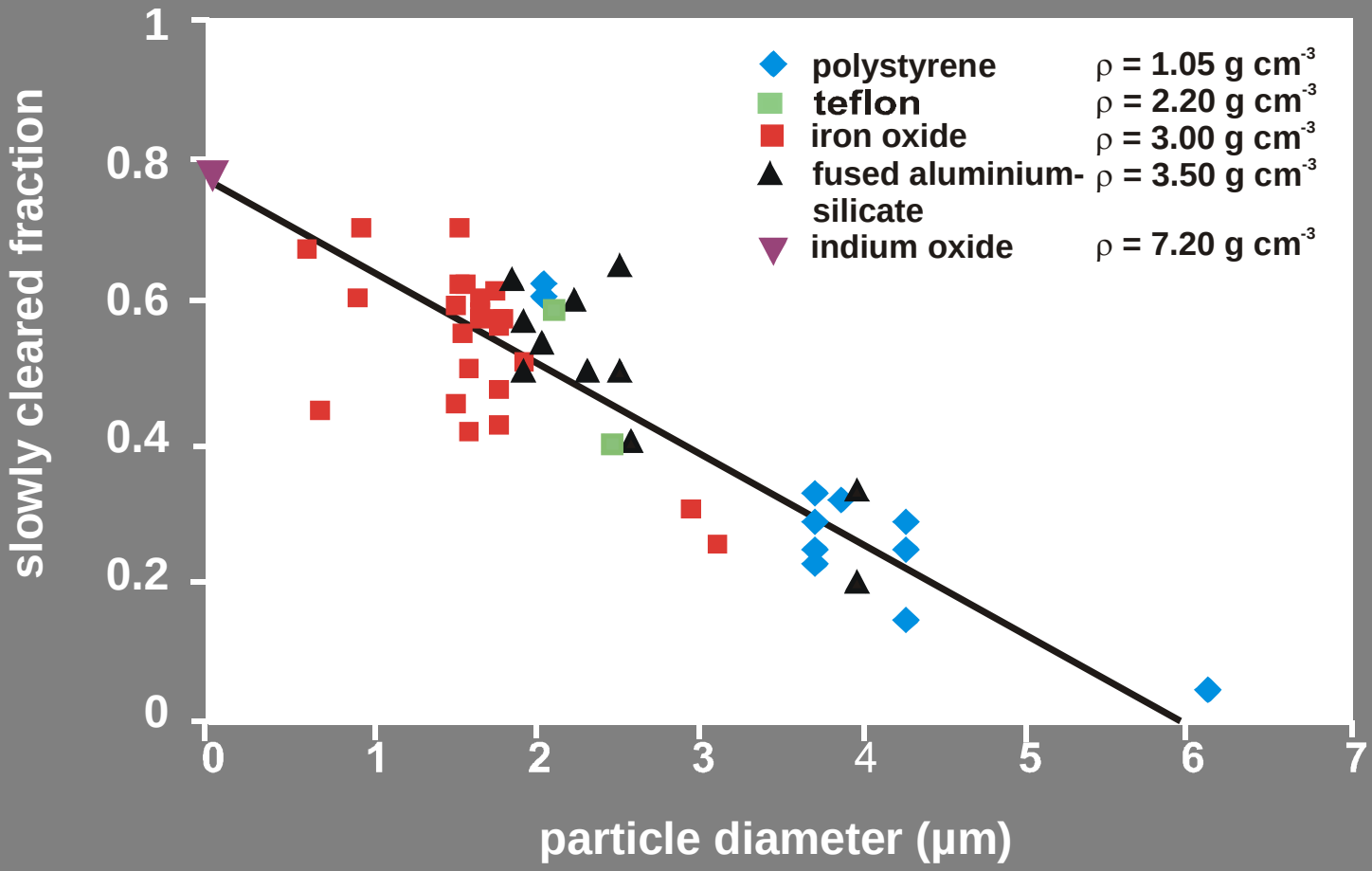
Slow Clearance from Bronchial Region



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