

A group of five workers in a tunnel, wearing hard hats and safety gear, standing in a line. The background is a dimly lit tunnel with wooden supports.

Health Effects of Exposure to Diesel Particulate

Part 2: Sandra Dorman, PhD

Centre for Research in Occupational Safety and Health

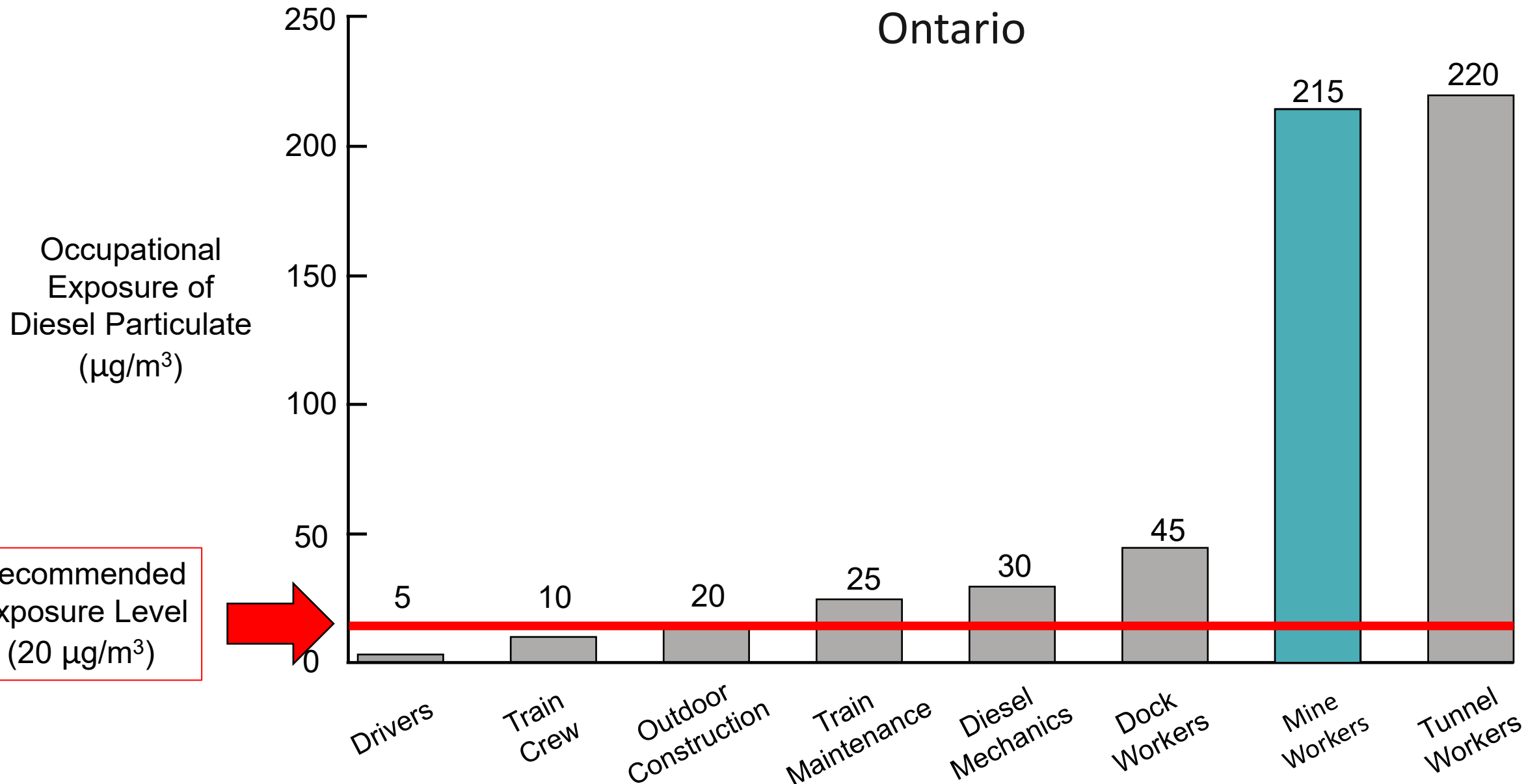
Thursday October 24, 9:00am



Composition of Particulate Matter



Many workers are regularly exposed to diesel particulate in Ontario



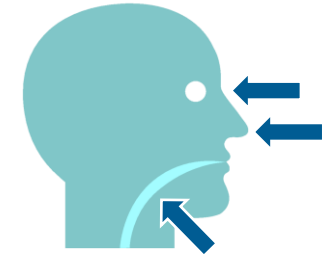
Within hours to days, exposure to high levels diesel particulate can cause:



Headaches



Dizziness



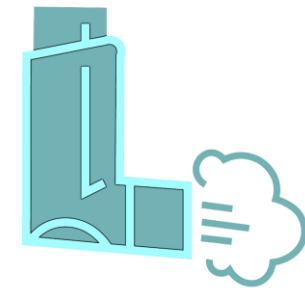
Irritation of eyes, nose,
and throat



Wet cough, phlegm



Runny nose, allergy
symptoms



Asthma attack

Chronic Exposure can cause:

Cancer

Idiopathic Pulmonary Fibrosis (IPF)

Chronic Obstructive Pulmonary Disease (COPD) /
Emphysema

Cardiovascular Disease (CVD)

Onset of asthma or worsening of asthma

Worsening of diabetic comorbidities

Why is diesel particulate so harmful?

Diesel particulate is classified as a Group 1 **known human carcinogen** (IARC)*: it causes or contributes to lung and bladder cancer.

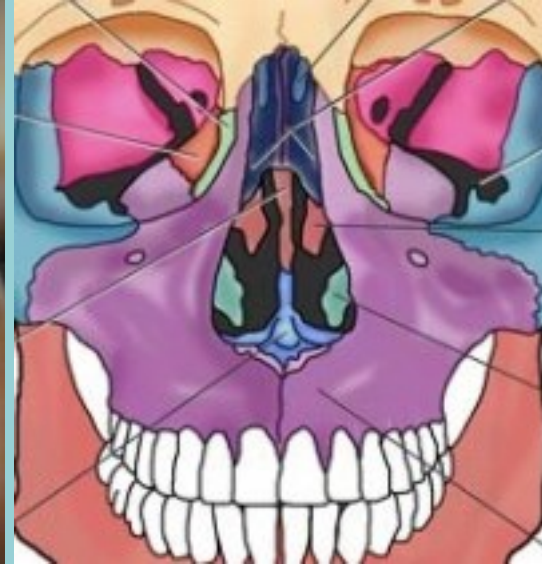
Inhaled diesel particulate **directly** damages lung tissue.

The smallest particles penetrate deep within the lungs and can enter the bloodstream, travelling to the heart and other organs.

The Nose

Filter

Exercise



The Lungs

23 branching generations

Conduction:

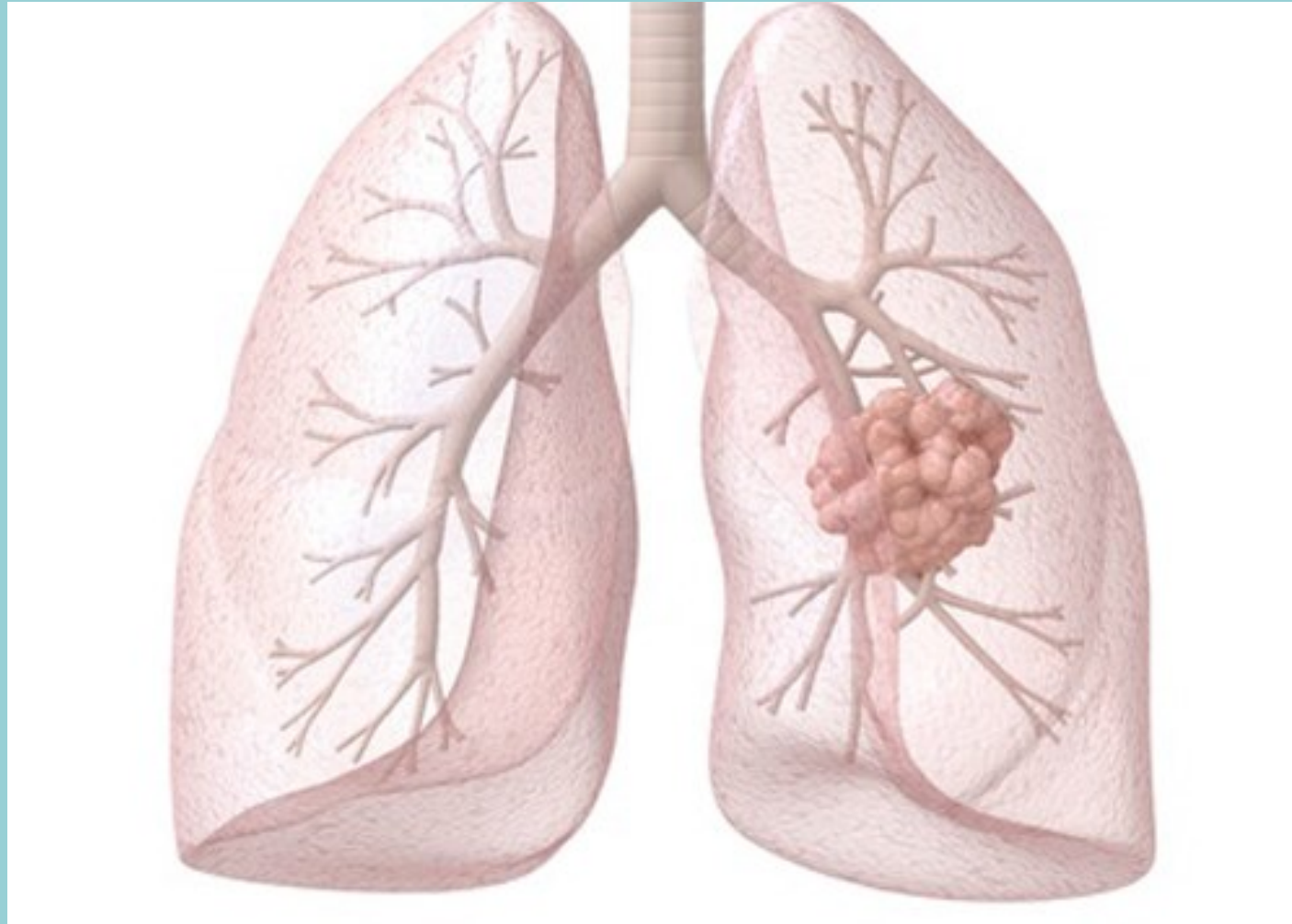
- 0-8 trachea and bronchi

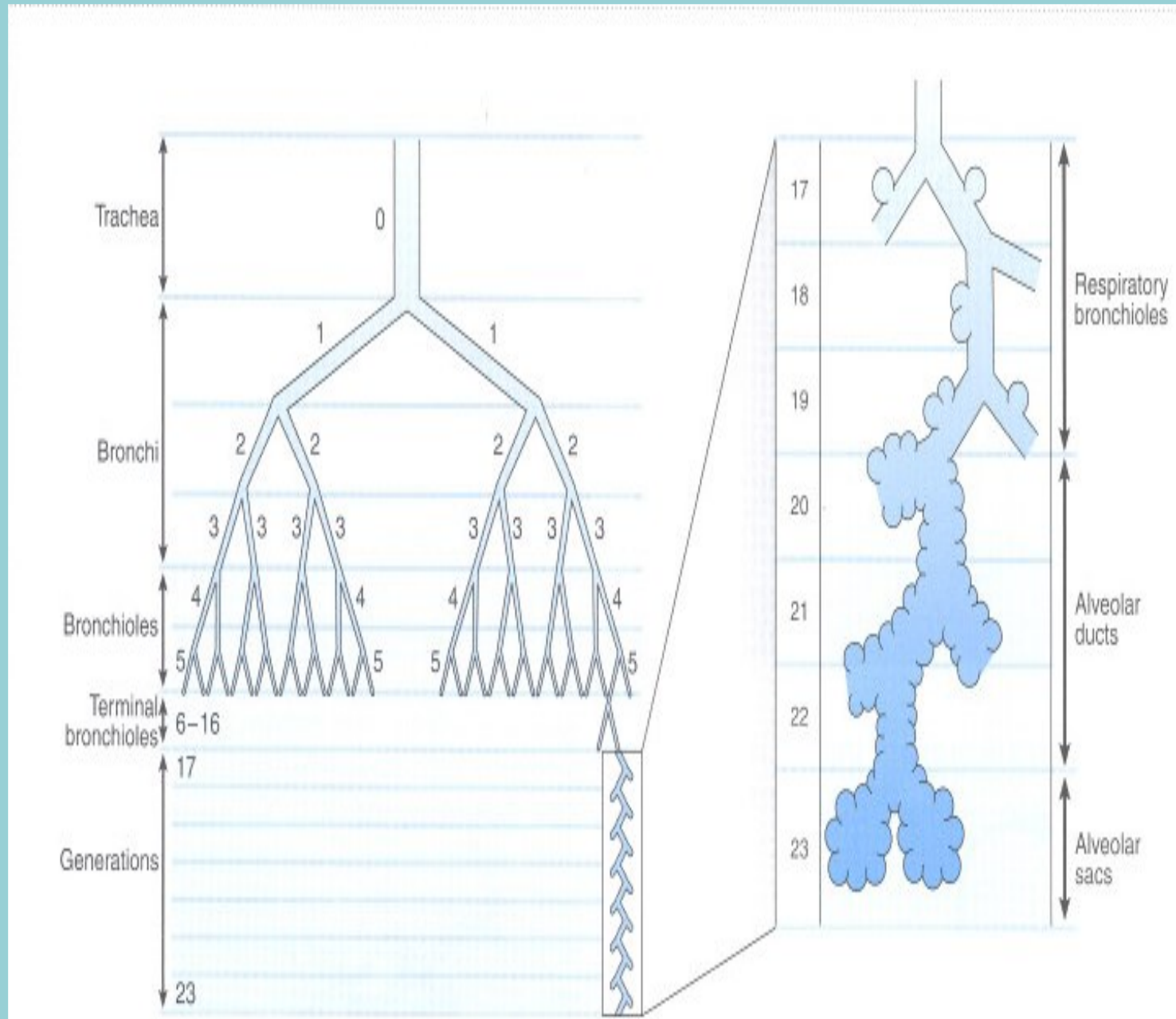
Conduction and diffusion:

- 9-16 bronchioles

Alveolar diffusion:

- 16-23





Weibel lung model 1963

Generation 0
1 airway
2 cm diameter

Total cross-sectional
area 3 cm²

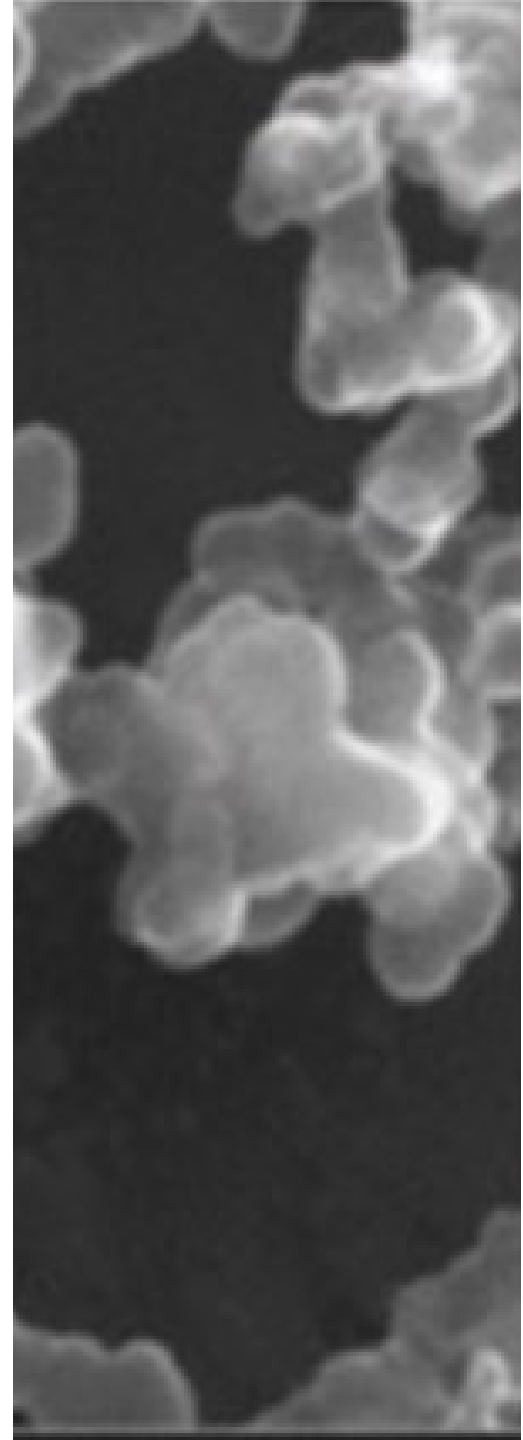
[1 cm
along
airways

Generation 23
3 x 10⁶ airways
0.04 cm diameter

Total cross-sectional
area 8 x 10⁵ cm²

1 2 10 100 1000 10000
Total cross-sectional area (cm²)

