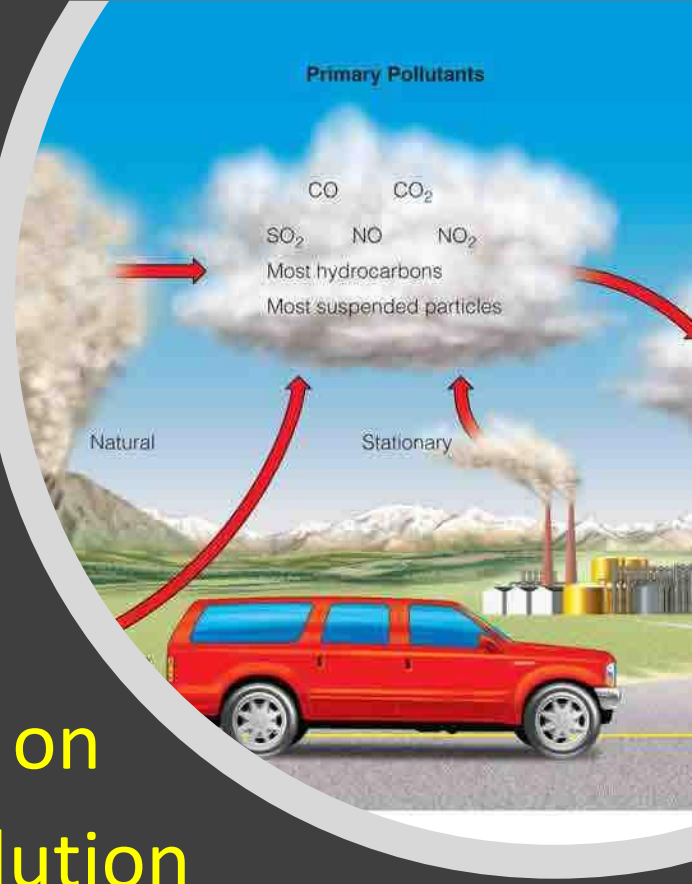


Fossil Fuels: Their Impact on Climate Change and Air Pollution

Stephen T Holgate, UKRI Clean Air Champion & Special Advisor to the RCP on Air Quality

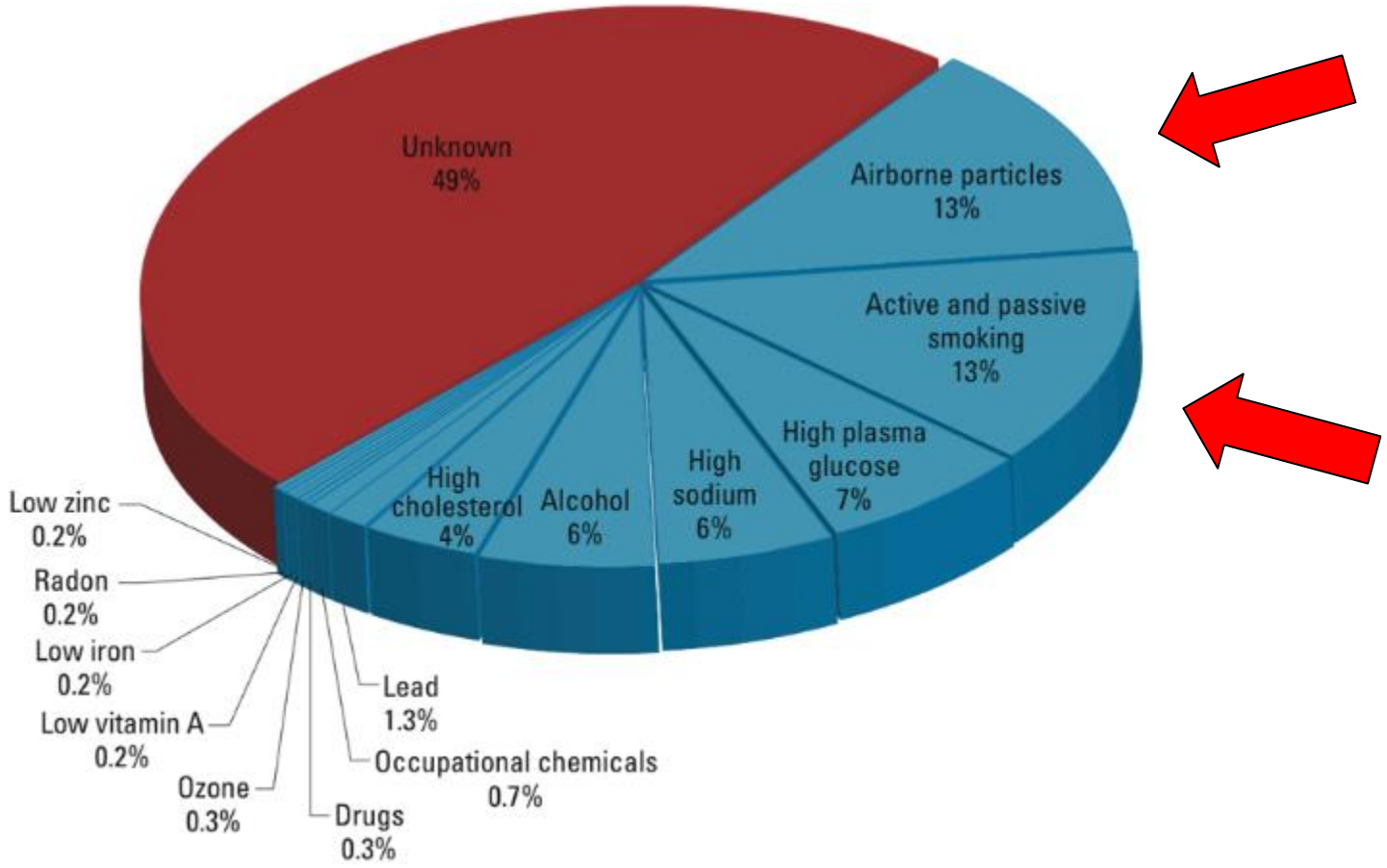
Faculty of Medicine, University of Southampton, UK

Health Effects of Air Pollution

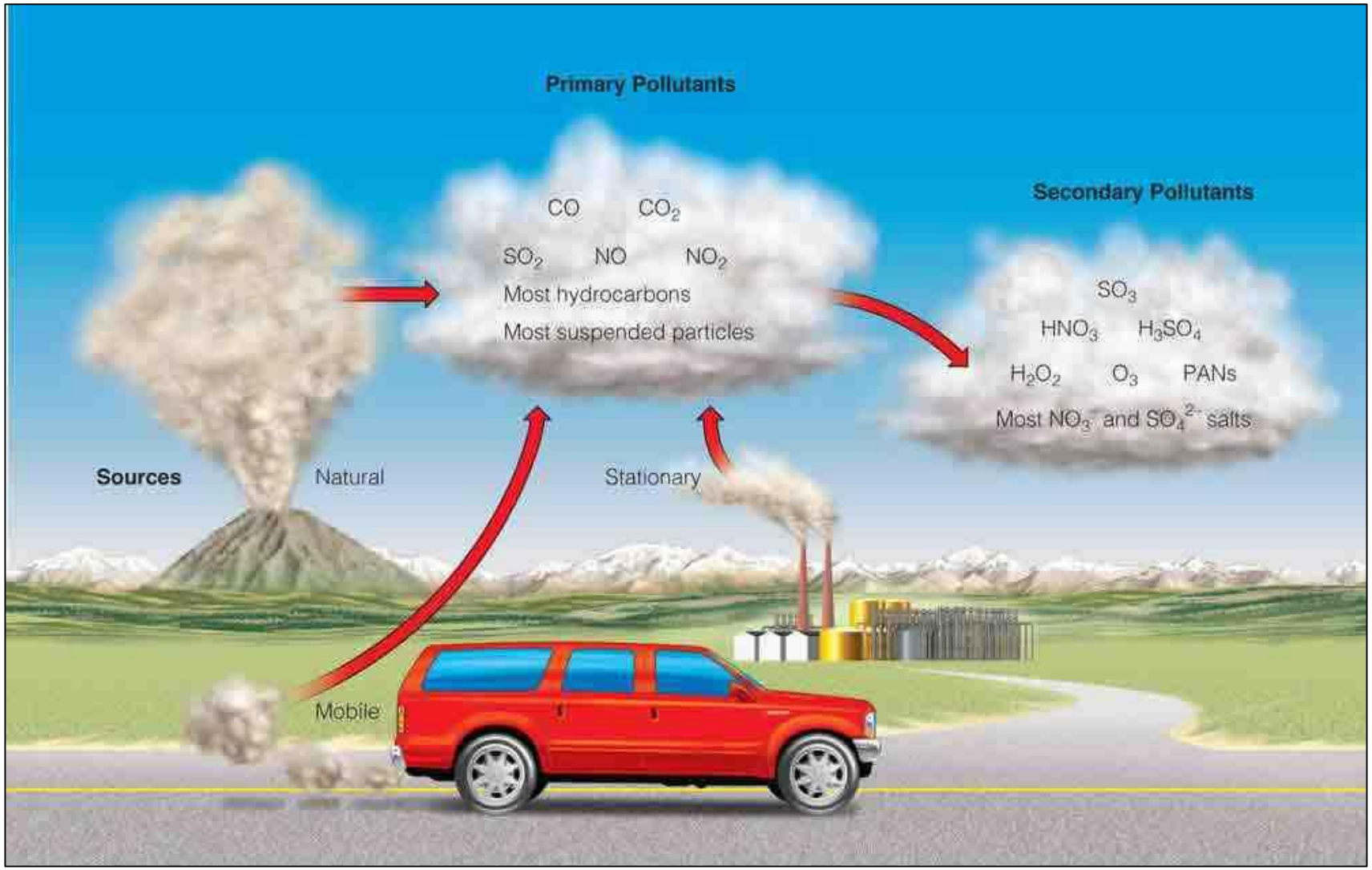
Risk factors for exposures that contribute to chronic-disease mortality. The chart was compiled from World Health Organization estimates of exposures affecting 50 million global deaths in 2010