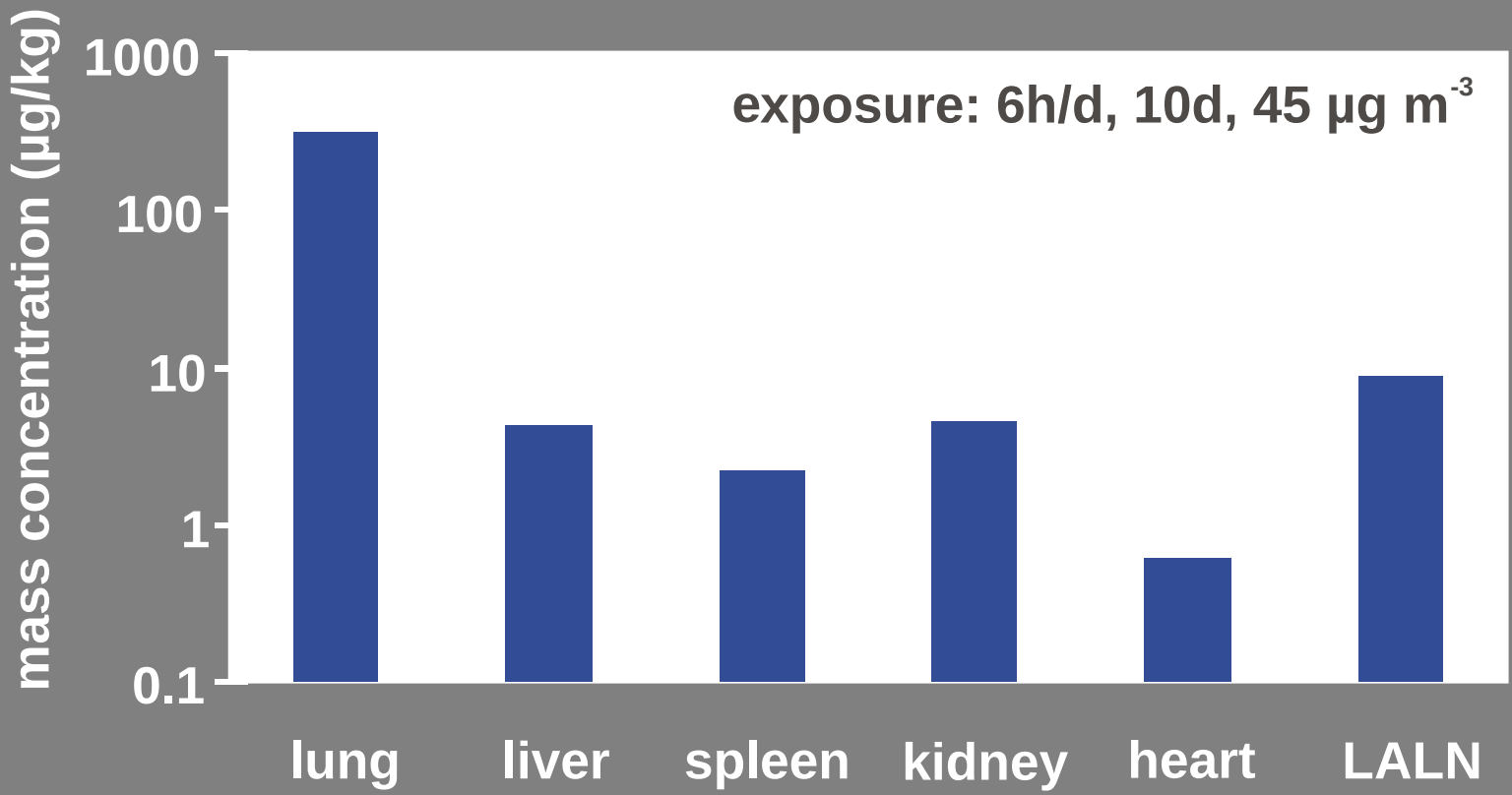
Distribution of Inhaled Ultrafine Silver Particles in Rat Organs



