Climate Change and Health Educational Resources for Postgraduate Medical Training

Erasmus+

CLIMATEMED

Project CLIMATEMED – 2024

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the European Union

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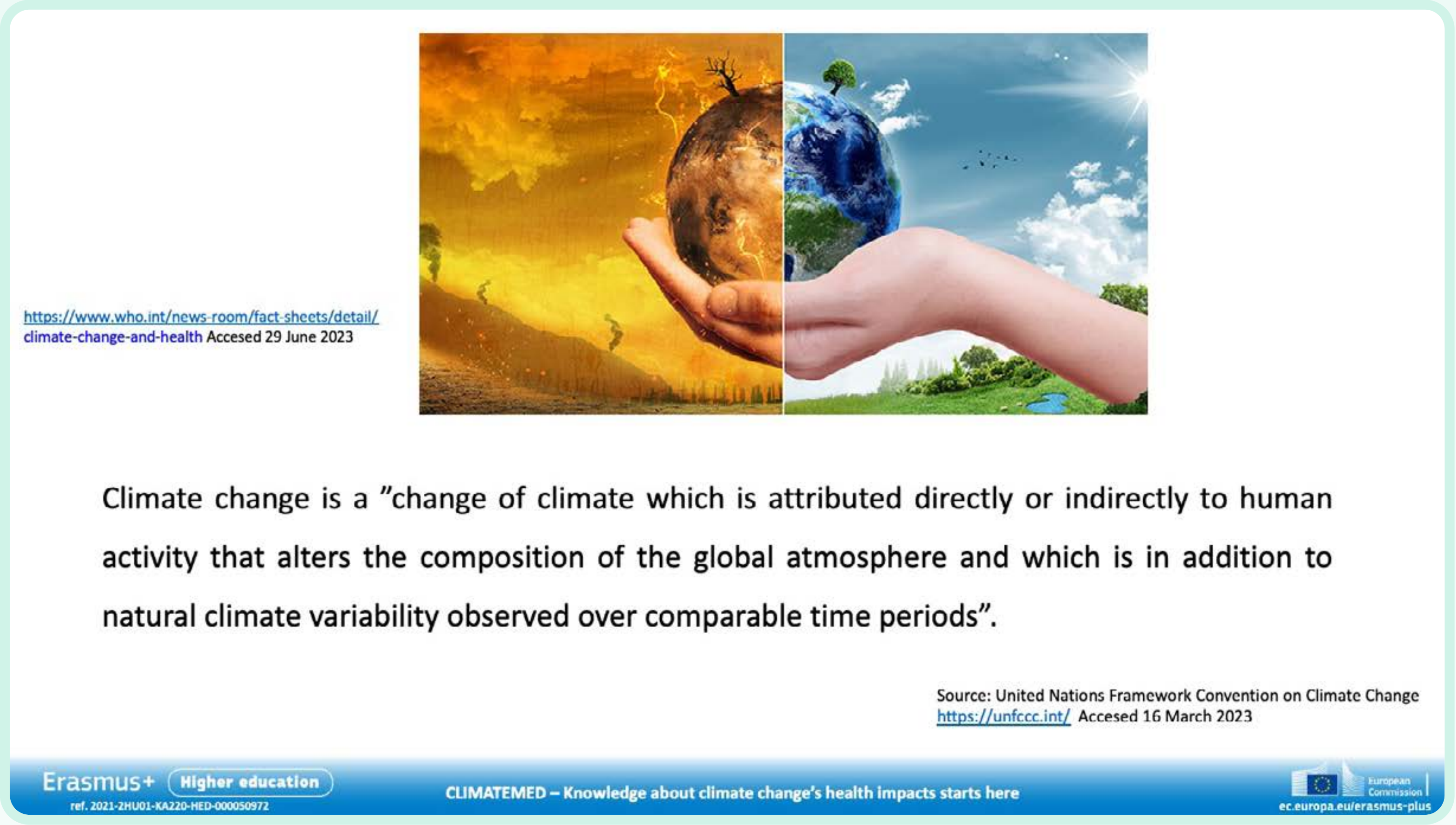
CLIMATEMED



Climate change is one of the greatest challenges of our time. It is now widely recognized that climate change and biodiversity loss are interconnected, and that both are increasingly influenced by human activity. With our educational series we want to drawn attention to a number of risks posed to human societies by the degradation of the earth's ecological and climatic systems, including threats to water and food security, air quality, the availability of natural resources used for medicinal, spiritual or recreational purposes and livelihoods, population displacement, conflict and disasters, and potential influences on patterns of disease.

→ Climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions, or persistent anthropogenic changes in the composition of the atmosphere or land use.

→ Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

→ UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric omposition, and climate variability attributable to natural causes.

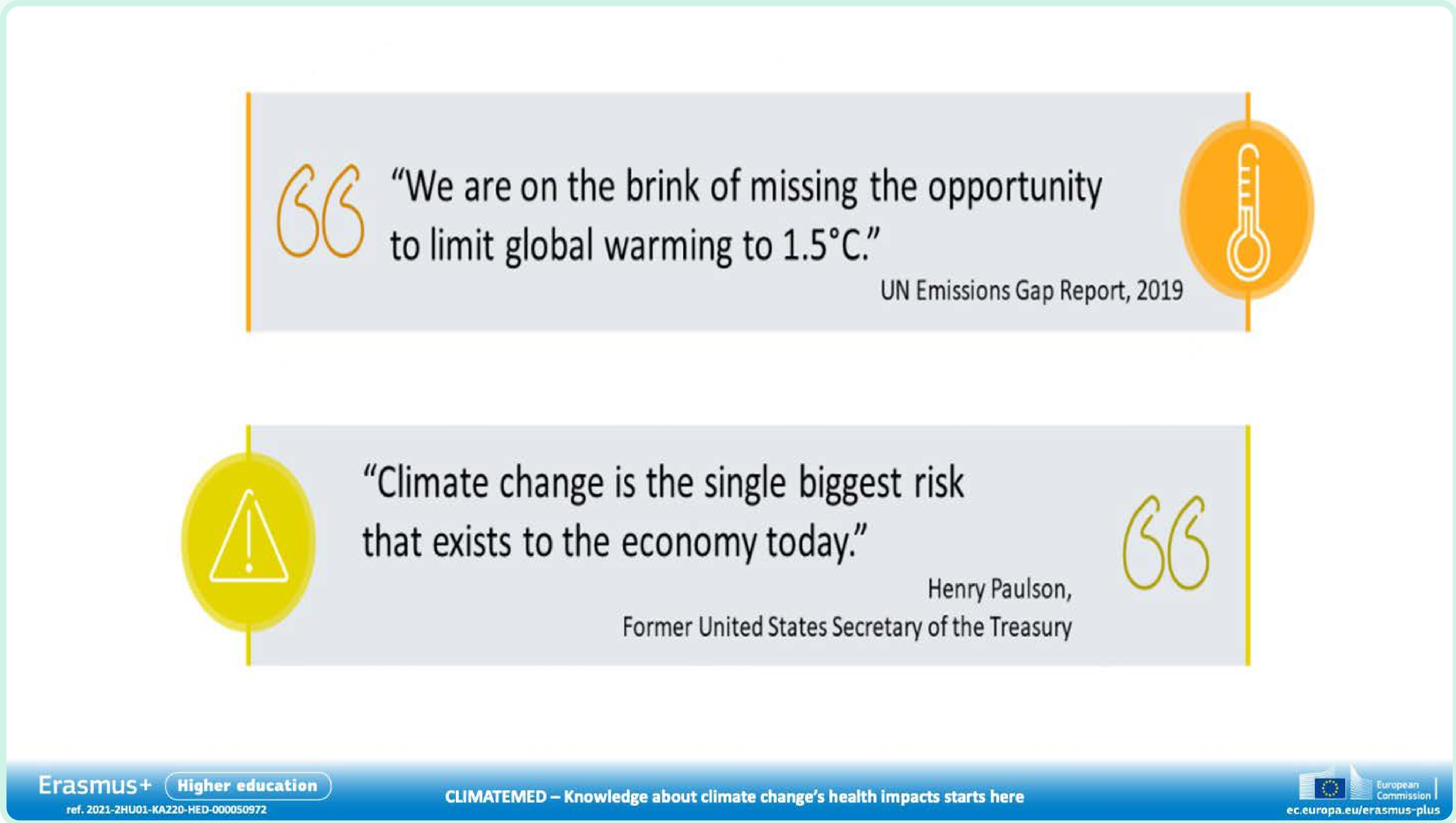
→ Climate change hazard - Process, phenomenon or human activity that may cause loss of life, injury or other health impact, property damage, social or economic disruption, or environmental degradation.

→ Climate change risk - Potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services) and infrastructure.

→ Anthropogenic climate change - climate change with the presumption of human influence, usually warming

→ Global warming (GW) -usually: the warming trend over the past century or so; also: any period in which the temperature of the Earth's atmosphere increases; also the theory of such changes.

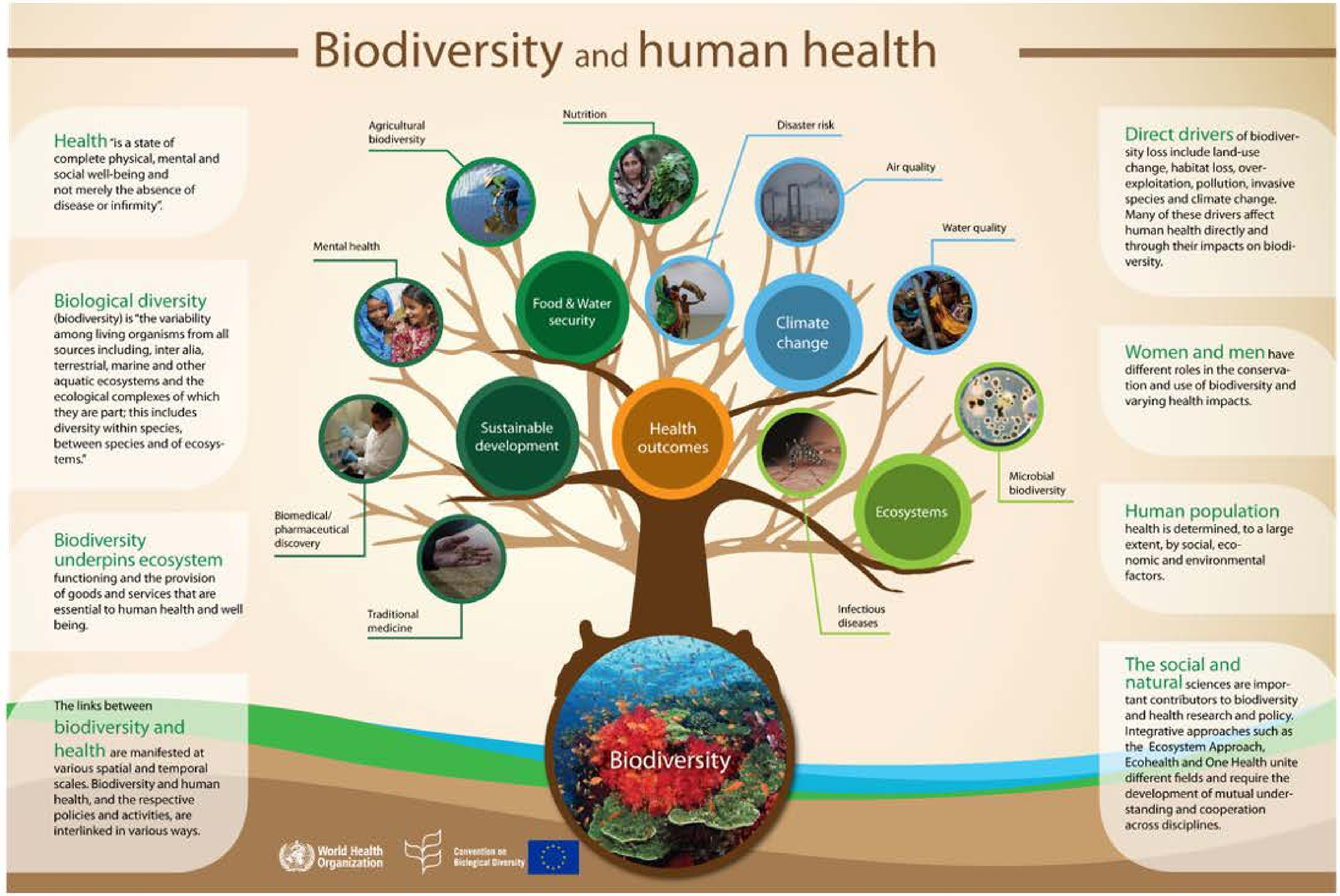
→ **https://unfccc.int**
↘ Accesed 16 March 2023



The Intergovernmental Panel on Climate Change (IPCC) has concluded that to avert catastrophic health impacts and prevent millions of climate change-related deaths, the world must limit temperature rise to 1.5˚C. Past emissions have already made a certain level of global temperature rise and other changes to the climate inevitable. Global heating of even 1.5˚C is not considered safe, however; every additional tenth of a degree of warming will take a serious toll on people's lives and health.

While no one is safe from these risks, the people whose health is being harmed first and worst by the climate crisis are the people who contribute least to its causes, and who are least able to protect themselves and their families against it - people in low-income and disadvantaged countries and communities.

→ **doi.org/10.4337/9781788974912.I.50**
↘ Solomon B: Intergovernmental Panel on Climate Change (IPCC)



https://www.cbd.int/health/images/infographic-sok-health.png, Accessed 16 March 2023

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CLIMATEMED – Knowledge about climate change's health impacts starts here

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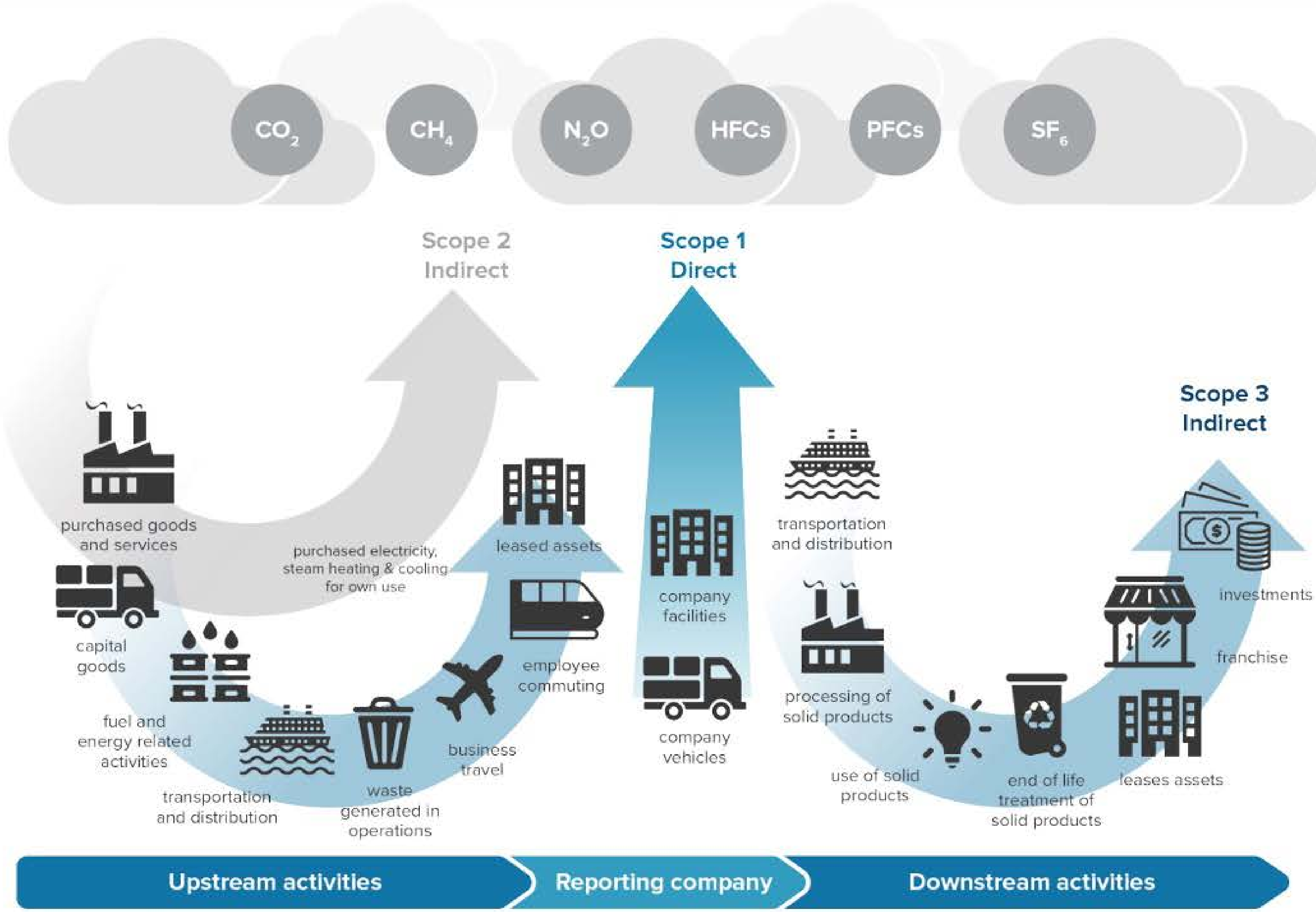
- → The links between biodiversity and health are manifested at various spatial and temporal scales.
- → At a planetary scale, ecosystems and biodiversity play a critical role in determining the state of the Earth System, regulating its material and energy flows and its responses to abrupt and gradual change.
- → At a more intimate level, the human microbiota the symbiotic microbial communities present on our gut, skin, respiratory and urino-genital tracts, contribute to our nutrition, can help regulate our immune system, and prevent infections.
- → **https://www.cbd.int/health/SOK-biodiversity-en.pdf**
  ↘ p. 15, Accessed 16 March 2023

GHG sources and activities



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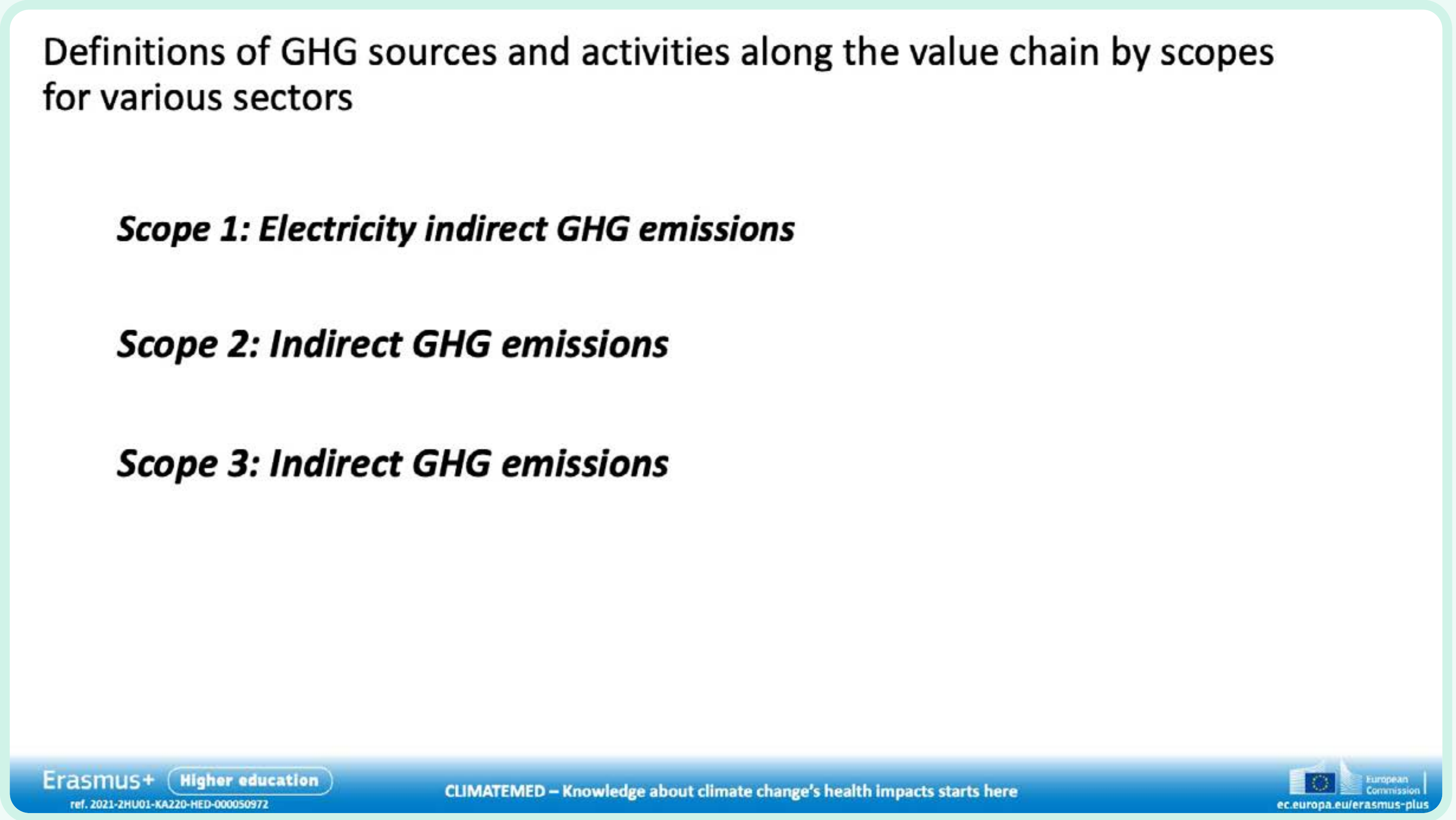