First WHO Global Conference on Air Pollution and Health
30th October 2018

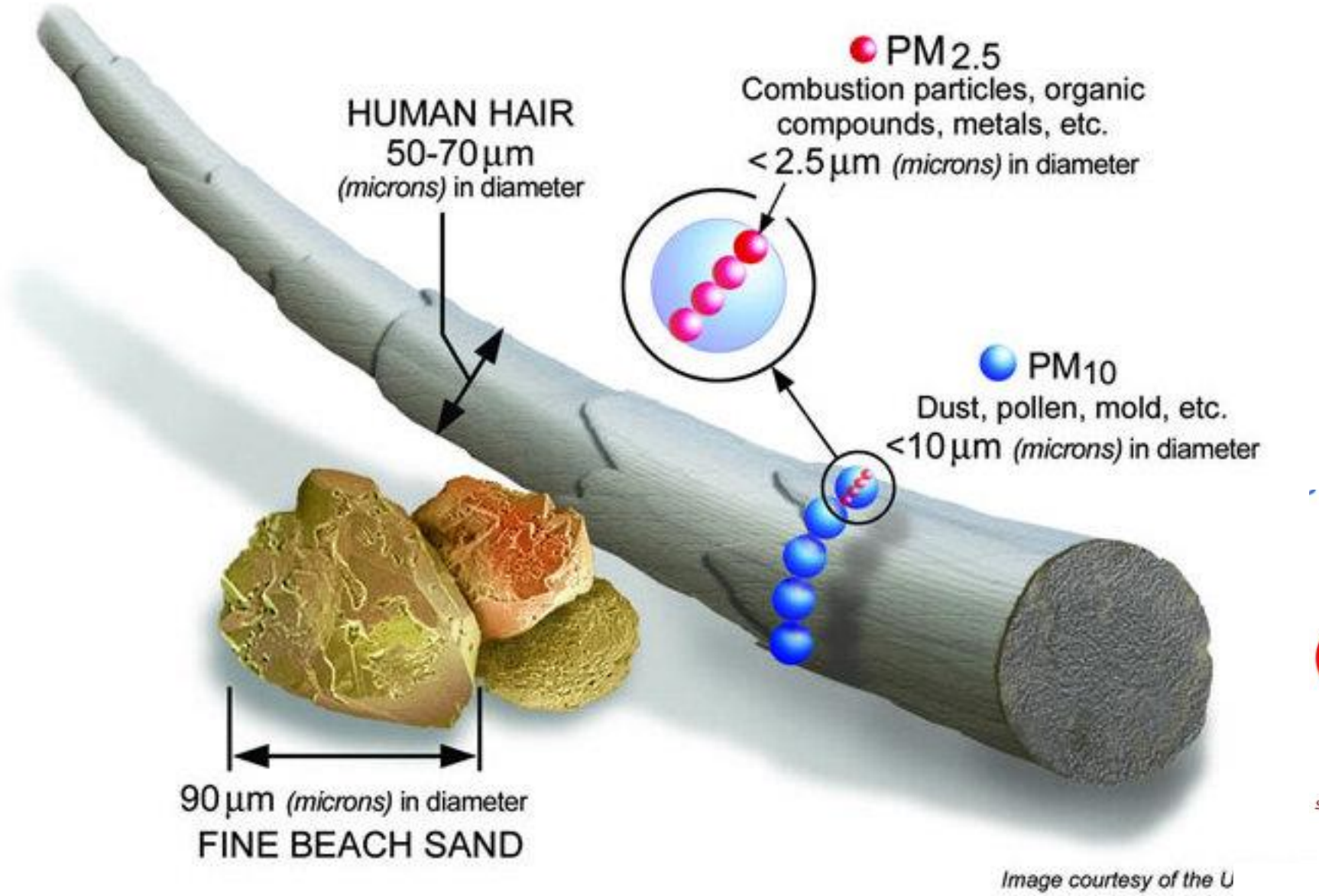
World Health Organization

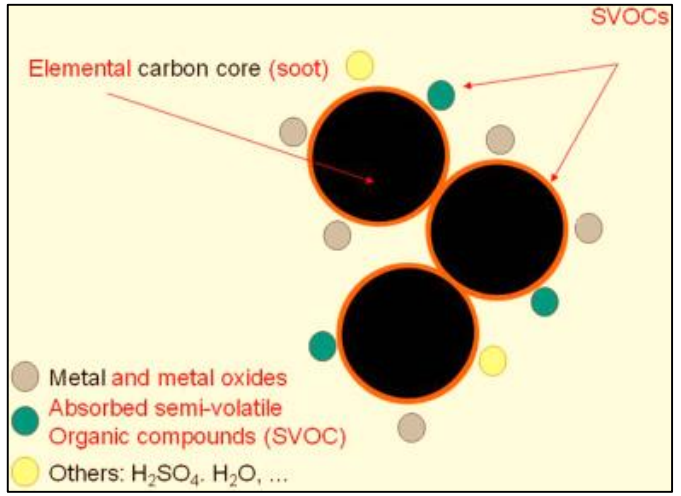


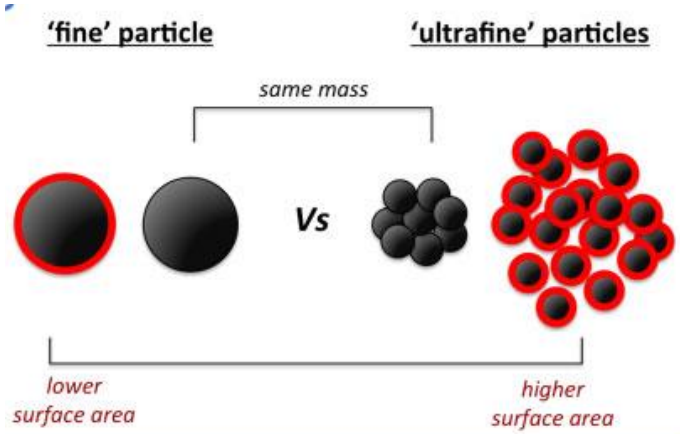
Pollutants that trigger air pollution -
Two types of pollutant – primary and secondary



Air pollutant particles ($PM_{2.5}$ and $PM_{0.1}$) become systemically bioavailable



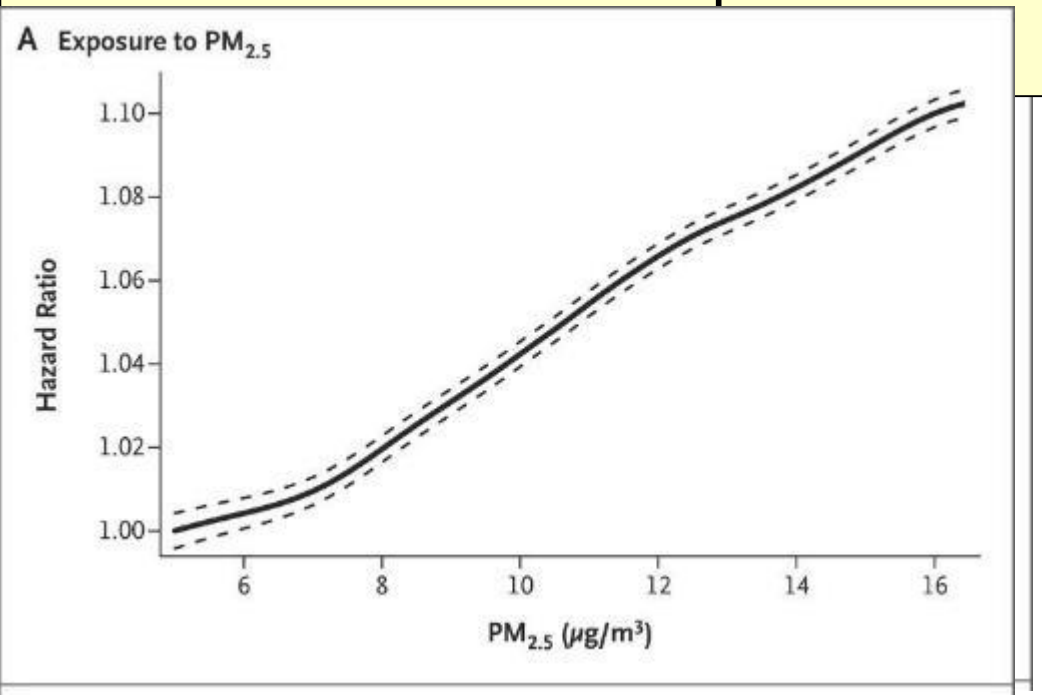


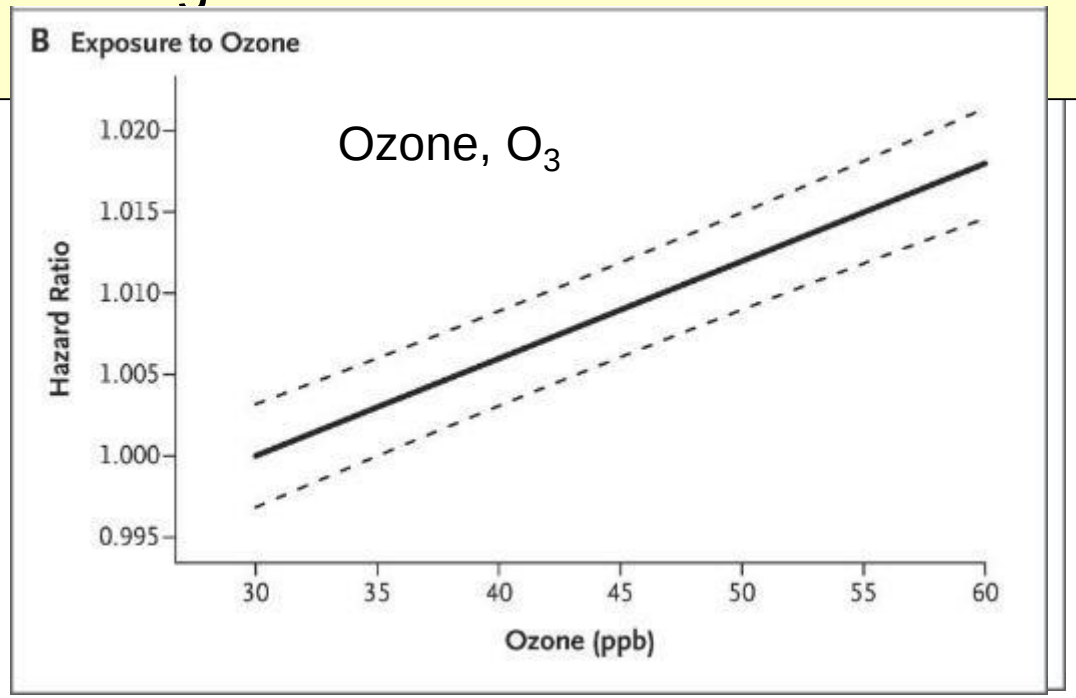


Air Pollution and Mortality in the Medicare Population

Di Q, et al. N Engl J Med. 2017 Jun 29; 376(26): 2513-22

- In the entire Medicare population, there was significant evidence of adverse effects related to exposure to $PM_{2.5}$ and ozone at concentrations below current national standards.
- This effect was most pronounced among self-identified racial minorities and





