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Measuring the Exposome

Swiss Public Health Conference 2024

Nicole Probst-Hensch, September 4 2024

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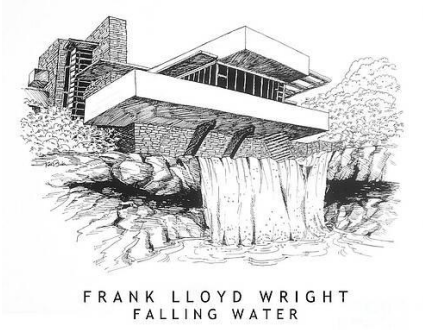
Our environment matters

Environmental implications of the great acceleration since 1950

enormous improvement in living standard in high income countries

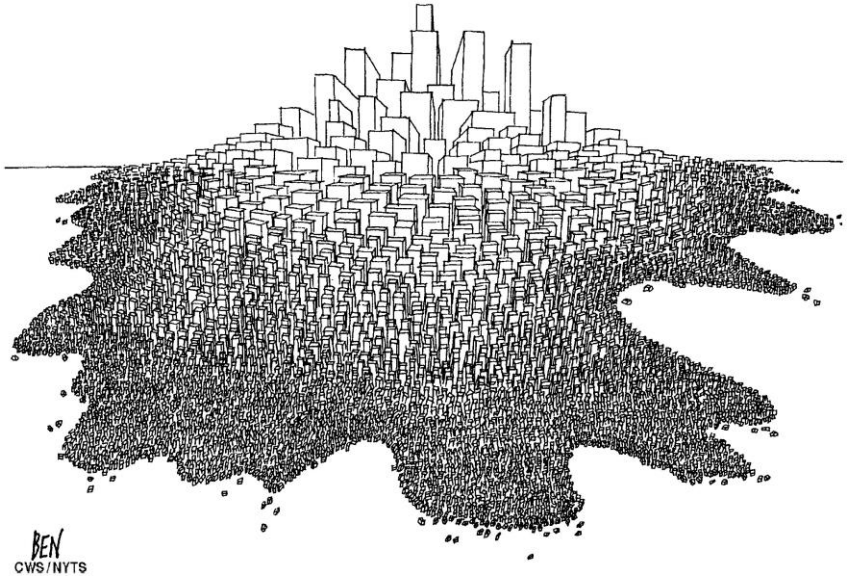


climate change and environmental degradation worldwide

World's urban population growing from >50% to 80% by 2050

Cities only cover 2% of the world's land surface, but activities within their boundaries consume over 75% of the planet's material

Urban living comes with more air pollution, less green & blue space, and heat islands



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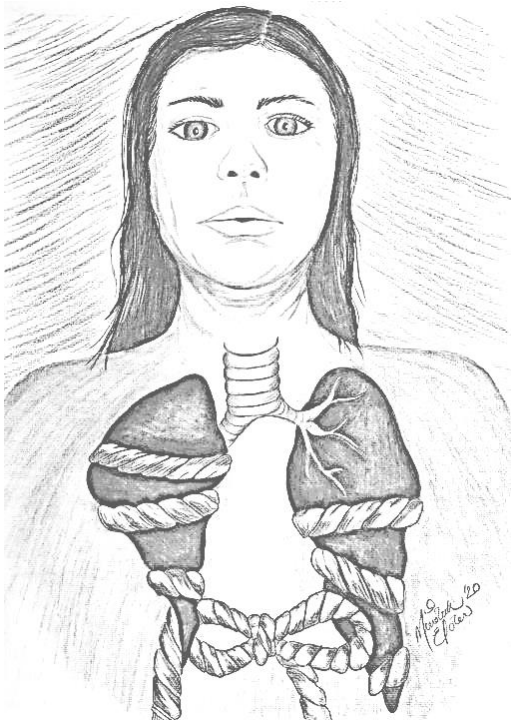
Japan Times Oct 2 2016
Word Economic Forum

NCDs in times of global changes – on top of emerging infections

- 24% of global deaths are due to modifiable environmental factors
- more than 20 million healthy life-years lost because of disease attributable to poor-quality environments

	Environmental risk factors					
Disease	**Ambient air pollution**	**Noise**	**Chemicals**	**Climate change**	**Indoor fuel combustion**	**Radiation**
Cancers	▲		▲		▲	▲
Neuropsychiatric disorders		▲	▲	▲		
Cataracts					▲	▲
Hearing loss		▲				
Cardiovascular disease	▲	▲	▲	▲	▲	
Chronic obstructive pulmonary disease	▲				▲	
Asthma	▲				▲	
Chronic kidney disease			▲			
Skin diseases			▲			
Congenital anomalies	▲		▲			▲

Population attributable fractions ▲ < 5 % ▲ 5–25 %

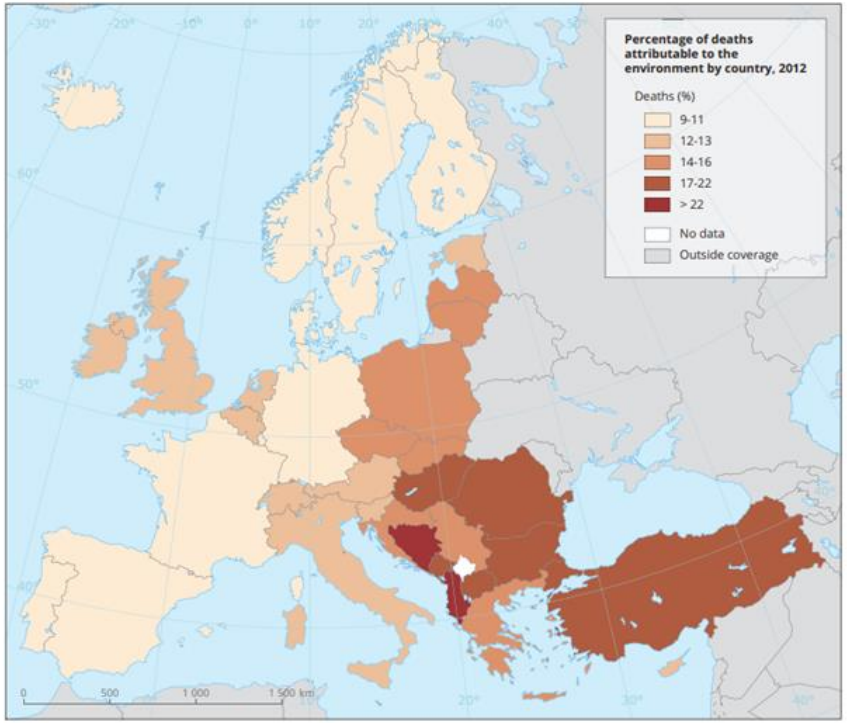


Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks (who.int)