Particulate Composition

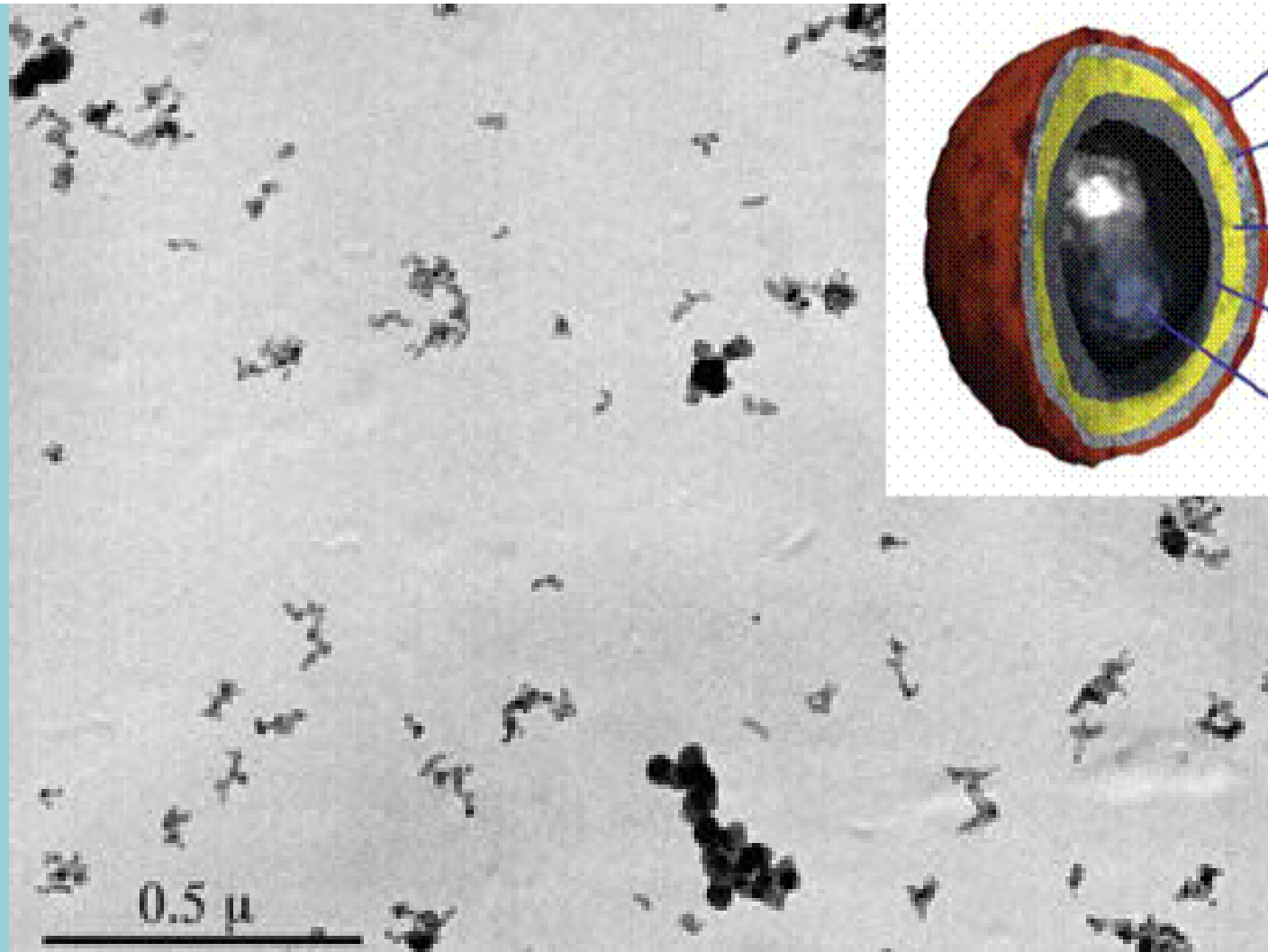


Mechanisms of Deposition

- Physical and chemical characteristics of the particle
- Properties of the particle kinetics in air
- Biological factors

Physical/Chemical Properties

- Shape
- Contents
- Size



Particle size

PM = Particulate Matter

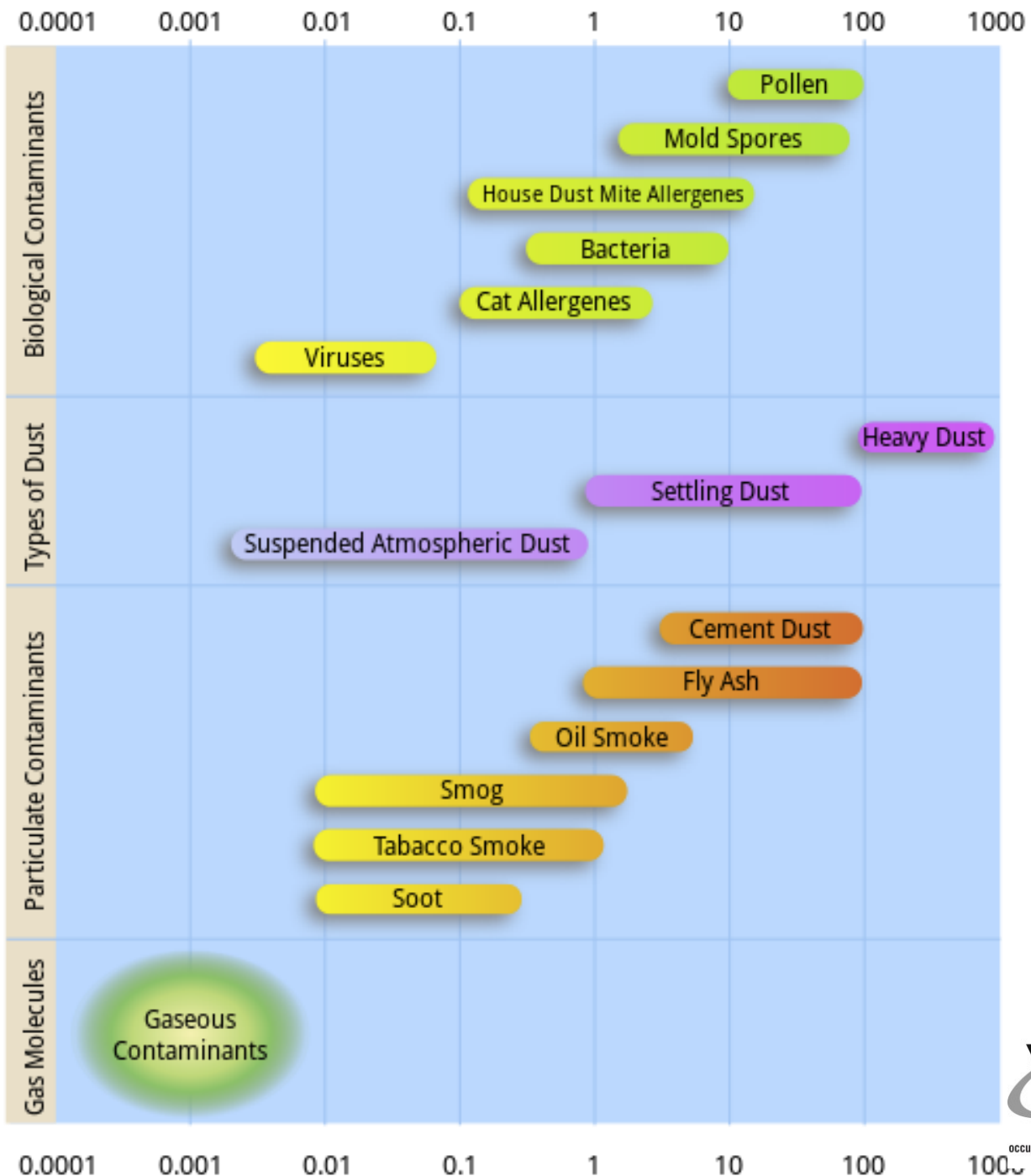
Inhalable particles are particles $10\mu\text{m}$ and smaller

PM_{10} : particles with a diameter between $2.5\text{-}10\mu\text{m}$

$\text{PM}_{2.5}$: particles with a diameter between $0.1\text{-}2.5\mu\text{m}$

Ultrafine: less than $0.1\mu\text{m}$

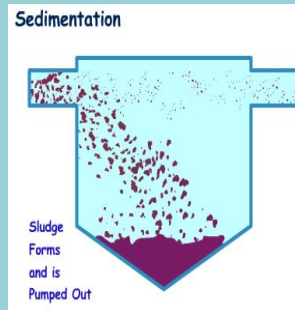
<https://en.wikipedia.org/wiki/Particulates>



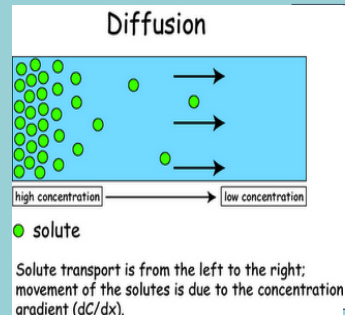
Particle Kinetics & Deposition



Impact

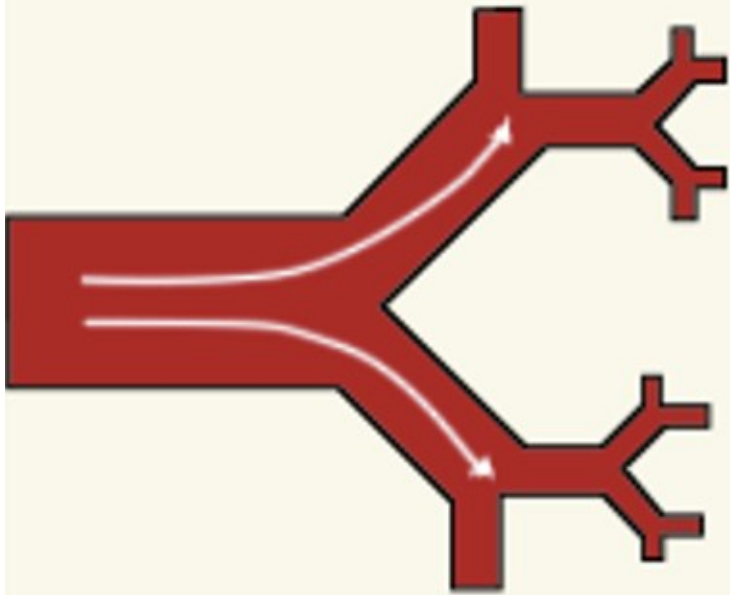


Sedimentation



Diffusion

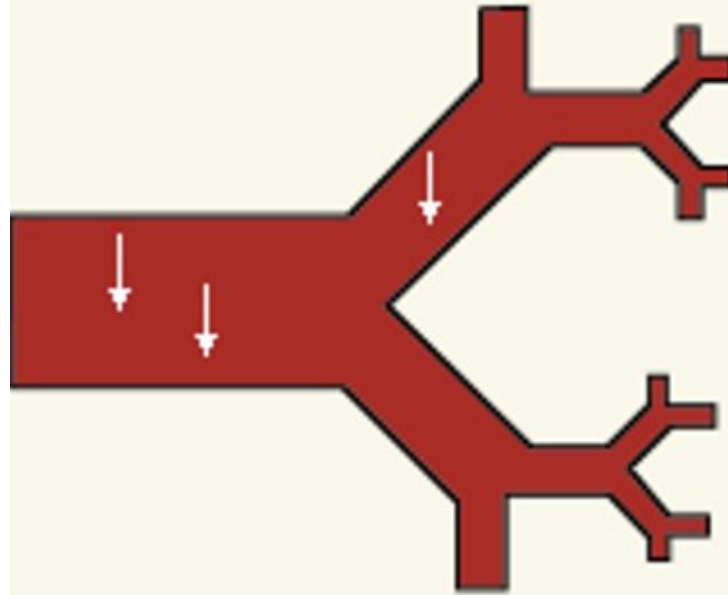
Impaction



Inertia

● 5-10 microns (dust, plant spore, mold)

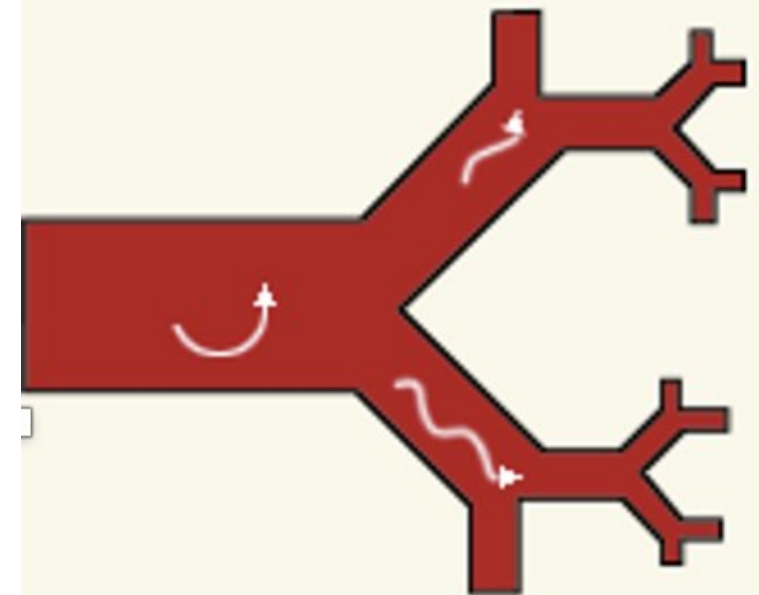
Sedimentation



Gravitation

· 0.3-1 microns (bacteria, tobacco, Cooking smoke, metallic fumes)