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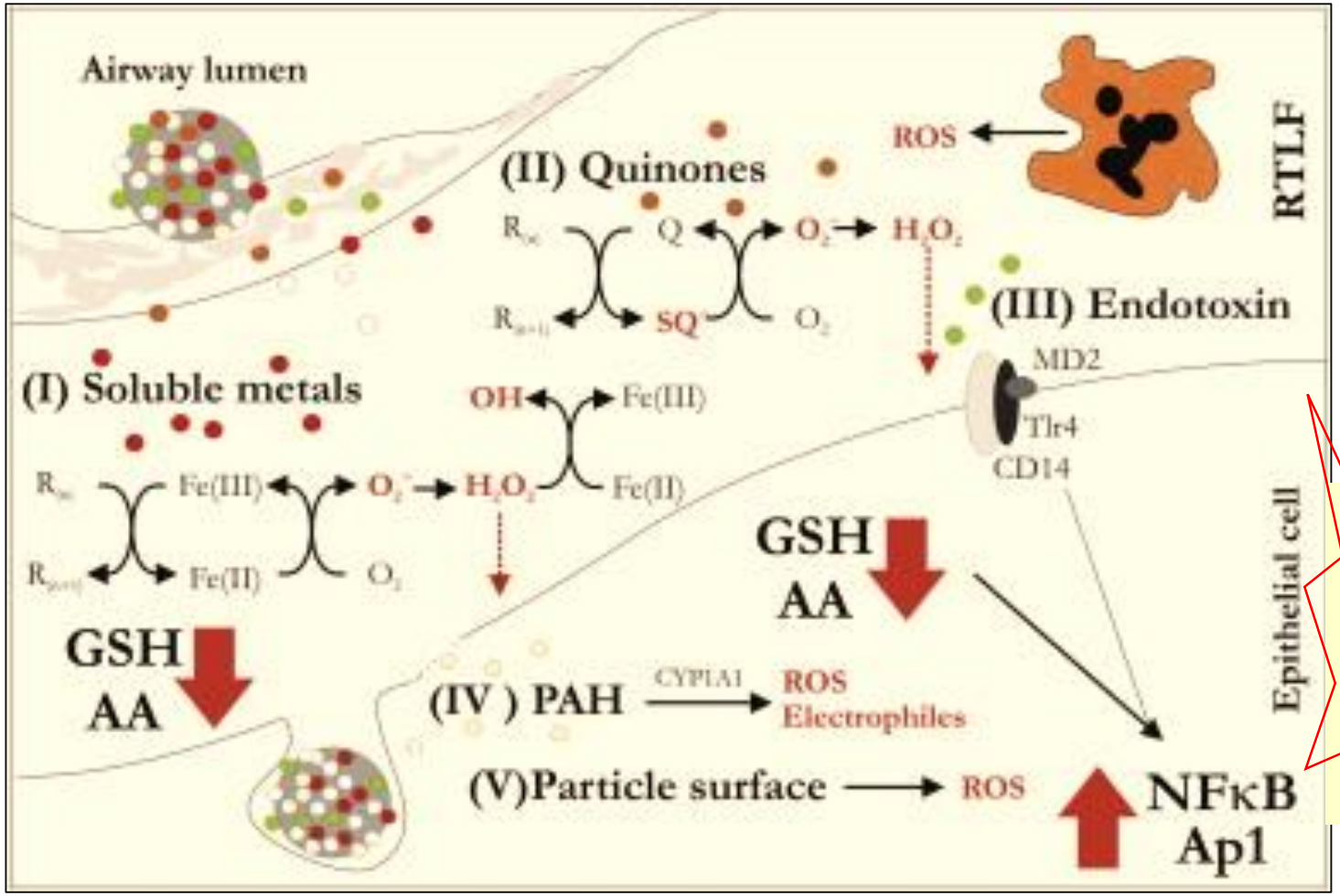
Size, source and chemical composition as determinants of toxicity attributable to ambient particulate matter

RTF= Respiratory Tract Lining Fluid

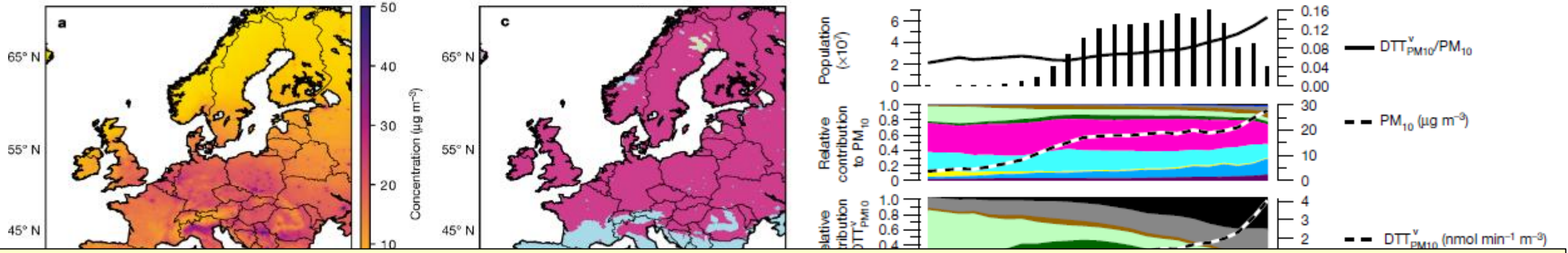
Pathways of particle induced toxicity at the air–lung interface. **Particles elicit oxidative stress through five inter-related mechanisms.**



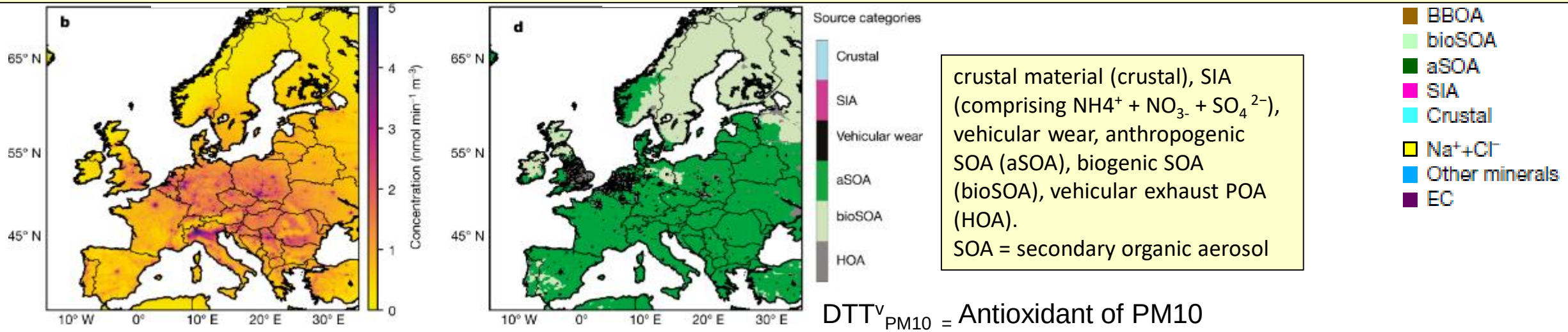
Fussell JC, Kelly JF. Atmospheric Environment. 2012; 60: 504-26

Daellenbach, K.R., Uzu, G., Jiang, J. *et al.* Sources of particulate-matter air pollution and its oxidative potential in Europe. *Nature.* 2020: 587: 414–419

PM_{10} PM_{10}



If Oxidative Potential is found to be related to major health impacts this could imply that controlling its specific sources might be more effective.

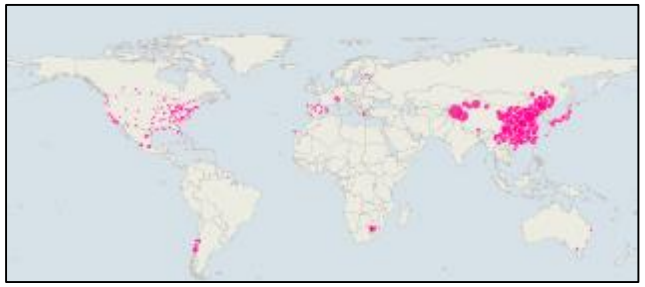


crustal material (crustal), SIA (comprising $NH4^+ + NO_{3-} + SO_4^{2-}$), vehicular wear, anthropogenic SOA (aSOA), biogenic SOA (bioSOA), vehicular exhaust POA (HOA).
SOA = secondary organic aerosol

DTT^v_{PM10} = Antioxidant of PM10

Ambient Particulate Air Pollution and Daily Mortality in 652 Cities

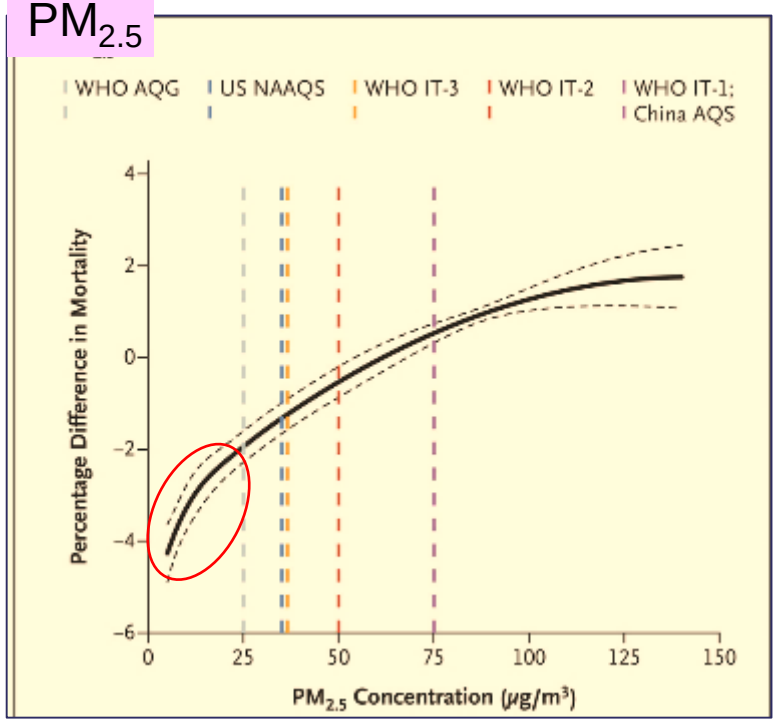
Cong Liu, M.S. et al. N Engl J Med. 2019; Aug 22, 381: 705-15



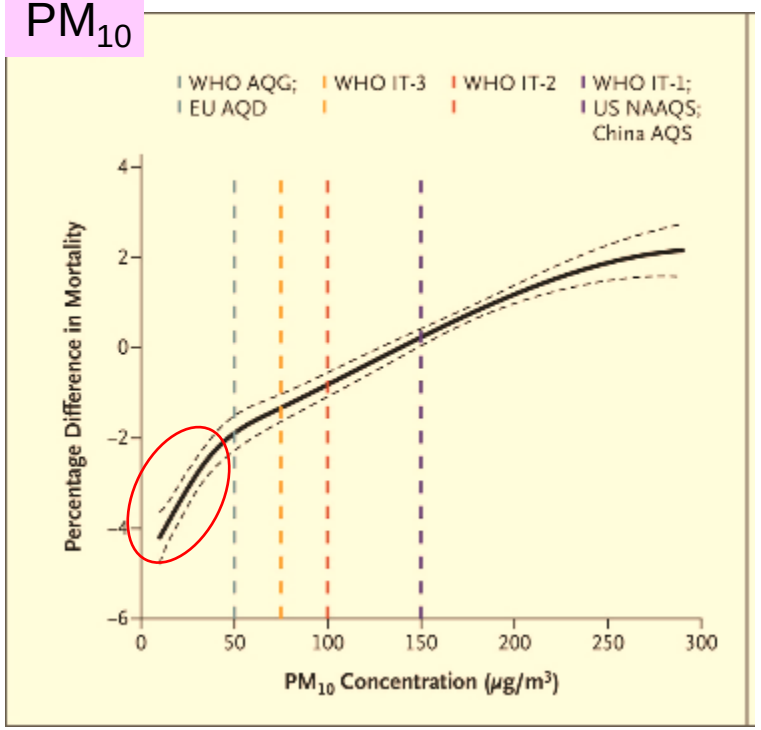
Annualised average Daily PM_{10} and $PM_{2.5}$

Pooled concentration–response curves for the associations of 2-day moving average concentrations of PM_{10} and $PM_{2.5}$ with daily all-cause mortality.