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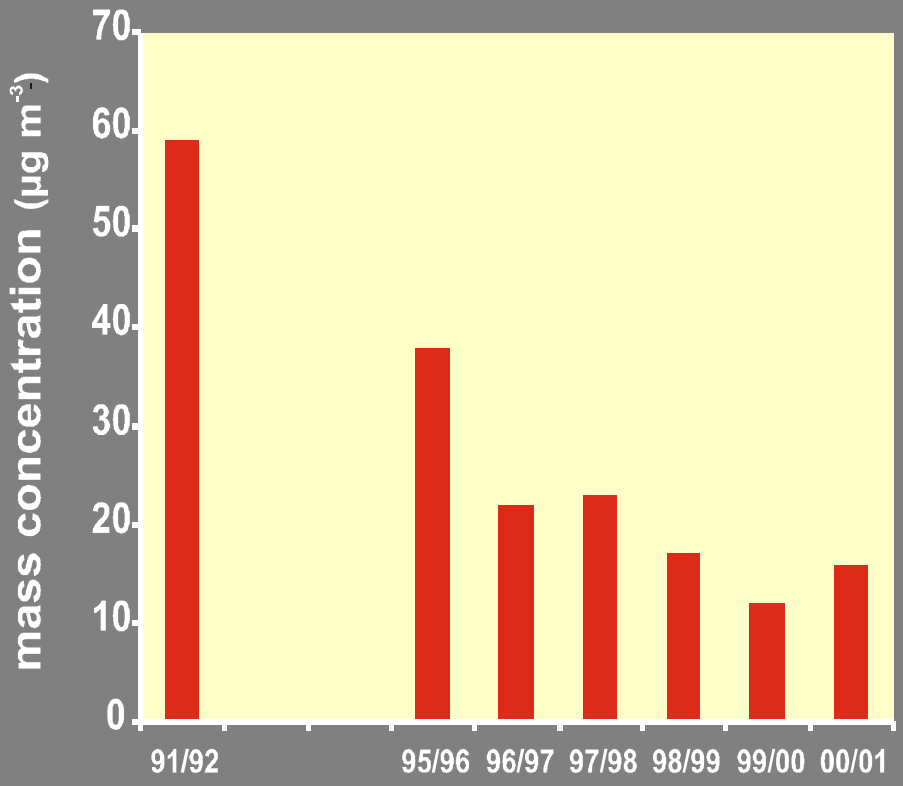
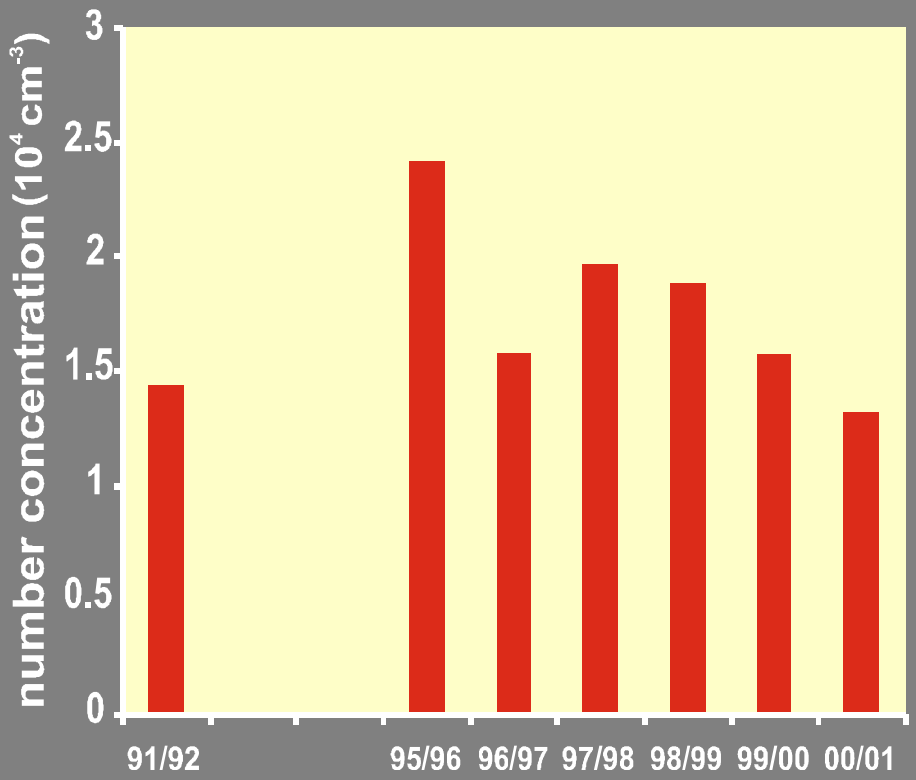
Dose Metrics of Inhaled Particles