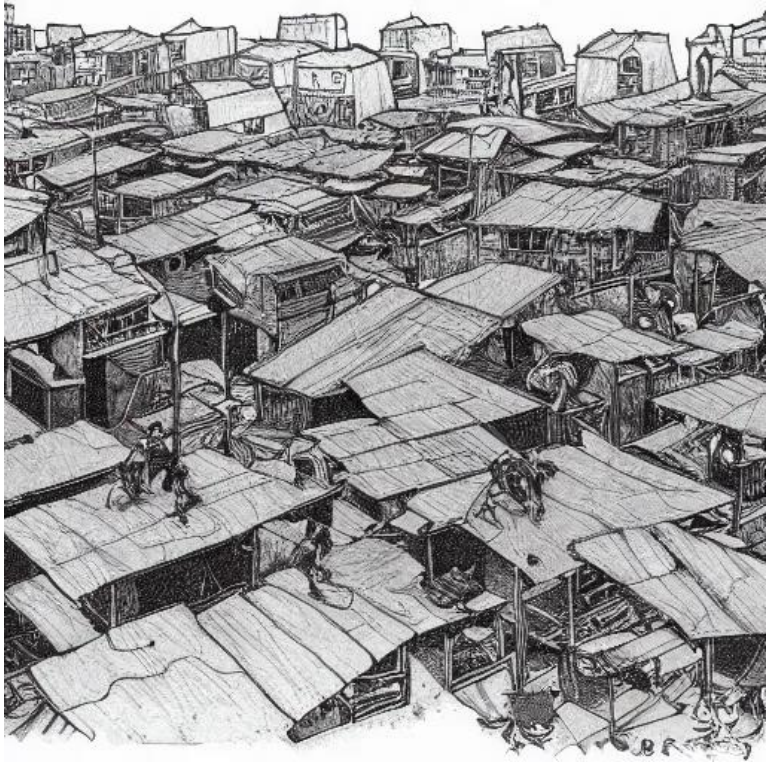
Uneven distribution of environmental disease

people in low- and middle income countries bear the greatest burden

European perspective



Global perspective



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Our environment is not one dimensional

The reality of exposure to pollutants

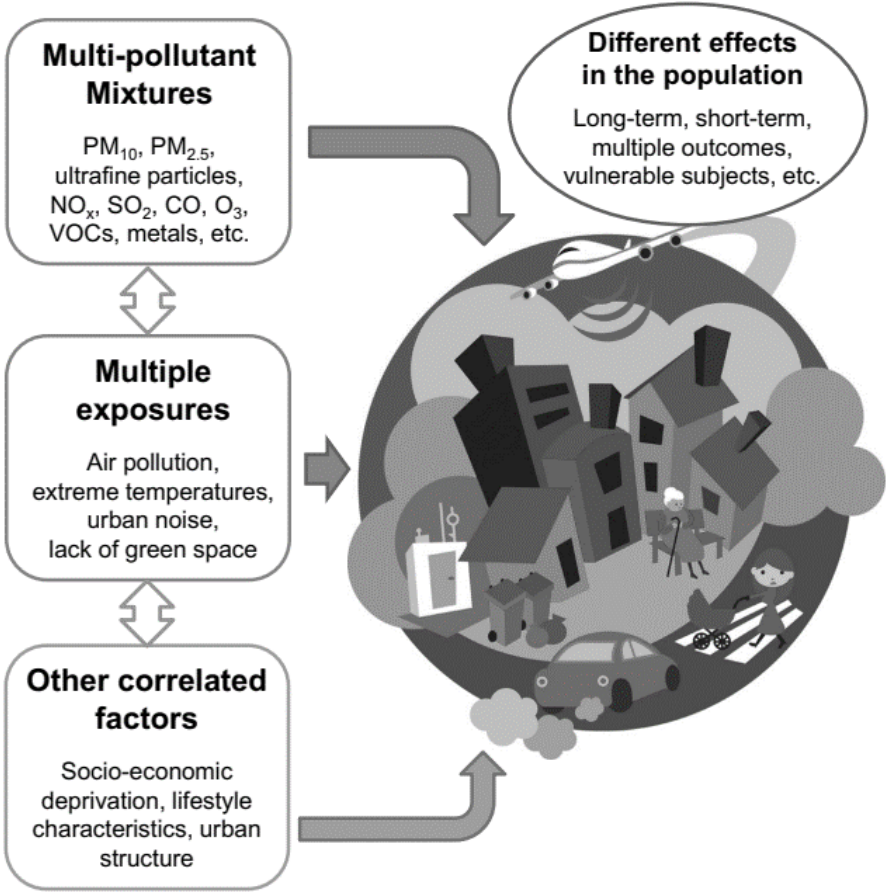
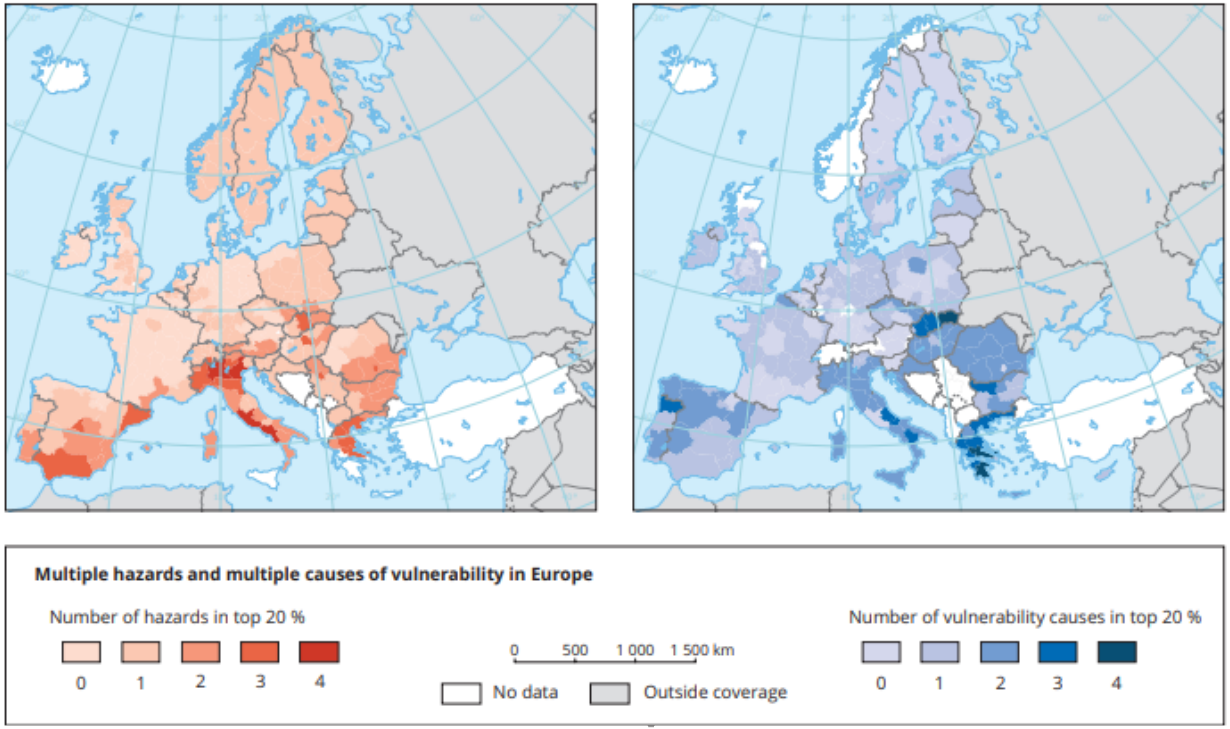