$PM_{2.5}$



PM_{10}



World Health Organization Air Quality Guidelines (WHO AQG), WHO Interim Target 1 (IT-1), WHO Interim Target 2 (IT-2), WHO Interim Target 3 (IT-3), European Union Air Quality Directive (EU AQD), U.S. National Ambient Air Quality Standard (NAAQS), and China Air Quality Standard (AQS).

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Fossil fuel air pollution blamed for 1 in 5 deaths worldwide.

Torjesen I. BMJ 2021;372:n406 http://dx.doi.org/10.1136/bmj.n406. Published: 10 February 2021

Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem.

Vohra K, Vodonos A, Schwartz J, etal Environ Res 2021; doi: 10.1016/j.envres.2021.110754.

Previous risk assessments have examined the health response to total $PM_{2.5}$, not just $PM_{2.5}$ from fossil fuel combustion, and have used a concentration-response function with limited support from the literature and data at both high and low concentrations.

This assessment examines mortality associated with $PM_{2.5}$ from only fossil fuel combustion, making use of a recent meta-analysis of newer studies with a wider range of exposure.

This study demonstrates that **the fossil fuel component of $PM_{2.5}$ contributes a large mortality burden**. The steeper concentration-response function slope at lower concentrations leads to larger estimates than previously found in Europe and North America, and the slower drop-off in slope at higher concentrations results in larger estimates in Asia





EU urban population exposed to harmful levels of air pollutant concentrations in 2012–2014, according to:

	EU limits/target values	WHO guidelines
$PM_{2.5}$	8–12 %	85–91 %
PM_{10}	16–21 %	50–63 %
O_3	8–17 %	96–98 %
NO_2	7–9 %	7–9 %
BaP	20–24 %	88–91 %
SO_2	<1 %	35–49 %

Number of children living in areas which exceed international limits, by UNICEF Region

120 million children
live in areas where outdoor air pollution exceeds international limits

20 million children
live in areas where outdoor air pollution exceeds 2 times international limits

unicef

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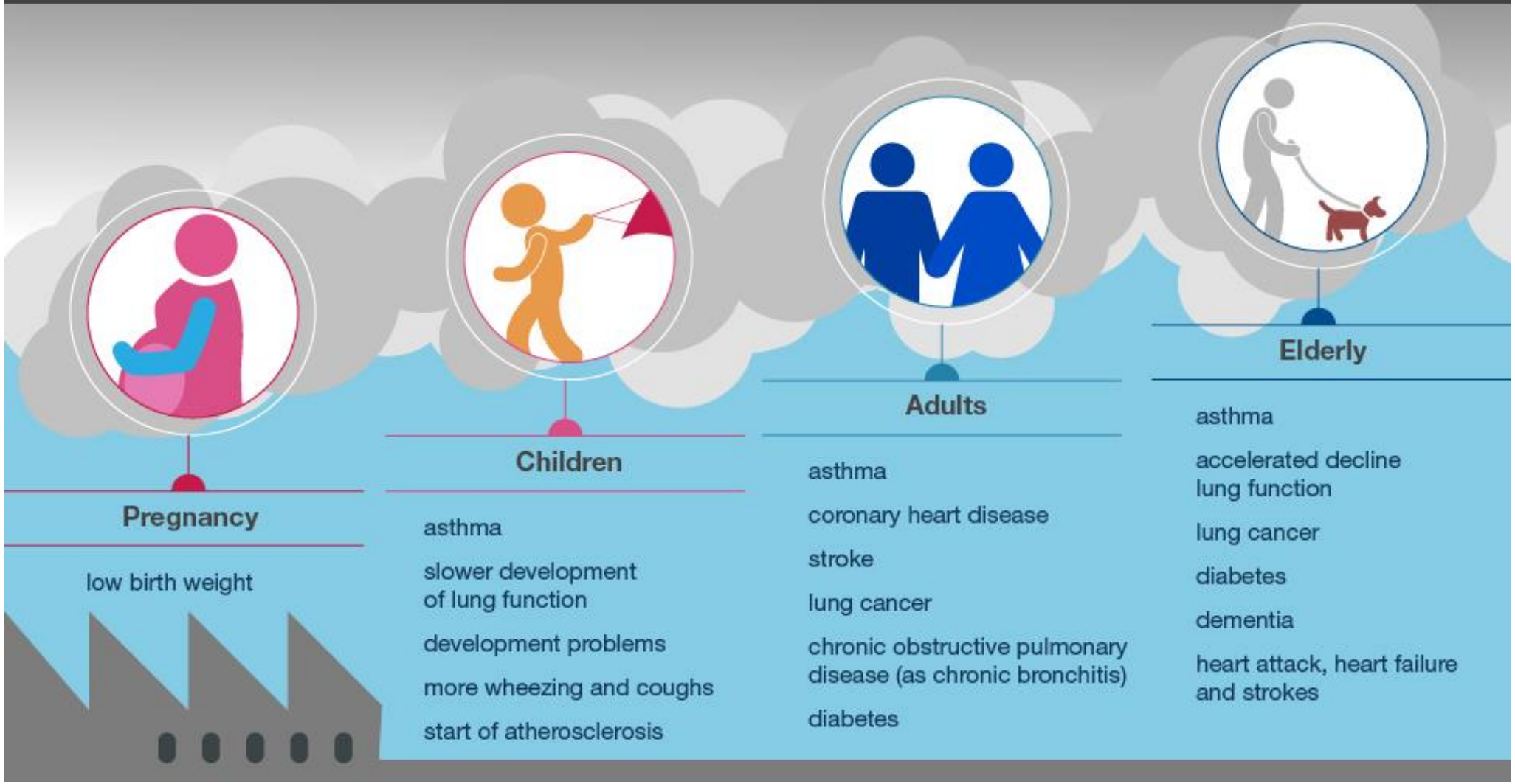
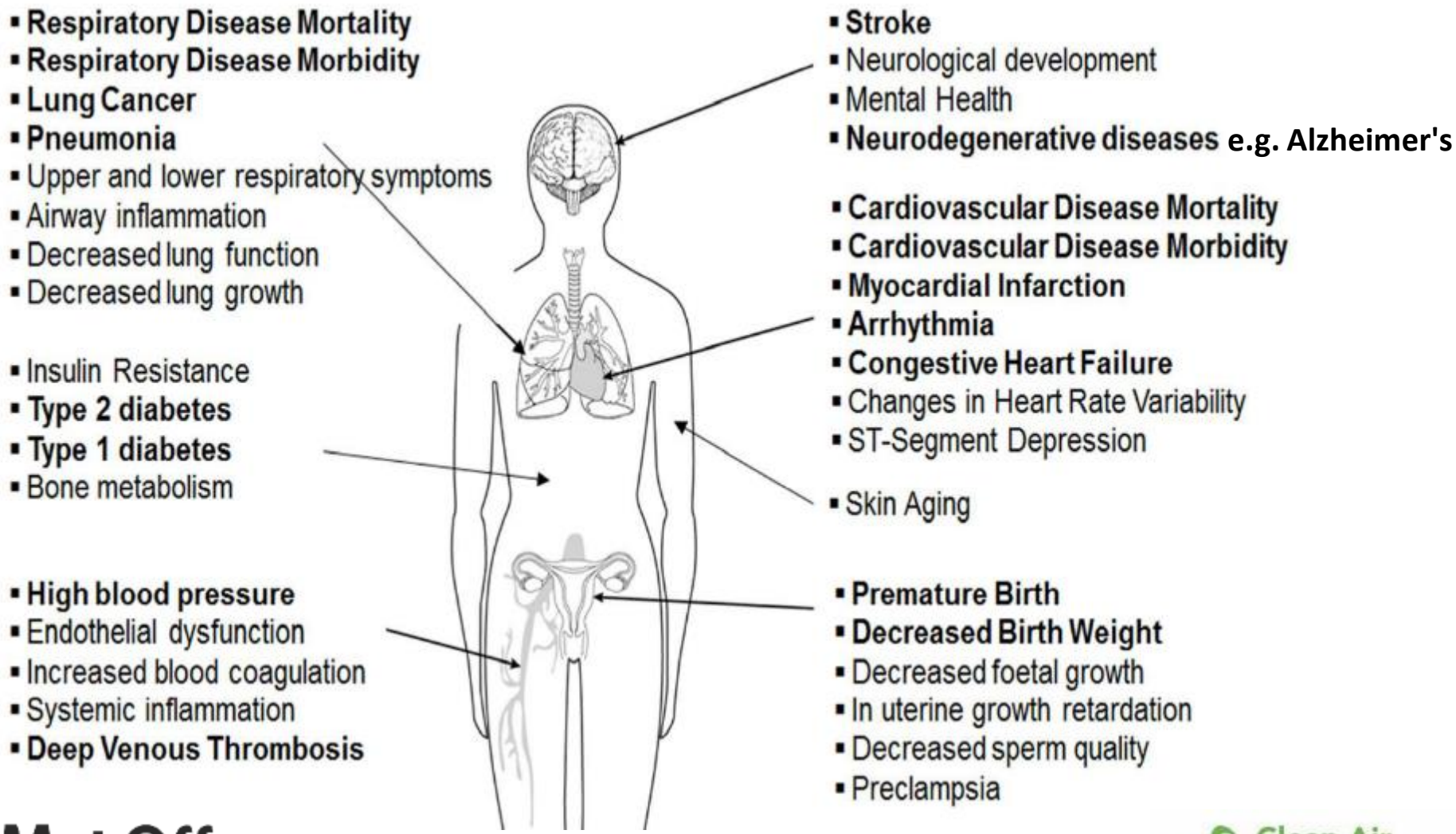
Air pollution affects people throughout their lifetime



Overview of diseases, conditions, and biomarkers affected by outdoor air pollution. Conditions currently included in the Global Burden of Disease categories are shown in **bold**

What Constitutes an Adverse Health Effect of Air Pollution? An analytical framework

A ERS & ATS Policy Statement: Aug 2016
Thurston GD, et al. Eur Respir J. 2017; 49: 1600419.