Scope 1 Electricity indirect GHG emissions

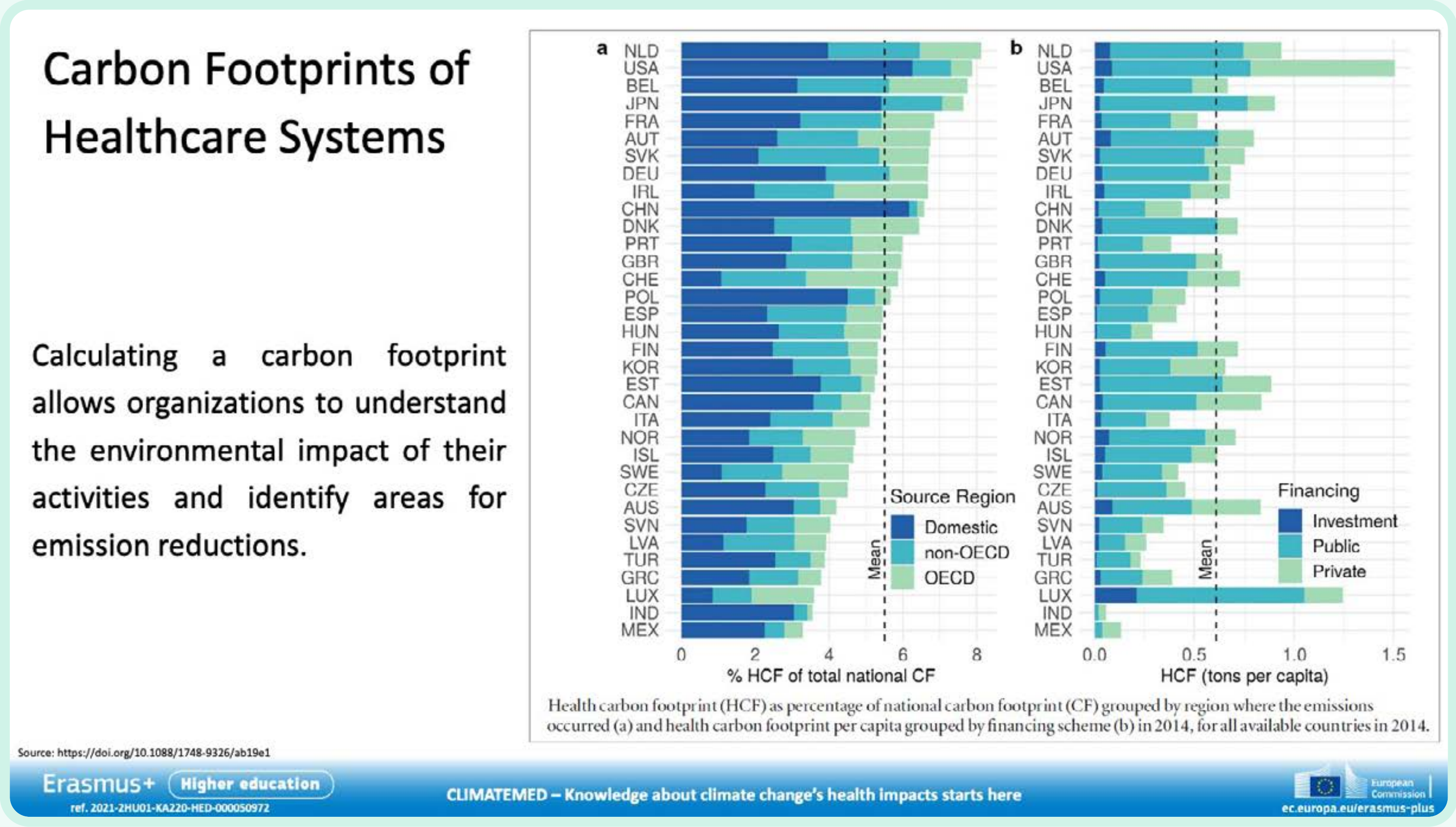
- → Generation of electricity, heat, or steam (emissions result from combustion of fuels in stationary sources)
- → Physical or chemical processing (emission result from manufacture or processing of chemicals and materials)
- → Transportation of materials, products, waste, and employees (emissions result from the combustion of fuels in company owned/ controlled mobile combustion)
- → Fugitive emissions (emissions result from intentional or unintentional releases, e.g., equipment leaks from joints, seals, packing, gaskets; coal mines' methane emissions)

Scope 2: Indirect GHG emissions

- → These emissions are indirect: they are generated by a third party, such as a utility company, but they are considered direct emissions for the reporting organization because they result from its consumption of electricity or heat.
- → It is necessary to know that Scope 2 emissions do not include the emissions associated with producing the purchased electricity, heat, or steam. These emissions are accounted for in Scope 1 (direct emissions) if the organization generates its energy or in Scope 3 (indirect emissions) if they are generated by an external supplier upstream of the organization's activities.

Scope 3: Indirect GHG emissions

- → These emissions are indirect: that occur in the value chain of an organization but are not directly owned or controlled by the organization.
- → It encompass a wide range of activities and sources that occur upstream or downstream of the organization's operations, including activities such as purchased goods and services, transportation and distribution, waste disposal, employee commuting, business travel, and the use and disposal of products sold.



The global healthcare sector had a carbon footprint of 2.0GtCO2e in 2014, equivalent to 4.4% of global net emissions.

A carbon footprint is the total amount of greenhouse gases (GHG) that are generated by a specific activity (e.g. production, processing and retailing of consumer goods, and provision of services).

The carbon footprint takes into account not only the direct emissions (Scope 1) but also the indirect emissions (Scope 2 and Scope 3) associated with the entire lifecycle of products, services, and activities.

It serves as a baseline for making informed decisions to mitigate climate change.

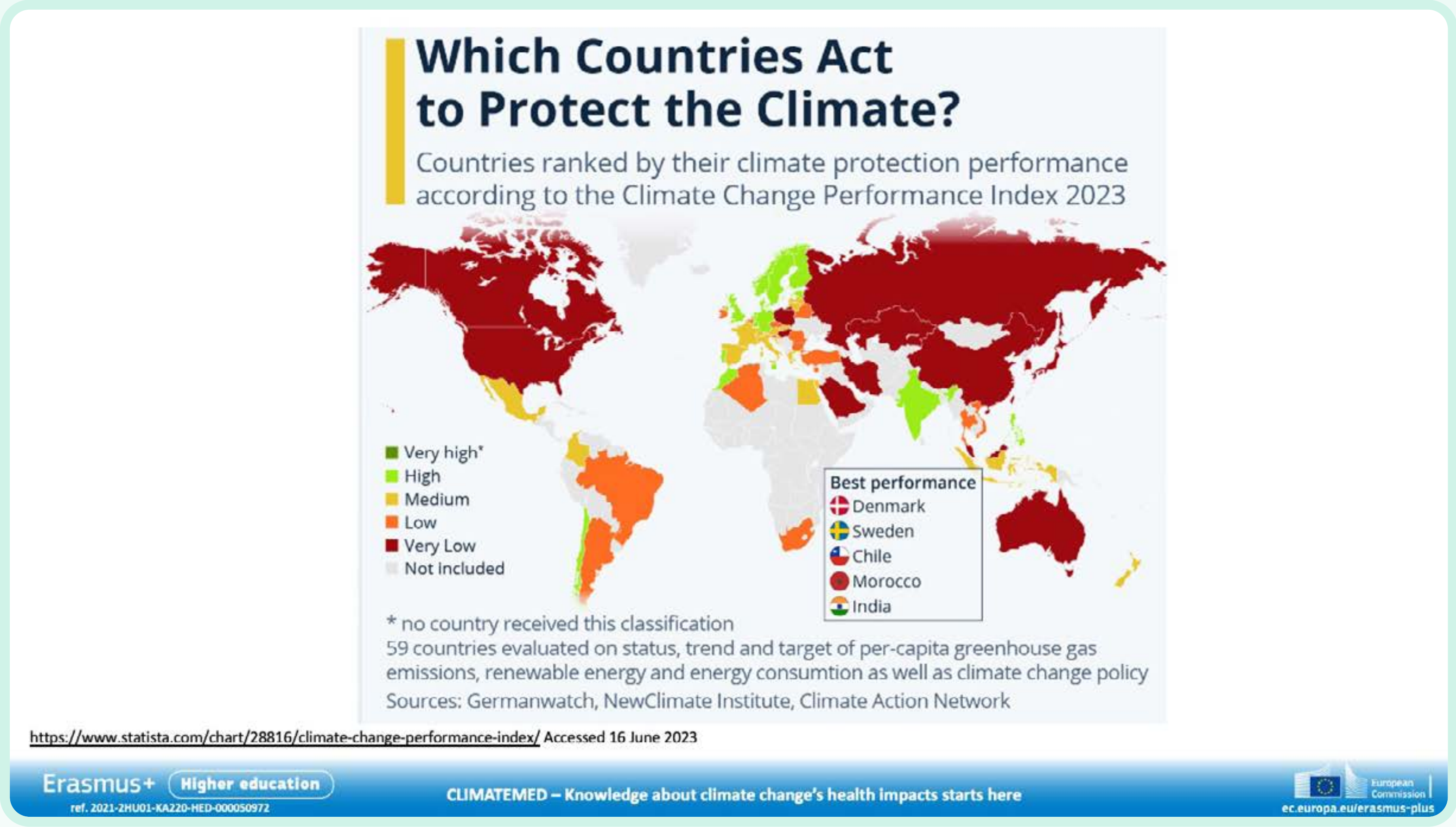
If healthcare system were a country, it would be the fifth largest emitter on the planet.

Emissions emanating directly from healthcare facilities (Scope 1) make up 17% of the sector's worldwide footprint.

Indirect emissions from purchased electricity, steam, cooling and heating

(Scope 2) comprise another 12%.

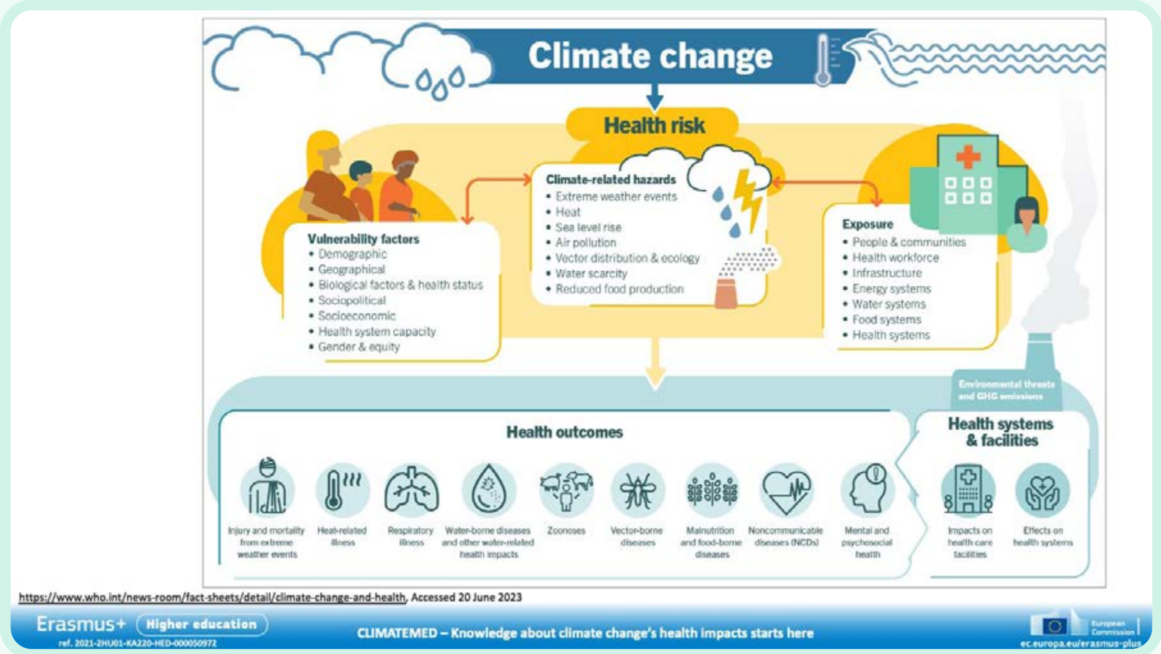
The majority of Healthcare Systems' emissions (71%) come from what is known as Scope 3, and are primarily derived from the healthcare supply chain — the production, transport, use, and disposal of goods and services that the sector consumes.



- → Climate change is already impacting health in a myriad of ways, including by leading to death and illness from increasingly frequent extreme weather events, such as heat waves, storms and floods, the disruption of food systems, increases in zoonoses and food-, water- and vector-borne diseases, and mental health issues. Furthermore, climate change is undermining many of the social determinants for good health, such as livelihoods, equality and access to health care and social support structures.
- → These climate-sensitive health risks are disproportionately felt by the most vulnerable and disadvantaged, including women, children, ethnic minorities, poor communities, migrants or displaced persons, older populations, and those with underlying health conditions.
- → Climate change impacts health both directly and indirectly, and is strongly mediated by environmental, social and public health determinants.
- → It threatens the essential ingredients of good health – clean air, safe drinking water, nutritious food supply and safe shelter – and has the potential to undermine decades of progress in global health.
- → Between 2030 and 2050, climate change is expected to cause approximately 250 000 additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress.
- → Areas with weak health infrastructure – mostly in developing countries – will be the least able to cope without assistance to prepare and respond.
- → Reducing emissions of greenhouse gases through better transport, food and energy-use choices can result in improved health, particularly through reduced air pollution.

Compendium of WHO and other UN guidance on health and environment, 2022 update. Geneva: World Health Organization; 2022 (WHO/HEP/ECH/EHD/22.01)

→ **https://www.who.int/teams/environment-climate-change-and-health**
↘ Accessed 20 June 2023



Vulnerable populations

Geography: Inhabitants of low-lying coastal settlements, socially and economically disadvantaged rural populations reliant on subsistence farming and with poorer access to services, and outdoor workers in countries with hot climates are more likely to experience health effects. Regions of Asia and Africa are projected to experience 85 to 95% of the global exposure to multi-sector risks (including risks to water, energy and land sectors, such as drought intensity and water stress, cooling demand change and heat wave exposure, habitat degradation, and crop yields)

Indigenous Identity: Climate change poses greater risks of health effects to Indigenous peoples who depend heavily on local resources and live in parts of the world where the climate is changing quickly such as Inuit populations in the Canadian Arctic.

Socioeconomic Status: The poorest countries and regions within them are most susceptible to the health effects of climate change; the socioeconomically poorest individuals living in a population experience the greatest risks during heat waves, flooding, and tropical cyclones.

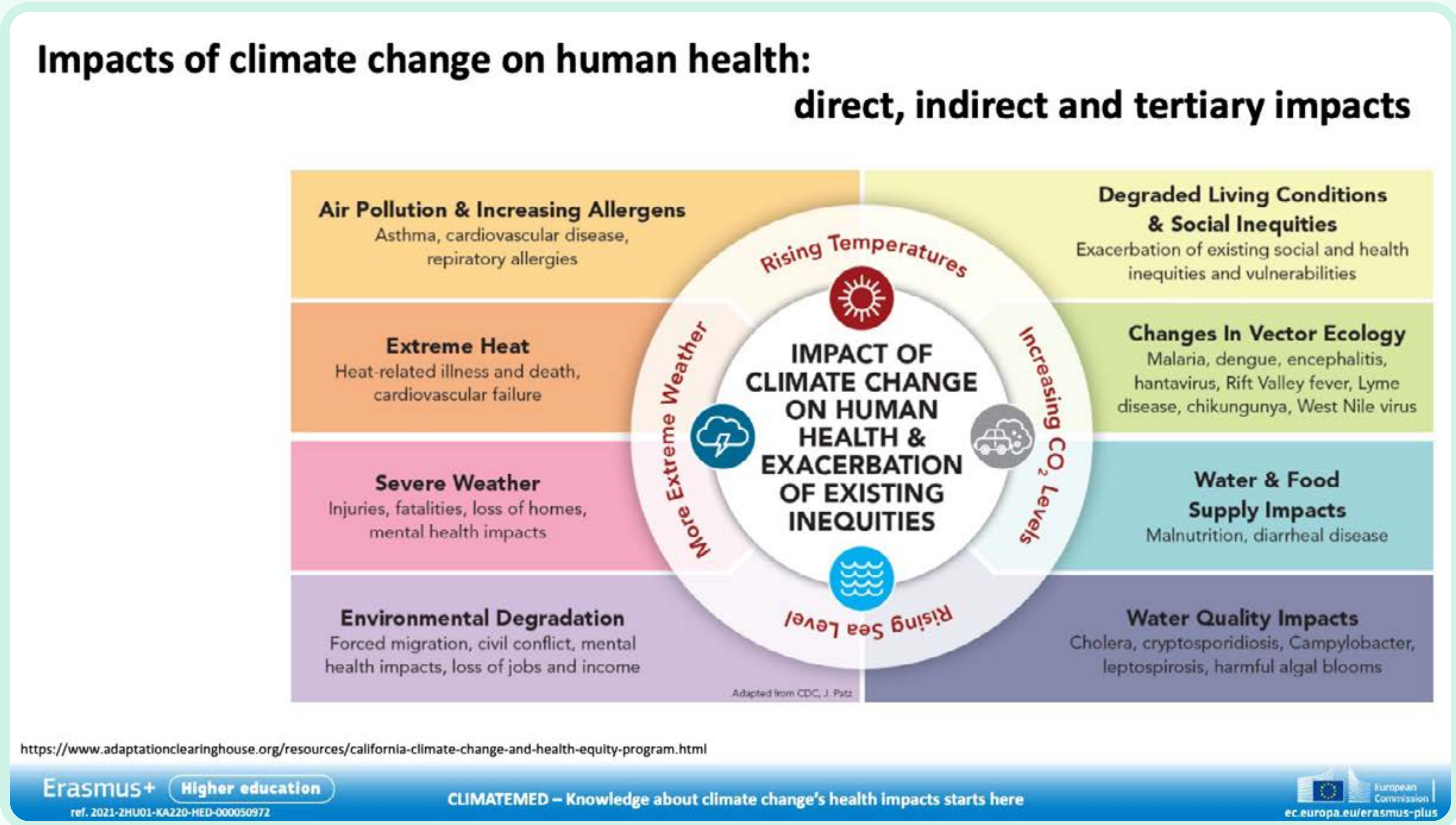
Current Health Status: Populations with a high prevalence of conditions such as diabetes, ischaemic heart disease, and HIV) will be at more sensitive to health effects. Populations exposed to baseline levels of pathogens and parasites such as dengue virus (dengue fever) and plasmodium (malaria) will be at greater risk of outbreaks following flooding events.