- particle mass concentration
- particle number concentration
- particle surface concentration

Concentrations of Ambient Particles in East Germany





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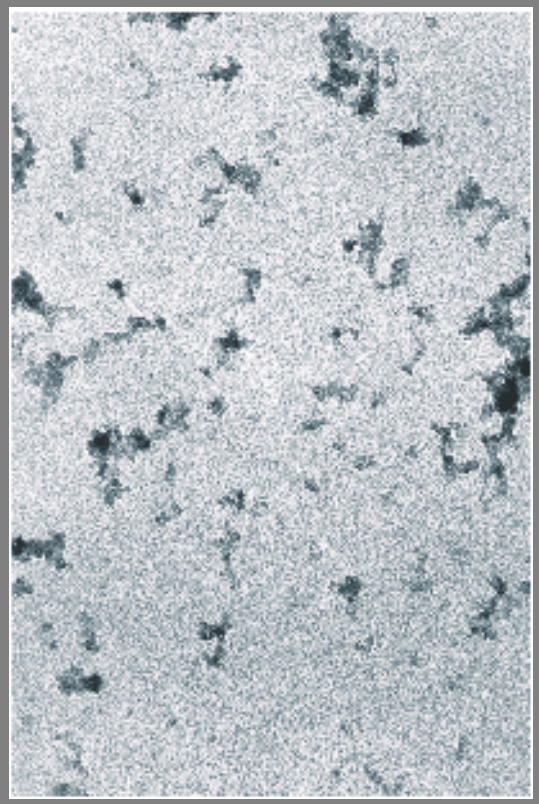
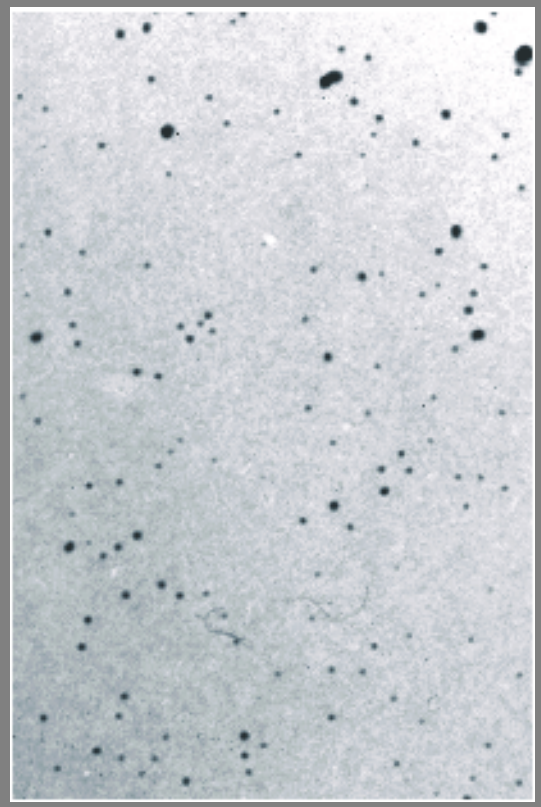
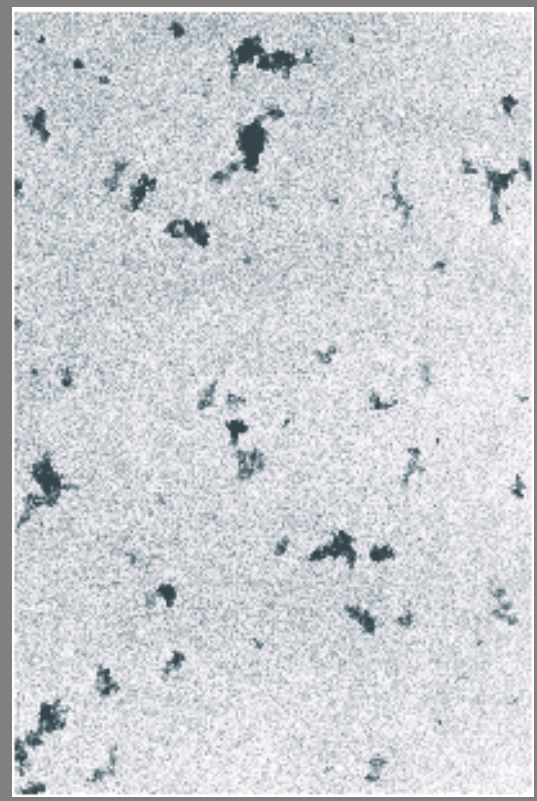
Micrographs of Ultrafine Particles