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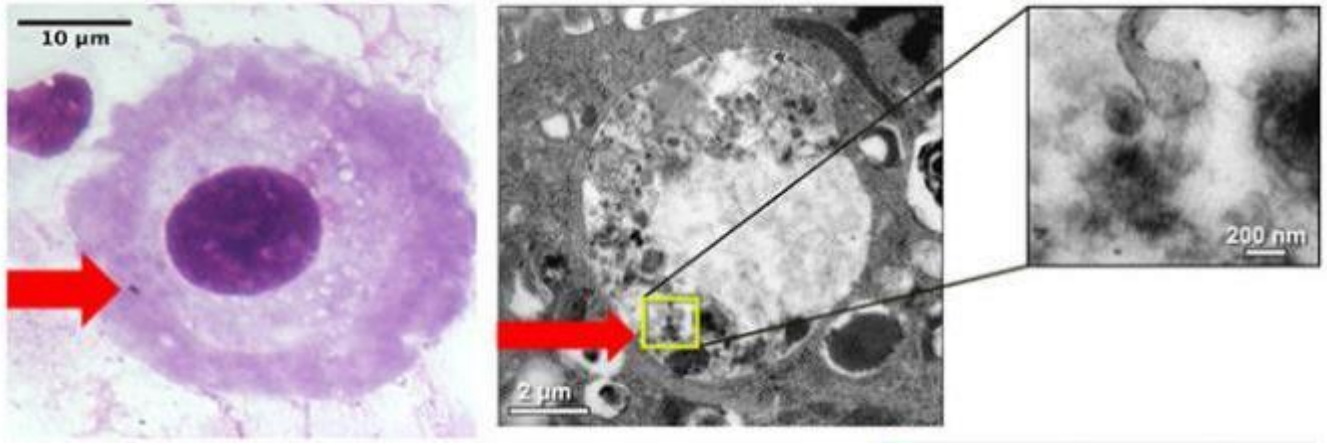
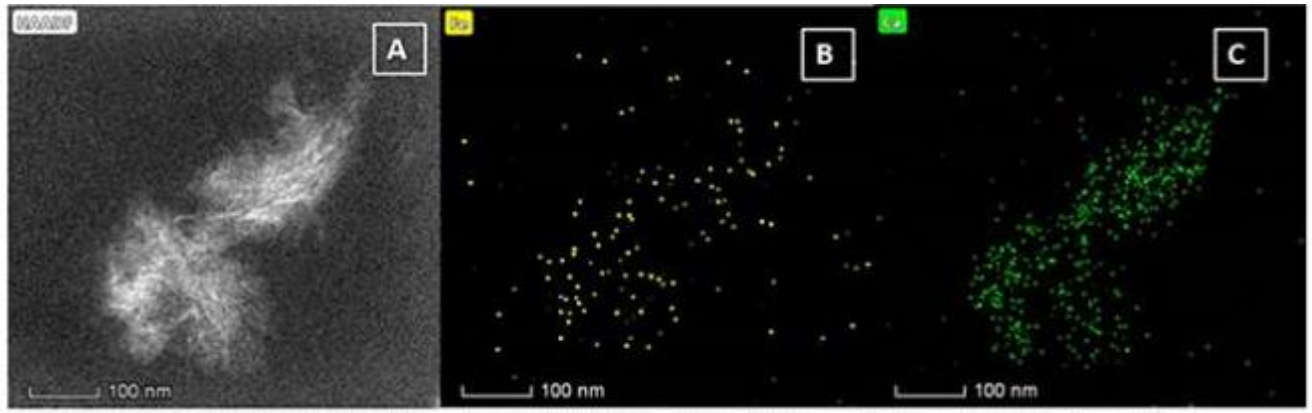
Evidence for the presence of air pollution nanoparticles in placental tissue cells.

Liu NM et al. *Science of The Total Environment*, 2021; 751: 142235



Translocated PM (red arrows) interacting with tissue phagocytes in distant



Elemental mapping shows elongate nanoparticle clusters containing calcium and iron (figure B and C).

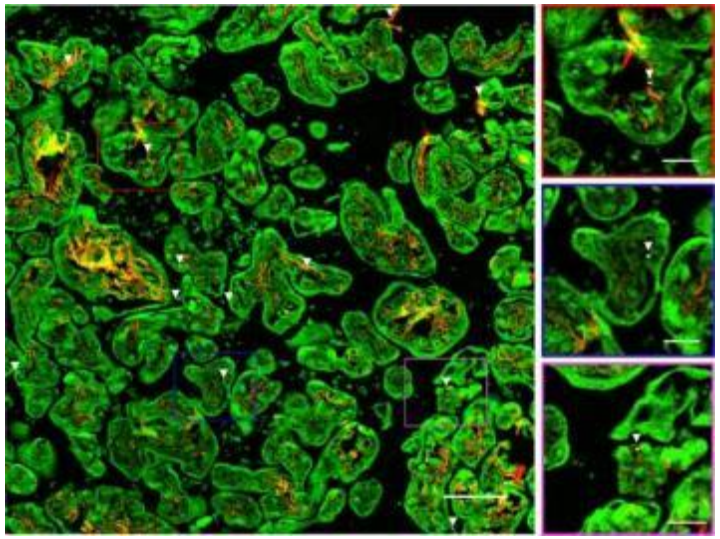
- Human placentas were used to investigate translocation of inhaled nanoparticles.
- Carbon and metal-bearing nanoparticles were found in tissue phagocytes in vivo.
- Size, shape and elemental composition of these exogenous particles were identified.
- Tissue phagocytes uptake of diesel exhaust particles was demonstrated *in vitro*.

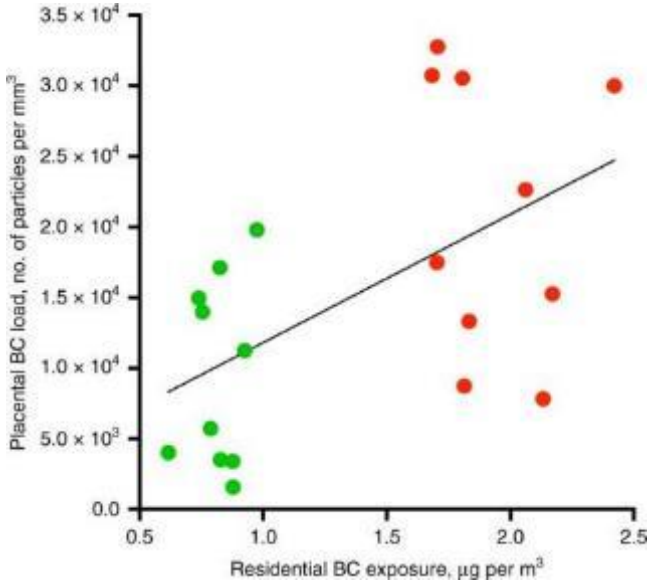
Ambient black carbon particles reach the fetal side of human placenta.

Bové H et al. Nat Commun. 2019; 10: 3866.

Using femtosecond pulsed laser illumination, Black Carbon identified in all screened placentae, with an average particle count of 0.95×10^4 and 2.09×10^4 particles/mm^3 for low and high exposed mothers, respectively.

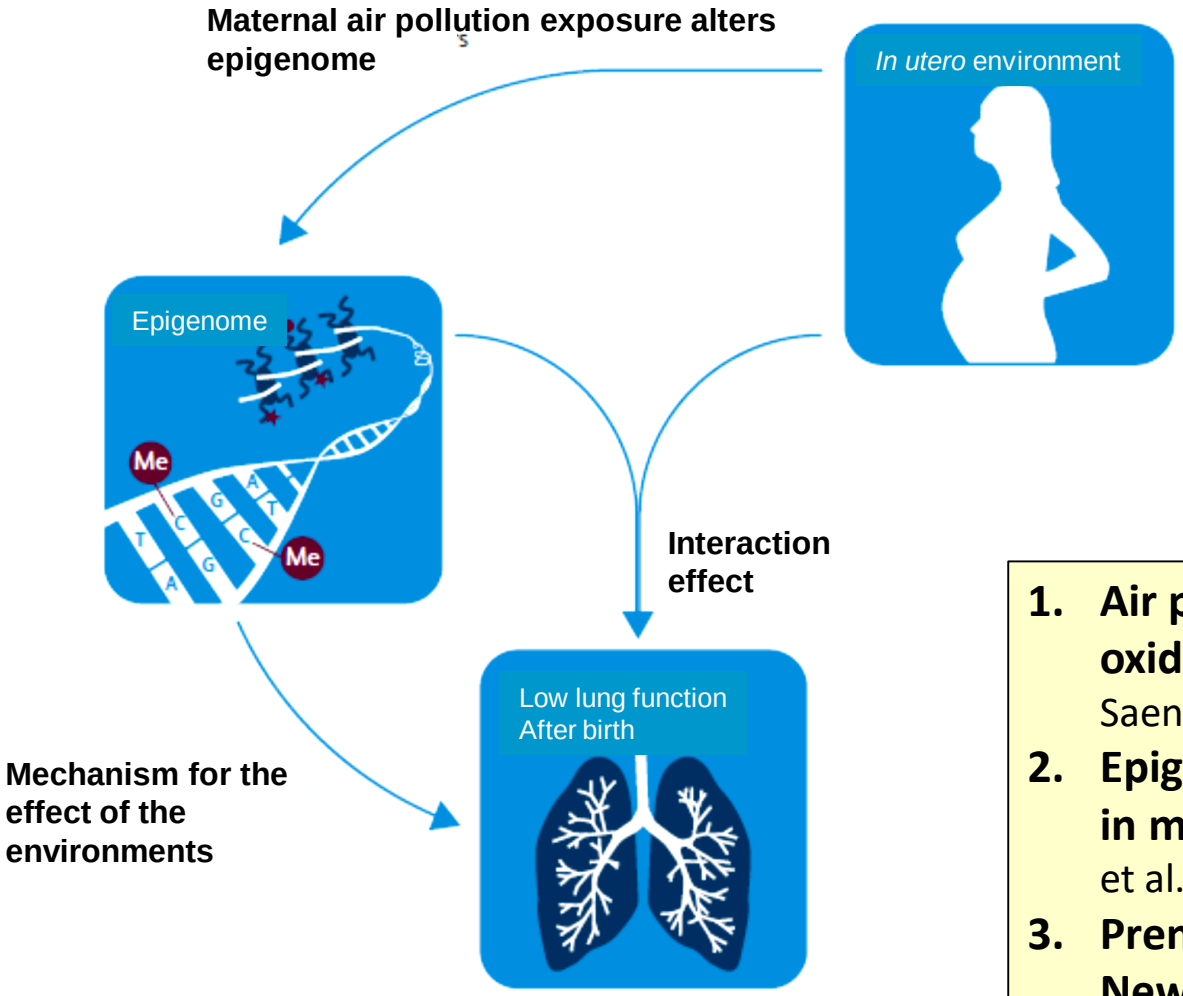
Placental BC load is positively associated with mothers' residential BC exposure during pregnancy (0.63-2.42 µg/m^3).