Figure adapted from Staffoggia M et al. Curr Envir Health Rpt (2017) 4:481–490

Uneven distribution of exposure to multiple environmental hazards in Europe



N of exposures for which a region falls into top 20% of EU:
1) PM10
2) NO2
3) ozone
4) number of cooling degree days
5) number of heating degree days

N of dimensions for which a region falls into top 20% of EU:
1) % of children under 5 years old
2) % of people aged ≥75 years
3) average household income
4) % of long-term unemployed
5) % of people without higher education

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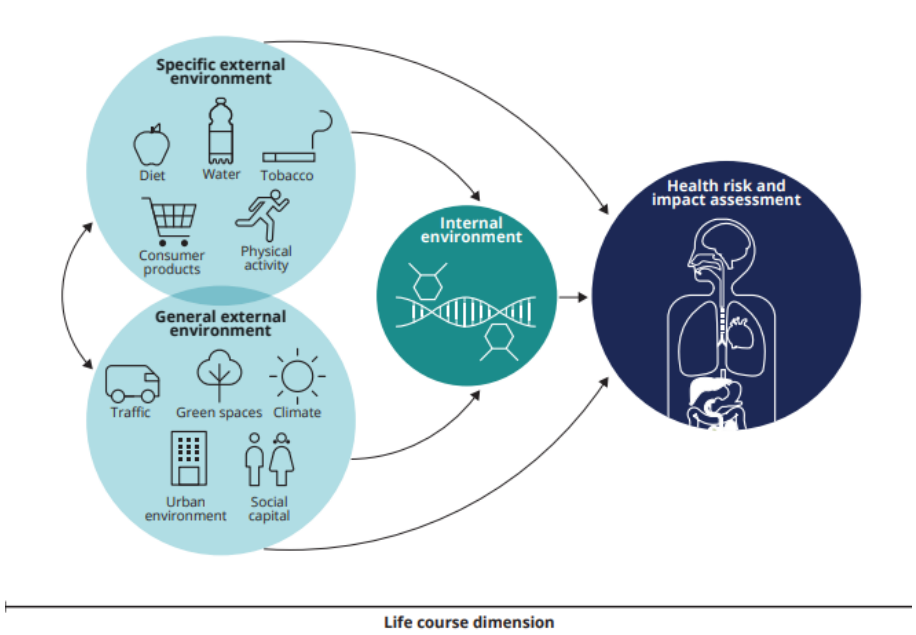
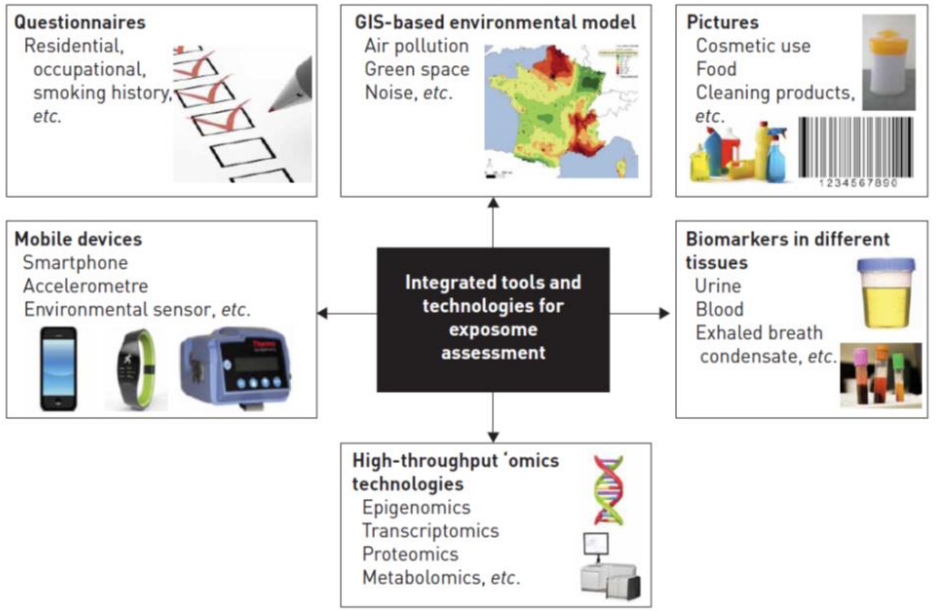
Our environment in it’s entirety: the exposome