Age: Children are physiologically more susceptible to undernutrition, diarrhea, malaria, and dengue fever. Households with children are likelier to have a lower than average income, rendering children more susceptible to food insecurity. Older people are often less physiologically able to respond to stressors like heat and air pollution, and tend to experience greater risks during extreme events, due to their poorer mobility and limited ability to extricate themselves from hazardous situations.

Gender: Women and girls can be at greater risk for the health effects of climate change due to lower socioeconomic status and limitations imposed by gender roles. In many countries, women and girls have lower baselines of nutrition, and experience greater risk of poor nutrition during periods of food scarcity. In developed countries, males are at greater risk of fatality due to flooding. However, females face a greater risk in developing countries, where the overall risk of flooding fatality is higher. During heat waves, working age men experience high risk of health effects due to higher numbers in manual work, although women of all ages maybe at greater risk during heat waves overall.

Access to Health Care and Services: Populations with poorer access to health care and services have generally poorer climate resilience. Reduced health care and services capacity in the wake of natural hazard events can enable the resurgence of climate-sensitive infectious diseases.

→ https://chasecanada.org/wp-content/uploads/2021/01/Climate-Change-Toolkit-for-Health-Professionals-Full-Toolkit.pdf
↘ Accessed 16 June 2023



Direct health impacts are those that are directly, causally attributable to climate change and/or climate variability, such as cardiovascular risk associated with heat waves, or risk of injury associated with more intense and frequent storms.

Indirect health impacts arise as downstream effects of climate change and variability. These impacts are broad and variable in their etiology, such as change in infectious disease vector distribution and air pollution interacting with heat waves.

The third – "tertiary impacts" – category is, by a number of magnitudes, the most important health risk associated with climate change. These include the health impacts of large-scale famine, forced migration and human conflict, which result from the geophysical and ecological consequences of climate change, including the alteration of ecosystems, sea-level rise, and long term disruptions in water supply and food production.

Direct health imapcts:

Heat exposure can have a direct effect on population-level morbidity and mortality, due to increases in heat-related illnesses (heat exhaustion and heat stroke) and greater risk of cardiovascular, respiratory, and renal disease. Both high temperatures and heat waves are associated with more hospital admissions for mental illness, and increased risk of suicide.

Heat and heat waves also affect the labour capacity of sectors of the economy such as agriculture, industry, and services.

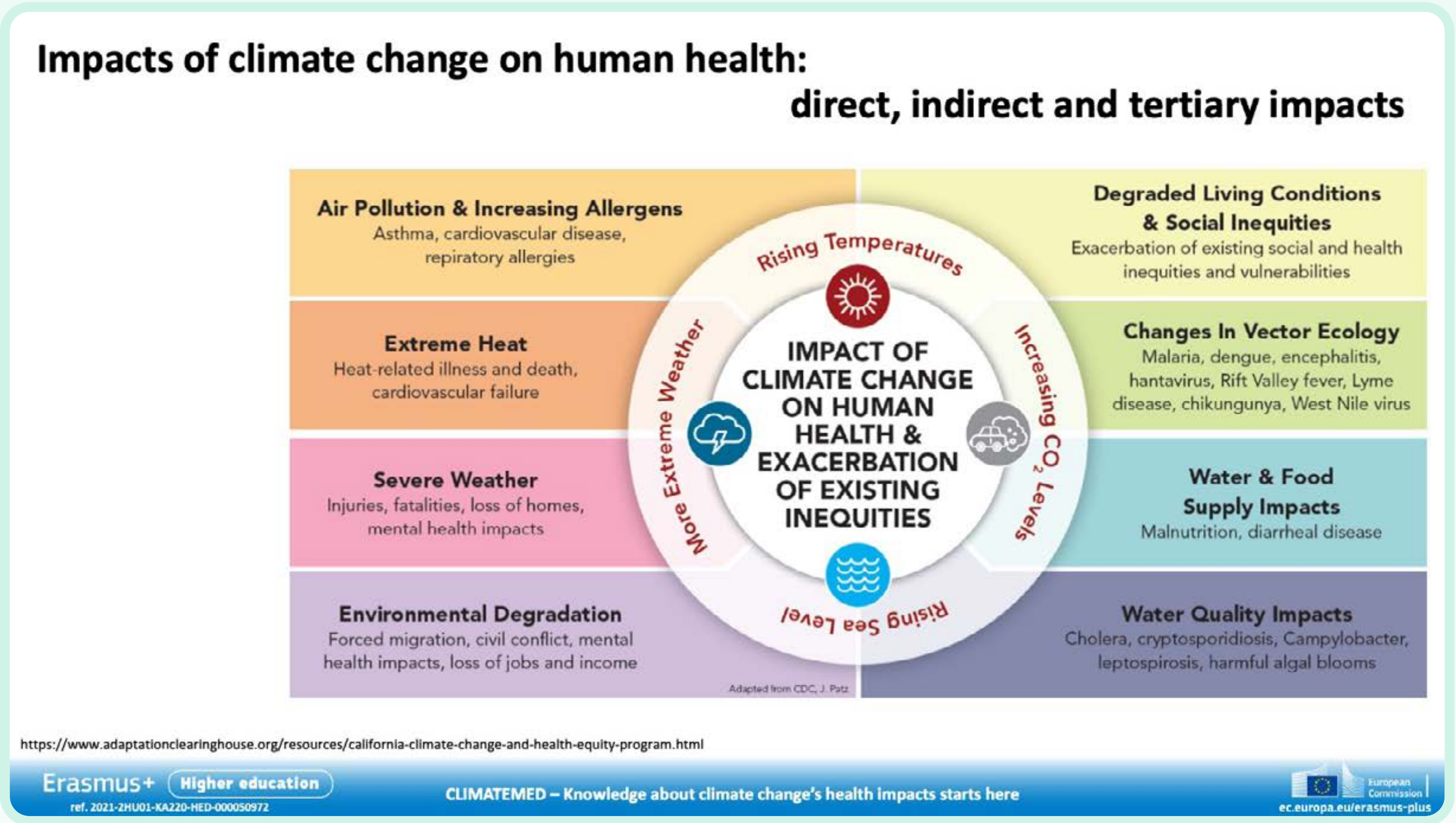
The health impact of a heatwave depends on the intensity and duration of the temperature, the acclimatization and adaptation of the population, and the infrastructure and preparedness.

People with chronic diseases that take daily medications have a greater risk of complications and death during a heatwave, as do older people and children.

Reactions to heat depends on each person's ability to adapt and serious effects can appear suddenly. This is why it is important to pay attention to the alerts and recommendations of local authorities.

Cold exposure: Although cold-related health exposures are projected to decrease with global warming, increases in heat-related morbidity and mortality will far outweigh any benefits from these reductions at the global level

Floods and storms: linked to climate change can adversely affect human health by damaging health services and other infrastructure; accelerating the spread of infectious diarrheal, leptospirosis, and vector-borne diseases; increasing the incidence of injuries, drowning, and hypothermia; and impacting mental health.



Indirect impacts

Air pollution: is estimated to cause seven million premature deaths per year globally. The majority of air pollution produced by human activity is due to the combustion of fuels for electricity, cooking, heating, transportation, industrial and agricultural processes.
Since these activities additionally produce greenhouse gases (GHG) emissions, climate change and air pollution are inextricably linked. Climate change affects the level of air pollution as higher temperatures increase the number of reactions giving rise to ground-level ozone in the atmosphere. Warmer conditions can increase the production and release of airborne allergens (such as fungal spores and plant pollen) and higher carbon dioxide (CO2) levels can stimulate growth of these plants. Increases in airborne allergens could trigger asthma and other allergic respiratory diseases.

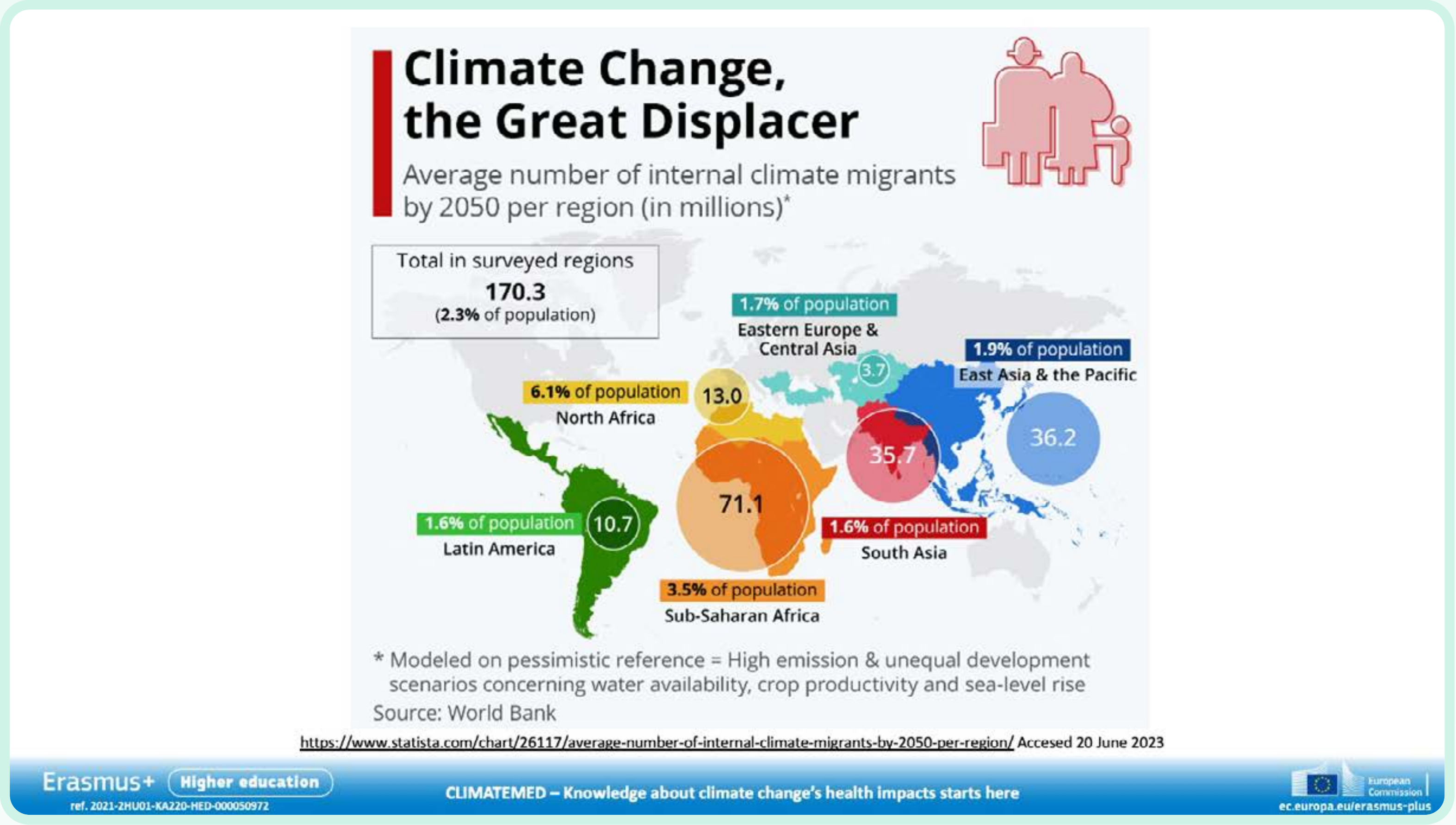
Wildfires: Extreme wildfires are predicted to increase in many parts of the world as a result of climate change. These events can lead to acute deaths due to burns and trauma, the need for emergent evacuation of healthcare structures and insomnia and post-traumatic-stress disorder symptoms in survivors of evacuations. Smoke can produce extremely high levels of air pollution.

Ultraviolet Radiation: The incidence and prevalence of non-melanoma skin cancers and cataract-related eye diseases are linked to levels of ultraviolet (UV) radiation and summertime maximum temperatures. It is uncertain how the rate skin cancers will be affected by climate change in the future

Food- and water-borne infectious diseases: Diarrheal and enteric disease transmissions are affected by changes in temperature and rainfall, with studies indicating that higher temperatures and water scarcity increase diarrheal diseases of all causes.

Climate change may influence the growth, survival, persistence, transmission, and/or virulence of certain pathogens by affecting the local ecosystem capacity to act as a reservoir for species as vectors of animal-borne diseases.

Vector-borne Diseases: The spread of vector-borne diseases (including malaria, dengue fever, West Nile virus, and Lyme disease) is influenced by temperature, rainfall, flooding, economic development, and public health programs. For example, economic development and public health programs can decrease the risk of malaria and dengue fever, however, in most cases, climate change will increase the risk.



Tertiary impacts

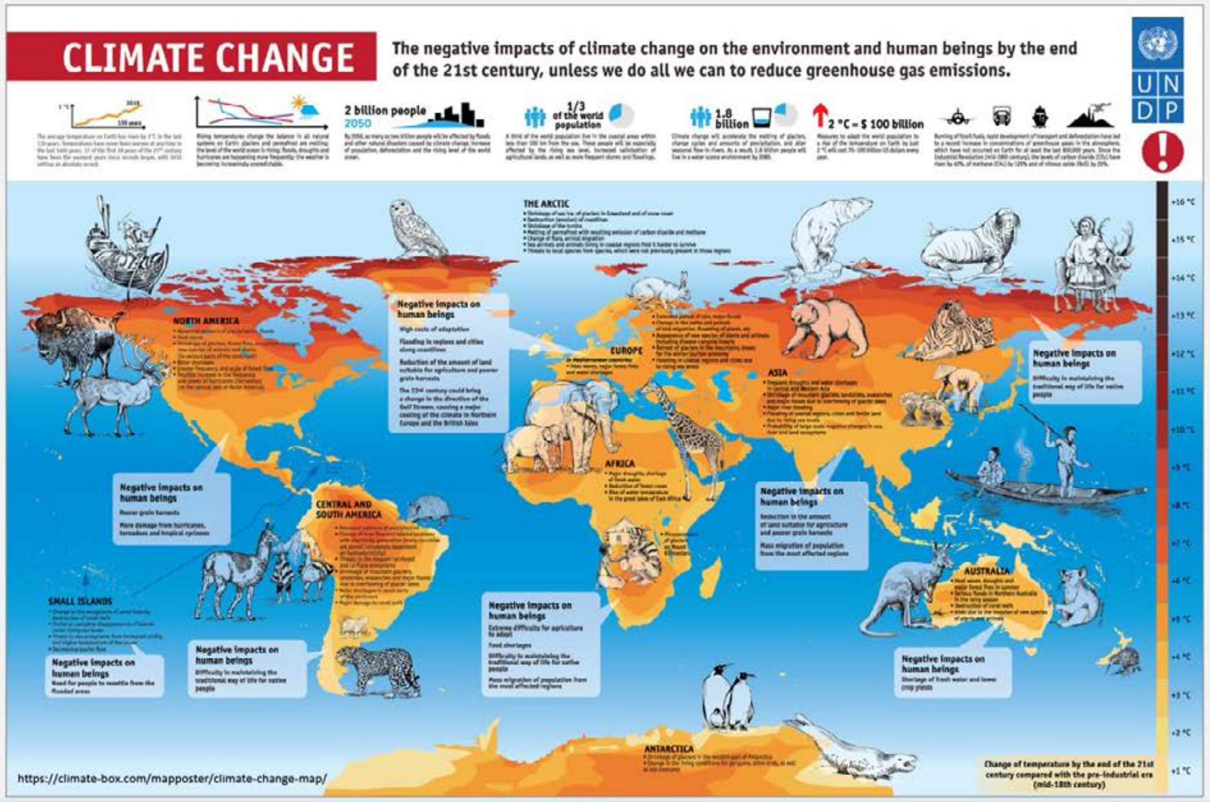
Livelihoods and Poverty: heat can have large effects on labour capacity, particularly in agriculture. Other risks to occupational health associated with climate change include increased risk of malaria and dengue fever in field workers, and injuries and mortality risks from extreme weather events and flooding

Migration and displacement: The social, economic, and environmental factors underlying migration decisions are complex and varied, making it difficult to observe or estimate the magnitude of climate change effects.

Populations living in the arctic, tropical regions, and on small-island developing states face the greatest threat of displacement. In the 2oC of global warming scenario, these populations may be required to move distances greater than 1000 km with evacuation from these areas to tropical margins and the subtropics increasing population density in these destinations by 300%

Conflict: Climate change could be one of the many drivers of conflict in various regions. For example, drought has been shown to significantly increase the likelihood of sustained conflict for nations or groups dependent on agricultural livelihoods

Regional impacts



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African continent Compounded stress on water resources

Reduced crop productivity adversely affecting national, regional, and household livelihoods and food security.

Changes in the geographic range and incidence of vector- and water-borne diseases.

Polar Regions: The Arctic and the Antarctic.

Risks to freshwater, terrestrial, and marine ecosystems with changes in ice, snow cover, permafrost, freshwater, and ocean conditions.

Increased food and water insecurity and damage to infrastructure.

Unprecedented challenges for northern communities due to complex inter-linkages between climate-related hazards and subsistence land use if rates of change exceed societal adaptation.

Australasia Degradation of coral reef systems in Australia. Increased frequency and intensity of flood damage to infrastructure and settlements. Increased risks to coastal infrastructure and low-lying ecosystems.

Europe Flooding in river basins and along coasts driven by increased urbanisation, rising sea levels, coastal erosion, and peak river discharges. Increased water restrictions. Higher frequency of extreme heat events and associated risk of wildfires in Europe and the Russian boreal region.

Central and South America Decreased water availability in semi-arid and glacier-melt dependent regions. Decreased food production and food quality. Spread of vector-borne diseases in higher altitudes and latitudes spreading further from the equator.

North America Wildfire-induced loss of property and ecosystem integrity, human morbidity and mortality. Increased heat-related mortality risk. Urban floods in riverine and coastal areas.

Asia Increased riverine, coastal, and urban flooding. Increased heat-related mortality risk. Increased risk of drought-related water and food shortages.

Small Island States Loss of livelihoods, coastal settlements, infrastructure, ecosystem services, and economic stability due to rising global mean sea level and high-water-level events.