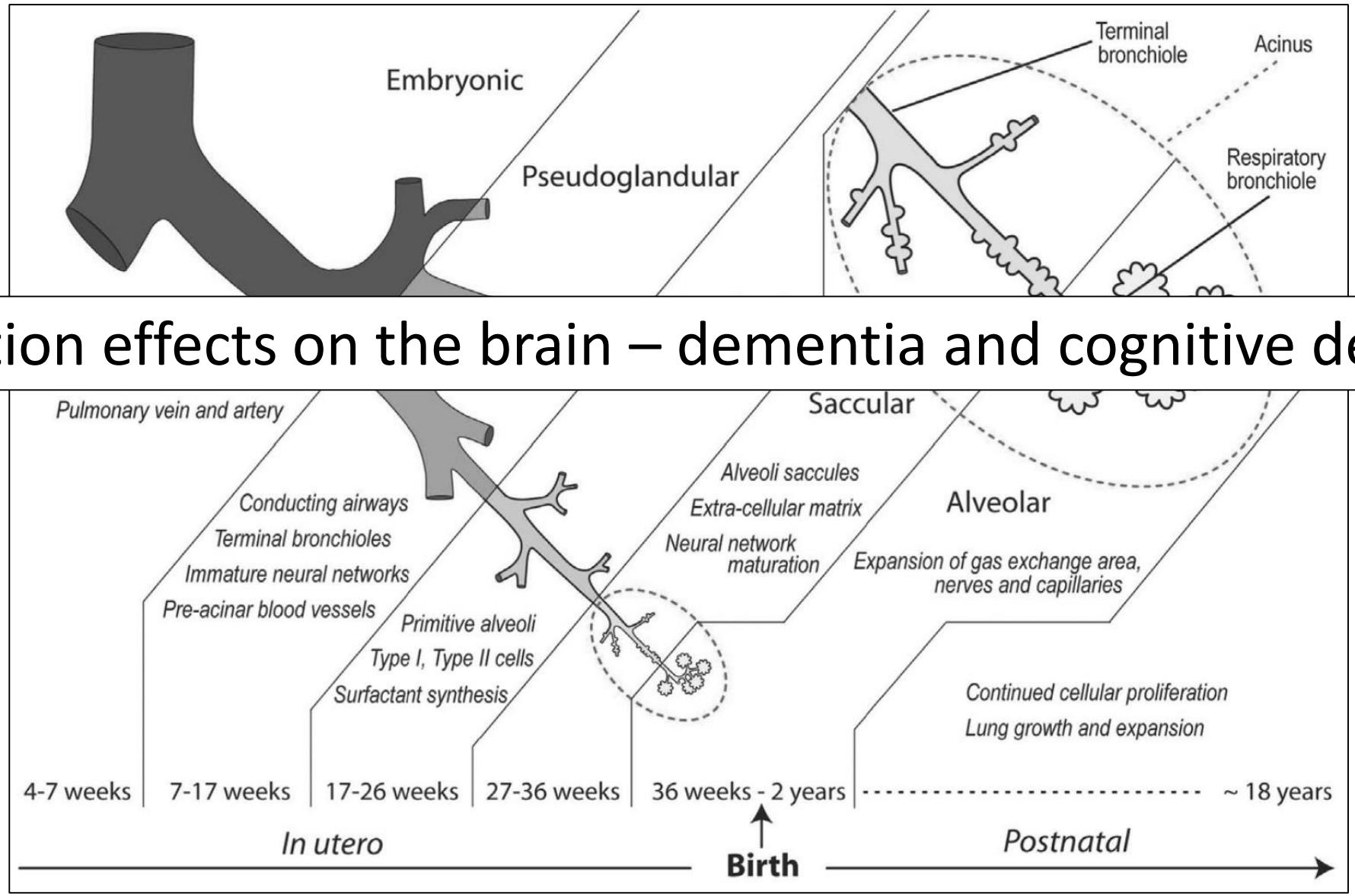
BC particles accumulate on the fetal side of the placenta suggests that ambient particulates could be transported towards the fetus and represents a potential mechanism explaining the detrimental health effects of pollution from early life onwards.

Effect of air pollution in modifying gene expression – epigenetics – CpG methylation



1. **Air pollution-induced placental alterations: an interplay of oxidative stress, epigenetics, and the aging phenotype**? Saenen, N.D., et al. Clin Epigenet. 2019; 11: 124
2. **Epigenetic marks of prenatal air pollution exposure found in multiple tissues relevant for child health.** Ladd-Acosta C, et al. Environ Int. 2019; 126: 363-76.
3. **Prenatal Particulate Air Pollution and DNA Methylation in Newborns: An Epigenome-Wide Meta-Analysis**. Gruzieva O, et al. Environ Health Perspect. 2019; 127: 57012.

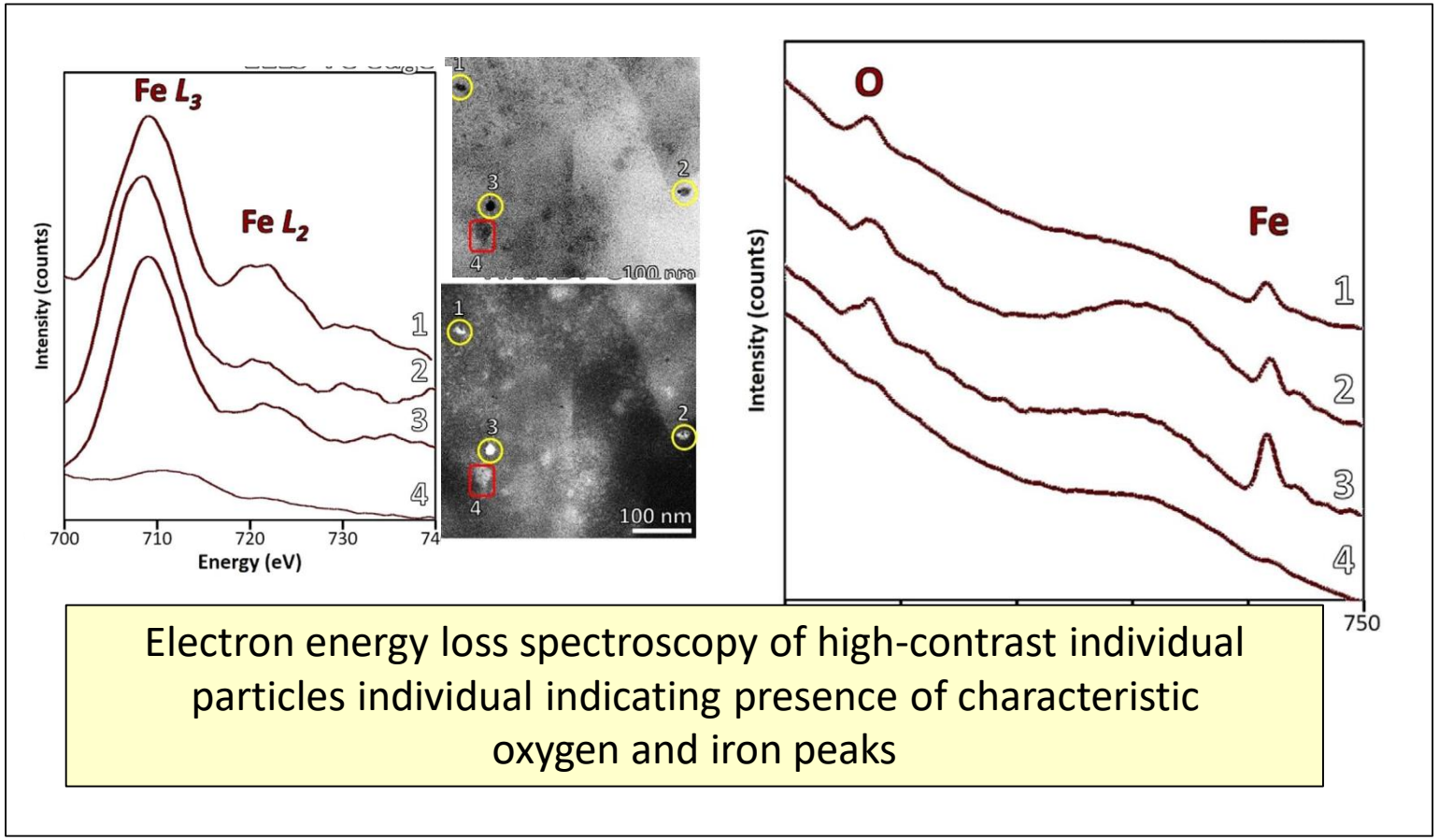
Principle stages of lung development in humans



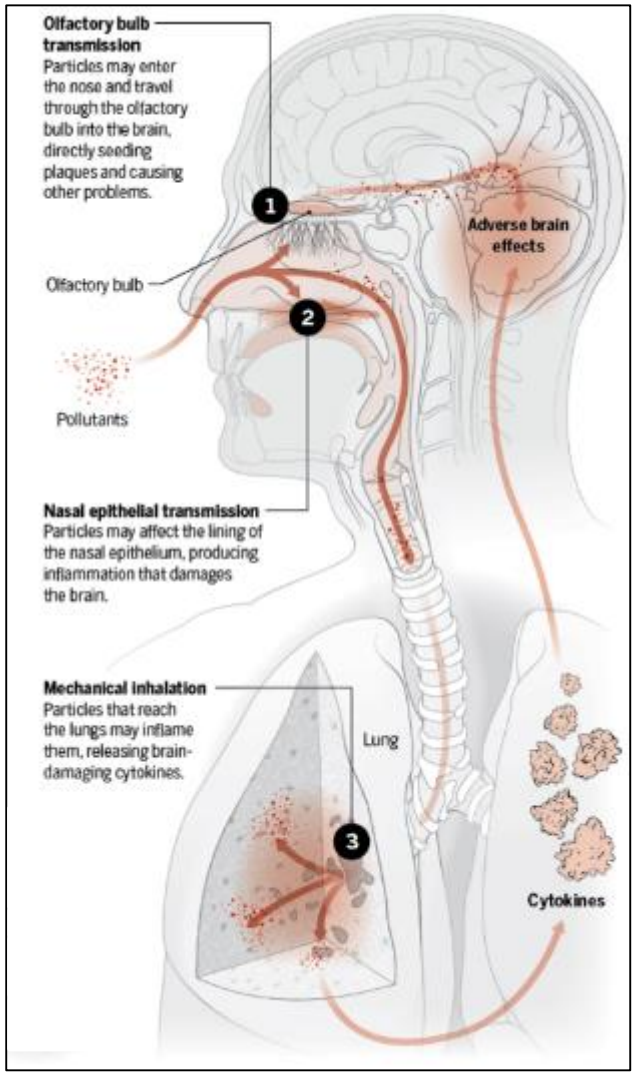
Pollution effects on the brain – dementia and cognitive decline

High-resolution analytical imaging and electron holography of magnetite particles in amyloid cores of Alzheimer's disease

Plascencia-Villa G et al. Sci Rep. 2016; 6: 24873.