The exposome concept and toolkit





Adapted from Vrieheid 2014

Wild CP. Cancer Epidemiol, Biomarkers Prev. 2005;14:1847; Rappaport SM and Smith MT. Science 2010;330:460;
Vermeulen R et al. Science 2020;367:392

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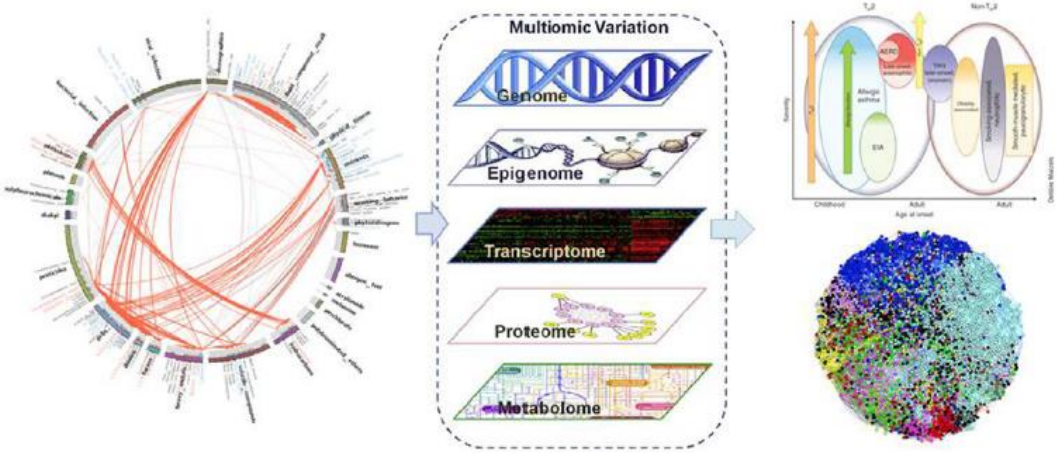
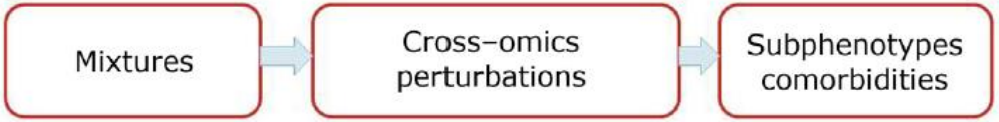
Application of exposome science: citizen cohorts & biobanks

Systems epidemiology



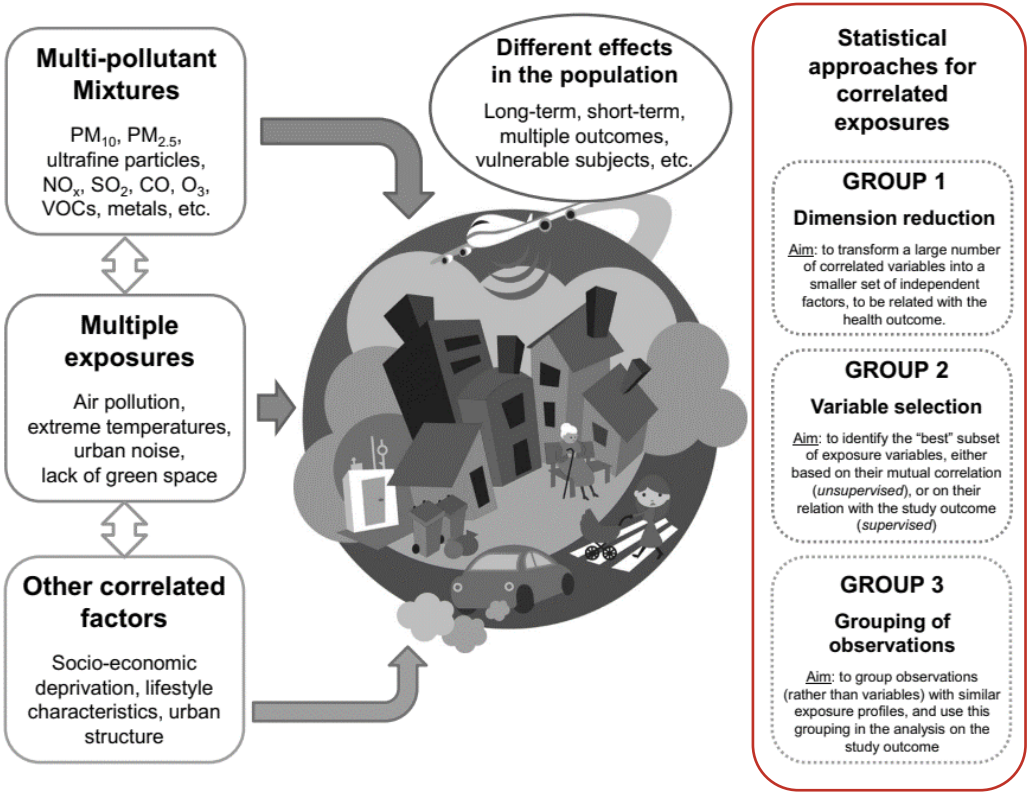
Meet-in-the-middle concept—prospective biosampling