Diffusion



Brownian*
movement

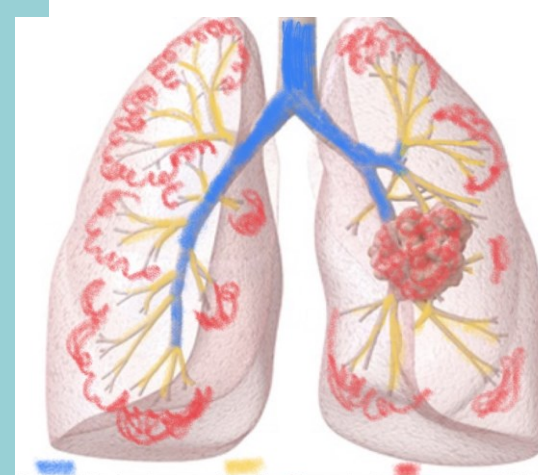
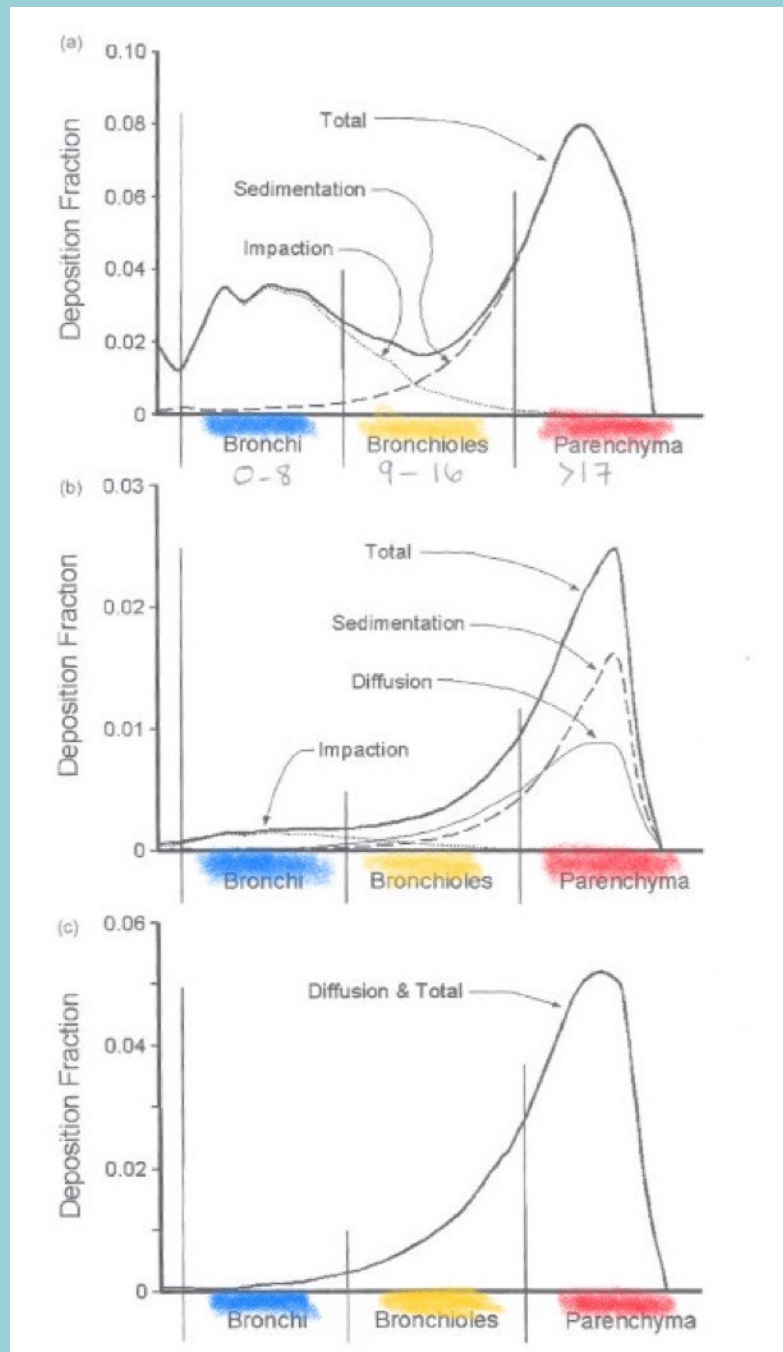
0.001-.01 microns (viruses)

0.001-0.01 Microns _ Viruses

Predicted lung Deposition by size

Smallest particles get into the deepest part of the airways

Foster & Costa. Lung Biology in Health and Disease. 2005



Bronchi 0-8	Bronchioles 9-16	Parenchyma >17
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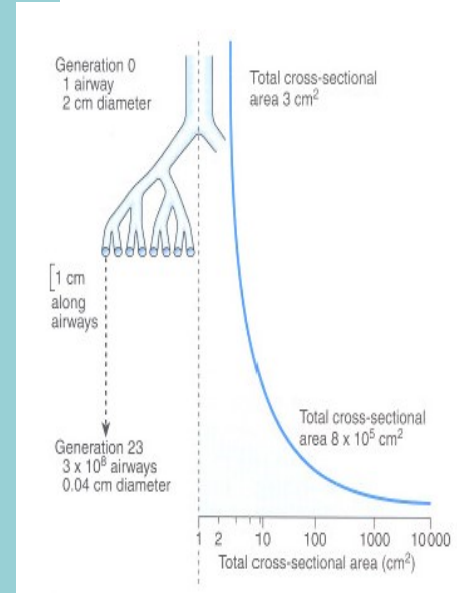
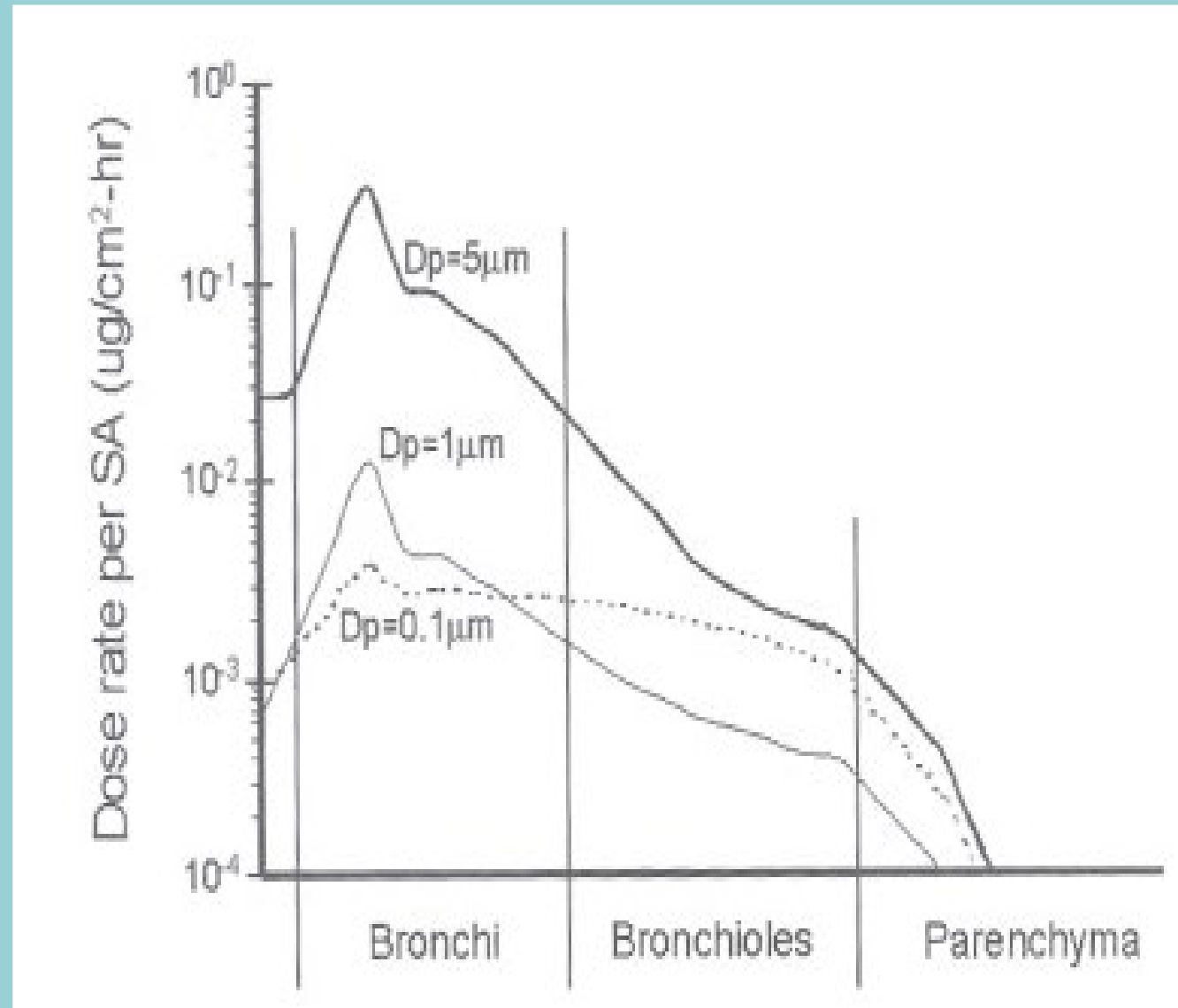
5 μm

1 μm

0.1 μm

Deposition by size and surface area

Most of the deposition occurs in the upper airways





Biology of individual

Different people have different lung volumes & breathing rates

EXPOSURE → DOSE → RESPONSE

Small



(4 liters)

Large



(6 liters)

Deposition increases with:

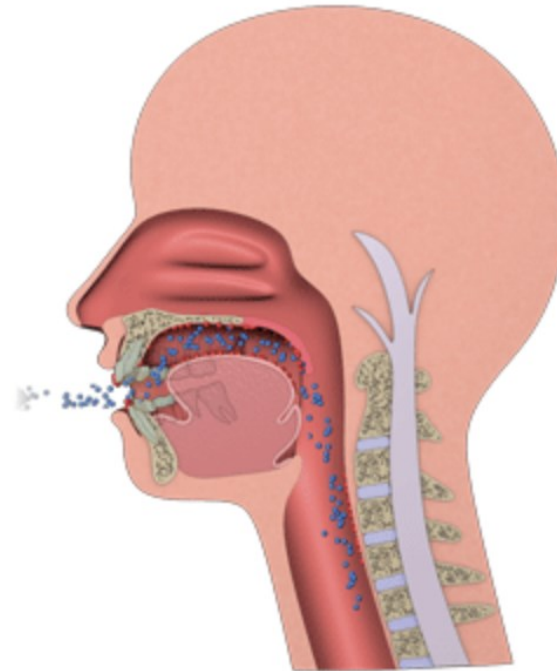
- increasing volume (larger person = larger volume);
- increased resistance;

Effect of Physical Activity

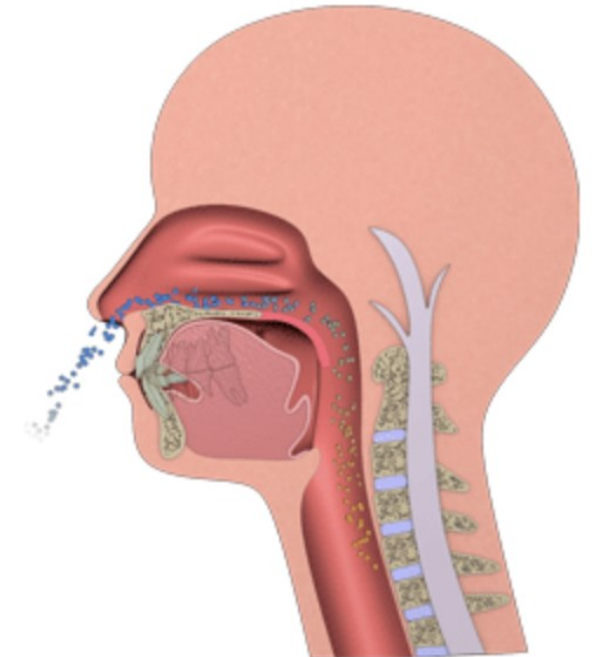
Deposition increases with increases in breathing rate (exercise).

Upper airway deposition increases with increased airway velocity

Nose to mouth breathing is an important aspect



MOUTH BREATHING

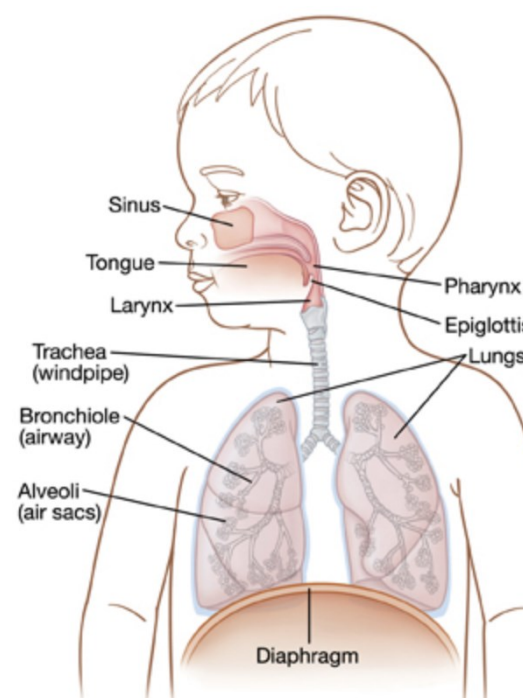
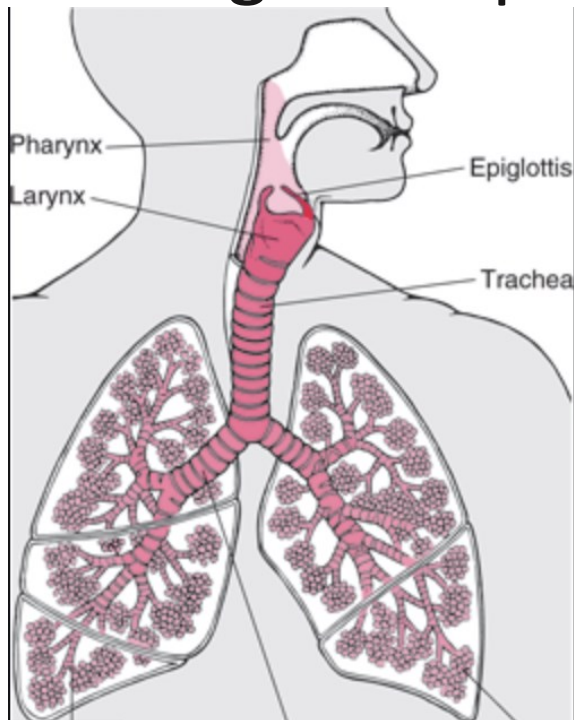


NOSE BREATHING

Gender / Size

Women have higher depositions per unit in the upper airways

Men have higher deposition in their lower airways



Age

Children will have higher upper airway deposition due to anatomical size

Older adults with normal lung function should have minimal changes in tidal volume and minute ventilation and so should not have altered deposition patterns

Lung Disease

Breathing patterns change with lung disease

These changes effect total deposition

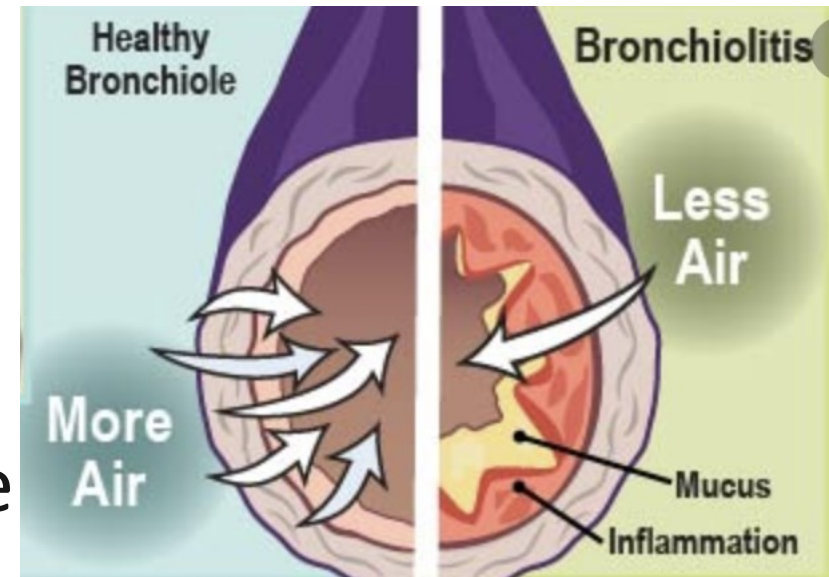
COPD – higher minute ventilation

Bronchitis – increased deposition (narrowed airspaces)