Climate-sensitive diseases and climate-sensitive health outcomes

CLIMATE HAZARD	CLIMATE-SENSITIVE DISEASES (INFECTIOUS DISEASES)	CLIMATE-SENSITIVE HEALTH OUTCOMES (NONCOMMUNICABLE DISEASES AND UNINTENTIONAL INJURIES)
INCREASED TEMPERATURE	Waterborne diseases (diarrhoeal diseases, *Naegleria fowleri* infection, campylobacter infection, cholera, harmful algal bloom toxins); vectorborne diseases (dengue, malaria, Lyme disease, West Nile virus, Rift Valley fever, tickborne encephalitis); zoonotic diseases (rodentborne diseases, hantavirus diseases, leptospirosis); foodborne diseases (salmonellosis, mycotoxin effects); airborne diseases (influenza and other respiratory infections)	Cardiovascular diseases; chronic respiratory diseases (asthma, chronic obstructive pulmonary disease (COPD), respiratory allergies); protein-energy malnutrition (adverse nutritional effects causing childhood stunting)

WHO. Checklists to assess vulnerabilities in health care facilities in the context of climate change, ISBN 978-92-4-002290-4 (electronic version) – pp. 17-19

CLIMATE HAZARD	CLIMATE-SENSITIVE DISEASES (INFECTIOUS DISEASES)	CLIMATE-SENSITIVE HEALTH OUTCOMES (NONCOMMUNICABLE DISEASES AND UNINTENTIONAL INJURIES)
FLOOD 	Water- and food-borne diseases (diarrhoea from bacterial, viral and parasitic diseases, hepatitis A, typhoid fever, gastroenteritis, salmonellosis, *Escherichia coli* infection, cholera, cryptosporidium, campylobacteriosis, intestinal nematode infections); vectorborne diseases (dengue, Zika virus disease, malaria, chikungunya, West Nile virus fever); zoonotic diseases (rabies, rodentborne diseases, hantavirus diseases, leptospirosis); acute respiratory infections (influenza, pneumonia); eye and skin infections; tetanus; legionellosis	Deaths; drowning; physical traumas; hypothermia; animal bites; chemical poisoning and intoxication; electrical shock; mental health effects (acute traumatic stress, anxiety and depression, insomnia); cardiovascular diseases (stroke, diabetes, heart attack); chronic respiratory diseases (asthma, COPD, respiratory allergies); venomous animal bites (snakes, scorpions); eye, nose and skin irritation; protein-energy malnutrition; renal failure (due to lack of access to health care, dialysis)

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STORM 	Diarrhoeal diseases; cholera; hepatitis A; vectorborne diseases; zoonotic diseases; intestinal nematode infections; tetanus; respiratory infections; polymicrobial wound infections (by *Escherichia coli, Klebsiella, Serratia, Proteus and Pseudomonas*); mucormycosis	Deaths; drowning; physical traumas; wounds; hypothermia; animal bites; chemical poisoning and intoxication; electrical shock; mental health effects (acute traumatic stress, anxiety and depression, insomnia); cardiovascular diseases; chronic respiratory diseases (asthma, COPD, respiratory allergies); protein-energy malnutrition; renal failure (due to lack of access to health care, dialysis)

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SEA-LEVEL RISE 	Diarrhoeal diseases; cholera; hepatitis A; vectorborne diseases; zoonotic diseases; respiratory infections	Deaths; drowning, electrical shock; mental health (acute traumatic stress, anxiety and depression); cardiovascular diseases (hypertension); chronic respiratory diseases (asthma, COPD, respiratory allergies); protein-energy malnutrition; kidney disease

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DROUGHT 	Diarrhoeal diseases; cholera; hepatitis A; vectorborne diseases (dengue, malaria, Zika virus disease, chikungunya, Lyme disease, West Nile virus fever, Valley fever); zoonotic diseases; intestinal nematode infections; respiratory infections; eye and skin infections (scabies, trachoma, conjunctivitis); meningococcal meningitis	Cardiovascular diseases; chronic respiratory diseases (asthma, COPD, respiratory allergies); kidney diseases; cancers (skin, bladder, lung); protein-energy malnutrition; mental health effects (stress, anxiety and depression); eyes, nose and skin irritation; musculoskeletal problems

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HEATWAVE	Respiratory infections; water- and food-borne diseases (campylobacteriosis, salmonellosis, diarrhoeal diseases, cholera, cryptosporidiosis); harmful algal bloom toxins	Death; cardiovascular diseases (stroke, heart diseases, diabetes, thrombogenesis); heat stress; heat exhaustion; heat syncope; heat oedema; heat rash; dehydration-induced heat cramps; chronic respiratory diseases (asthma, COPD, respiratory allergies); protein-energy malnutrition; kidney disorder; aggravated chronic pulmonary conditions; eyes and skin irritation; mental illness; metal and chemical toxicity

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CLIMATE HAZARD	CLIMATE-SENSITIVE DISEASES (INFECTIOUS DISEASES)	CLIMATE-SENSITIVE HEALTH OUTCOMES (NONCOMMUNICABLE DISEASES AND UNINTENTIONAL INJURIES)
WILDFIRE 	Increased susceptibility to respiratory infections	Death; burns; injuries; mental health effects (acute traumatic stress, anxiety and depression, insomnia); chronic respiratory diseases (asthma, COPD, respiratory allergies); cardiovascular diseases (heat stroke, diabetes); dehydration-induced heat cramps; smoke intoxication (from particulate matter and other air pollutants); wheezing and shortness of breath; adverse pregnancy outcomes (e.g. low birth weight and preterm birth); carbon monoxide poisoning; eyes, nose and skin irritation (corneal abrasion)

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COLD WAVE 	Respiratory infections (such as influenza)	Deaths; cardiac workload leading to cardiovascular stress (heart diseases); exposure to extreme cold which causes veins and arteries to narrow and blood to become more viscous increasing cardiac workload; hypothermia leading to cardiac workload; aggravation of pre-existing chronic diseases such as diabetes, respiratory diseases (asthma, chronic bronchitis and emphysema) and cardiovascular conditions (heart diseases, stroke); frostbite (freezing of skin exposed to the cold)

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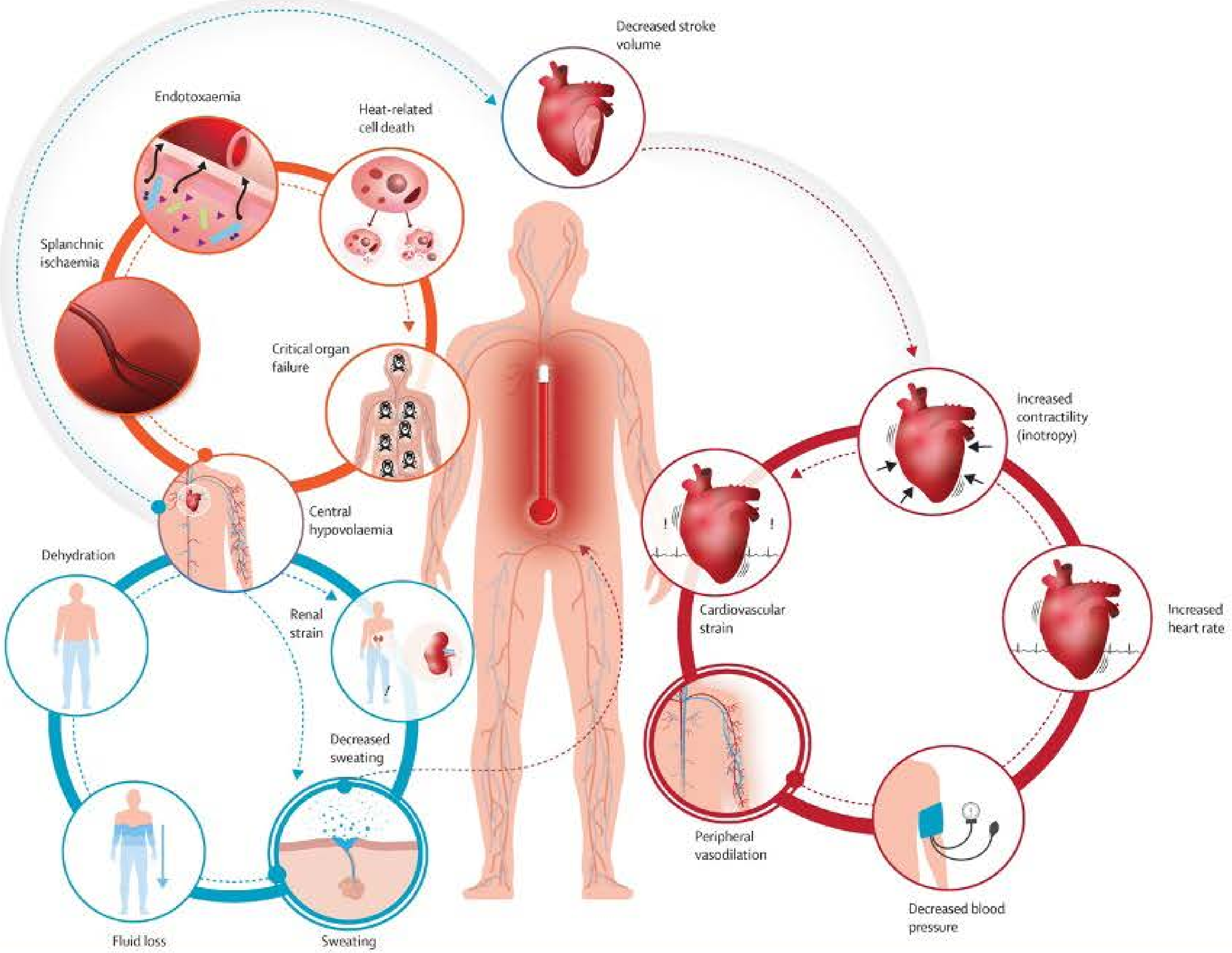
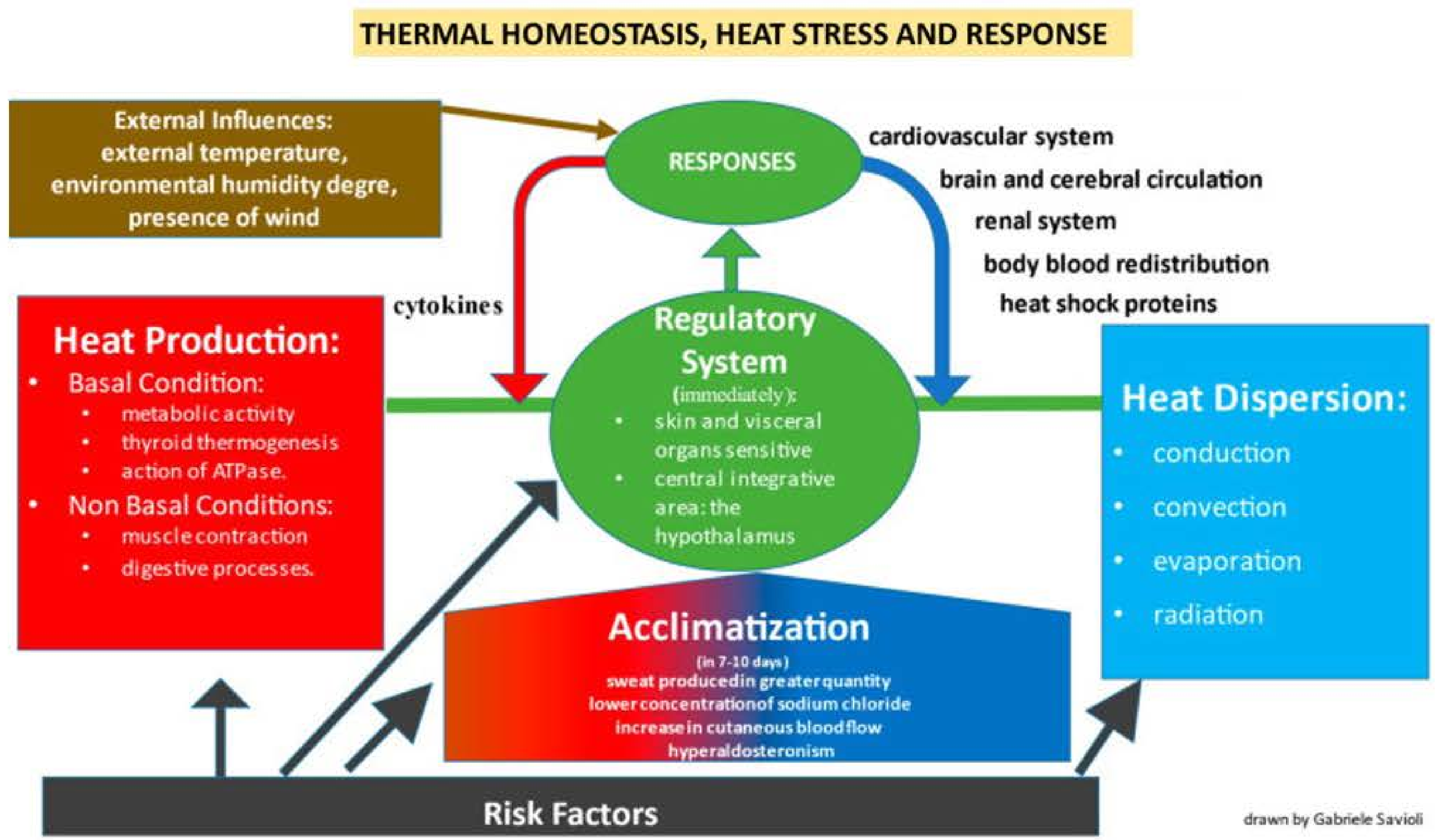
Health risks of high temperature



Temperature, heat waves:

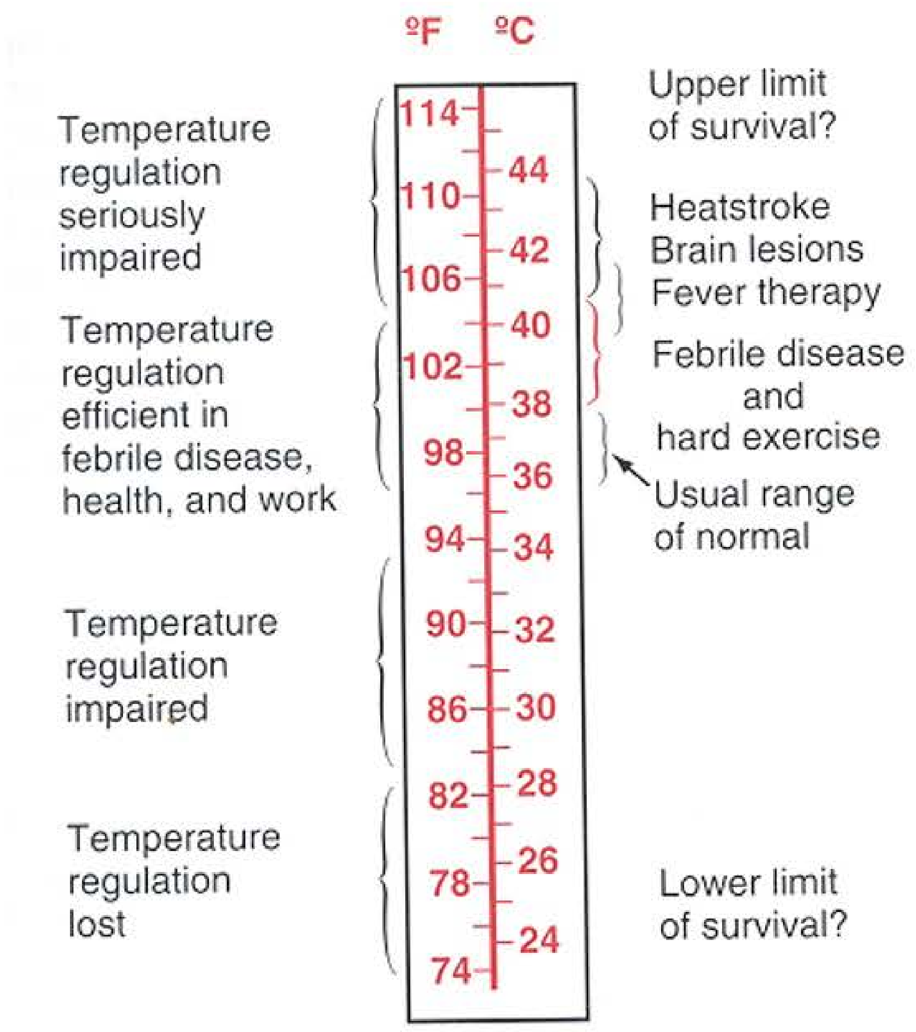
- Cardiovascular diseases,
- Respiratory diseases,
- **Renal and metabolic diseases**
- Mental diseases



When the body is under heat stress, thermal homeostasis is maintained through the regulated balance (immediately for the regulatory system and after 7–10 days through the acclimatization process) among the factors that produce heat (red square) and heat dissipation (blue square). However, modifiable and non-modifiable risk factors can compromise both the regulation and acclimatization systems and the factors capable of producing or dispersing heat.

Source: doi: 10.3390/biomedicines10102542

Body temperature and health effects

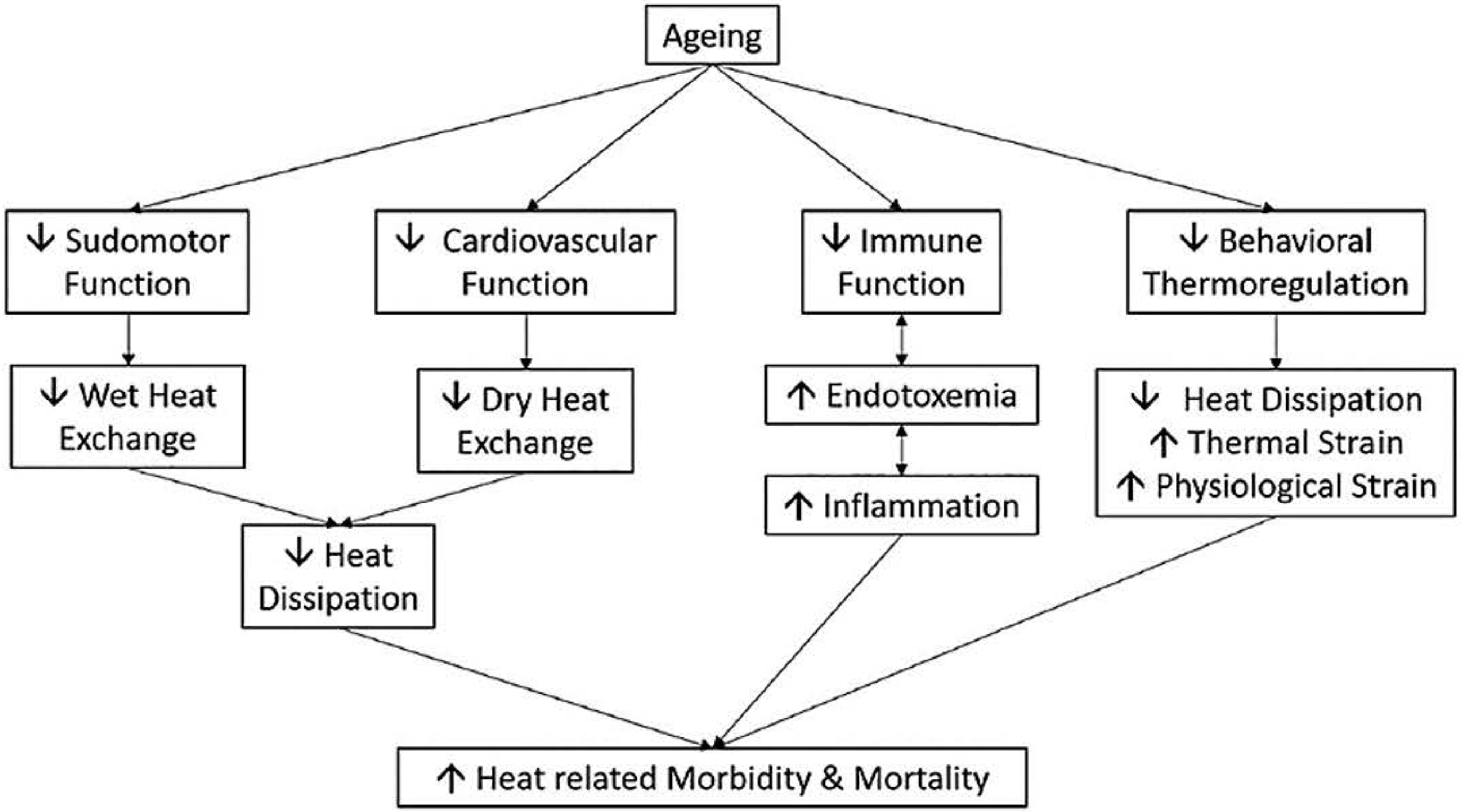


At-risk groups

EVERYBODY can be affected by high temperatures, but there are certain factors that increase an individual's risk during a heatwave. These include:

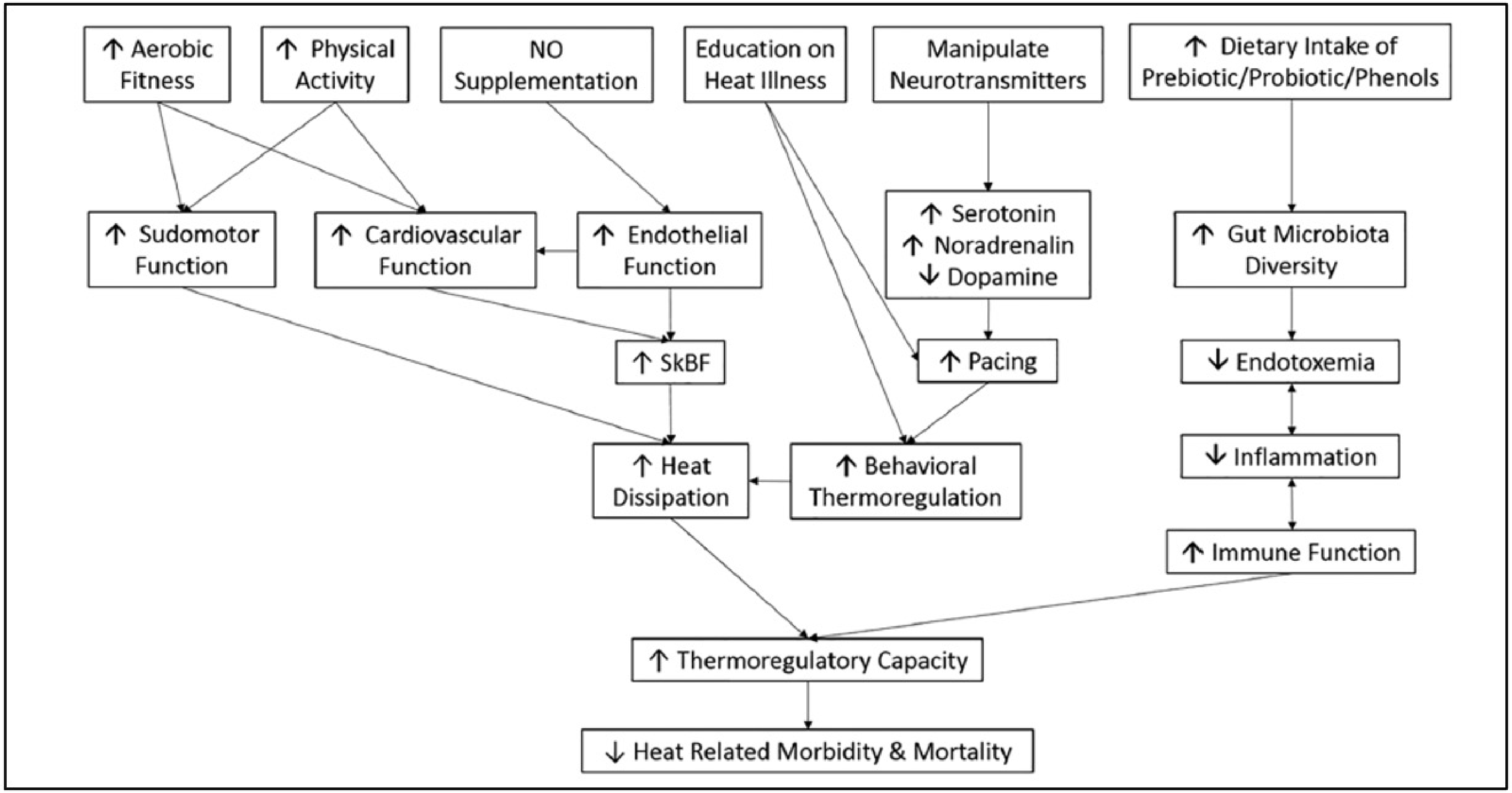
- **older age**: especially those over 75 years old, or those living on their own and who are socially isolated, or those living in a care home
- **chronic and severe illness**: including heart or lung conditions, diabetes, renal insufficiency, Parkinson's disease or severe mental illness
- **inability to adapt behaviour to keep cool**: babies and the very young, having a disability, being bed bound, consuming too much alcohol, having Alzheimer's disease
- **environmental factors and overexposure**: living in a top floor flat, being homeless, activities or jobs that are in hot places or outdoors and include high levels of physical exertion

Source: The health impacts of hot weather and the Heatwave Plan for England
https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_TechnicalSummary.pdf



Factors contributing to increased risk of heat illness and death in aging

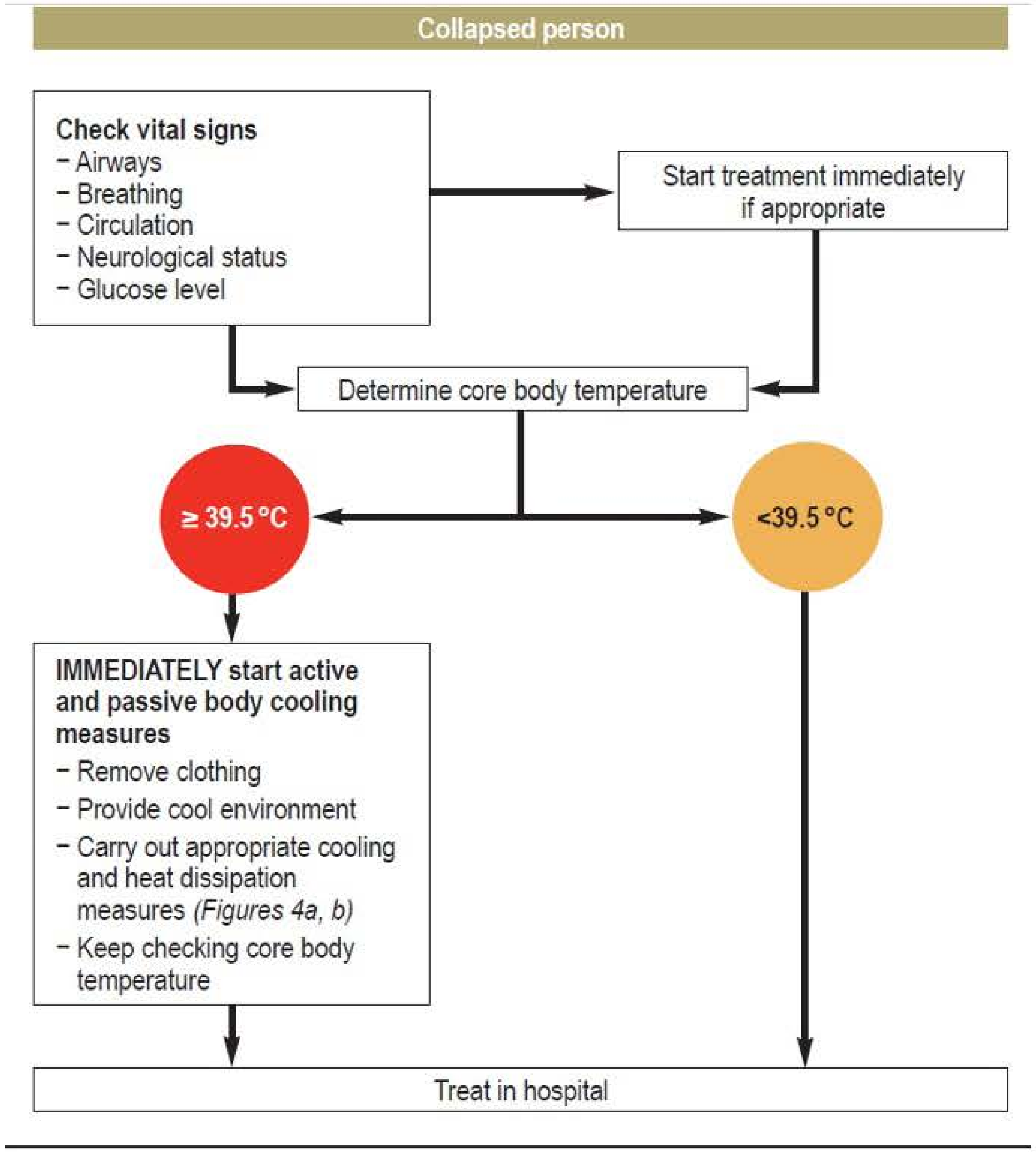
Source: Balmain BN, et al.:. Aging and Thermoregulatory Control: The Clinical Implications of Exercising under Heat Stress in Older Individuals. doi: 10.1155/2018/8306154.



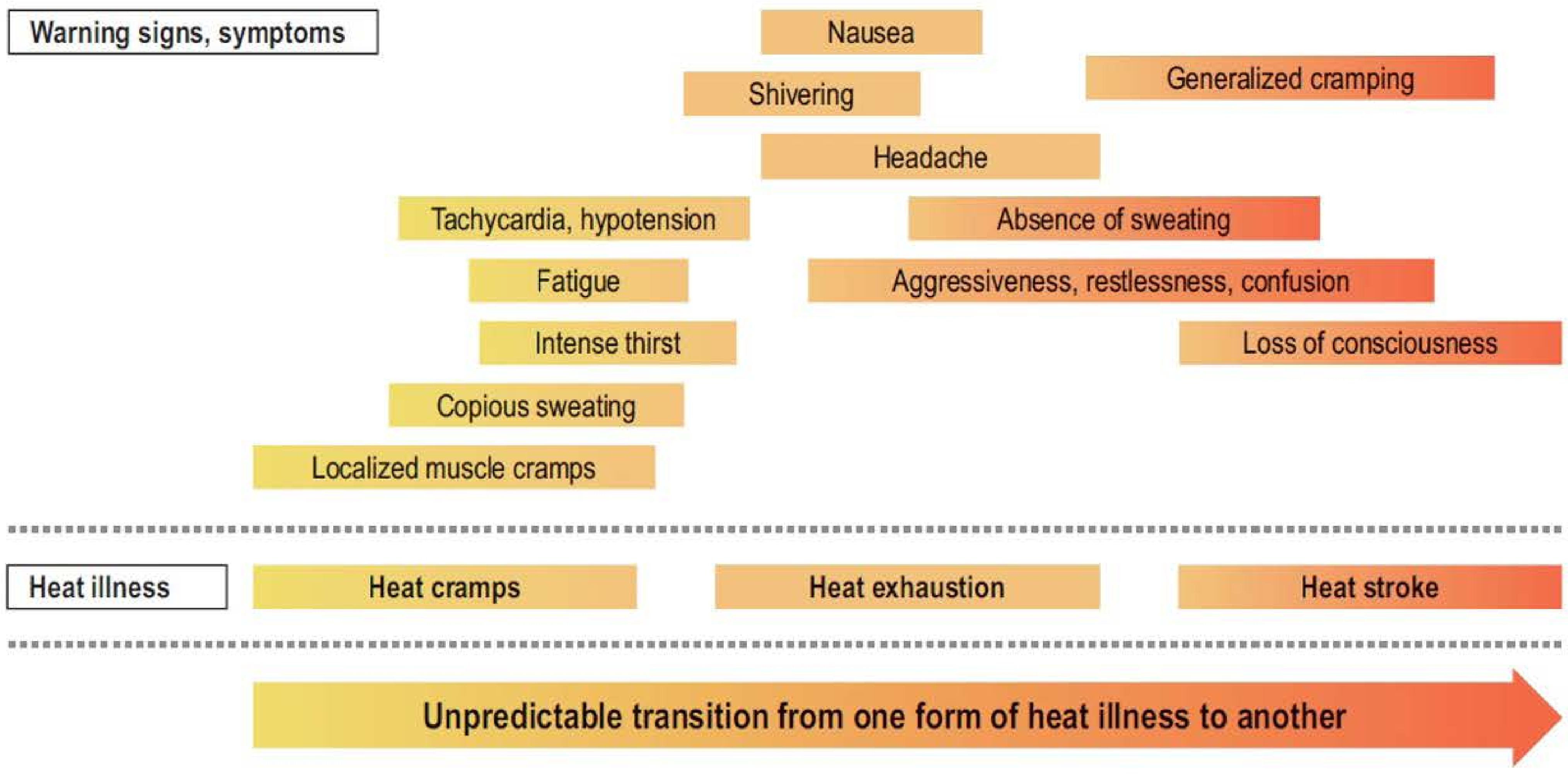
Proposed interventional strategies and mechanisms to improve thermoregulation in the elderly.

Source: Millyard A, et al. Impairments to Thermoregulation in the Elderly During Heat Exposure Events.. doi: 10.1177/2333721420932432.

How can we recognise a heatstroke?
Flowchart for use in a case of suspected exertional heat stroke



Source: Leyk D et al.:. Health Risks and Interventions in Exertional Heat Stress. doi: 10.3238/arztebl.2019.0537.

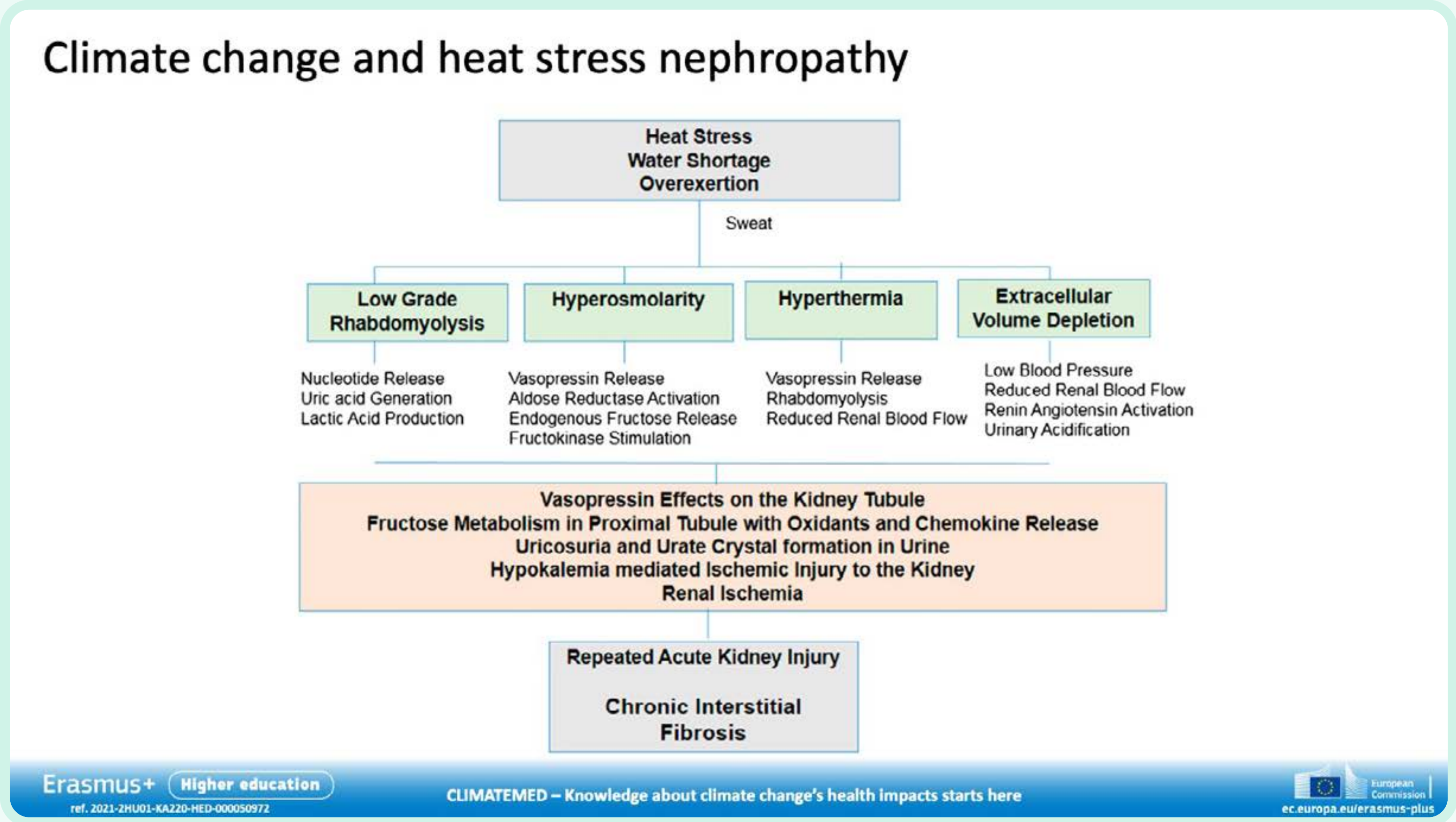


Symptoms of heat illness

Source: Leyk D et al.:. Health Risks and Interventions in Exertional Heat Stress. doi: 10.3238/arztebl.2019.0537.

Temperature and kidney diseases

- Important risk factor for many adverse health outcomes, including mortality and morbidity for specific causes
- Chronic kidney disease (CKD) is an important cause of disease and economic burden due to the expensive renal replacement therapy for end-stage kidney disease
- In 2017, 697 million people were diagnosed with CKD, and 1.2 million deaths were attributed to CKD worldwide, a 41.5% increase in mortality rate from 1990.
- Among the risk factors for CKD, diabetes, hypertension, and glomerulonephritis are known to be the most common causes.



→ This would involve the activation of the RAS, which also plays an important role in kidney disease

Heat stress nephropathy

→ One of the consequences of climate-related extreme heat exposure is dehydration and volume loss, leading to acute mortality from exacerbations of pre-existing chronic disease, as well as from outright heat exhaustion and heat stroke.

→ Recent studies have also shown that recurrent heat exposure with physical exertion and inadequate hydration can lead to chronic kidney disease (CKD) that is distinct from that caused by diabetes, hypertension.

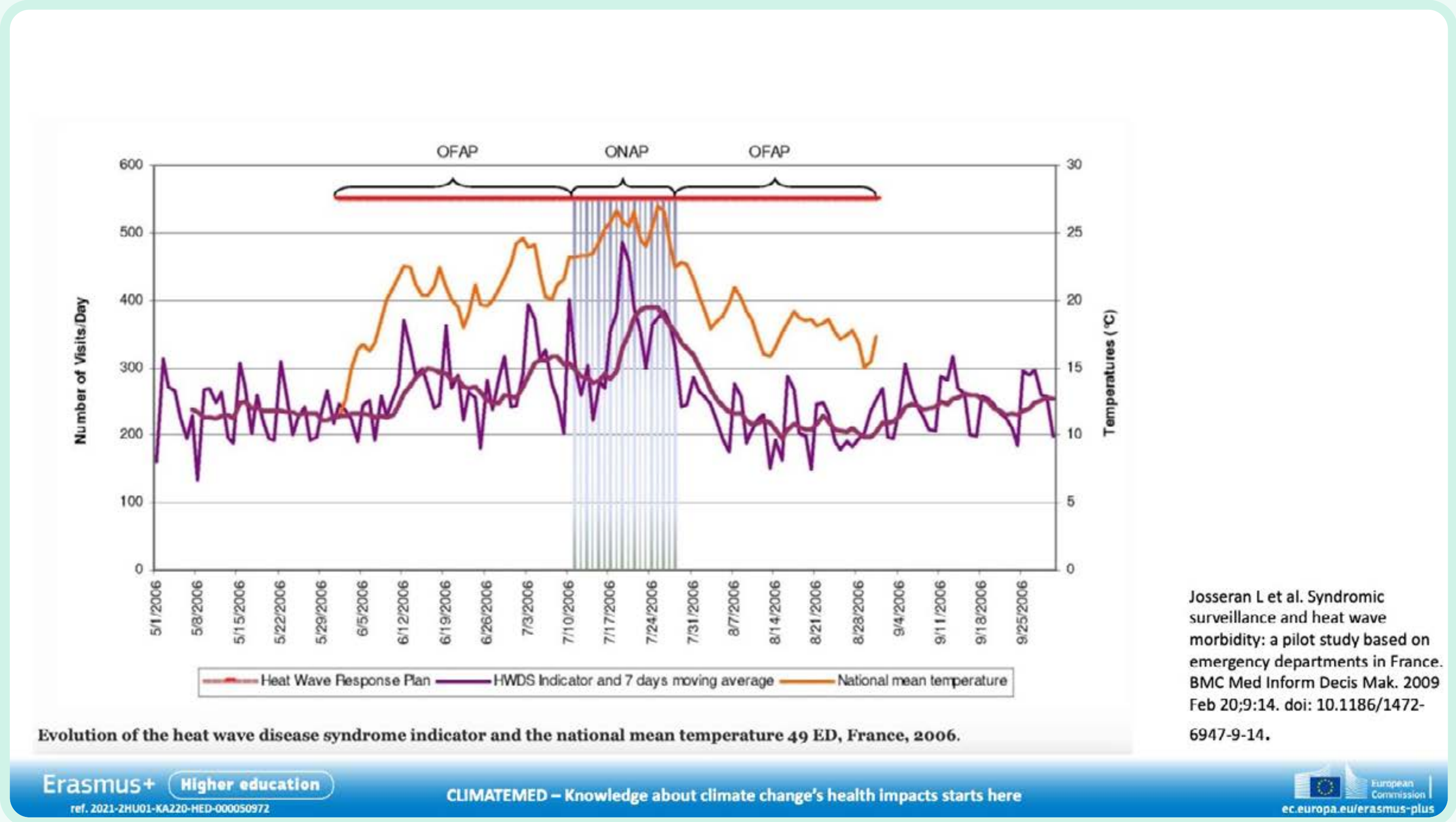
→ Epidemics of CKD consistent with heat stress nephropathy are now occurring across the world.