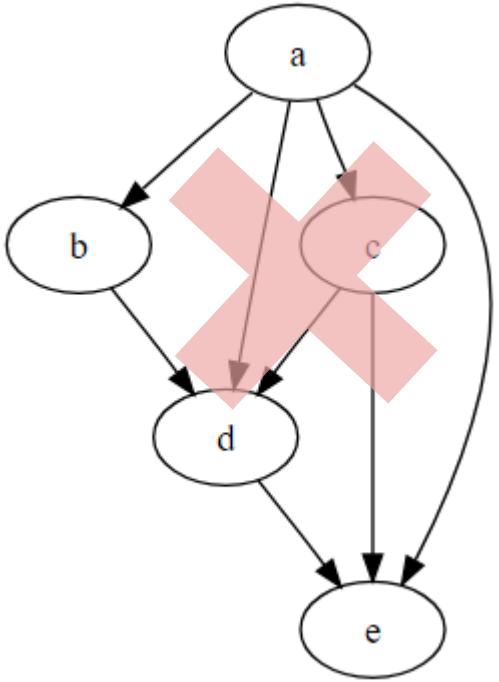


towards improved causal understanding

Probst-Hensch N. In: Patrinos GP, (ed). Applied Genomics and Public Health.San Diego: Elsevier Inc./Academic Press, 2020: pp-pp.

Statistical approaches to exposome science





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The era of exposome epidemiology

EXPOSOME POWERED TOOLS

for healthy living in urban settings

IMPROVING URBAN POPULATION HEALTH

By 2030 more than 80% of Europe's population will live and interact with a complex urban environment, consisting of a mixture of social and environmental factors. Individually or collectively these factors, known as the Urban Exposome, have an often modifiable impact on our health and provide important targets to improve population health.

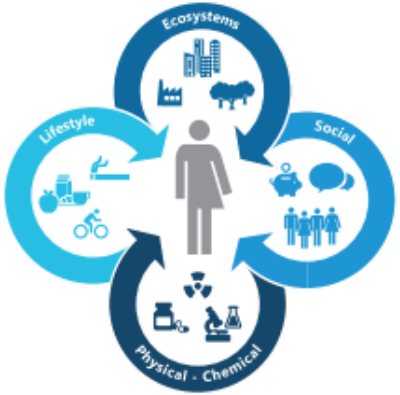
EXPANSE will address one of the most pertinent questions for urban planners, policy makers, and inhabitants in Europe: "How to maximize one's health in a modern urban environment?"

READ MORE ABOUT

> Urban Exposome
> Publications
> Work Packages
> Exposome MOOC

External Exposome

Pan-European fine resolution spatial-temporal exposure maps 2000-2020



Ecosystems

- Food outlets, alcohol outlets
- Built up environment and urban land uses
- Population density
- Walkability
- Green/Blue space

Lifestyle

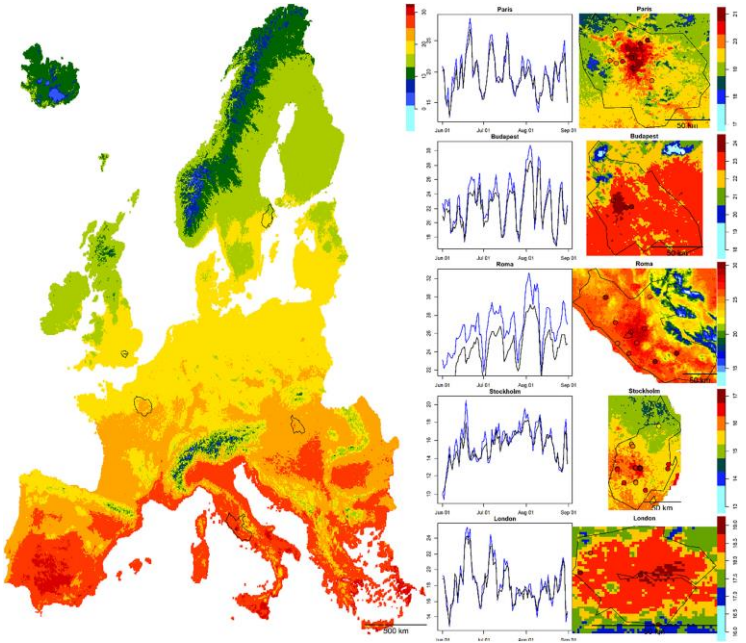
- Physical activity
- Sleep behaviour
- Diet
- Drug use
- Smoking
- Alcohol use

Social

- Household income
- Inequality
- Social capital
- Social networks
- Cultural norms
- Cultural capital
- Psychological and mental stress

Physical - Chemical

- Temperature/ Humidity
- Electromagnetic Fields
- Ambient Light
- Odour & noise
- Point, line sources e.g. factories, ports
- Outdoor and indoor Air Pollution
- Agricultural activities, livestock
- Pollen/Mold/Fungus
- Pesticides
- Fragrance products (Musk, musk ketone)
- Flame Retardants (PBDEs)
- Persistent Organic Pollutants
- Plastics and plasticizers
- Food contaminants
- Soil contamination
- Drinking water contamination
- Groundwater contamination
- Surface water contamination
- Occupational exposures