carbon particles



silver particles



iron oxide particles

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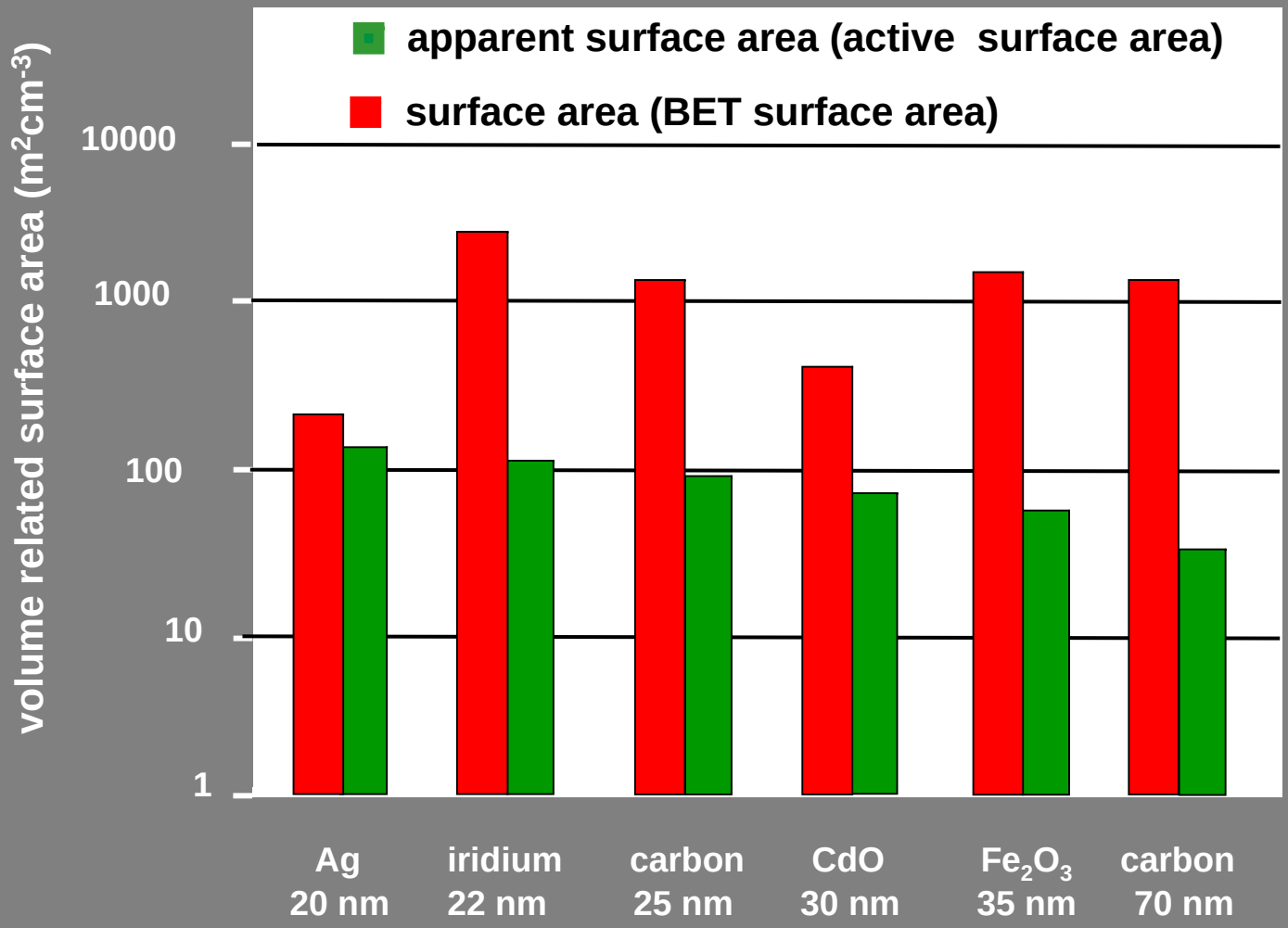
Surface Areas of Ultrafine Particles