→ Heat stress nephropathy may represent one of the first epidemics due to global warming.

Development of chronic kidney disease associated with heat

→ In addition to these mechanisms, there may be others involved, such as:

- → muscle damage due to strenuous physical exercise with onset of subclinical rhabdomyolysis,
- → intake of nonsteroidal anti-inflammatory drugs (NSAIDs) and
- → low blood pressure due to volume depletion.



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Temperature and kidney diseases

- → The epidemiological evidence suggests that exposure to high temperature, defined as ambient temperature that are warmer than the optimum temperatures, is an important risk factor for many adverse health outcomes, including mortality and morbidity for specific causes
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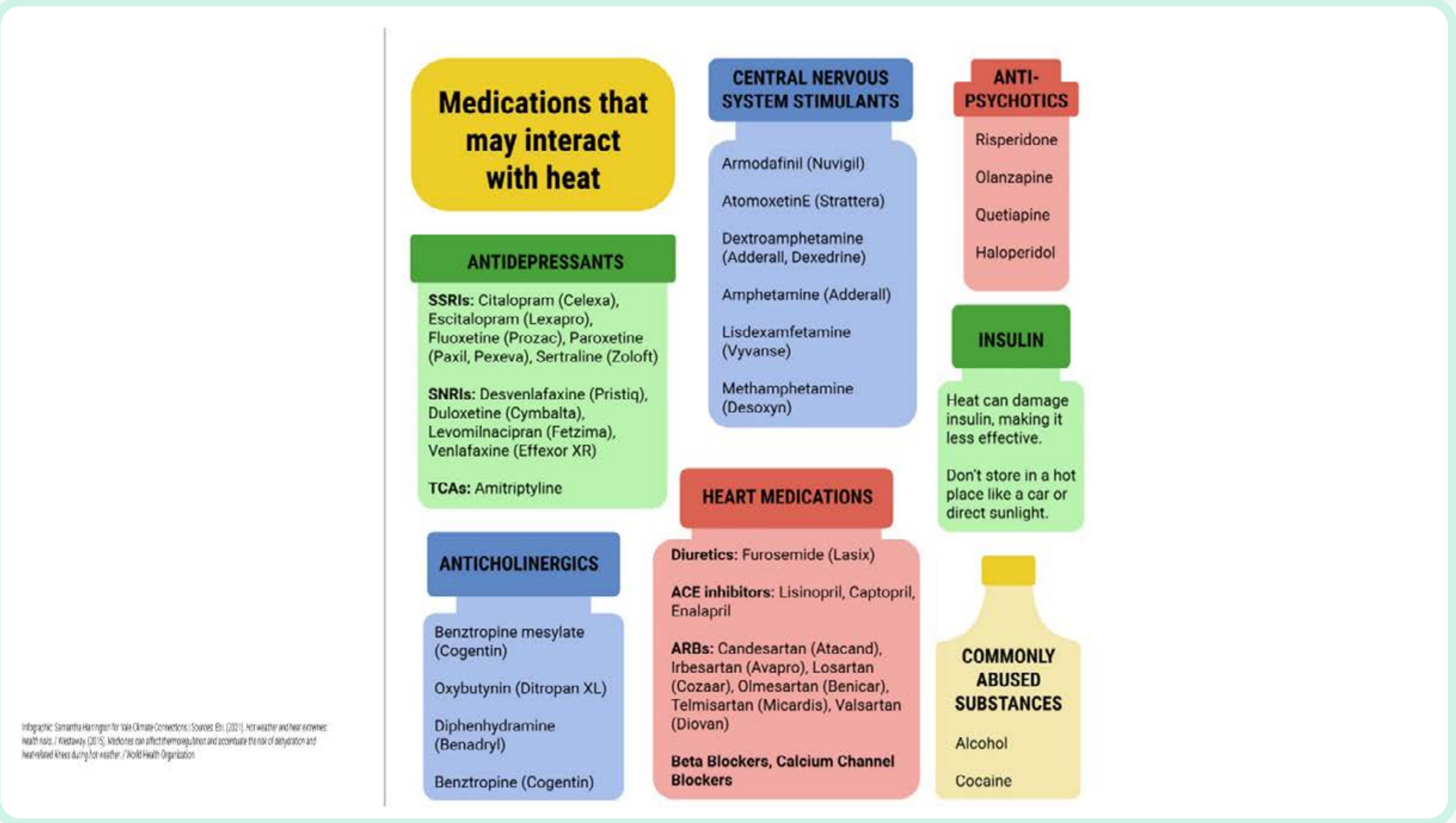

Medication

- → Antidepressants
- → Anxiolytics and muscle relaxants
- → Antiadrenergics and beta -blockers
- → Sympathomimetics
- → Antihypertensives and diuretics

Mechanism

- → Reduce sweating, some can decrease centrally induced thermo-regulation and cognitive alertness
- → Reduce sweating and increase dizziness, decrease cardiac output and therefore reduce cooling by vasodilation, and worsen respiratory symptoms
- → Can prevent dilation of the blood vessels in the skin, reducing the capacity to dissipate heat by convection
- → Vasodilators, including nitrates and calcium channel blockers, can worsen hypotension in vulnerable patients
- → Can lead to dehydration and reduce blood pressure; hyponatraemia is a common side

effect and can be worsened by excess fluid intake

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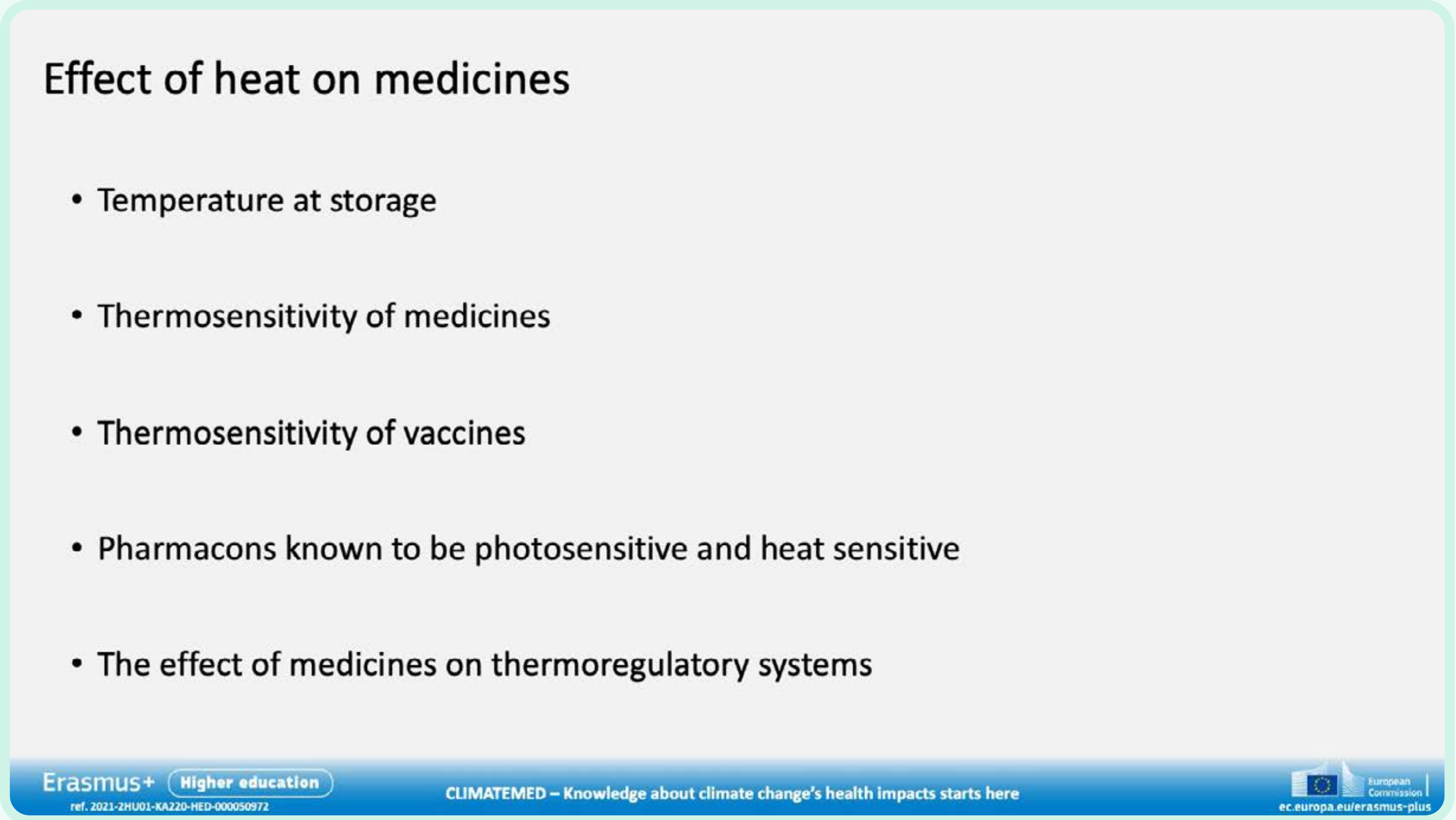


Many pharmacological products act on receptors, in fact they act on families of receptors.

Even small changes in structure can have very different effects (e.g. a ligand binds irreversibly as a result of the change, etc.).

Therefore, heat reduces the drug content, changes the action, even causes unwanted side effects, and deteriorates the consistency of the drug

Temperatures in medical bags in ambulances can reach 40˚C (or even more!) in summer.

The maximum storage temperature for medicines in general (and by no means for all medicines!) should not be more than 25˚C.

Heat can also change the structure of carriers and active substances, sometimes leading to interactions between them.

Thermosensitivity of medicines:

→ Compounds containing peptide bonds (e.g. staphostatins) are highly sensitive to high external temperatures

Some examples:

→ Doxorubicin should be kept at 2-8 ˚C before use

→ The active ingredients of nitroglycerine, bavacizumab, ritonavir, beta-blockers and eye drops should be protected from temperatures above 20˚C, etc.

→ It can be assumed that, especially in non-air-conditioned emergency units and wards, the effects and efficacy of the drugs are different from the „producer's description".

→ A general cooling of drugs is required, in contrary to general practice.

It is a misconception that solid phase drugs are not degradable.

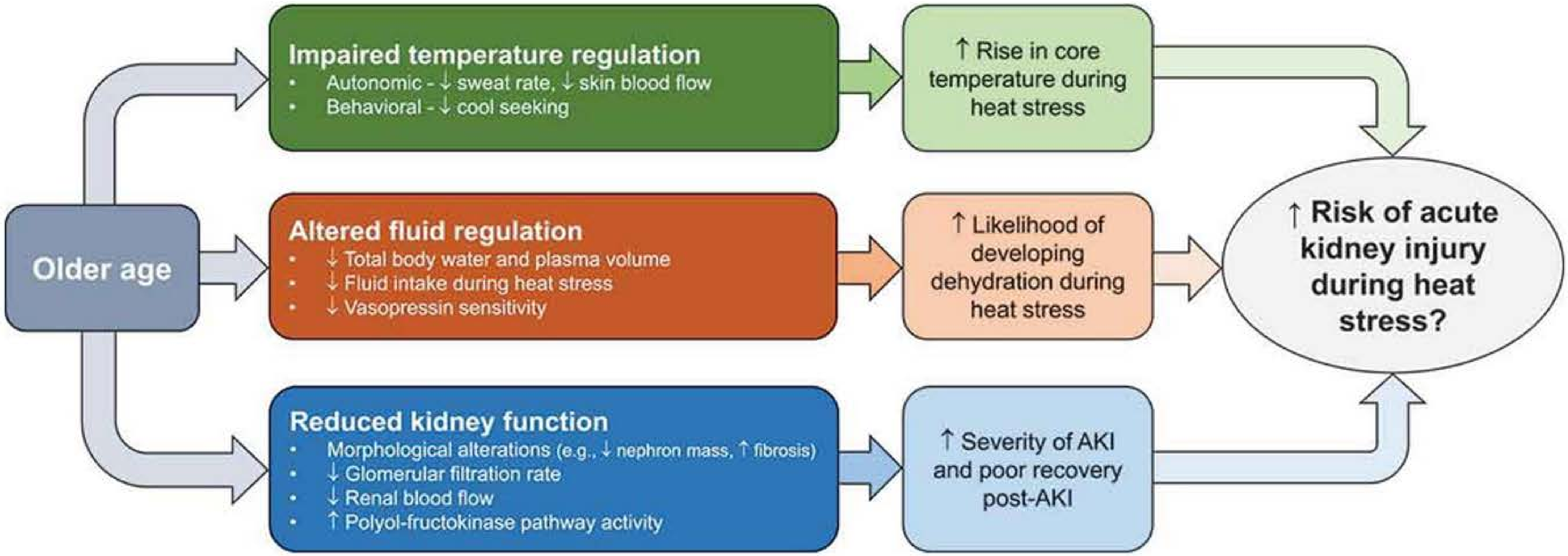
Thermosensitivity of vaccines

- Since all vaccines, both viral and bacterial, are most stable at exactly 2-8 °C, providing adequate storage has turned out to be an immense challenge.
- In general, killed whole-cell bacterial vaccines, like pertussis vaccine, show a higher degree of stability of potency compared to live attenuated vaccines, such as BCG.
- However, when tested in high-temperature conditions, BCG vaccine has proven to be more stable than Pertussis vaccine.
- Also, diphtheria and tetanus toxoids have proven to be most stable during exposure to various conditions.

Stability of vaccines commonly used in national immunization programmes

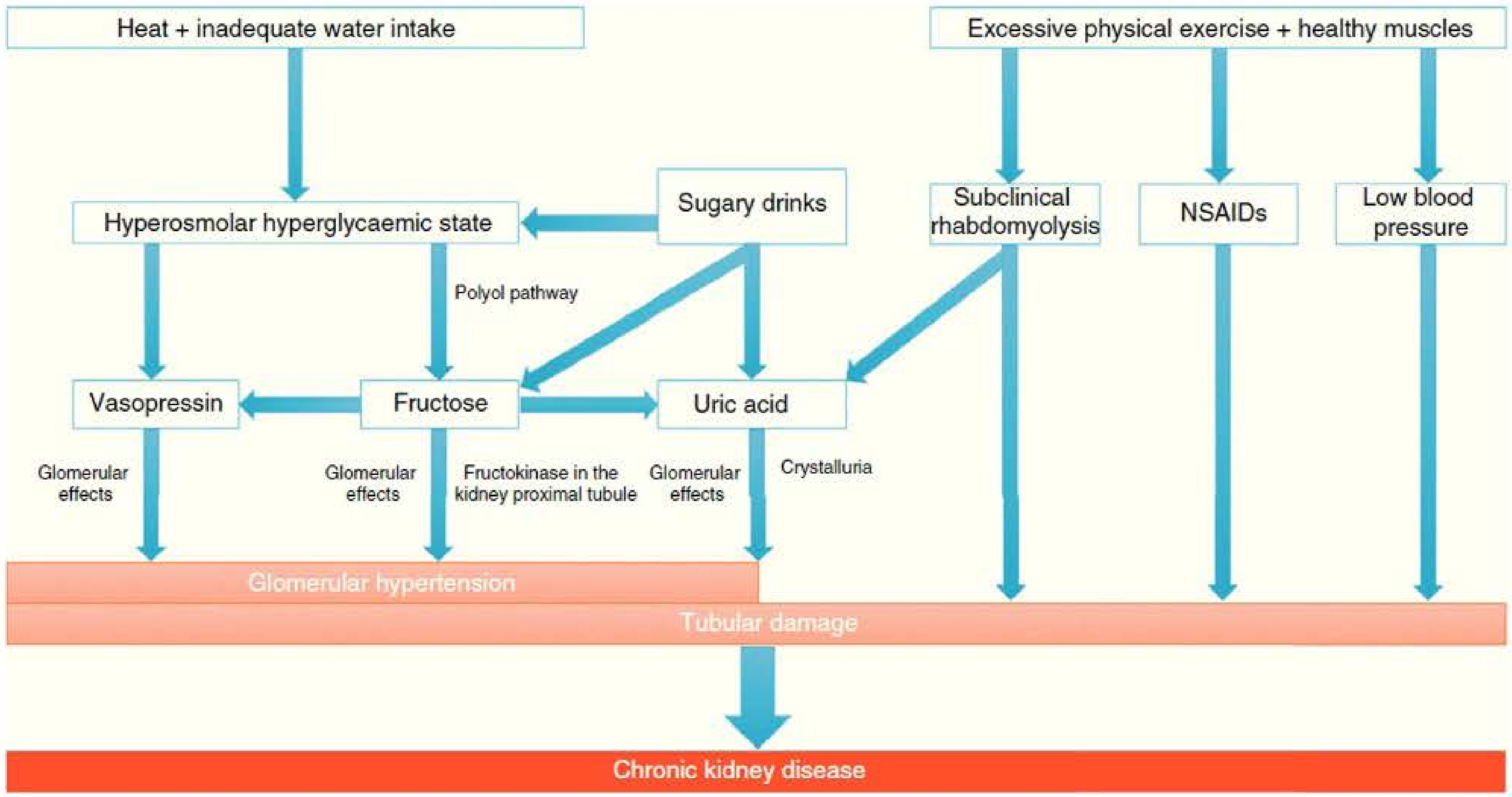
Type	Vaccine	Storage temperature, °C 2-8	20-25	37	>45	Freezing
Viral vaccines	Oral poliovirus vaccine	Stable for up to 1 year	Stable for weeks	Stable for 2 days	Unstable	Stable
	Inactivated poliovirus vaccine	Stable for 1-4 years	Stable for weeks	Stable for weeks	Little data available	Unstable
	Hepatitis B vaccine	Stable for >4 years	Stable for months	Stable for weeks	At 45C, stable for days	Unstable
	Measles, mumps, rubella vaccines	Stable for 2 years	Stable for at least one month	Stable for at least one week	Unstable	Stable
	Yellow fever	Stable for >2 years	Stable for months	Stable for two weeks	Unstable	Stable
Bacterial vaccines	Pertussis vaccine	Stable for 18-24 months	Stable for 2 weeks	Stable for one week	10% or more loss of potency per day	Unstable
	BCG vaccine	Stable for 1-2 years	Stable for months	Loss of no more than 20% after one month	Unstable	Stable
	Tetanus and diphtheria toxoids, monovalent or components of combined vaccines	Stable for >3 years	Stable for months	Stable for months	Unstable above 55C	Unstable

World Health Organization: Temperature sensitivity ofvaccines Immunization, Vaccines and Biologicals. 2006; 1-62. https://apps.who.int/iris/handle/10665/69387