Asthma – increased deposition

Smokers – increased deposition

Smokers - with small airways disease



Other



Smoking



Air pollution



Particle Clearance

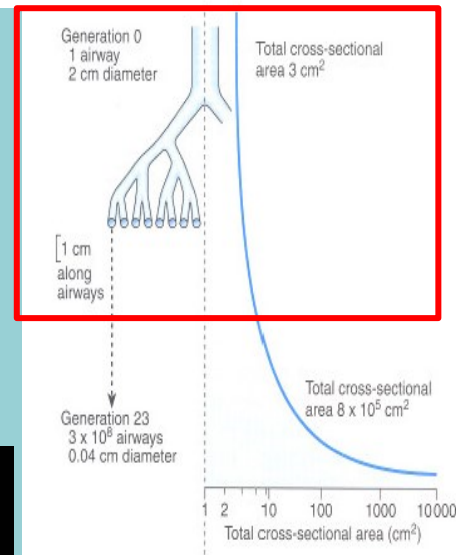
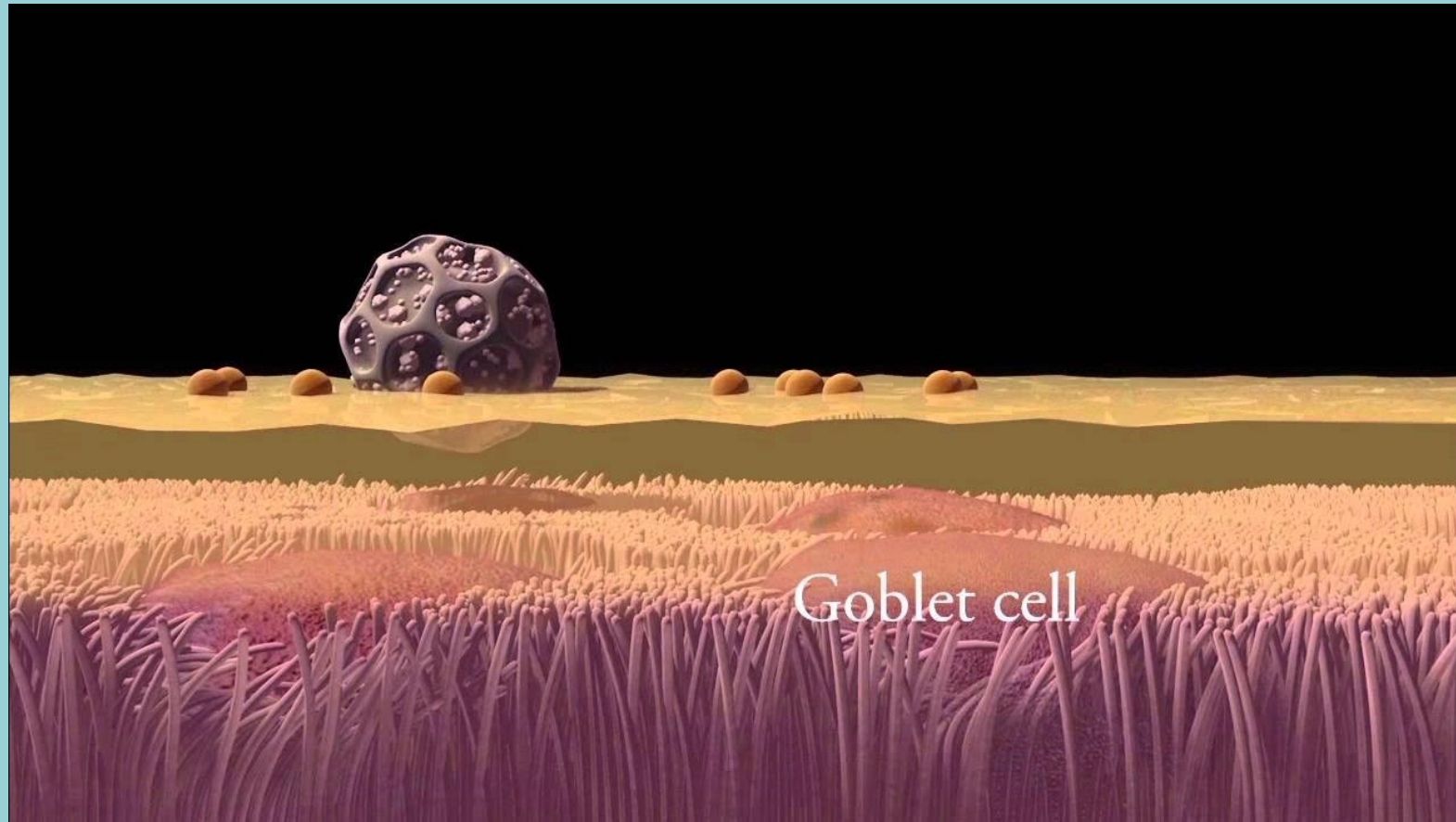


Two main methods:

Particles get trapped in mucus layer (1)
Ciliated cells sweep the mucus and particles up and out (2)
Cough spit/swallow

Upper Airways:
1. physical removal

clearance Time:
~ 2-24 hours

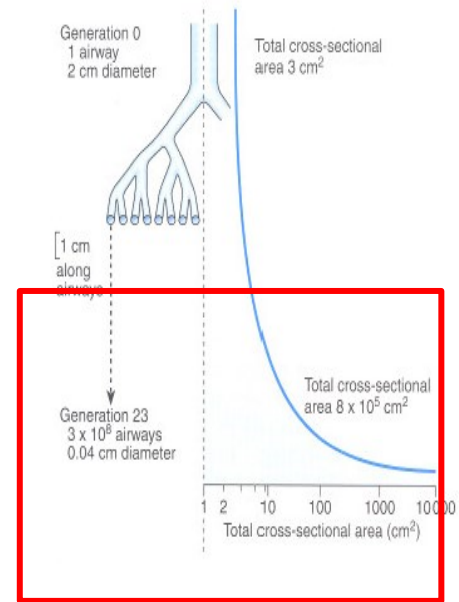
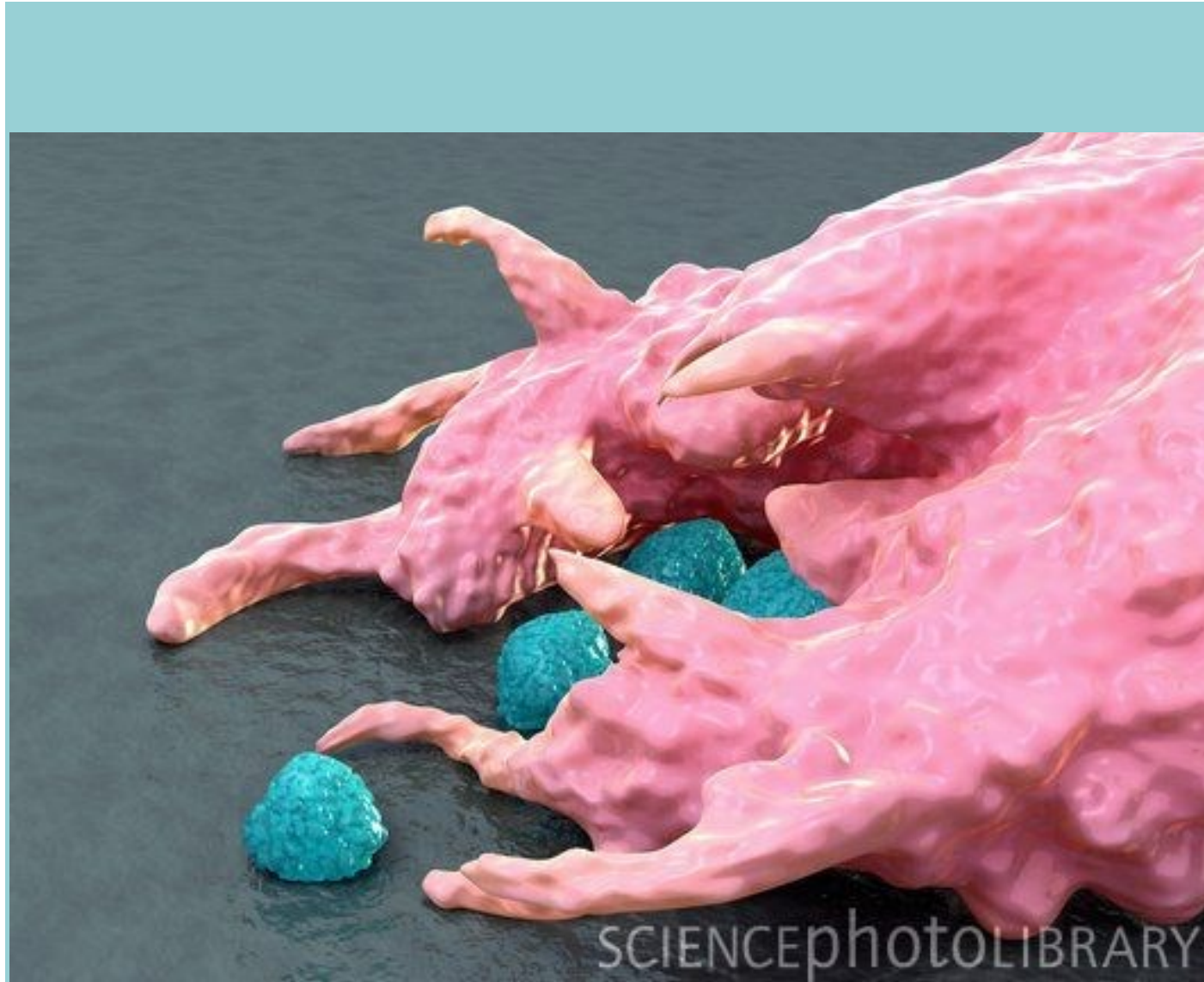


Lower Airways

2. Absorption

direct
or via cell
uptake

clearance Time:
>24 hours -
Months



Clearance Rates

- Location matters
- Size matters
- Total number matters

Biologic alterations in clearance



Drugs

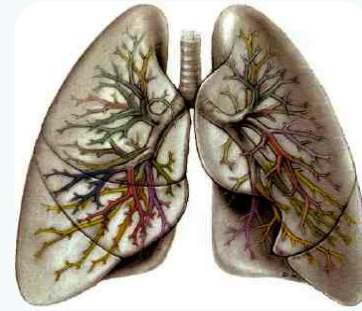


Age

Immune
system



Physical
activity

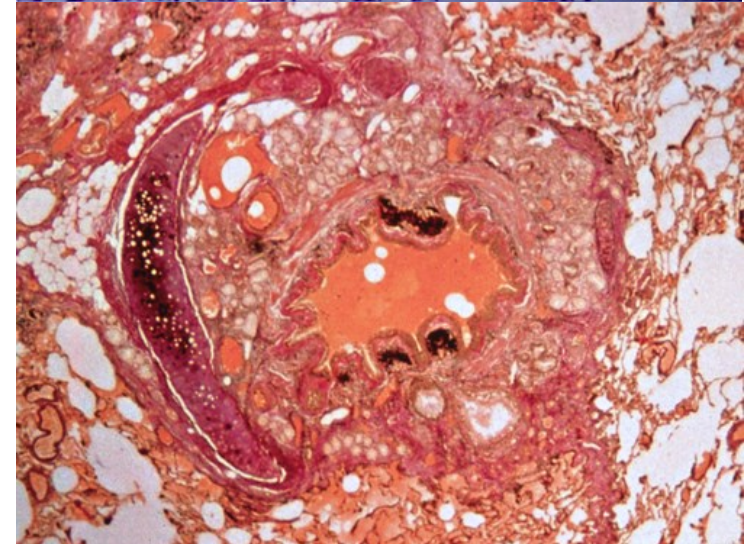
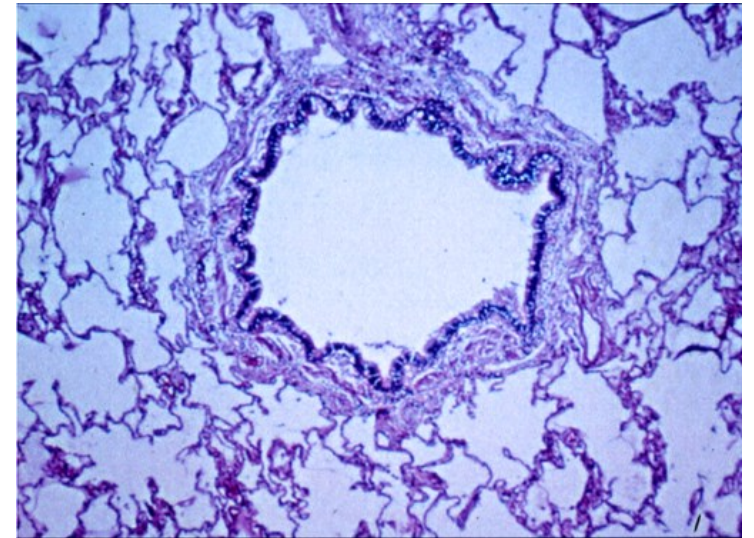
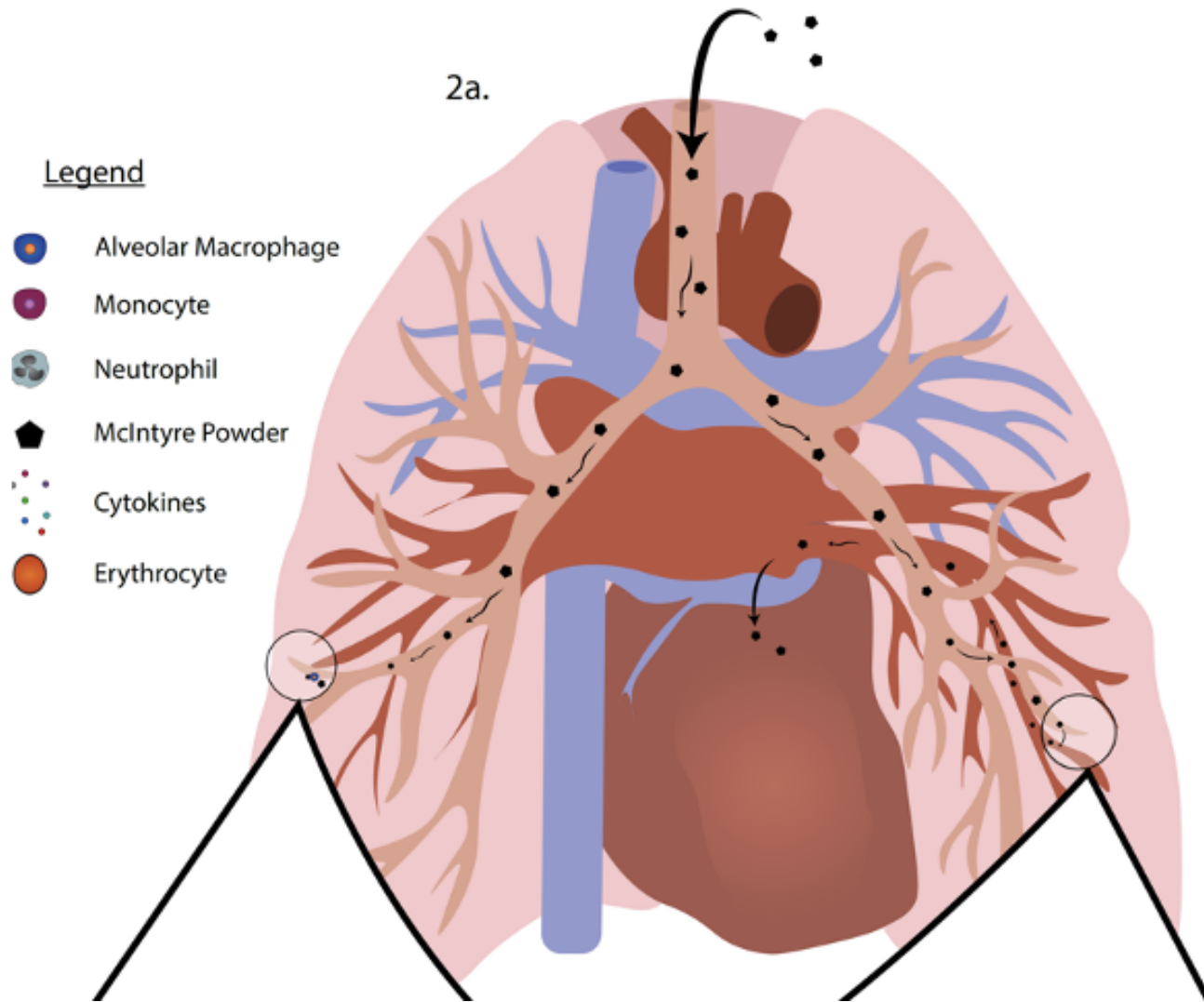