Summer Temperature Europe 2017

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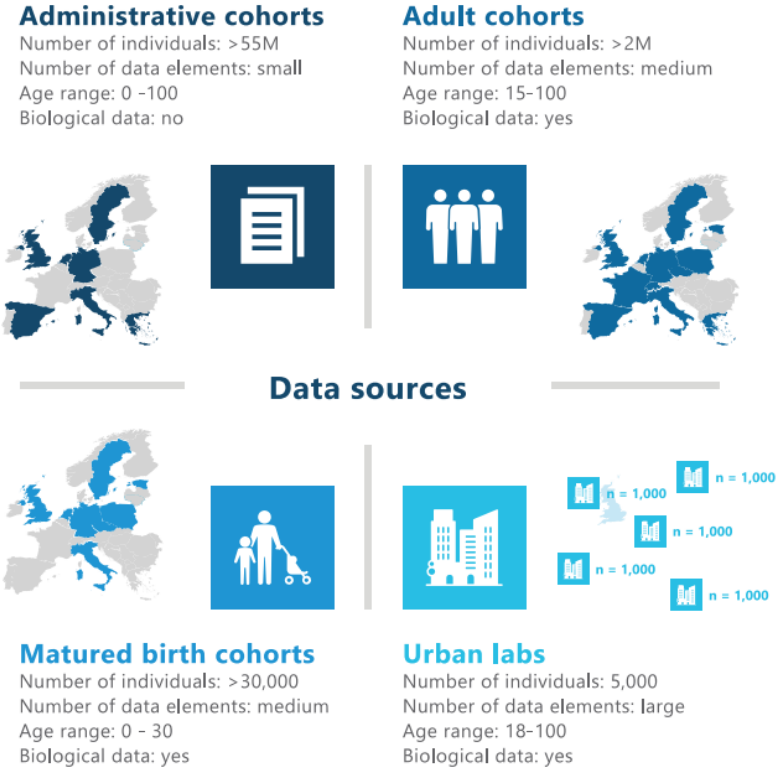
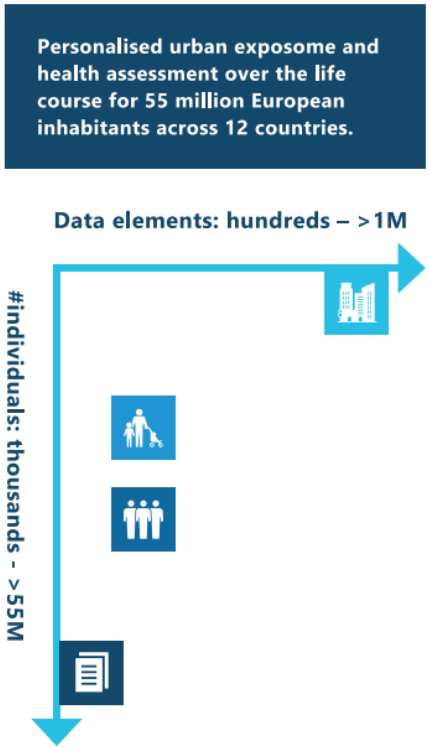
Bussaleu et al. Sci Tot Environ 2024

Different Expanse cohort types
external exposome-health associations





Administrative cohorts
for large sample size - exposome and all-cause mortality

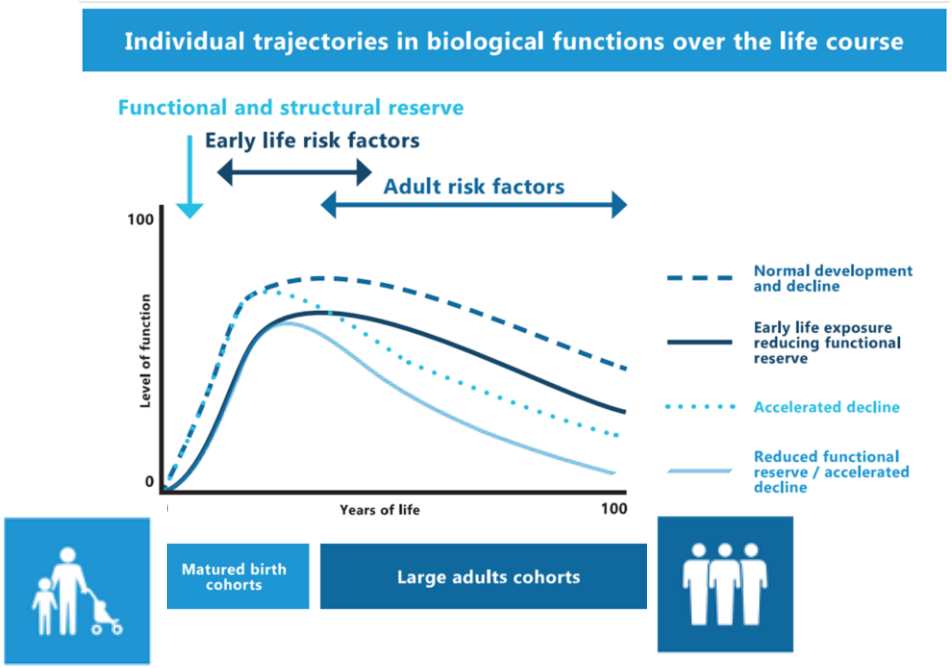
- established through record linkage e.g., with population-based archives and census registers
- ~30 Mio. participants across Europe
- ~205 Mio. person-yeas of follow-up
- ~3 Mio. deaths
- air pollution, built environment, temperature (mean/SD warm & cold season)
- domain-specific principal component analysis
- cumulative risk index

Cumulative risk Index (CRI) estimates
for each domain and for all domains simultaneously

	Air pollution	Land/built environment	Air temperature	Air pollution + land/built environment (sensitivity)	Air pollution + land/built environment + Air temperature
Catalonia	1.066[a]	0.973	0.966	1.042	0.997
	(1.047–1.086)	(0.964–0.983)	(0.948–0.985)	(1.022–1.062)	(0.971–1.025)
Greece	1.026	1.009	1.054	1.021	1.038
	(1.013–1.040)	(1.002–1.016)	(1.046–1.062)	(1.007–1.034)	(1.023–1.052)
Rome	1.011[a]	1.029	1.011	1.033	1.040
	(1.005–1.018)	(1.019–1.04)	(1.003–1.020)	(1.022–1.045)	(1.025–1.054)
Sweden	1.043	1.079	0.999	1.085	1.099
	(1.035–1.050)	(1.075–1.084)	(0.993–1.004)	(1.075–1.094)	(1.088–1.109)
Switzerland	1.047	1.108	0.993	1.106	1.085
	(1.040–1.053)	(1.102–1.113)	(0.989–0.998)	(1.098–1.114)	(1.076–1.094)
Netherlands	1.009	1.008	1.011	1.012	1.019
	(1.004–1.013)	(1.004–1.012)	(1.005–1.018)	(1.006–1.017)	(1.011–1.027)

- increased risk for all-cause mortality for the combination of higher air pollution and poorer land/built environment for almost all the cohorts
- associations for the CRI were generally higher than those for the single exposures pointing to interactions between different environmental stressors

«Active» cohorts
for deep phenotyping across the lifecourse



Lung function-associated exposome profile in the era of climate change

pooled analysis of 8 European cohorts within the EXPANSE project

A. Jeong , G. Lovison,

A. Bussalleu, M. Cirach, P. Dadvand, K. de Hoogh, C. Flexeder, G. Hoek, M. Imboden, S. Karrasch, G.H. Koppelman, S. Kress, P. Ljungman, R. Majewska, G. Pershagen, R. Pickford, Y. Shen, R.C.H. Vermeulen, J.J. Vlaanderen, M. Vogli, K. Wolf, Z. Yu, E. Melén, A. Pac, A. Peters, T. Schikowski, M. Standl, U. Gehring,

N. Probst-Hensch

How are long-term exposure to air pollution, greenness, and temperature, as well as their interactions associated with lung function across the life course?