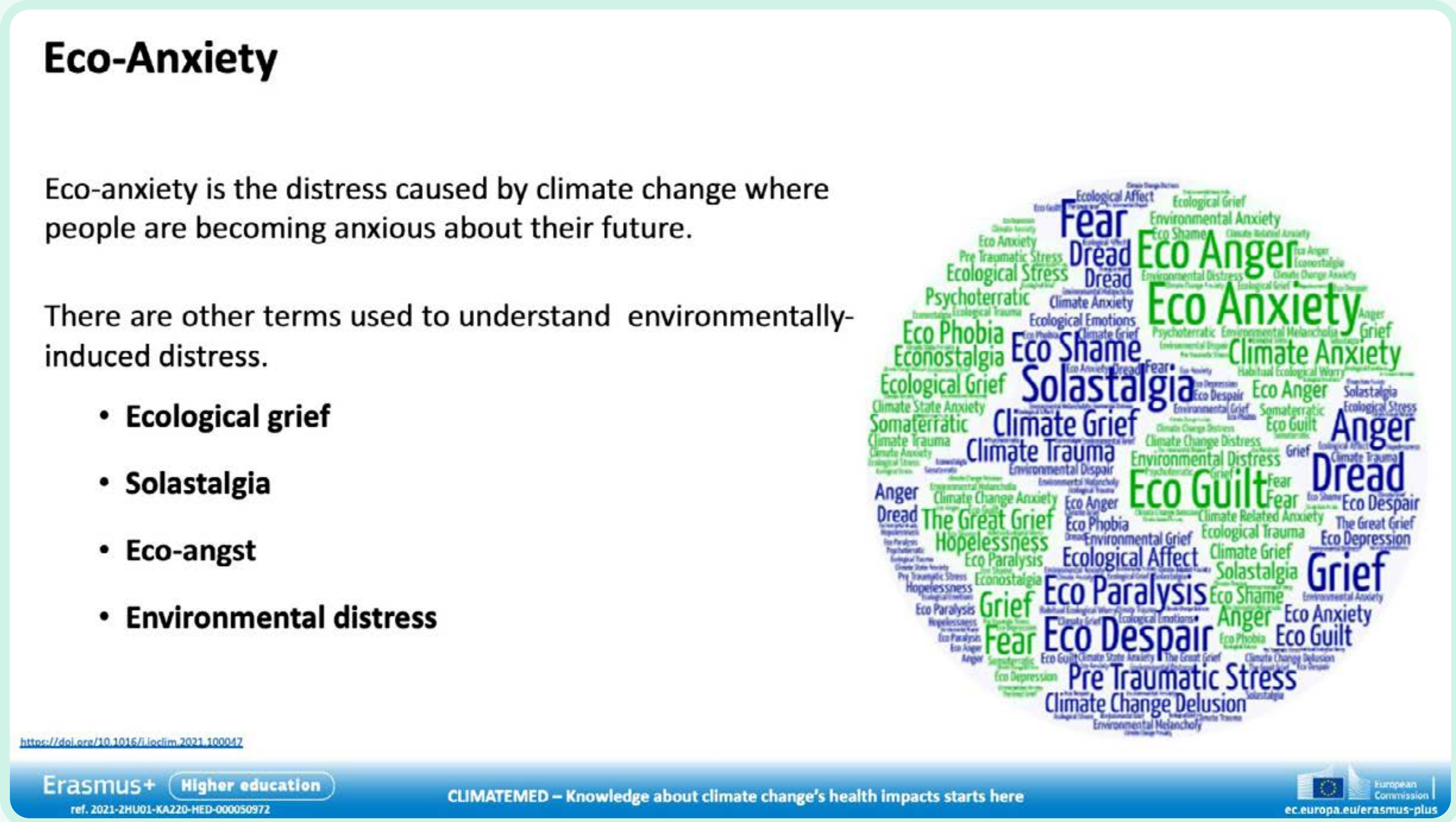


Chapman CL et al. Kidney physiology and pathophysiology during heat stress and the modification by exercise, dehydration, heat acclimation and aging. doi: 10.1080/23328940.2020.1826841.

Development of chronic kidney disease associated with heat



de Lorenzo A, Liaño F. High temperatures and nephrology: The climate change problem. doi: 10.1016/j.nefro.2016.12.008. PMID: 28946962.



Many people report fearing for themselves, their children and future generations with deep feelings of loss, hopelessness, and anger as they witness the effects of climate change.

Ecological grief explains grief felt in response to experienced or anticipated losses in the natural world

Solastalgia is defined as the distress that is produced by environmental change impacting on people while they are directly connected to their home environment

Eco-angst is a feeling of despair at the fragile condition of the planet

Environmental distress is due to people's lived experience of the desolation of their home and environment.

Emotions associated with eco-anxiety link to general anxiety - a negative emotionality characterized by physical symptoms and future-oriented apprehension where eco-anxiety focuses on concerns for climate change.

While negative emotions are often associated with eco-anxiety, they can also be a healthy psychological adaptation and response to threat.

Negative physical behaviors associated with climate change:

→ Being physically sick

→ Experiencing panic attacks

→ Adverse emotional reactions such as irritability, weakness, sleeplessness, sadness, depression, numbness, helplessness, hopelessness, guilt, frustration or anger

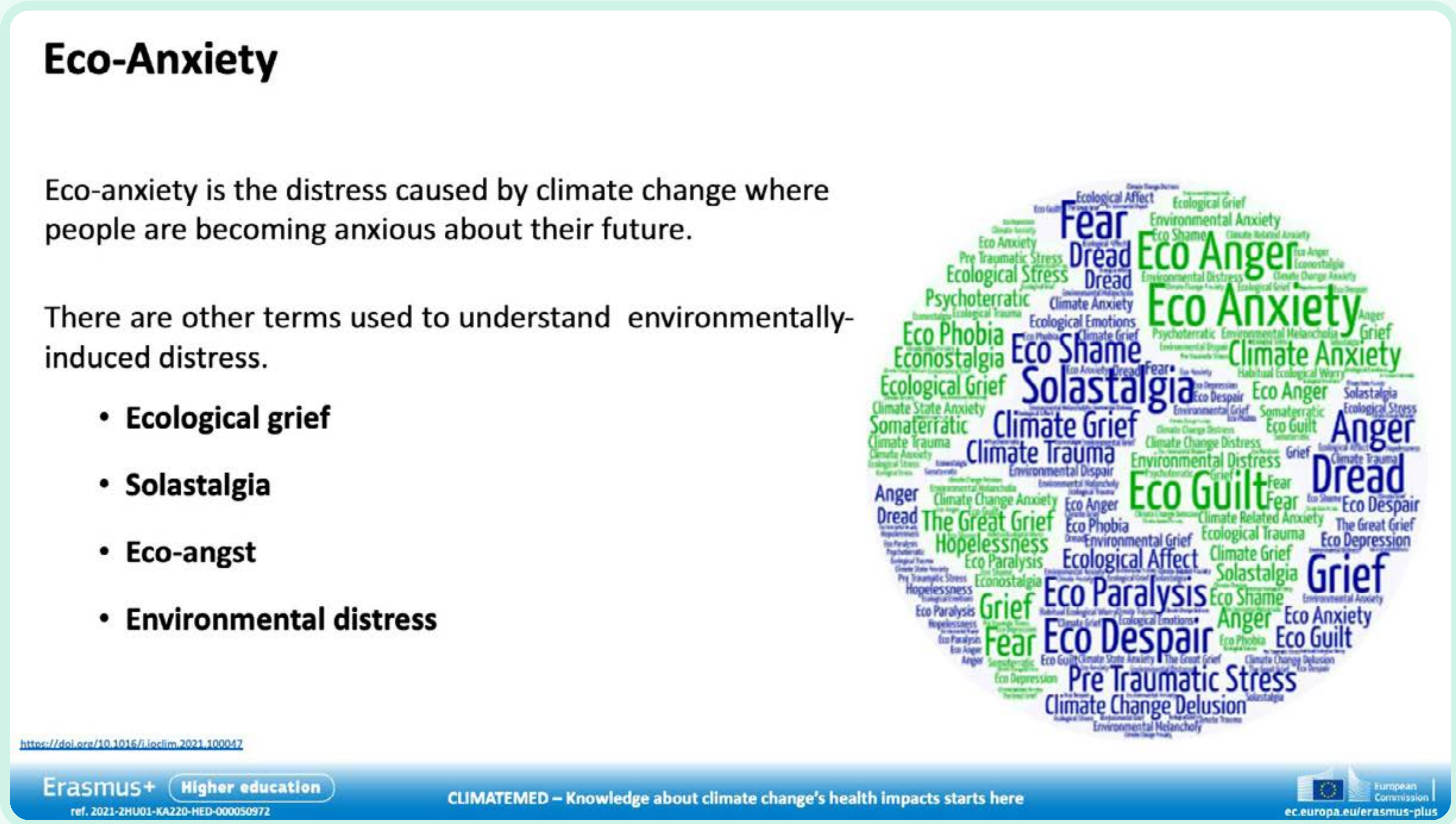
→ Feeling scared or uncertain

→ Being in a state of paralysis that manifests as apathy

Positive emotions or behaviors:

→ Feelings of hope, empowerment, and connection, particularly when associated with collective action

→ These feelings can also be a source of motivation for active engagement and focus on mitigation efforts



Eco-Anxiety – Demographic characteristics

Most studies focused on youth experiences and their emerging concerns for climate change

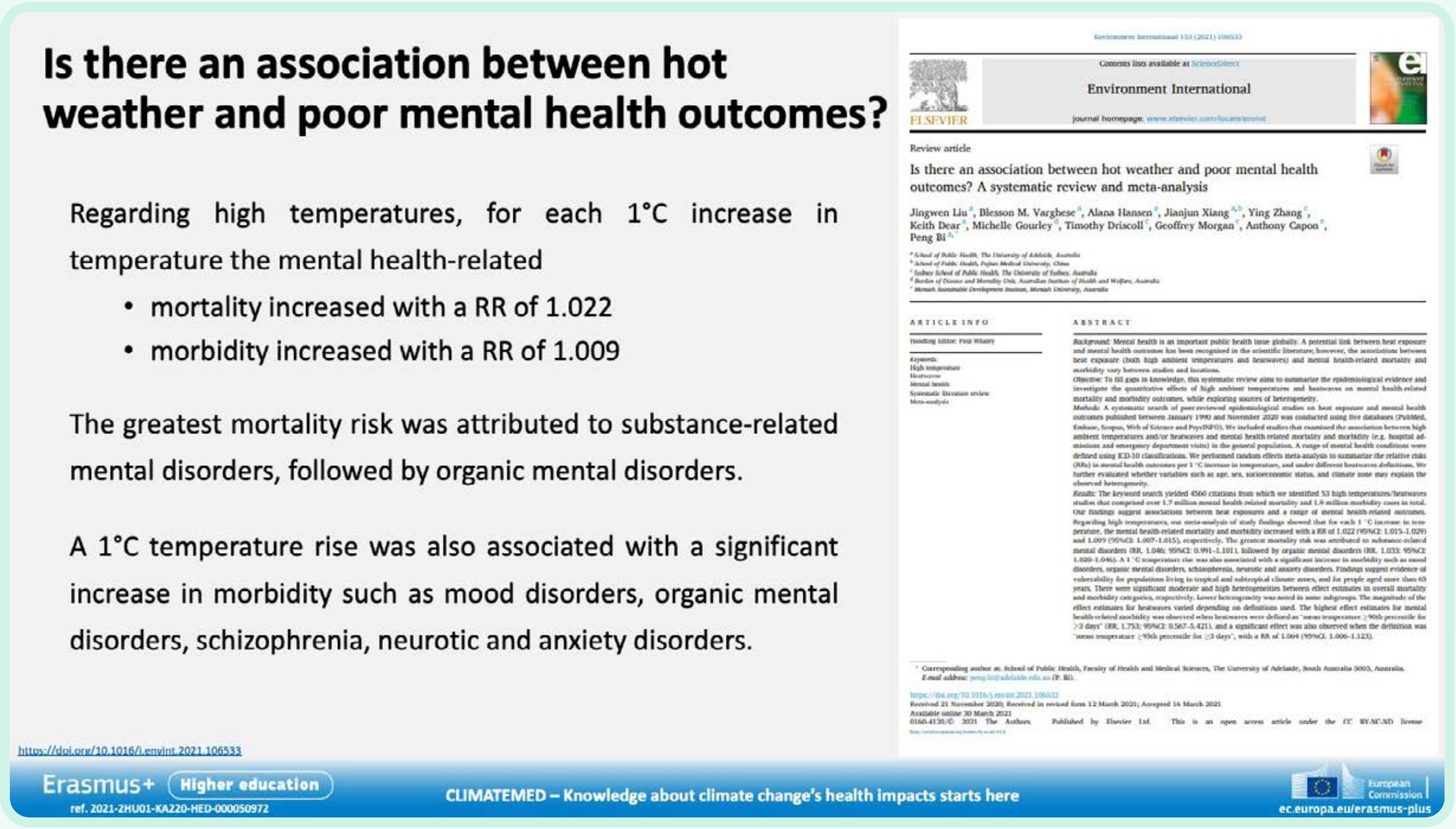
Children are more vulnerable to climate change's mental health effects as they have stronger responses to extreme weather events like PTSD, depression, and sleep disorders.

Younger participants (18–35 years) reported higher scores than older adults when reporting on the degree of climate anxiety impacting their ability to function.

Females and those in younger age groups were more distressed overall about climate change than males and those over the age of 35 years.

Women have more significant stress and anxiety as they are more behaviorally engaged with higher rates of post-traumatic stress disorder (PTSD) following a disaster compared to men.

→ | https://doi.org/10.1016/j.joclim.2021.100047



Is there an association between hot weather and poor mental health outcomes? A systematic review and meta-analysis

Regarding high temperatures, for each 1 ˚C increase in temperature the mental health-related

→ mortality increased with a RR of 1.022 (95%CI: 1.015–1.029)

→ morbidity increased with 1.009 (95%CI: 1.007–1.015)

The greatest mortality risk was attributed to substance-related mental disorders (RR, 1.046; 95%CI: 0.991–1.101), followed by organic mental disorders (RR, 1.033; 95%CI: 1.020–1.046).

A 1 ˚C temperature rise was also associated with a significant increase in morbidity such as mood disorders, organic mental disorders, schizophrenia, neurotic and anxiety disorders.

Findings suggest evidence of vulnerability for populations living in tropical and subtropical climate zones, and for people aged more than 65 years.

→ | **https://doi.org/10.1016/j.envint.2021.106533**

Climate change and occupational safety and health

- The relationship between global climate change and occupational safety and health has not been extensively characterized.
- A framework was developed for identifying how climate change could affect the workplace, workers and occupational morbidity, mortality, and injury.
- Seven categories of climate-related hazards are identified:
  1) ***increased ambient temperature***
  2) ***air pollution***
  3) ***ultraviolet exposure***
  4) ***extreme weather***
  5) ***vector-borne diseases and expanded habitats***
  6) ***industrial transitions and emerging industries***
  7) ***changes in the built environment***
- Climate change may result in increasing the prevalence, distribution, and severity of known occupational hazards.

https://doi.org/10.1080/15459620903066008

Climate change and occupational safety and health

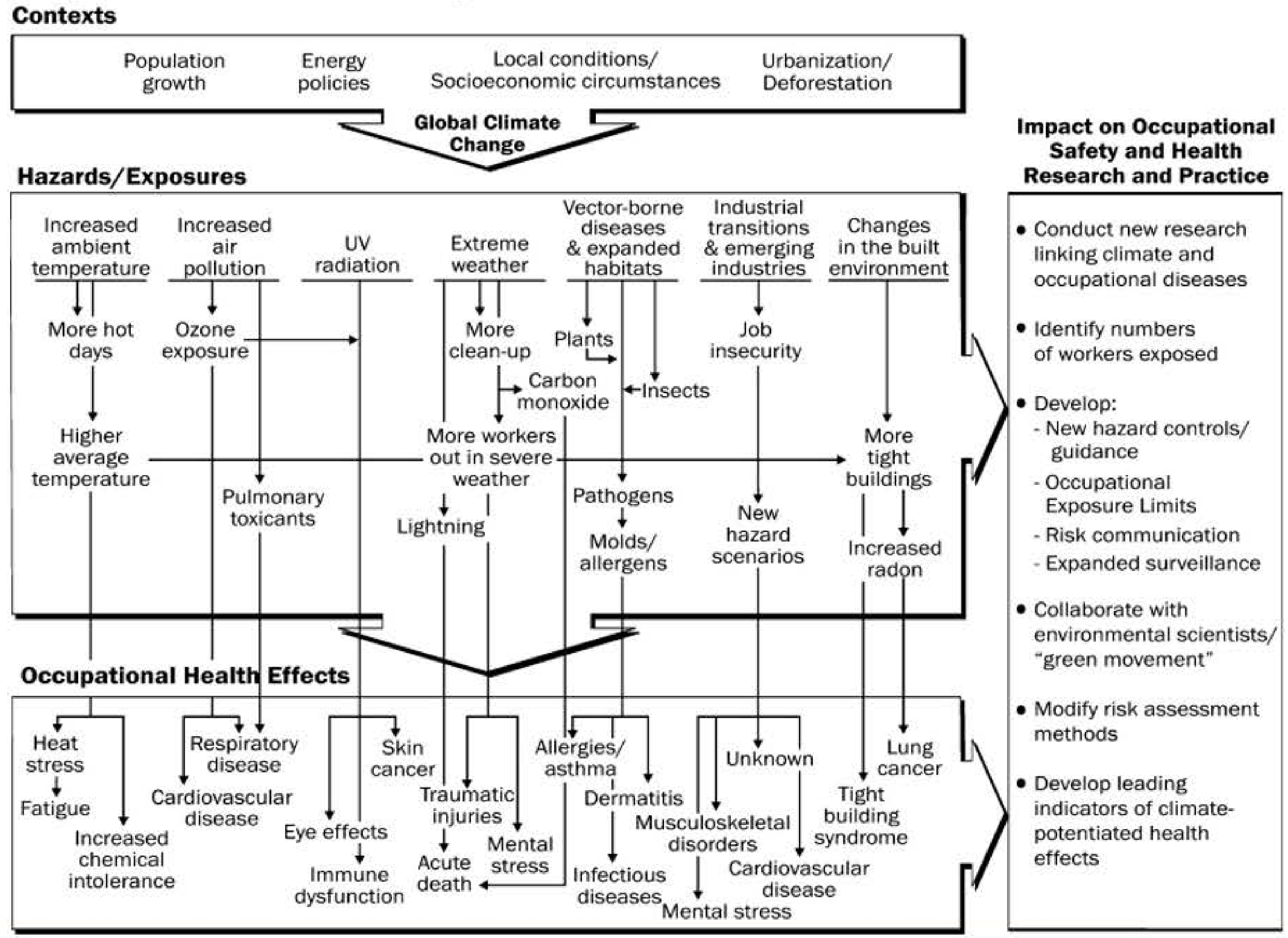
Factors that Could Increase Susceptibility to Climate-Related Occupational Hazards

Age	Older workers may have slower elimination of many toxicants. They are also less able to thermoregulate.
Obesity	Inherited and acquired differences in heat tolerance and sweat rate: excess body weight raises metabolic heat production.
Pre-existing disease	Workers with prior heat injury, obesity, or pre-existing illness such as cardiovascular disease or chronic respiratory diseases, elderly, children or others in thermally stressful occupations and who are not acclimatized may be at a greater risk of heat illnesses.
Very small body size, lower socioeconomic status	Those who live in poverty or who have small body size are vulnerable to heat stress because of the potential for multiple exposures, poorer diets, and lack of access to medical care.
Pregnancy	Some individuals with underlying health conditions (who have weakened immune system by pregnancy, diabetes and autoimmune disease) may be more sensitive to molds.
Immunologic status	People who have human immunodeficiency virus infection or immunosuppressed as a result of cancer therapy or health hazards are more at risk for serious infections.
Type of work clothing	Workers required to wear semipermeable or impermeable protective clothing or PPE such as Tyvek suits, gloves, air-purifying respirators are at risk of heat disorders.
Genetic characteristics	Genetic host factors (e.g., hemochromatosis gene) that modify pathophysiological effects of particles may play a role in predicting susceptibility to air pollution. Heat shock proteins and some genes (i.e., C-reactive protein, ICAM-1, metallothionein, and cNOS) change expression with heat stress.