Lung
disease

Mechanisms of Particulate Damage



Direct Damage to Lung Cells

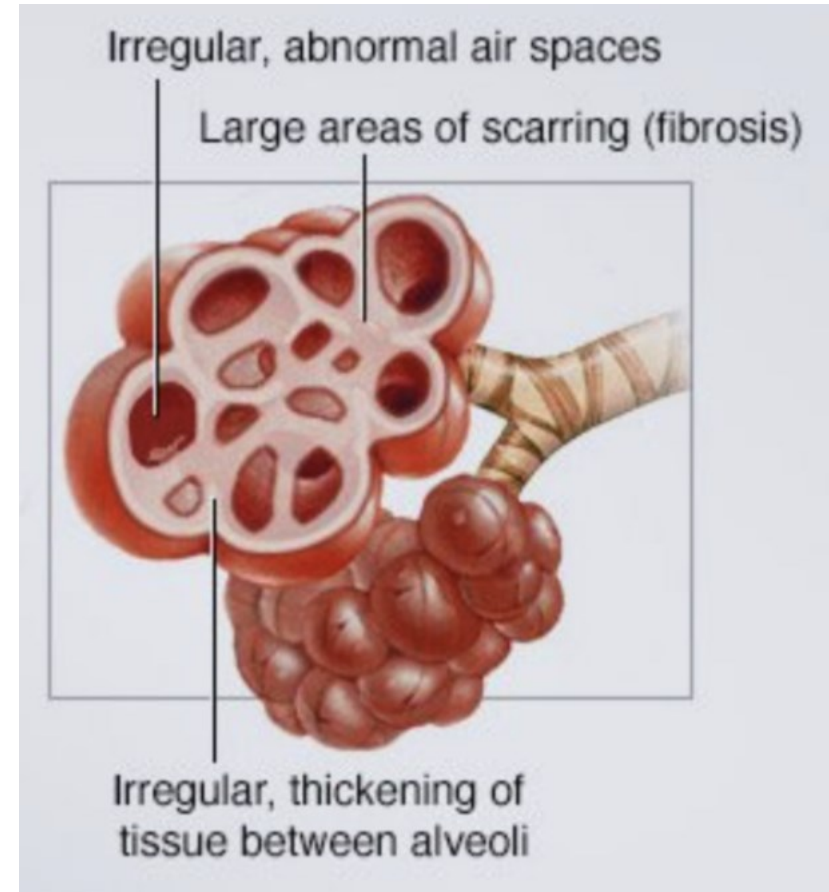
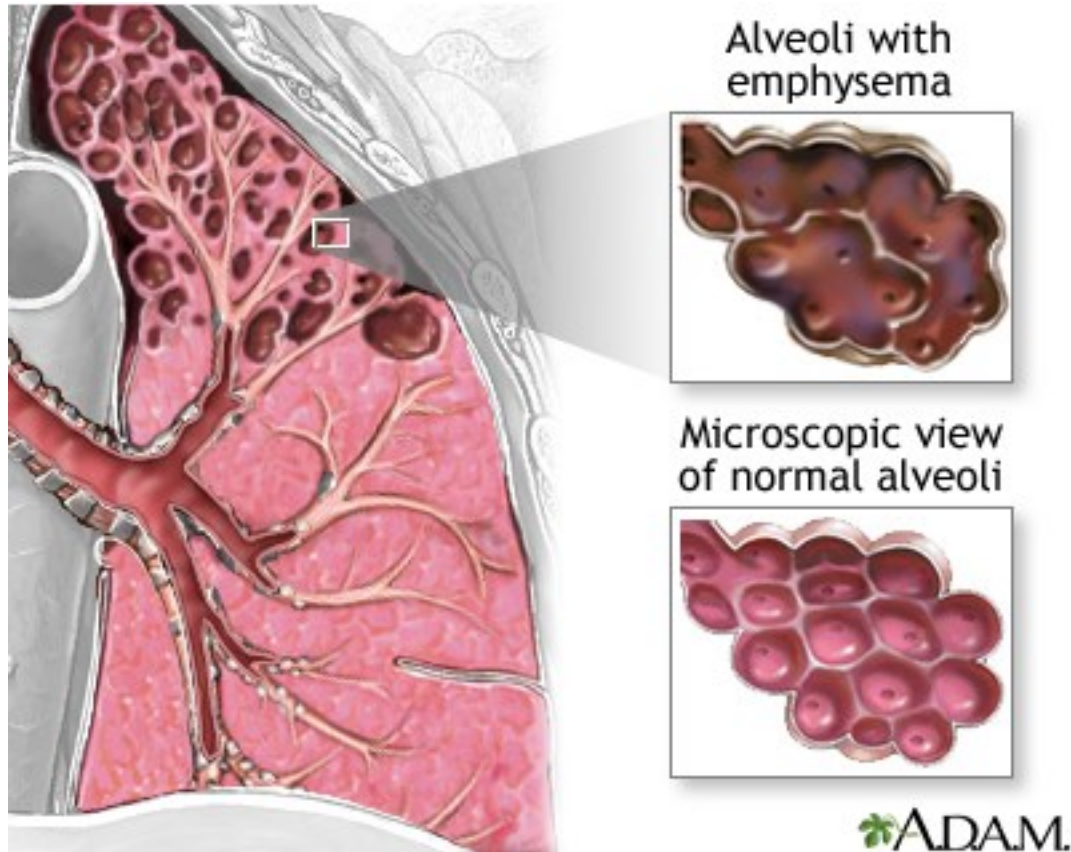




COPD & Idiopathic Pulmonary Fibrosis



COPD & Idiopathic Pulmonary Fibrosis

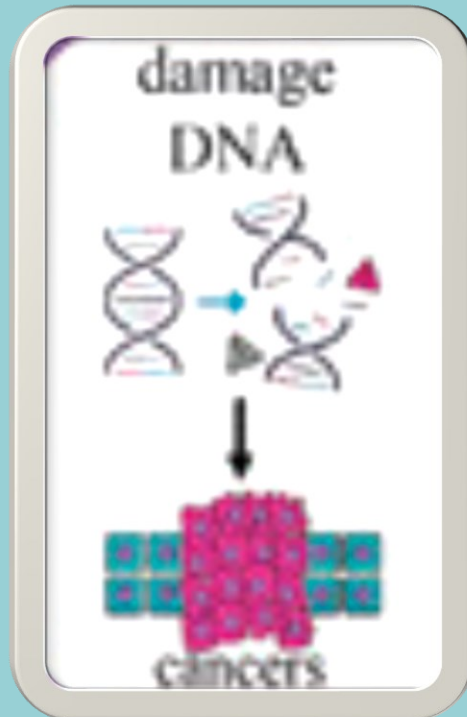




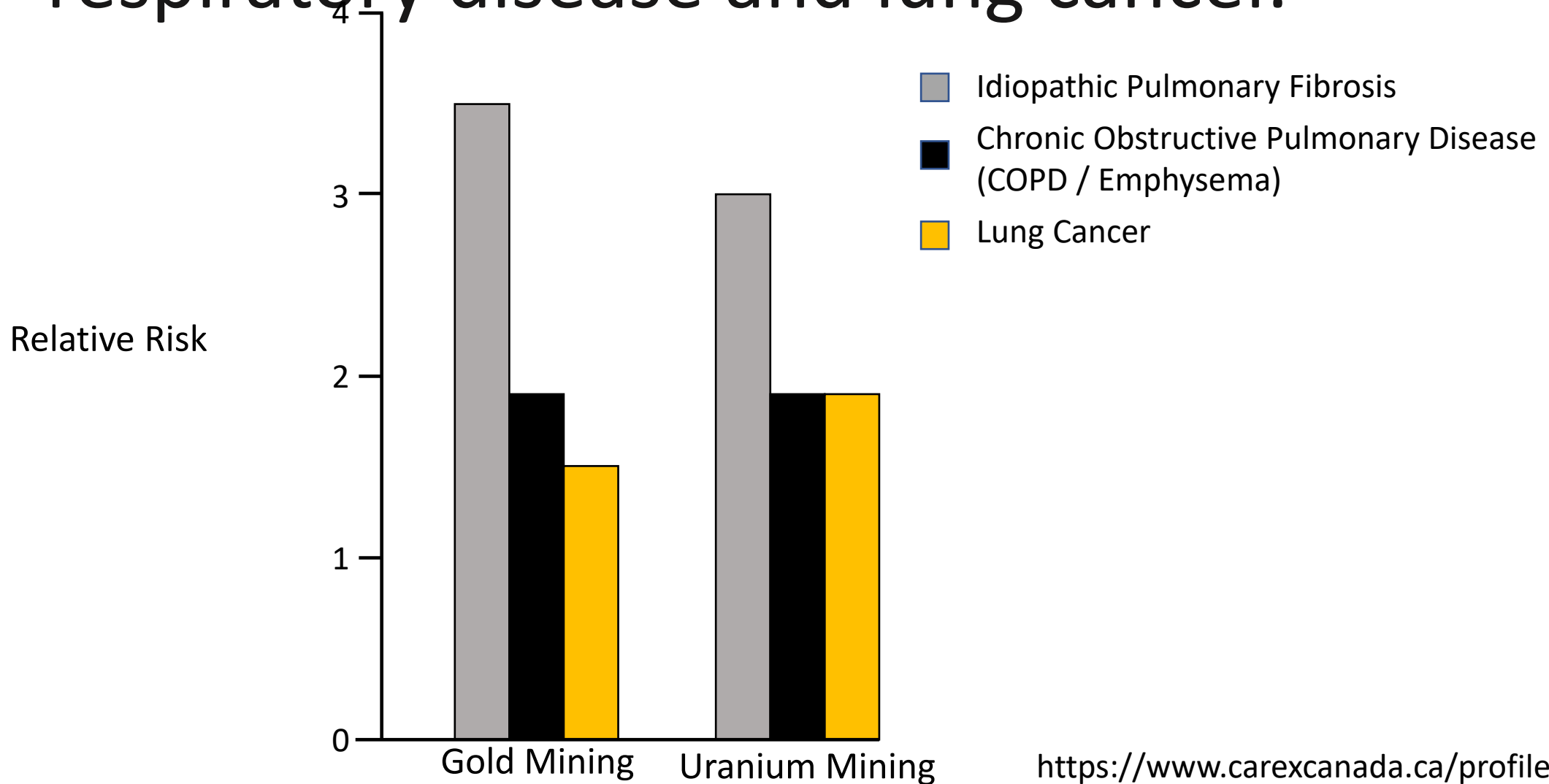
Cancer

Cancer: Properties of Cells

- Starts from a single cell
- Assaults on the cell can cause changes to the cell's DNA



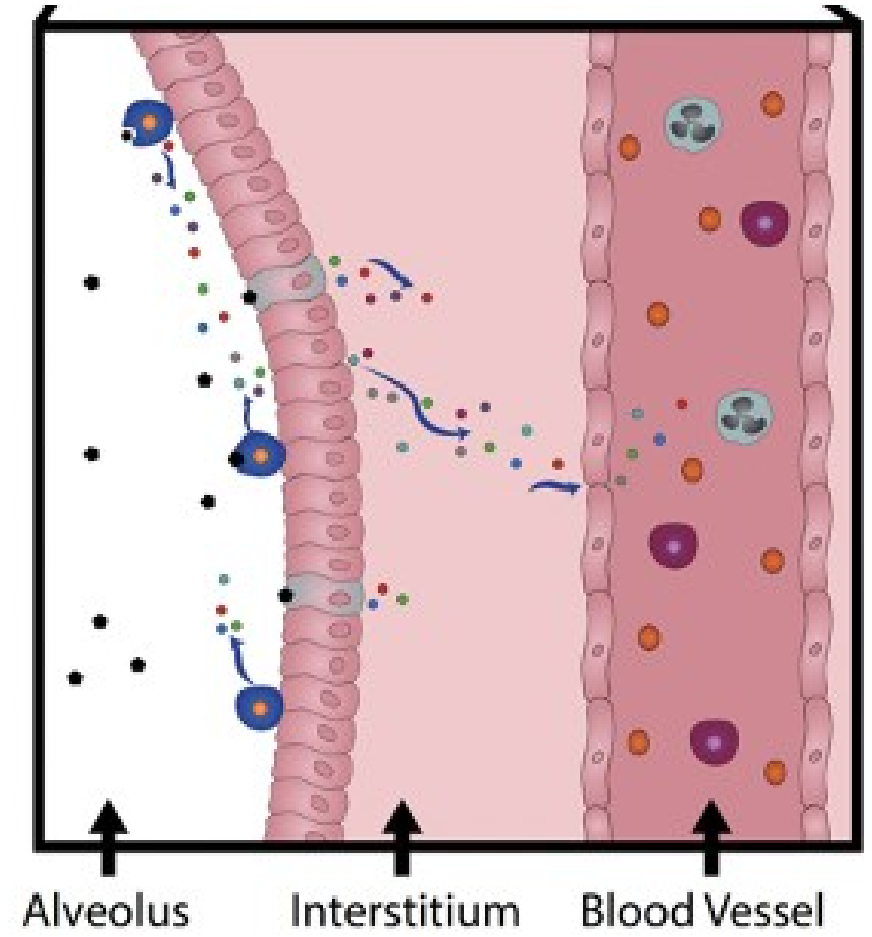
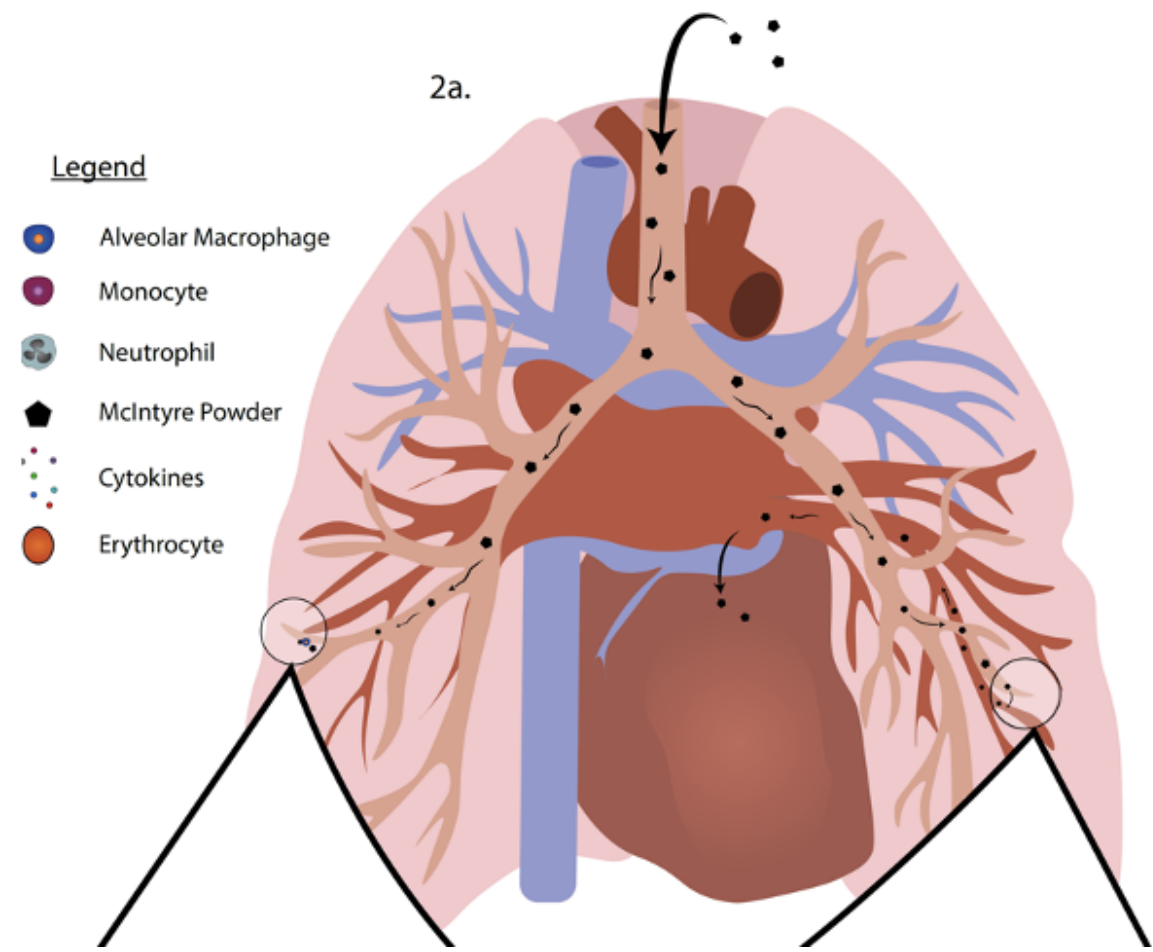
Underground miners are at increased risk for respiratory disease and lung cancer.