Harmonized exposome layers developed in EXPANSE

Air pollution

- Annual mean exposure to NO2
- Annual mean exposure to PM2.5
- Annual mean exposure to PM10
- Warm season mean exposure to ozone

Greeness

- NDVI within 300m buffer
- Distance to the nearest green space

Temperature

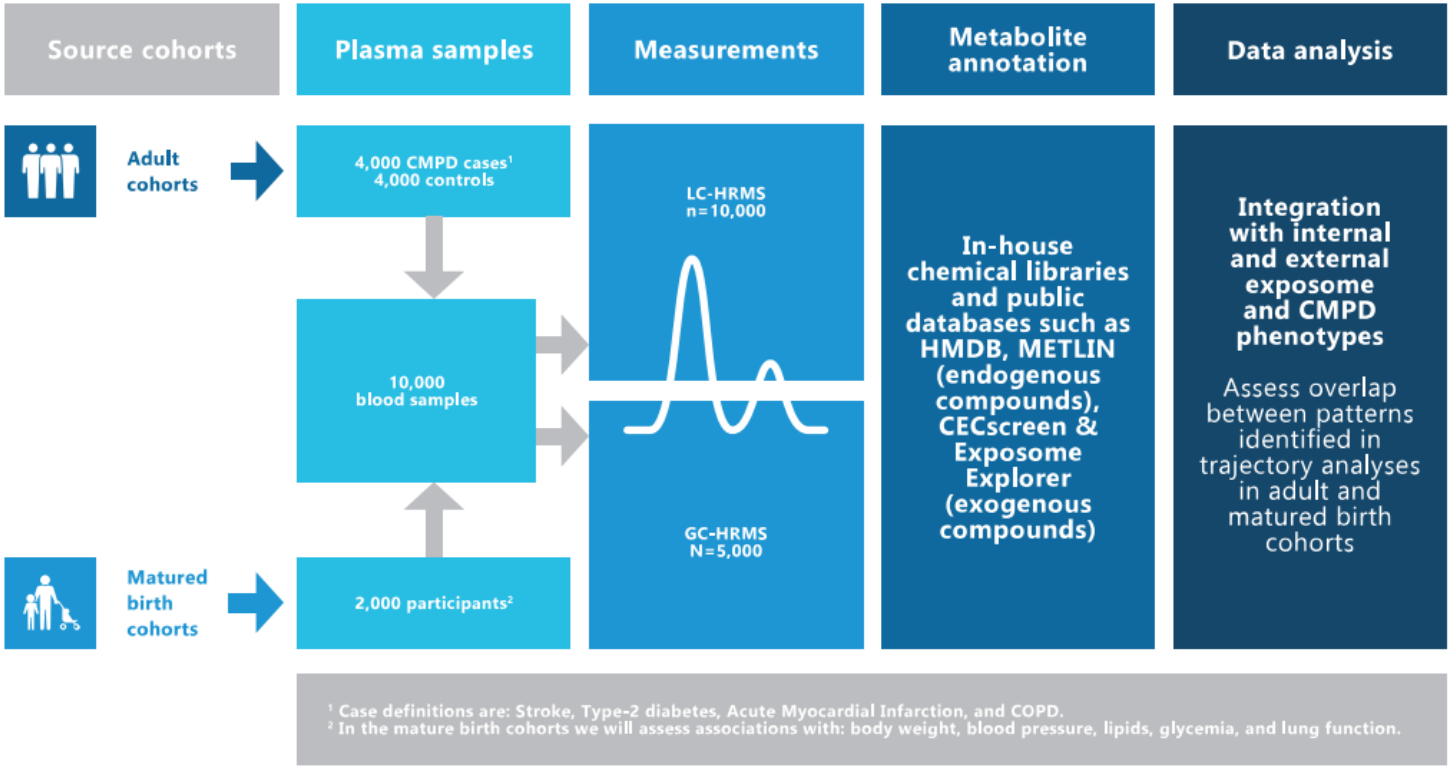
- Annual average of daily mean temperature
- Annual standard deviation of daily mean temperature
- Warm season average of daily maximum temperature
- Cold season average of daily minimum temperature

Environmental scenarios

Interpretation of elastic net regression results in the context of different scenarios