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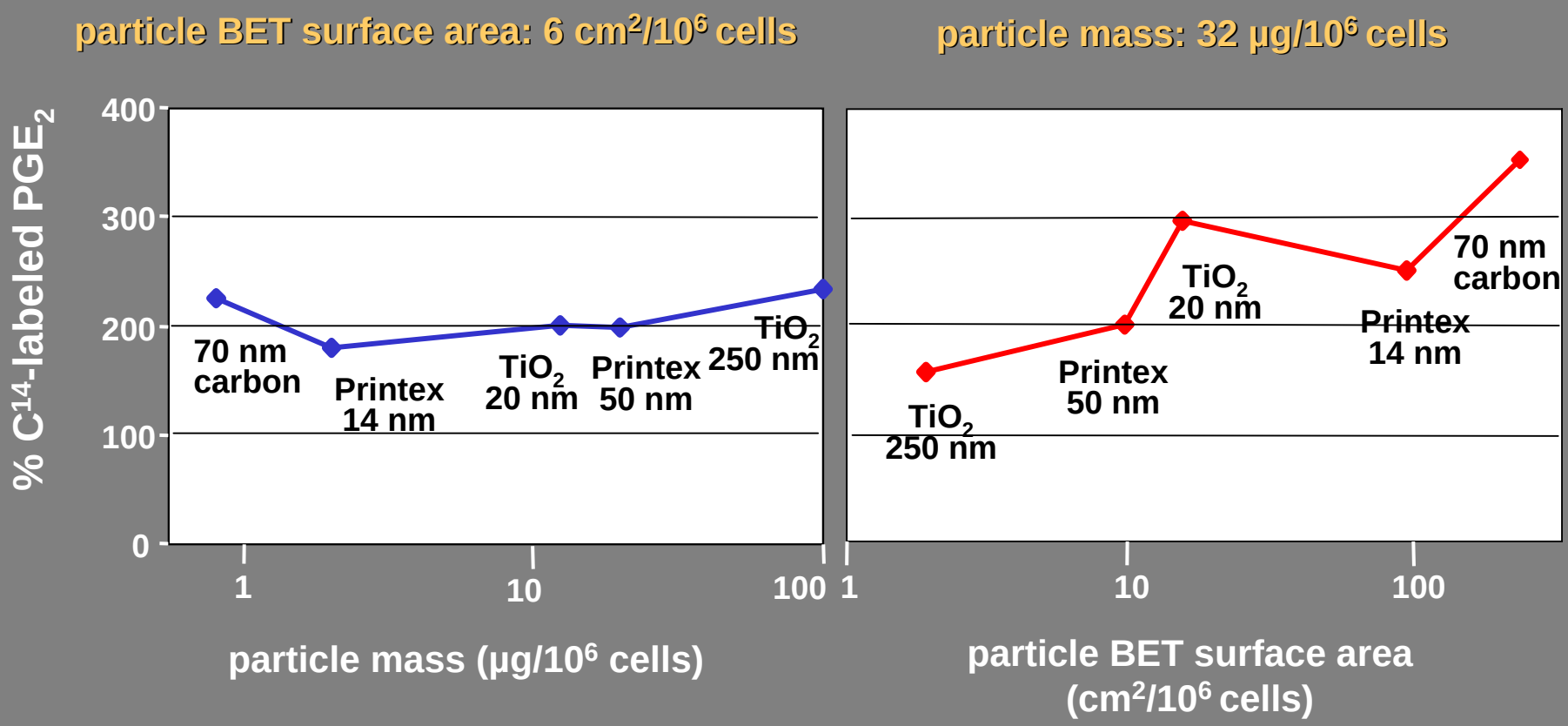
Response of Canine Alveolar Macrophages to Particles



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