Electron energy loss spectroscopy of high-contrast individual particles individual indicating presence of characteristic oxygen and iron peaks

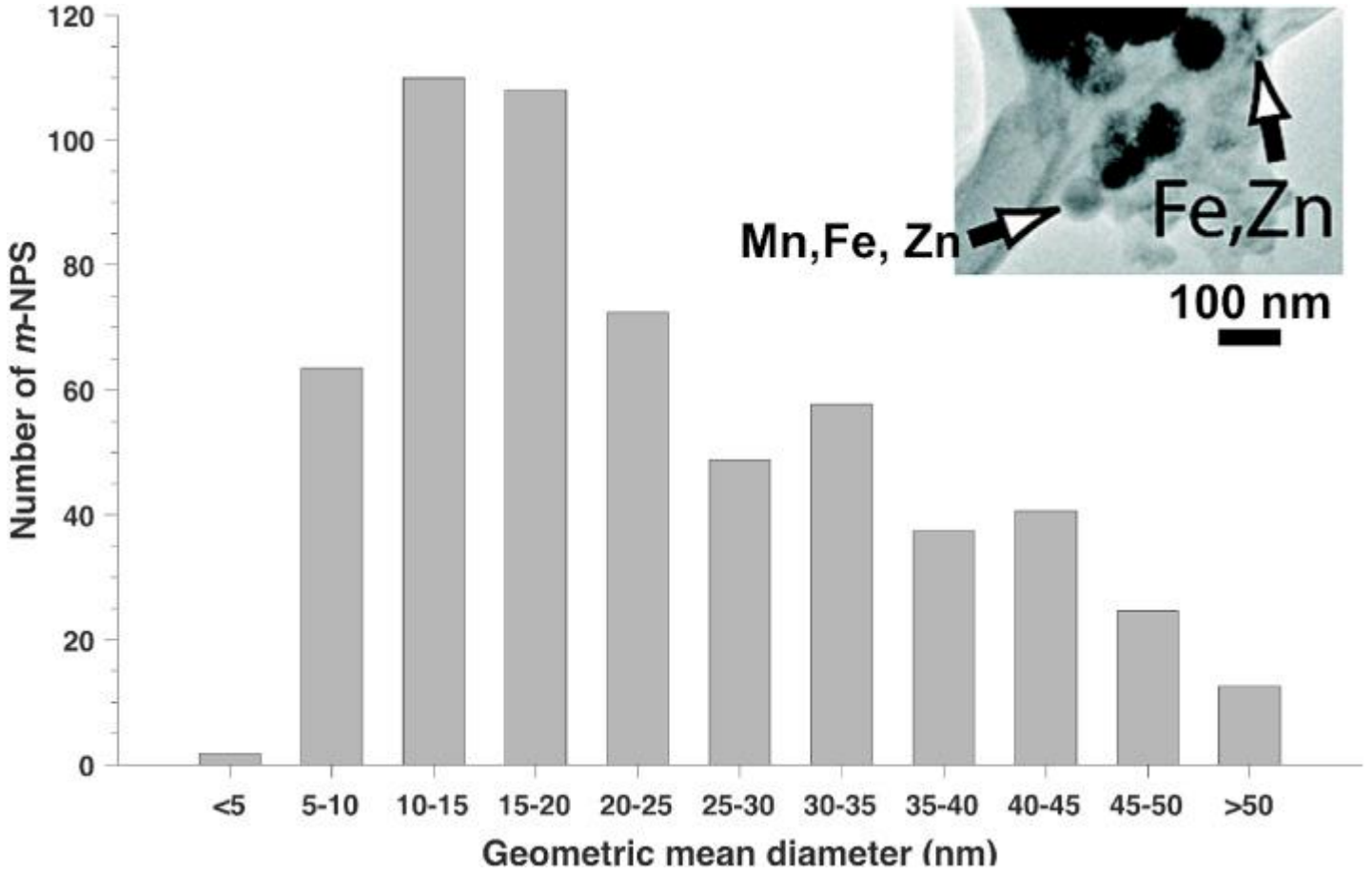


Combustion- and friction-derived magnetic air pollution nanoparticles in human hearts.

Calderón-Garcidueñas L, et al. Environ Res. 2019 Sep;176:108567.

- 27 clinically healthy subjects ~age 23yrs in Mexico City who died suddenly in RTAs, without chest or head trauma
- Heart magnetic content - 2G RAPID cryogenic and JR6 magnetometers and saturation magnetic remanence (SIRM) of freeze-dried left ventricle samples.
- After tissue digestion papain, heart magnetic particles examined directly by high resolution TEM analyses of magnetically-extracted particles,
- Iron-rich, strongly magnetic combustion- and friction-derived nanoparticles are present in abundance in young urbanites' hearts.
- Mexico City residents have up to ~22 billion magnetic NPs/g of ventricular tissue.
- Oxidative and endoplasmic reticulum (ER) stress are significant in human ventricular tissues.
- Exposure to abundant, highly oxidative, iron-rich pollution nanoparticles is a plausible route into CVD pathogenesis.

The particle size distribution of metal-bearing NPs samples in Mexico City air; inset transmission electron micrograph shows the typical rounded shape of these pollution ‘nanospheres’, rich in Fe and other associated transition metals.



Combustion- and friction-derived magnetic air pollution nanoparticles in human hearts.

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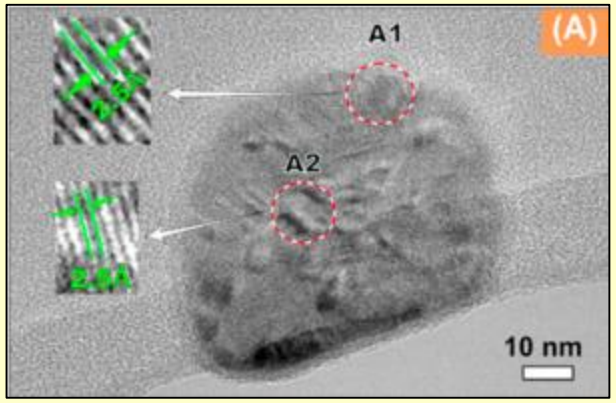
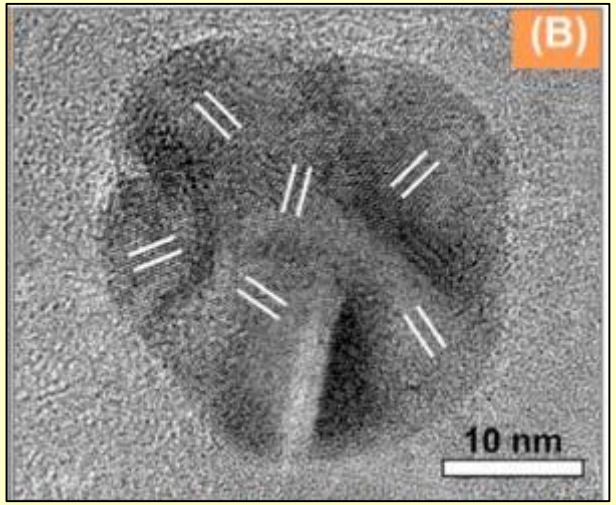
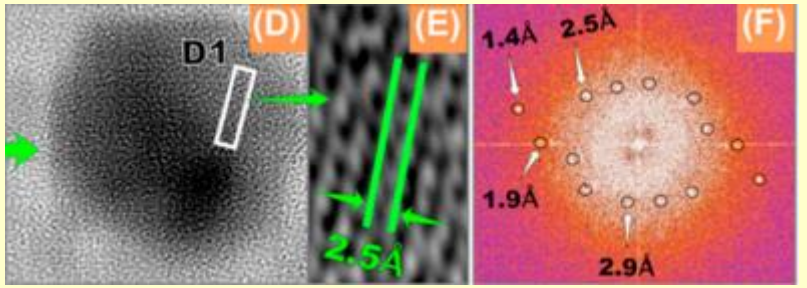


HRTEM micrographs of (A) magnetic NPs ~80 nm diameter with fused interlocking nanocrystallites (note the varying orientations of the individual crystallite faces) extracted from left ventricle sample in a 48 yr old male.



(B) for comparison, airborne pollution particle collected by air sampling near a power generating plant (Didcot, U.K.)



(D–F) Aggregated heart nano-magnetite (hkl plane = 311) or nano-maghemite (hkl plane = 312) particles, with lattice spacing of 2.5 Å

2017 – Ribble Cycles surveyed 1,060 UK adults

The average person in Britain spends just 8 per cent of their time outside on a week day, meaning less than two hours a day out of doors.

Most of this time is spent walking to the shops or the car, but men are slightly better at getting out than women, at 28 minutes more per weekday.

Brits also admit to spending 1 hour 37 minutes per day less outside during winter in comparison to summer.

- Taking pets for a walk (17%)
- Walking to the shop at lunchtime (16%)
- Walking to and from the car (15%)
- Walking to work from my bus/train (14%)
- Going for a run (6%)
- Walking the kids to school (5%)
- Smoking (4%)
- Cycling to work (2%)

‘The Indoor Generation'

RCPCH
Royal College of Paediatrics and Child Health
Leading the way in Children's Health

Royal College of Physicians

Clean Air Programme

January 2020

The inside story:
Health effects of indoor air quality on children and young people

+

Improving indoor air quality

NICE National Institute for Health and Care Excellence

Actions for local authorities

Checking people's homes and giving advice

Use inspections and home visits to identify poor indoor air quality.

Staff who visit people's homes should:
- know about sources of indoor air pollutants and their effects on health
- give advice on avoiding activities that increase pollutants and improving ventilation (see below)
- know who can provide help with repairs and necessary improvements
- give advice on requesting a housing assessment if poor indoor air quality is suspected.

Advise private and social tenants to contact their landlord if:
- ventilation is inadequate
- repairs are needed to prevent water from entering the home
- improvements are needed to heating or insulation to prevent condensation.

Advise tenants to contact their local authority if no action is taken to improve ventilation or carry out repairs.