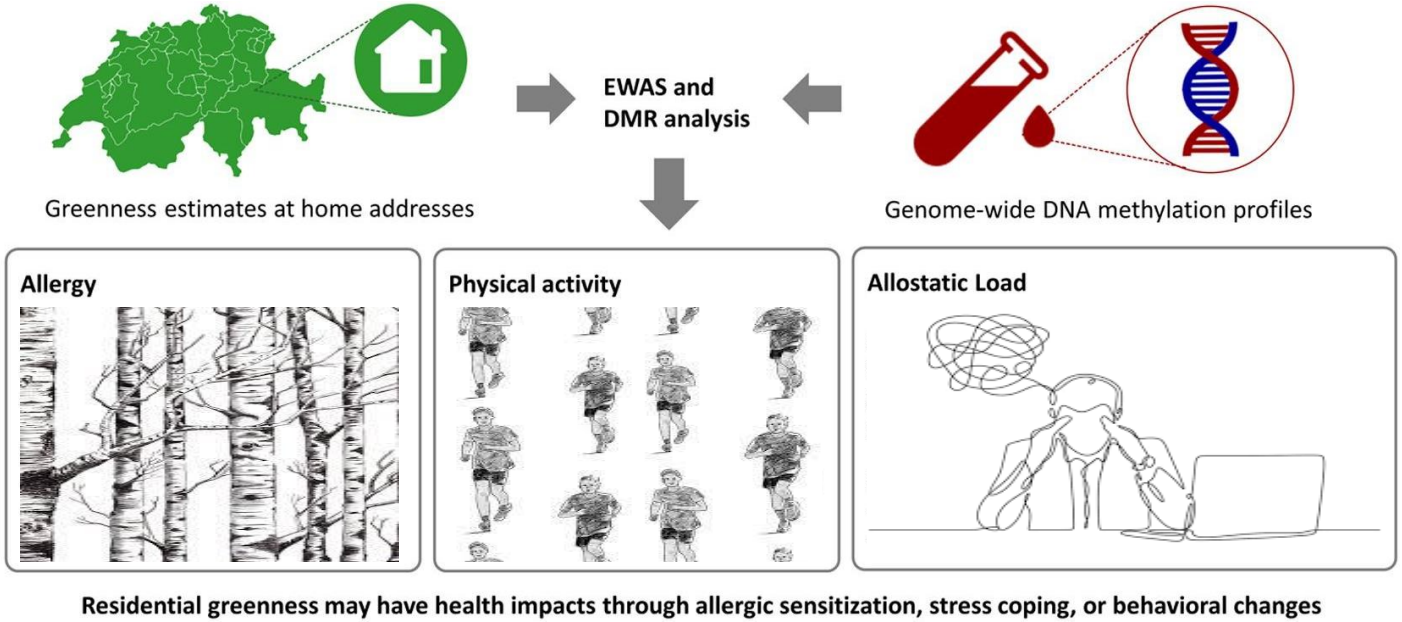
1. **Improving air quality**
   decrease in NO2, PM10, ozone by 10µg/m^3, and PM2.5 by 5µg/m^3
2. **Improving greenness**
   increase in NDVI by 0.1 and reduction in the distance to green by 100m
3. **Climate change**
   daily mean temperature increase by 2°C in summer and decrease by 1°C in winter
4. **1 + 3**
5. **2 + 3**
6. **1 + 2 + 3**

Internal exposome
for interrogation of mediating biological pathways



Greeness at residence

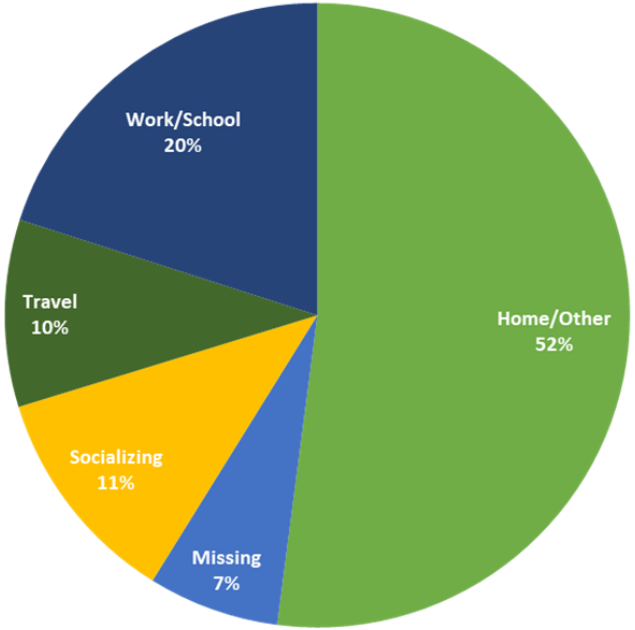
Sustainable influence on DNA methylation in the SAPALDIA cohort



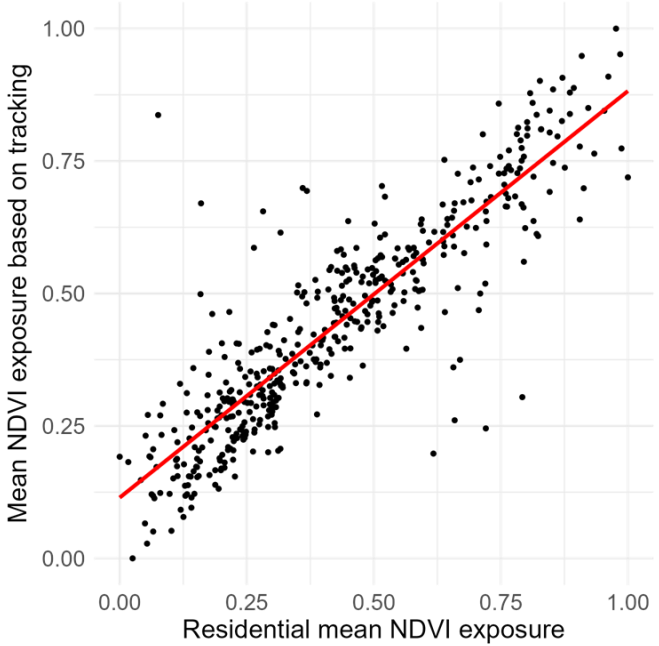
Residential greenness may have health impacts through allergic sensitization, stress coping, or behavioral changes

SAPALDIA Kohorte & Biobank; Jeong et al. Environ Int 2021

Expanse Urban Lab GPS Tracking:
Residential exposure versus actual exposure to greenspace



Average time spent in different activities



Fake data for illustration purpose

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Outlook on health promotion

Less efficient from a Public Health perspective: personalised health optimization

More efficient from a Public Health perspective: environment optimized health promotion

Policy-to-Science

Shift from curiosity-driven to policy-driven research ?

The «personalized health» trap of environmental science

Looking deeper and deeper
is not always of utility

–

Sometimes it is just
expansive

Decision taking in the light of uncertainty

- Chronic health risks cannot be randomized
- Mixture effects are challenging to assess
- Observational epidemiology can only approximate causality

Is causality as a main principle of biomedical and clinical research the right standard?

How much certainty do we need to act?