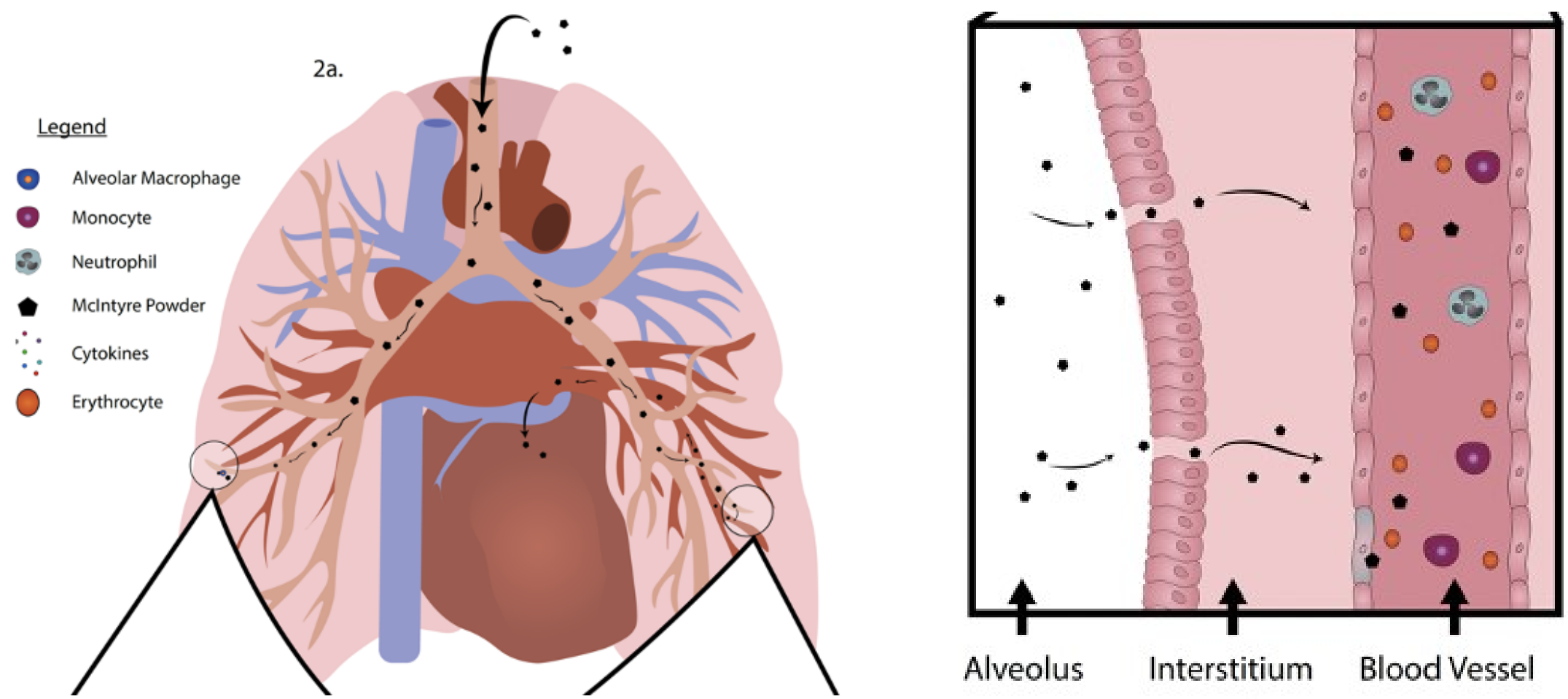
Mechanisms of Particulate Damage



Inflammation



Movement from the airways to the blood

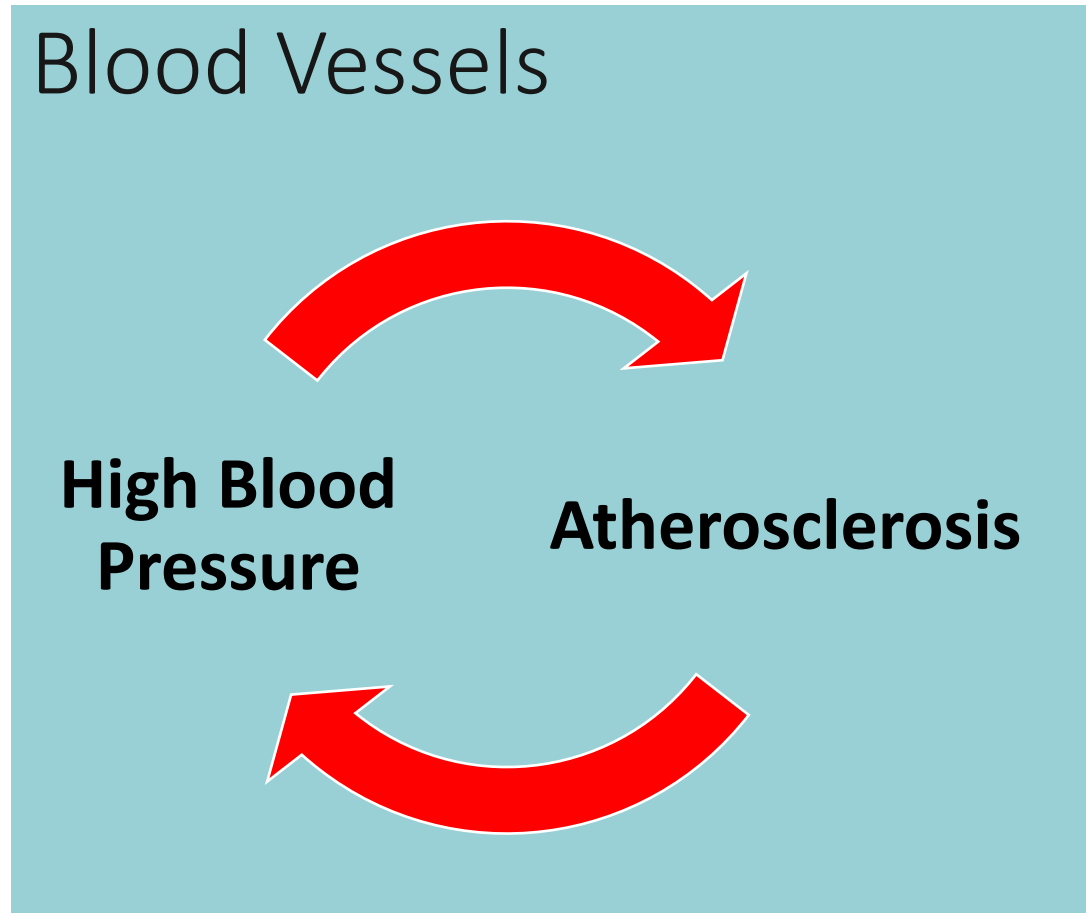




Cardiovascular Disease & Stroke



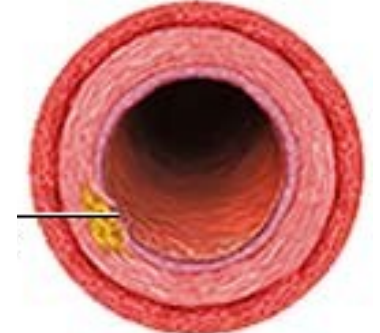
Major Vascular Diseases



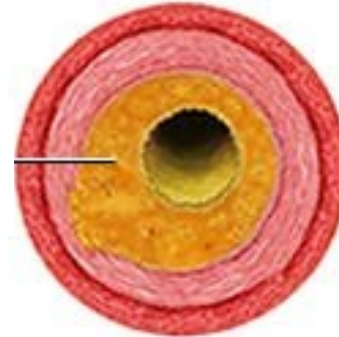
Normal artery



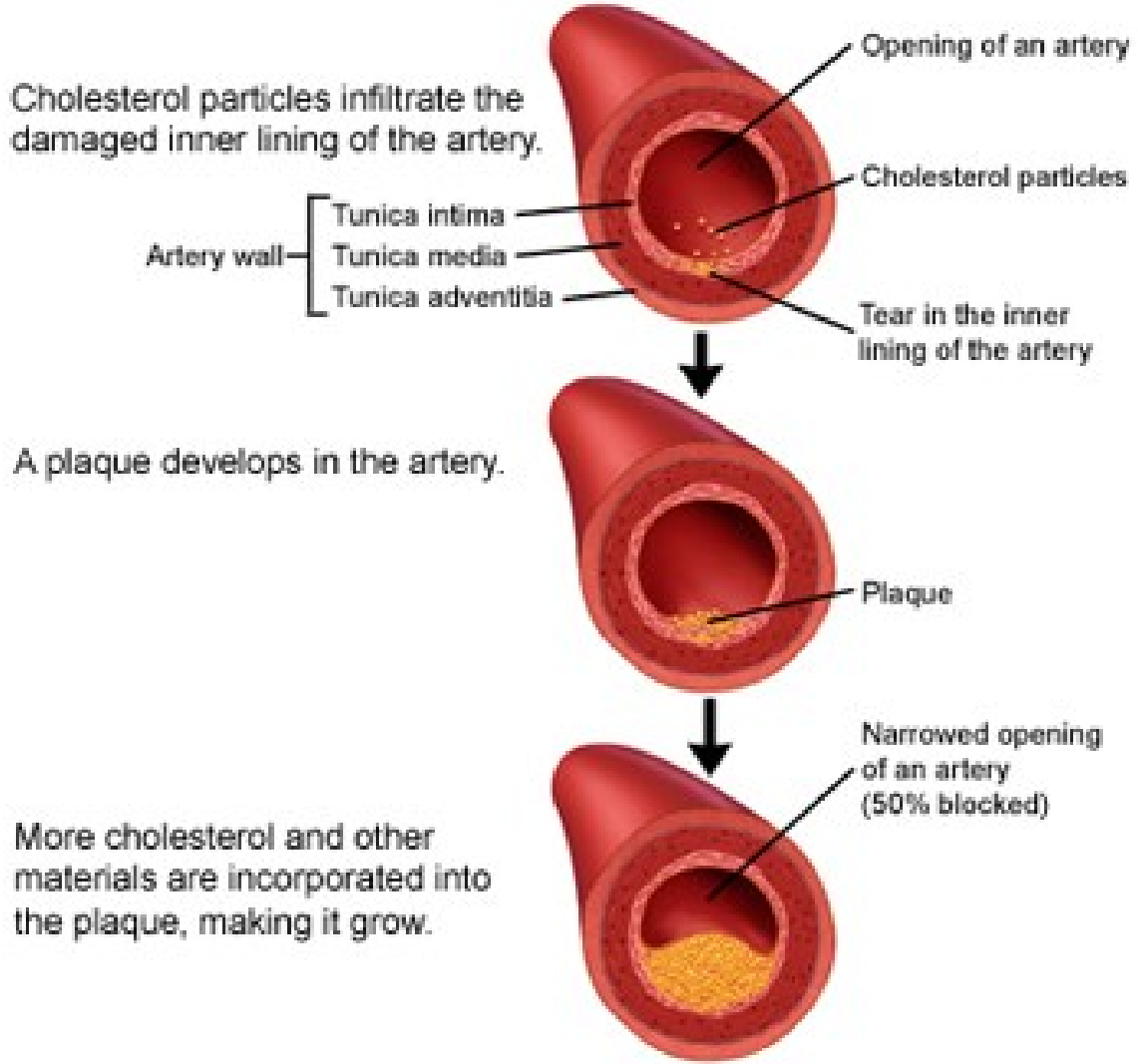
Tear



Fatty plaque



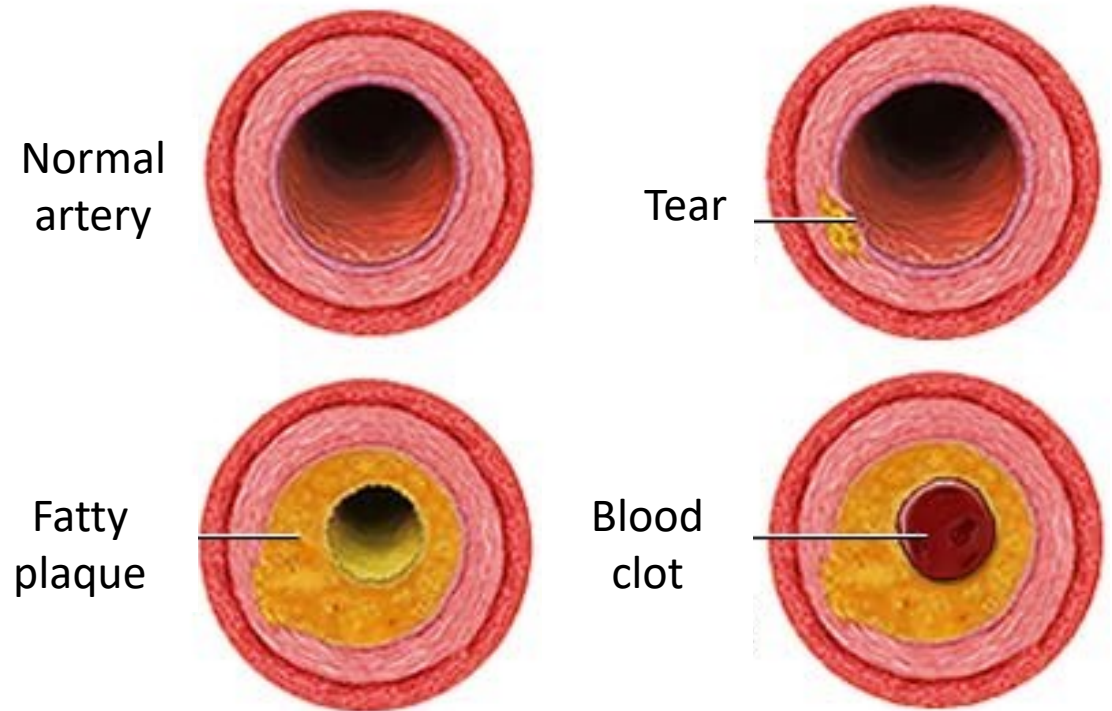
Tears



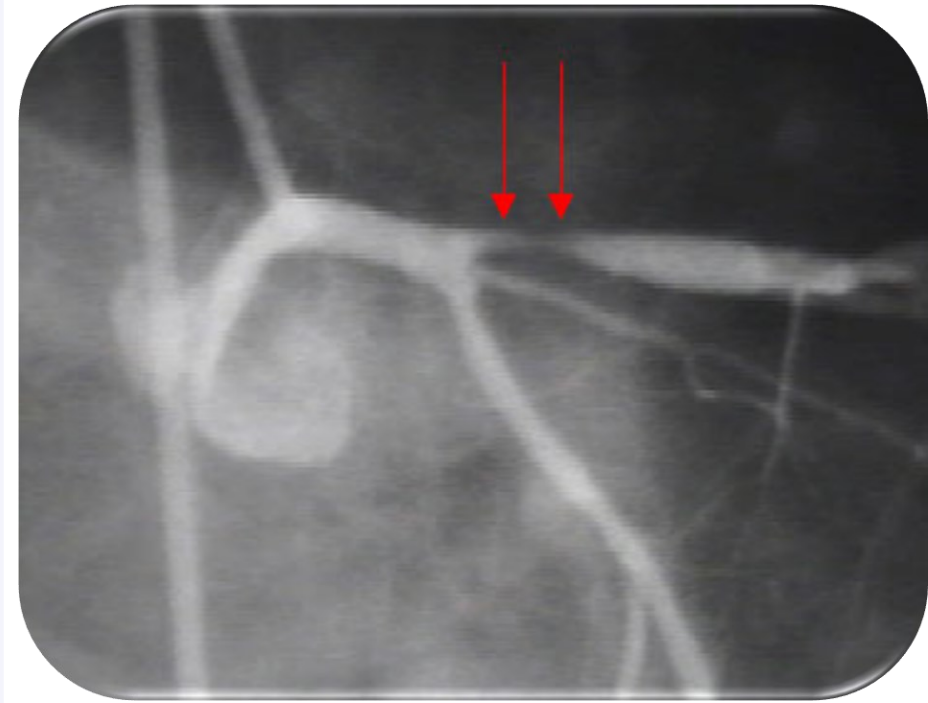
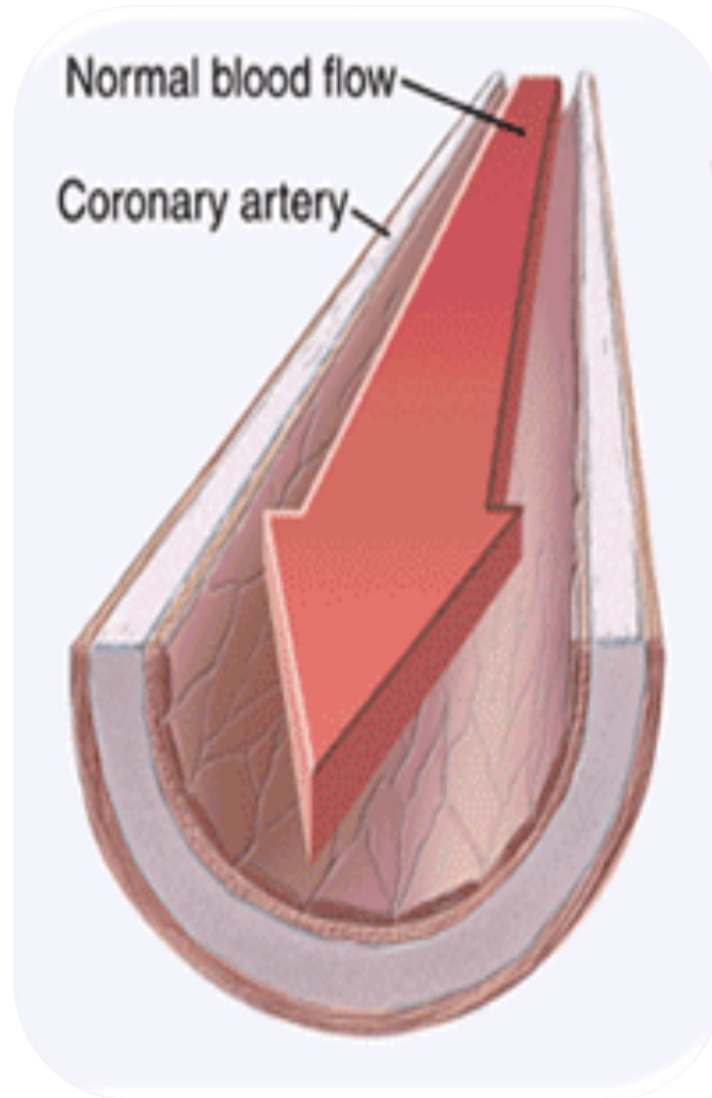
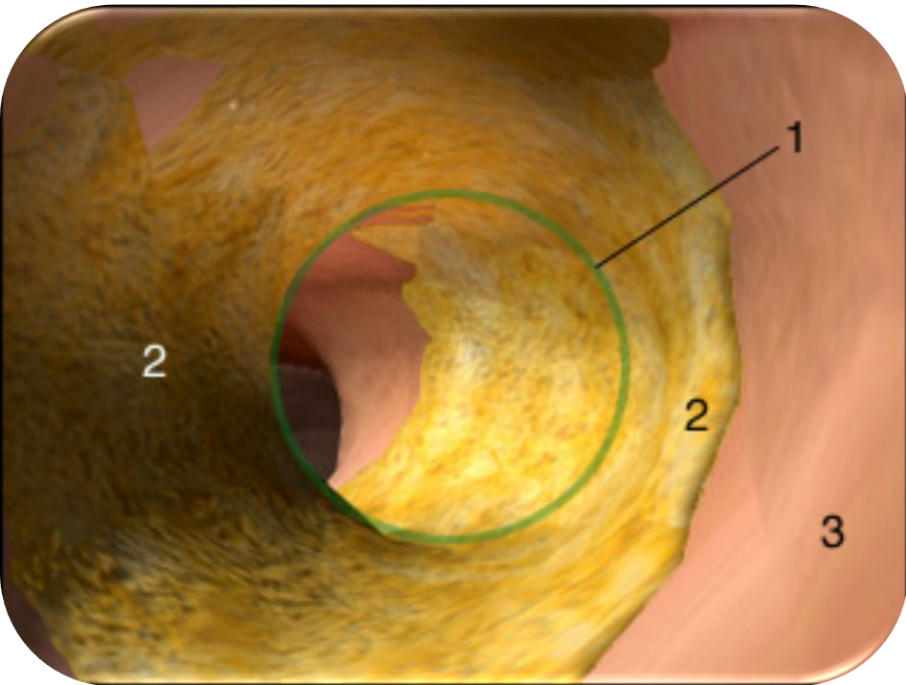
Major Cardiovascular Diseases