Advice on reducing damp and condensation
- Use background ventilation (trickle vents or whole-house mechanical ventilation)
- Use extractor fans and open windows (if possible and safe)
- Avoid moisture-producing activities (such as air-drying clothes) or, if unavoidable, improve ventilation
- Repair sources of water damage and remove residual moisture

Advice on increasing ventilation

Use extractor fans in bathrooms and kitchens, or open windows (if possible and safe) when:
- using cookers
- using open solid-fuel fires or free-standing gas heaters
- using candles
- using cleaning products, household sprays or aerosols and paints
- having a bath or shower
- air-drying clothes

Other advice
- Do not use unflued paraffin heaters
- Follow product instructions if using, for example, paint, glue and solvents
- Choose low-emission materials if replacing furniture or flooring
- Ensure adequate ventilation when installing a new cooker
- Do not use gas cookers to heat a room
- Avoid smoking in the home

Actions for healthcare professionals

Advice for people with breathing or heart problems
- Explain that indoor air pollutants can trigger or exacerbate asthma, other respiratory conditions and cardiovascular conditions
- If repeated or worsening cough or wheezing, ask about housing conditions and help request a housing assessment if concerned
- If household sprays or aerosols trigger asthma, advise avoiding them or using non-spray products

Advice for people allergic to house dust mites

Advise on how to reduce exposure to to house dust mites, including:
- avoiding second-hand mattresses if possible
- using allergen barriers such as mattress and pillow covers
- washing bedding regularly

Advice for pregnant women and babies under 12 months
- Advise on the increased risks from poor indoor air quality
- Explain the risks of tobacco smoke
- Ask about housing conditions and help request a housing assessment if concerned
- Advise on reducing use of household sprays and aerosols
- Advise on avoiding or reducing use of open solid-fuel fires or candles
- Advise on avoiding smoking in the home or around the woman and baby

UK Research and Innovation

Clean Air Programme

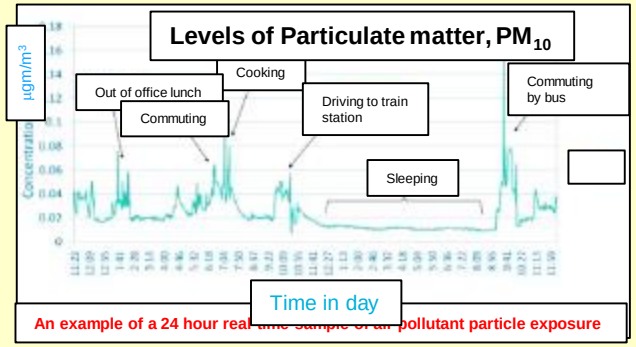
January 2020

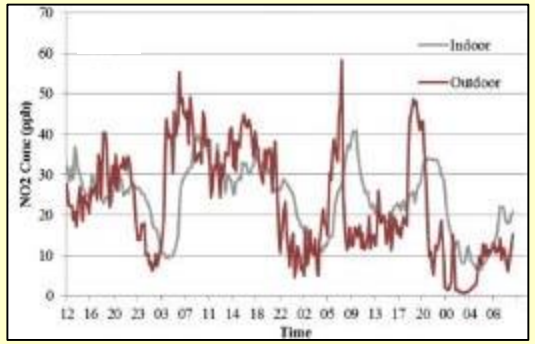
Wave 2 - Clean Air:
Addressing the Challenge of the Indoor/Outdoor Continuum

Clean Air Programme

BACKGROUND

- The scientific, technical, behavioural and policy approaches used to assess and manage exposure to air pollution need radical change to reflect the indoor/outdoor continuum of exposure.





- Human exposure to air pollution occurs in the home, at school and in workplaces, whilst travelling, and during leisure activities.

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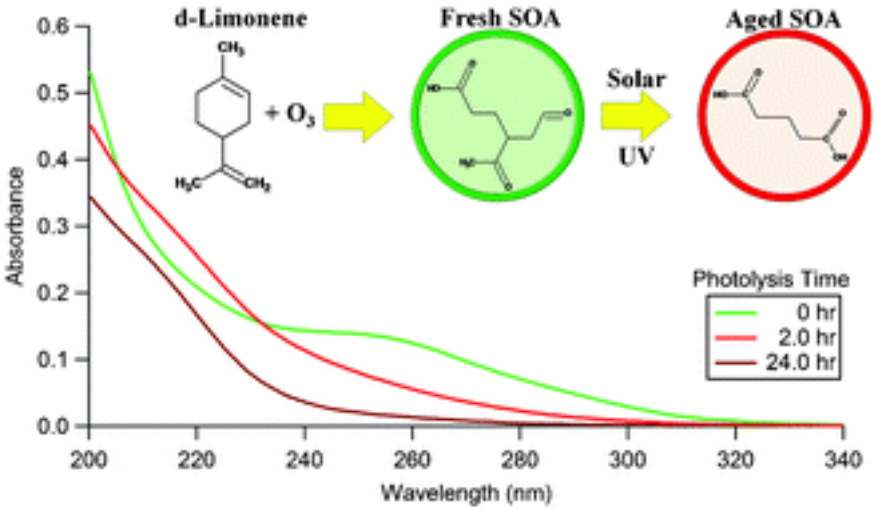
An indoor chemical cocktail: The chemistry that determines human exposure to indoor pollutants is incompletely understood - Gligorovski S, Abbatt JPD. Science 2018: 359; 632-3

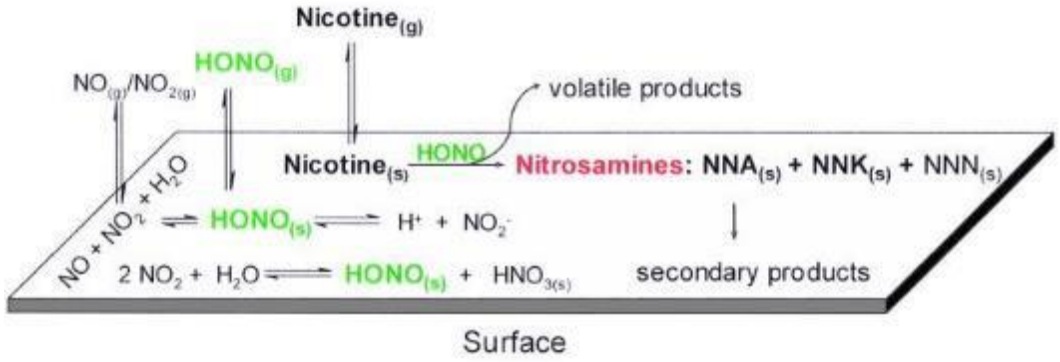


- Recent work has highlighted the wealth of **chemical transformations** that occur indoors to generate **Secondary Organic Aerosol (SOA)**.
- This chemistry is associated with 3 of the top 10 risk factors for negative health outcomes globally: **household air pollution from solid fuels, tobacco smoking, and ambient particulate matter pollution**.
- **Highly oxidised organic compounds** arise via auto-oxidation mechanisms initiated by either ozone or radical attack.
- Reaction with a single oxidant molecule can form multiple oxygenated functional groups on an organic reactant within seconds, changing it from a volatile gas to a molecule that will condense to form **secondary organic aerosol (SOA) particles**.

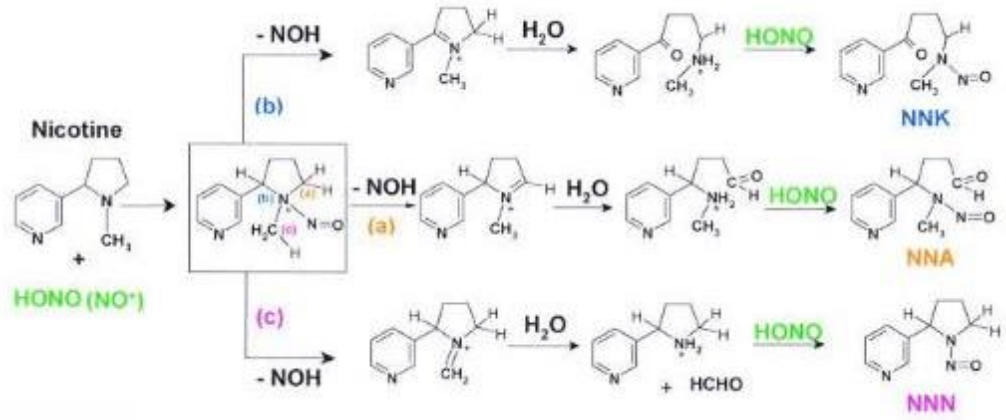
Third-hand Smoke: New Evidence, Challenges, and Future Directions

Jacob P 3rd et al. Chem Res Toxicol. 2017; 30: 270-94.

Third-hand smoke is residual - or leftover - nicotine and other chemicals that remain on clothing and surfaces after someone smokes in the area. Dangerous residue from tobacco smoke sticks to carpets, walls and other surfaces after the smoke clears.



1. Third-hand smoke may be a culprit in more cancer cases
2. Third-hand smoke may damage DNA
3. Residue may react with airborne chemicals to form carcinogens
4. Children are most at risk
5. Removing the residue is very difficult



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SPF Clean Air – Two Waves

Wave 1 - Clean Air: Analysis & Solutions
Developing solutions to air pollution to help policymakers and businesses protect health and work towards a cleaner economy. (£20.5m)

Wave 2 - Clean Air: Addressing the Challenge of the Indoor/Outdoor Continuum
The programme aims to equip the UK to proactively tackle new air quality challenges related to changing emissions and exposure patterns, in order to protect human health and support clean growth. (£22m)

Clean Air Programme

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Air quality dependencies and basis for Clean Air systems analysis framework

Failure of engagement and ownership of the health problems by medical community

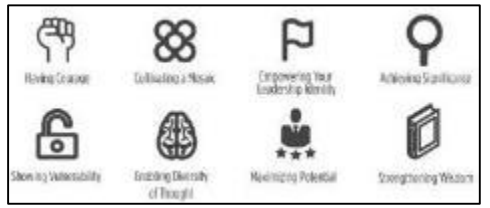
Clean Air Programme

Communication barriers between physical and biological/health scientists

Lack of public understanding

Little motivation for behaviour change

X X X X



Feedbacks

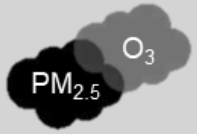
Global/Local Weather

- Weather forecast
- Multi year weather analysis
- Nested finer scale local weather models
- Climate change

Emissions

- Anthropogenic and biogenic
- Temporal and spatial variation
- Street, local, national, regional, global
- Observations

Air Quality



- Street to global
- Hourly to climatic variation
- Gas and aerosol chemistry, deposition, etc
- Weather and climate feedbacks
- Observations

Impacts

- Hazard x Vulnerability x Exposure
- Economic cost/benefit
- Health and Environmental
- Measurement of impact/mitigated impact

Action

- Long term policy e.g. energy mix, vehicle, clean air zones, international
- Tactical e.g. health advice, industrial and traffic management, individual choice

X

Lack of interfaces to promote innovations

X

Industry/economic pushback

Capability/Linkages limited, fragmented and not aligned: Street ⟺ Global a particular challenge

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Clean Air Programme

https://www.ukcleanair.org/

People will change their behaviour only if they see the new behaviour as easy, rewarding, empowering and normal

UK Research and Innovation