Coronary (heart) Artery Disease

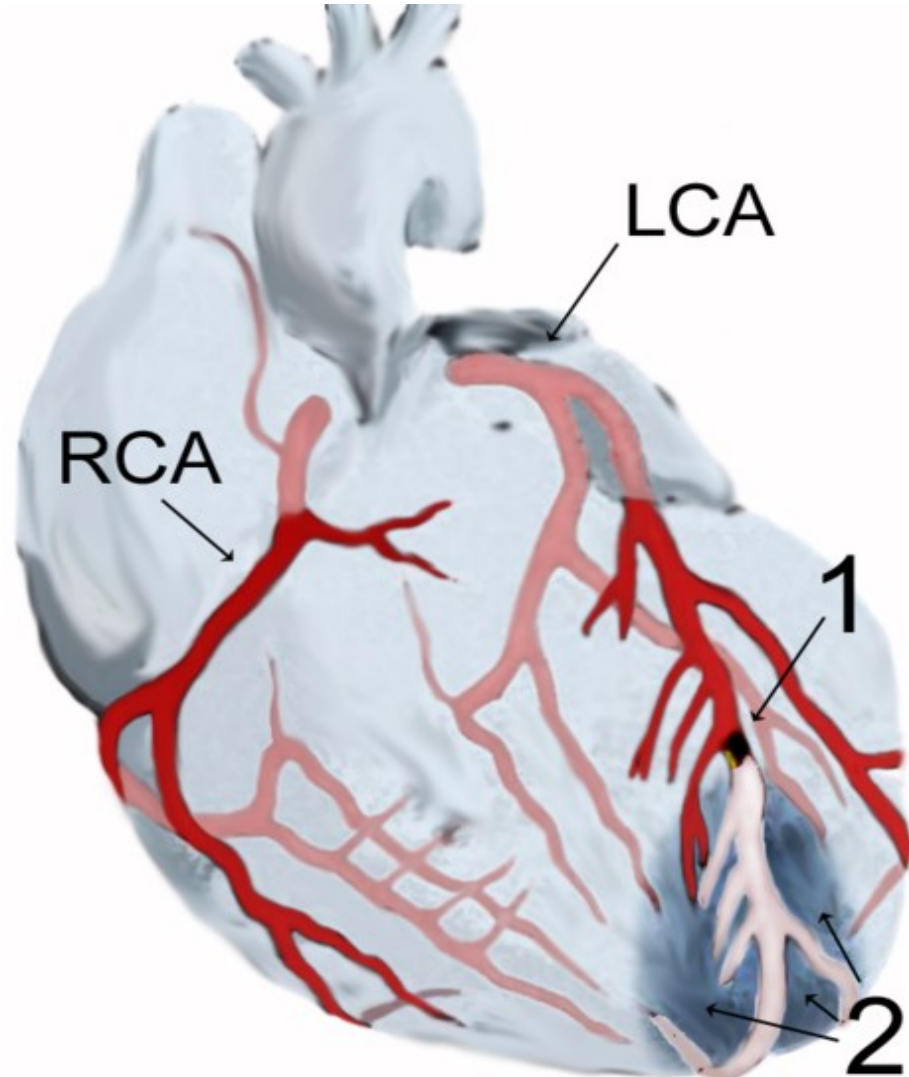
- Angina
- Myocardial Infarction (Heart Attack)



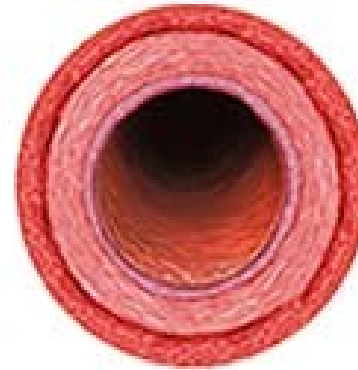
Angina



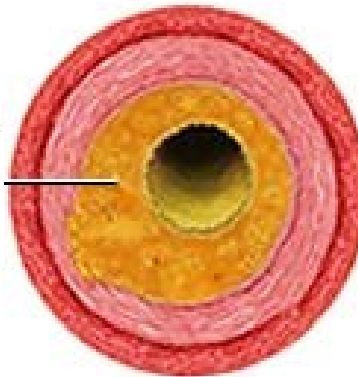
Heart Attack



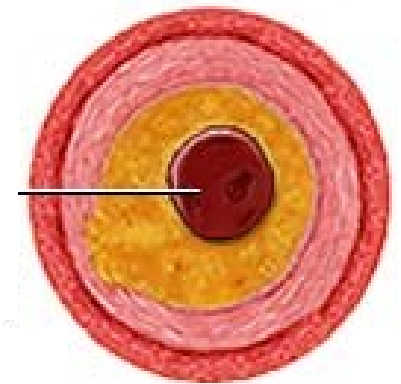
Normal artery



Angina



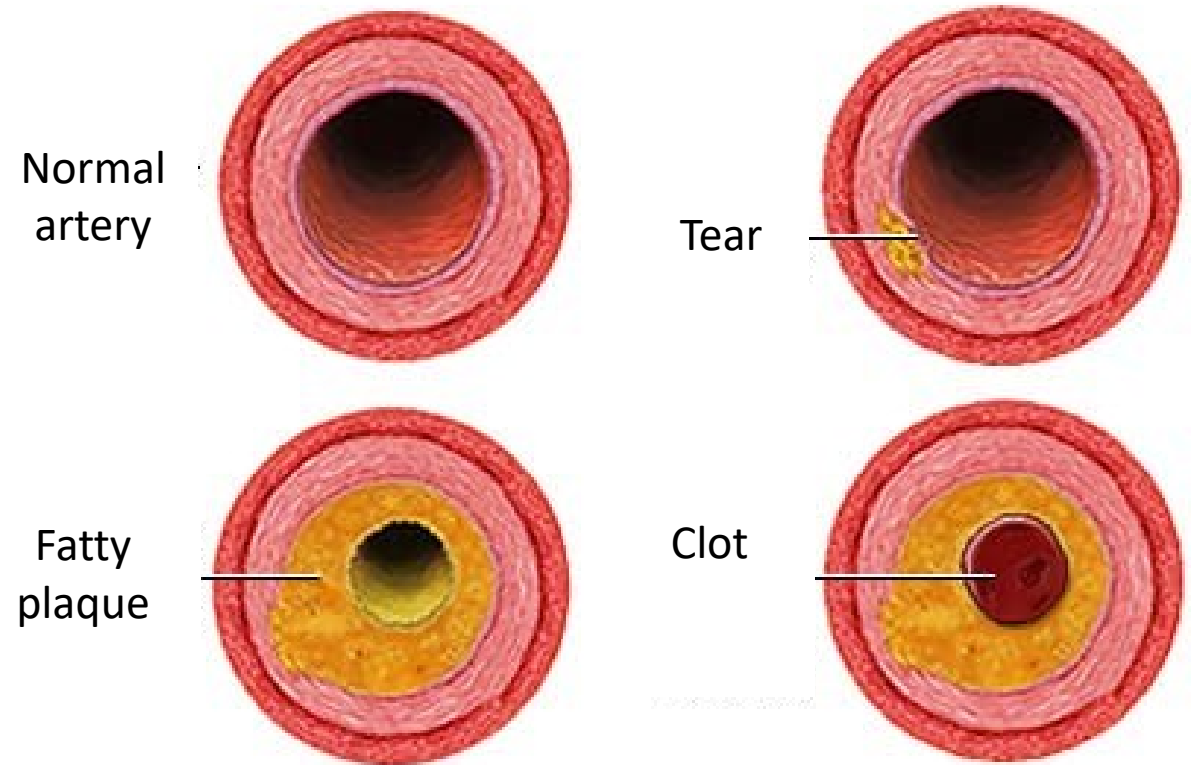
Heart Attack



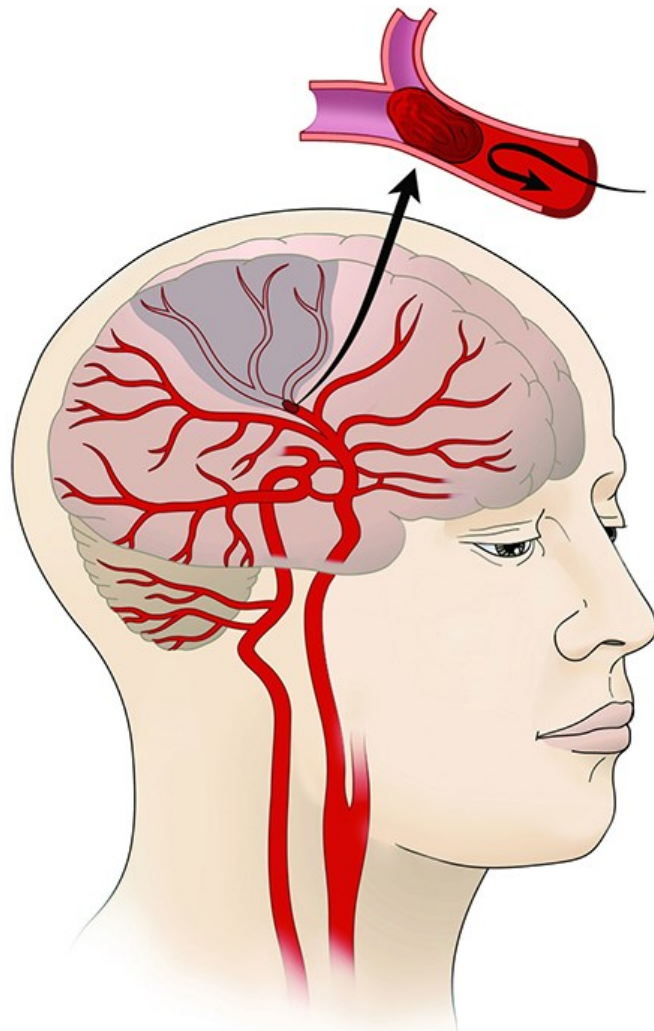
Major Vascular Diseases

Brain

- **Stroke**



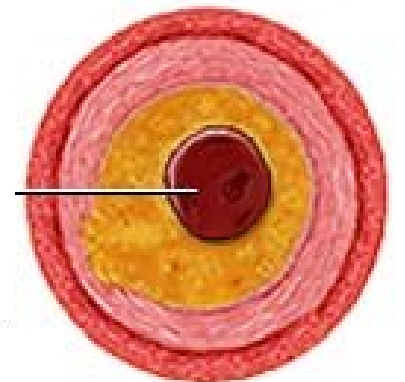
Stroke



Normal artery



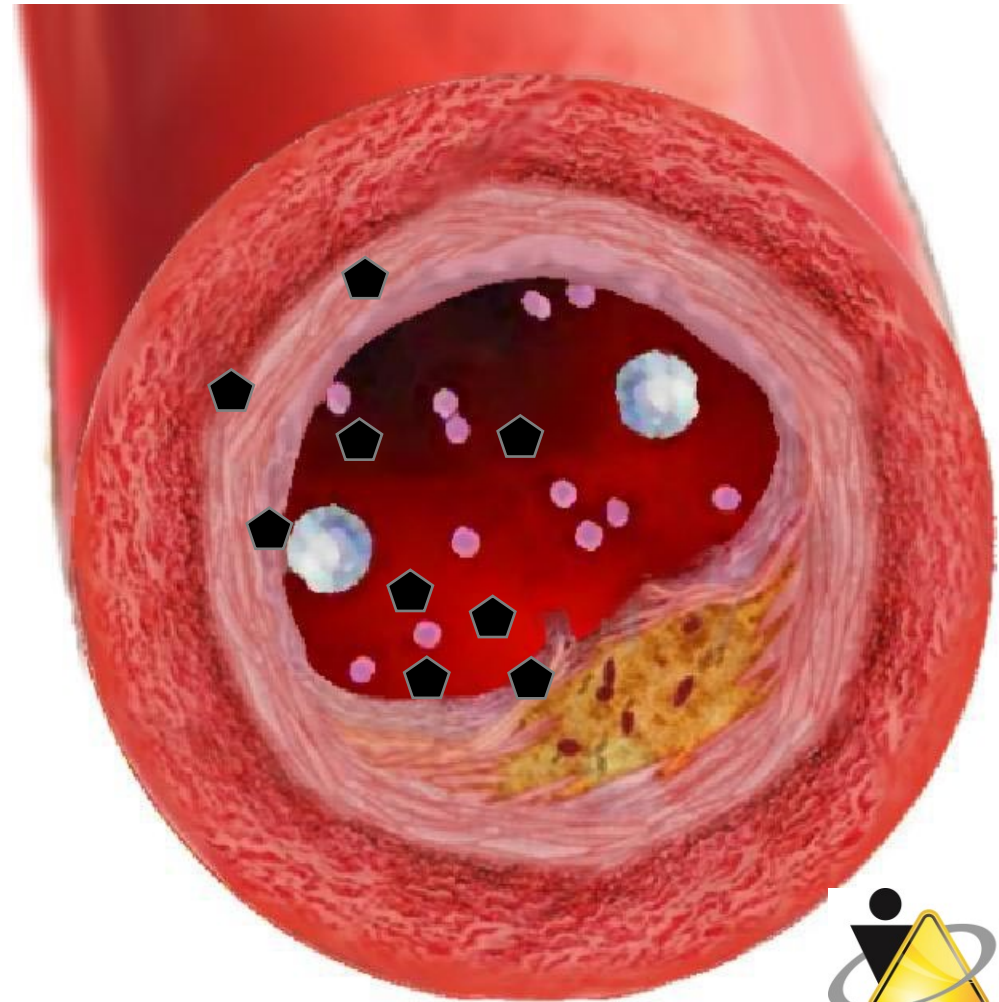
Stroke



Cardio-vascular Effects

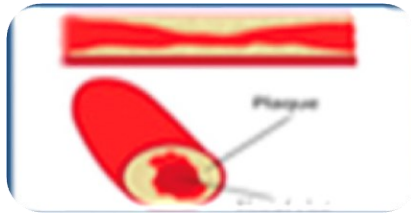
Two Effects:

- Diesel Particulates directly damage vessel wall
- Induced inflammation increases stickiness of the vessel wall

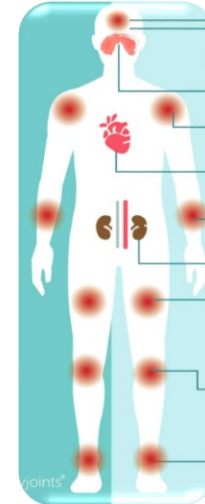


Chronic Inflammation Can Cause or Worsen Chronic Disease

Diabetes / Pre-diabetes
Metabolic Syndrome



Atherosclerosis

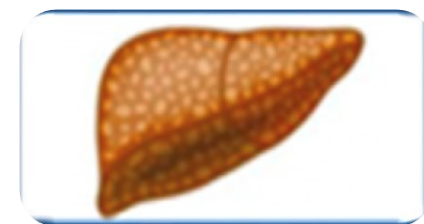


Autoimmune
Disease /
Fibromyalgia



Cardiovascular Diseases

Fatty Liver Diseases



Inflammation

Arthritis

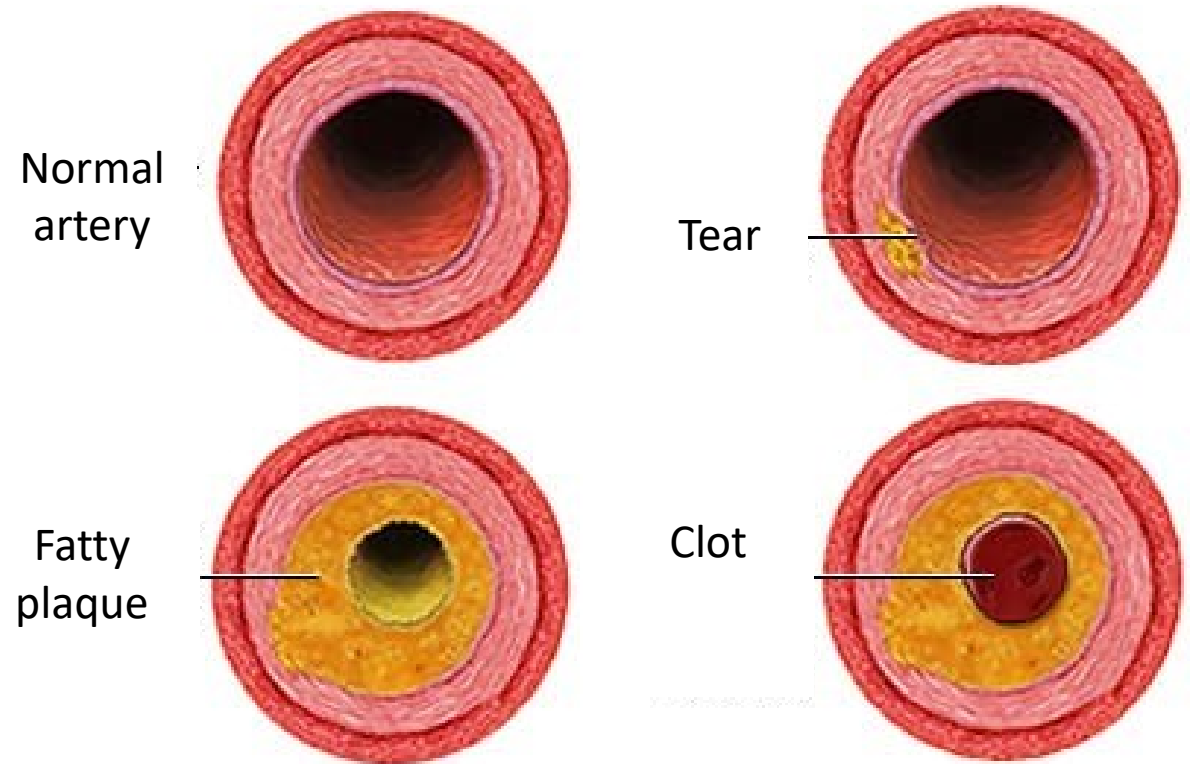


Obesity



Summary

- Small, reactive particulate matter can directly damage blood vessels and increase inflammatory conditions conducive to developing atherosclerosis, angina, heart attack, and stroke.



Questions

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Conference Reference

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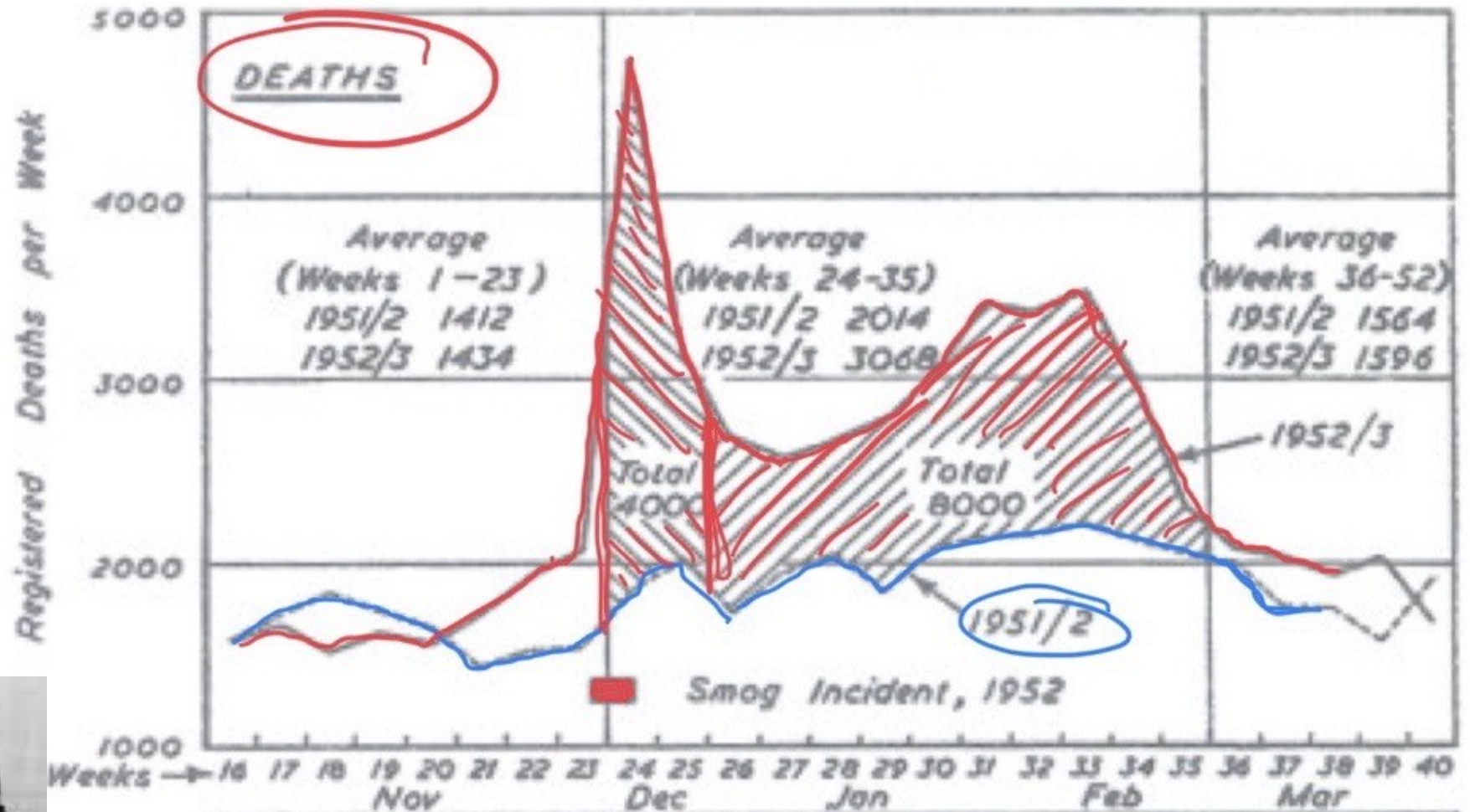
sdorman@laurentian.ca

To reference:

S.C. Dorman. (2024) Health Effects of Exposure to Diesel Particulate

Center for Research in Occupational Safety and Health (CROSH)
MDEC Conference, October 24th, 2024.

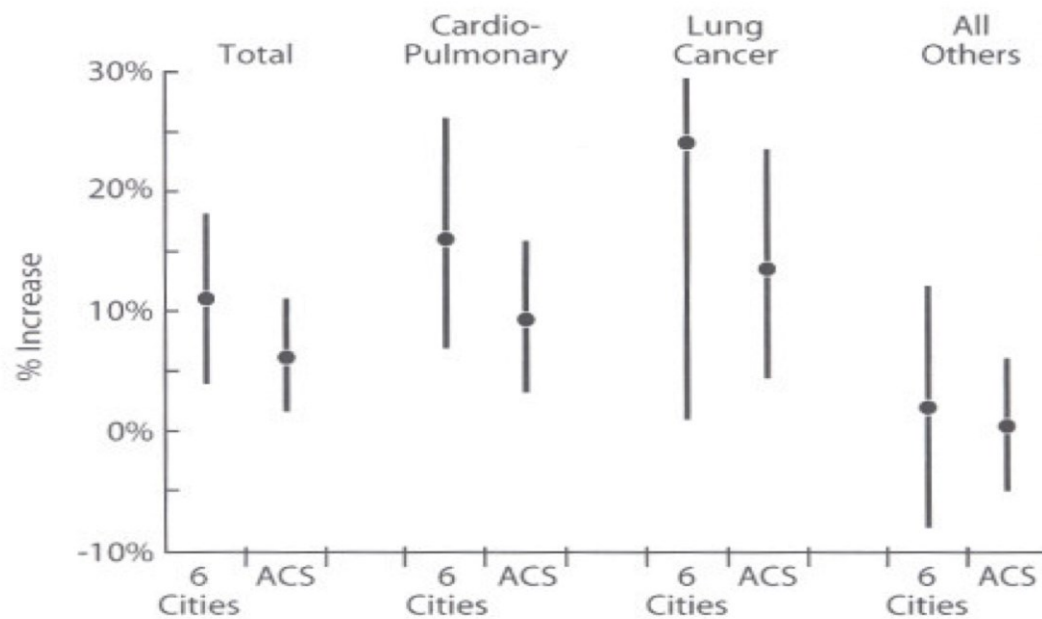
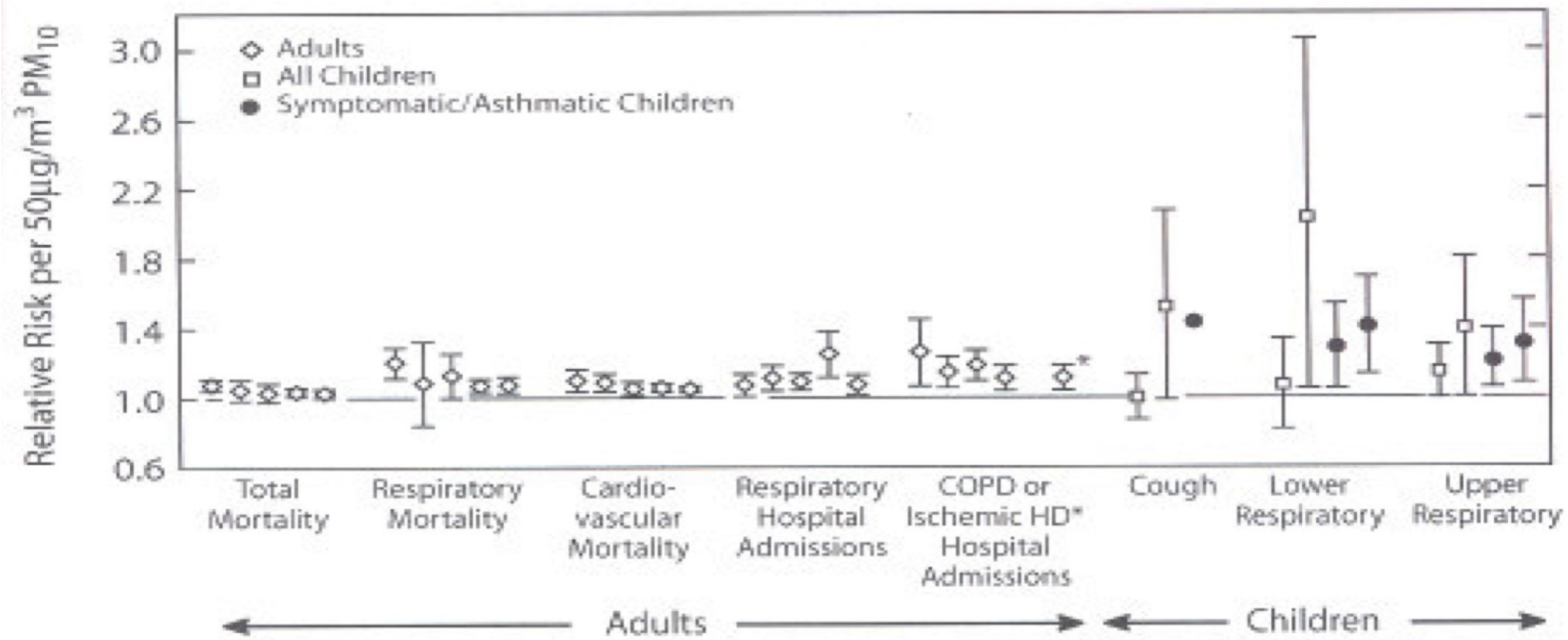
London "Killer Smog" 1952



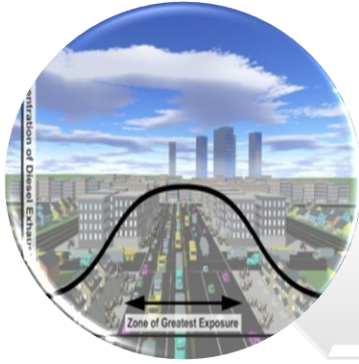
BUSHFIRE smoke over eastern Australia during the 2019-20 fire-ravaged summer was responsible for 417 excess deaths, 1124 hospitalisations for cardiovascular problems and 2027 for respiratory problems, as well as 1305 presentations to emergency departments with asthma, according to the authors of research **published online today by the *Medical Journal of Australia*.**

March 23, 2020 – Med J Aust doi:10.5694/mja2.50545

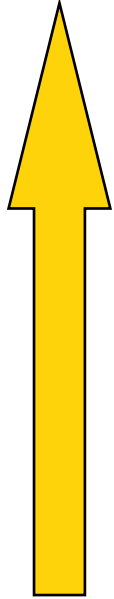




Lung Biology in Health and Disease. Vol 204.



Epidemiologic Data



**1% Daily mortality/
10 μ g/m³PM₁₀
4% Daily mortality
for every
10 μ g/m³PM_{2.5}**

**Cardio-
vascular
deaths**

**Respiratory
related
deaths**

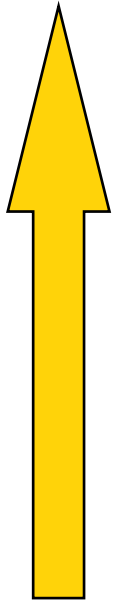
**Hospital
admissions**

**Cardio-
vascular &
Airway
emergencies**

**Risk to
susceptible
populations**



Experimental Data Diesel Particulate Matter



**Inflammatory
cells**

**Inflammatory
proteins**

**Oxidative
stress**

**Asthma
symptoms**

**Blood
pressure**