Source: Schulte and Chun: Climate Change and Occupational Safety and Health: Establishing a Preliminary Framework. J Occup Environ Hyg 2009. https://doi.org/10.1080/15459620903066008

Climate change and occupational safety and health

Conceptual framework of the relationship between climate change and occupational safety and health



https://doi.org/10.1080/15459620903066008

Erasmus+ Higher education
ref. 2021-2HU01-KA220-HED-000050972

CLIMATEMED – Knowledge about climate change's health impacts starts here

European Commission
ec.europa.eu/erasmus-plus

The impact of climate change on workers' health is affected by other contextual factors, such as:

→ population growth

→ energy policies

→ increasing urbanization and deforestation

These factors along with climate change may lead to an increase in the magnitude and severity of known hazards and result in increasing numbers of workers who would be exposed to them.

→ | https://doi.org/10.1080/15459620903066008

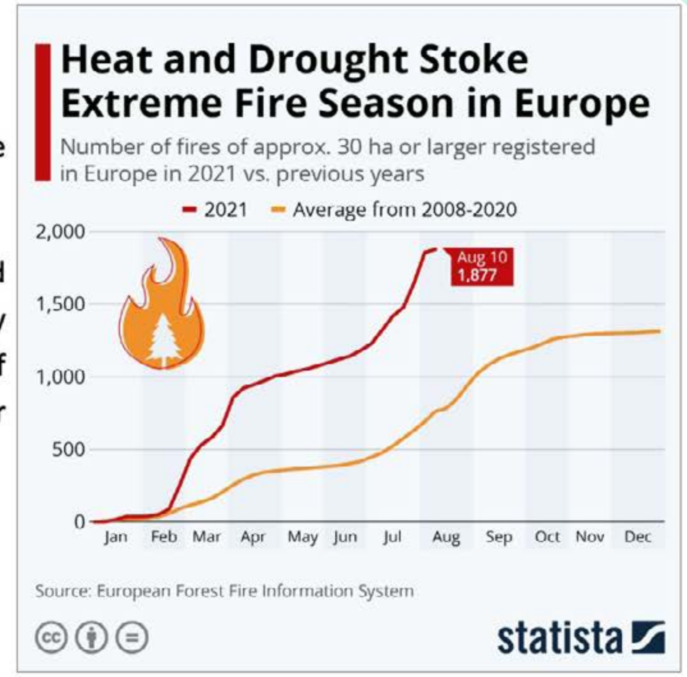
Wildfire

The size and frequency of wildfires are growing due to climate change.

Hotter and drier conditions are drying out ecosystems and increasing the risk of wildfires. Wildfires also simultaneously impact weather and the climate by releasing large quantities of carbon dioxide, carbon monoxide and fine particulate matter into the atmosphere.

Wildfire can cause a range of health issues including

- burning demages and other injuries;
- detrimental effects on mental health and psychosocial well-being;
- smoke pollution.



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Health hazards of wildfire - burning demages and other injuries

→ The most common injury caused by wildfires is burns. Most of the cases, these injuries are second- or third-degree burns. Due to the extraordinary circumstances of the injury, patients with wildfire burns may need psychological services and support groups in addition to professional care for their burns.

→ The other frequent injuries in addition the burns are

- → eye, nose, throat and lung irritation
- → decreased lung function, including coughing and wheezing
- → pulmonary inflammation, bronchitis, exacerbations of asthma, and other lung diseases
- → exacerbation of cardiovascular diseases, such as heart failure

→ Wildfires also release significant amounts of mercury into the air, which can lead to impairment of speech, hearing and walking, muscle weakness and vision problems for people of all ages.

Health hazards of wildfire – impacts on mental health

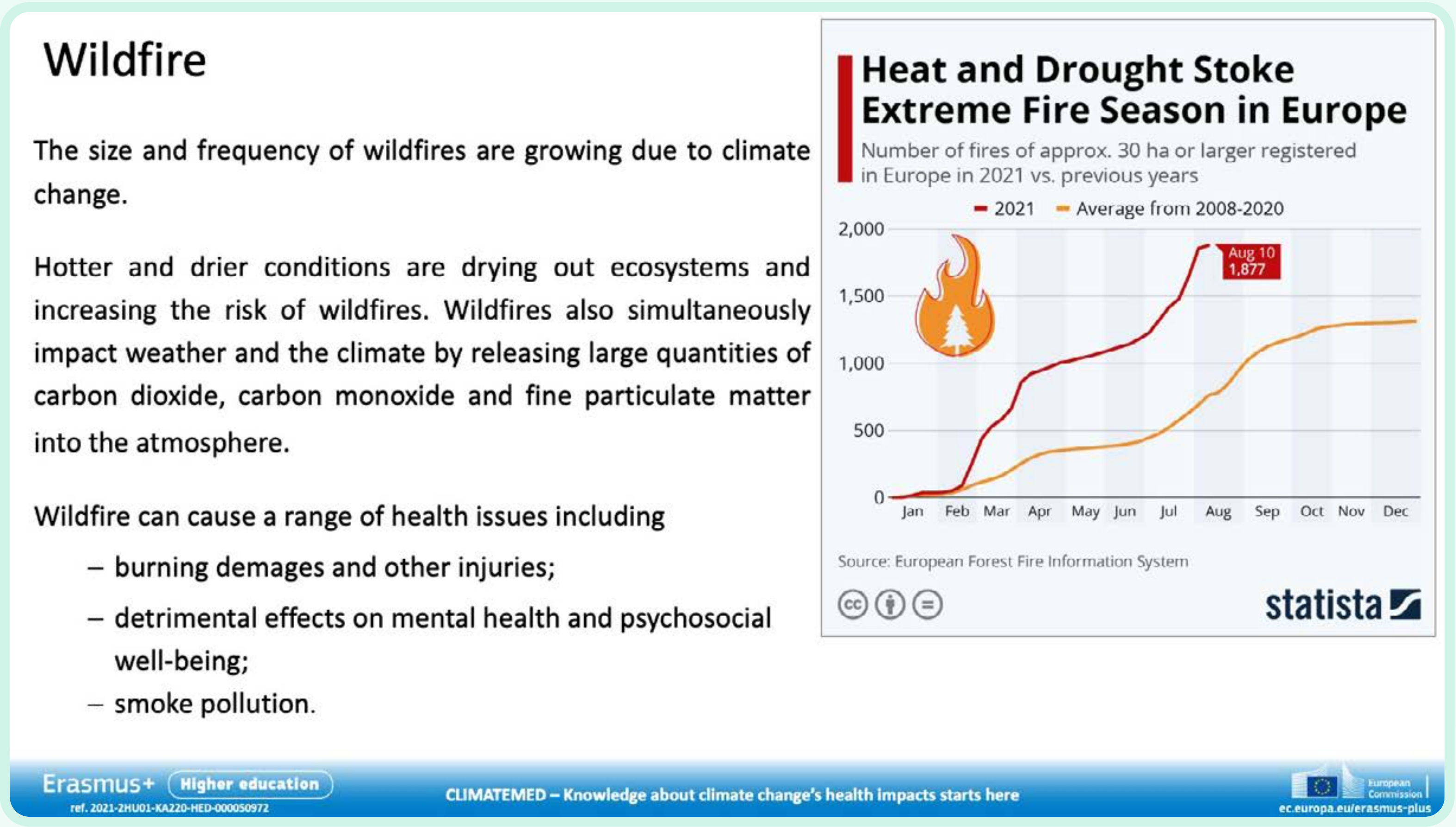
→ The psychological impacts of wildfires can be long-lasting and far-reaching. People may experience

- → depression,
- → anxiety,
- → post-traumatic stress disorder, and
- → other mental health issues due to their experiences with the fires.

→ People who have experienced wildfires may experience trauma-related symptoms such as

- → difficulty sleeping,
- → flashbacks,
- → intrusive thoughts, and hypervigilance.

→ The fear of future wildfires and their potential destruction can be a source of ongoing distress. The disruption of daily life, loss of community and social networks, and financial strain can also cause mental health issues.



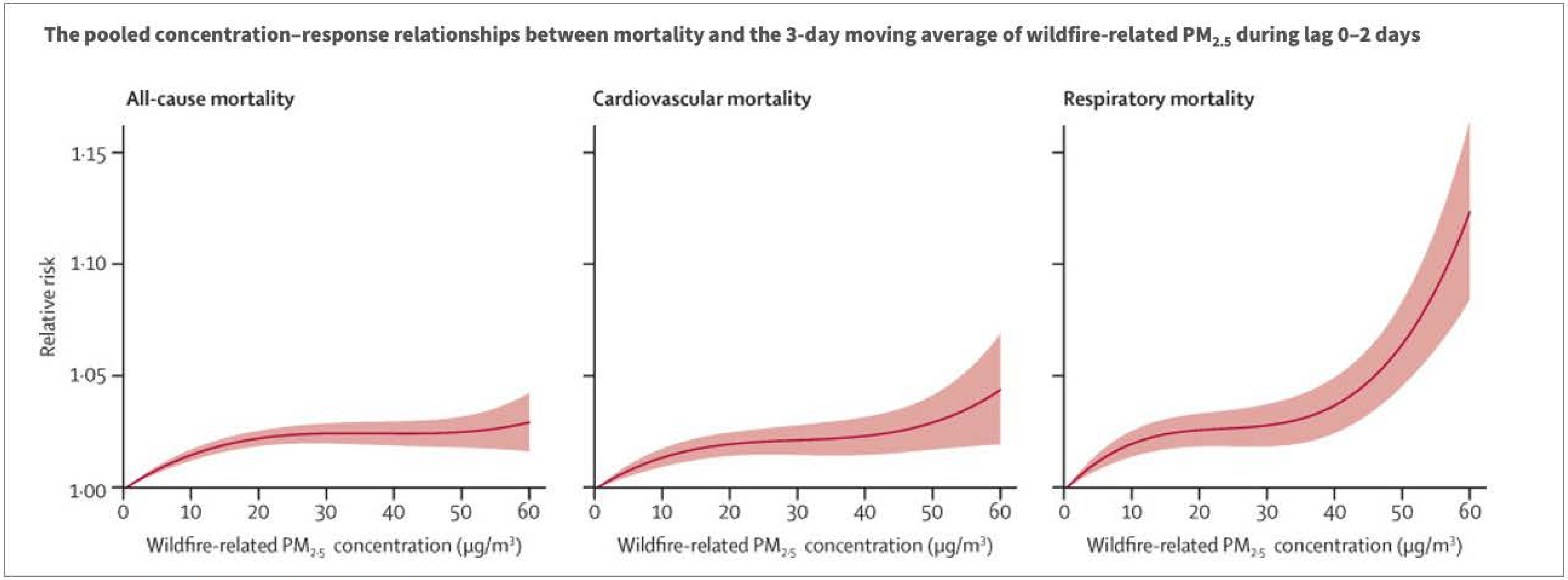
Health hazards of wildfire – smoke pollution

→ Wildfire smoke is a complex mixture of particulate matter (PM) and gaseous pollutants. Among the various air pollutants emitted by wildfires, fine particulate matter (PM2.5) is of great concern, as particles in this size range enter into the lungs and reach the alveoli where the small particles can translocate through the alveolar epithelium and enter the circulation.

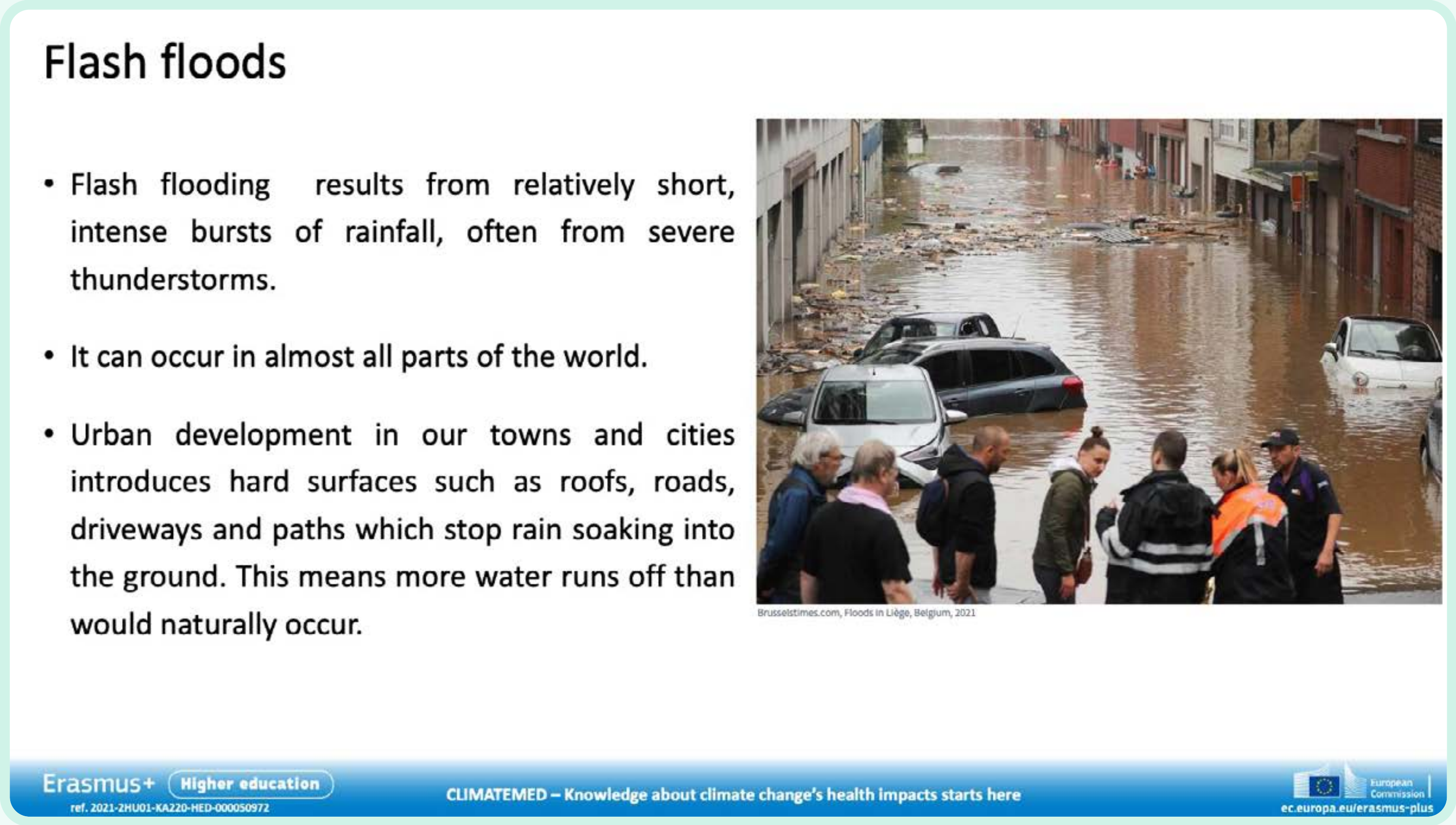
→ Compared with PM2.5 from urban sources, wildfire-related PM2.5 tends to be more toxic due to its chemical composition and smaller particle size, and is often accompanied by co-exposure to other harmful environmental factors, particularly high temperatures.

Health hazards of wildfire – smoke pollution

Chen and colleagues analysed mortality data for 750 cities in 43 countries in 2021 and found that wildfire smoke pollution increases all-cause, cardiovascular and respiratory mortality. Thus, wildfire smoke exposure can be interpreted as a complex mortality factor.



Chen et al. 2021 The Lancet https://doi.org/10.1016/S2542-5196(21)00200-X



→ In urban areas, the floodwater picks up potentially harmful substances from roads, factories, gutters and drains, including oil, household chemicals, and transfers them to streets and urban watercourses. This water poses risks to human health as it may contain toxins and pathogens such as E. coli and the virus that causes hepatitis A.

→ There is also an increased risk of wound infections, dermatitis, conjunctivitis, and ear, nose and throat infections from polluted waters.

→ In the case of flash flooding, people are often swept away after entering floodwaters on foot or in vehicles.

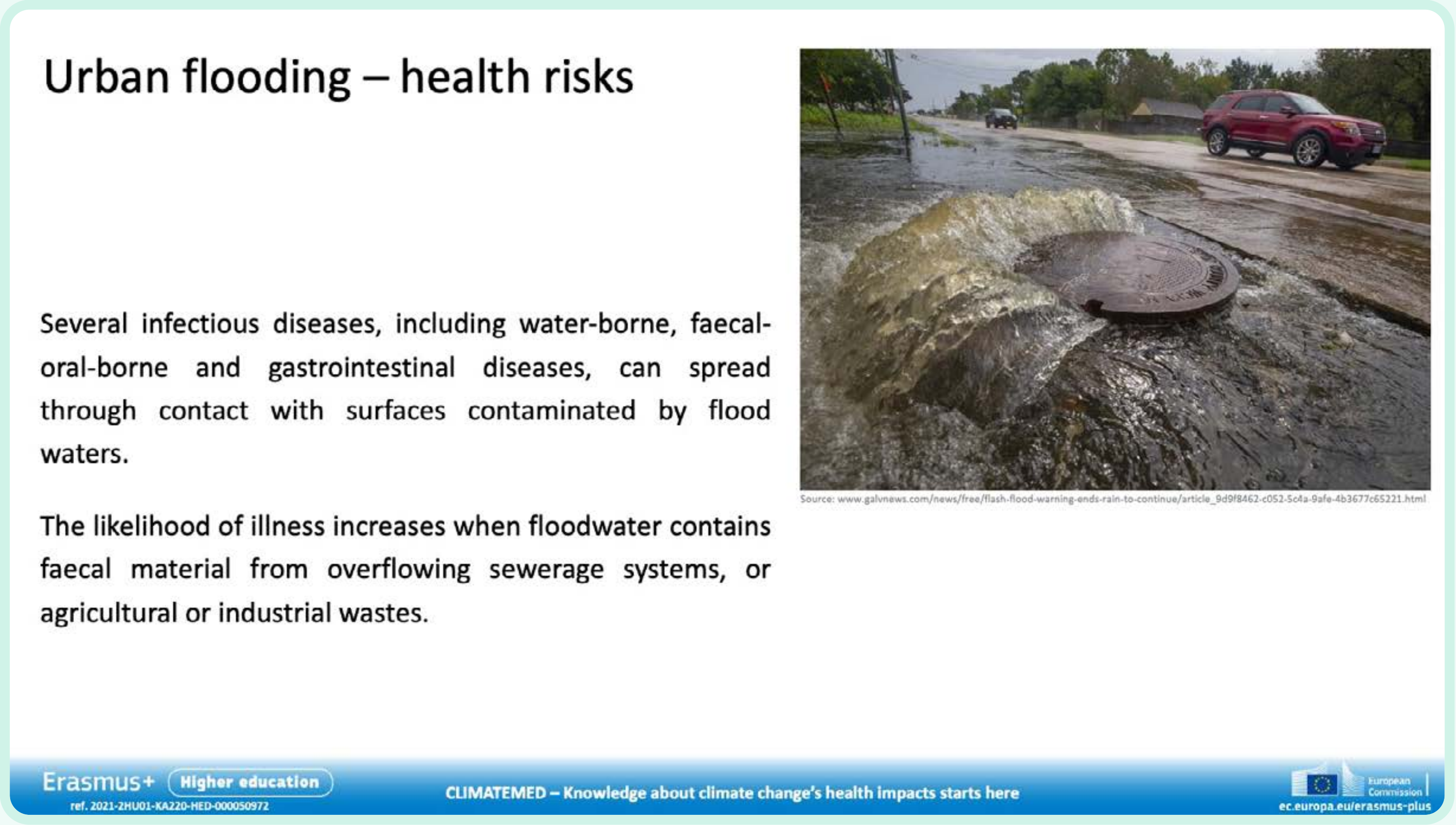
→ Flash floods can occur in rural areas where the nature of terrain and steepness of the streams can lead to very rapid development of flooding.

→ These floods can also result in significant property damage and major social disruption.

→ During falsh floods the risk of traffic accidents in both urban and rural environments is elevated.

→ There can be significant risks from slip and trip hazards beneath the water. The flood waters may contain sharp objects, such as glass or metal fragments, that can cause injury and lead to infection.

→ Water can also hide trip or slip hazards, such as rocks, steps, kerbs, tree roots, grass, mud or other debris. If water is fast moving, these hazards can lead to serious puncture wounds, bone breaks, or worse.



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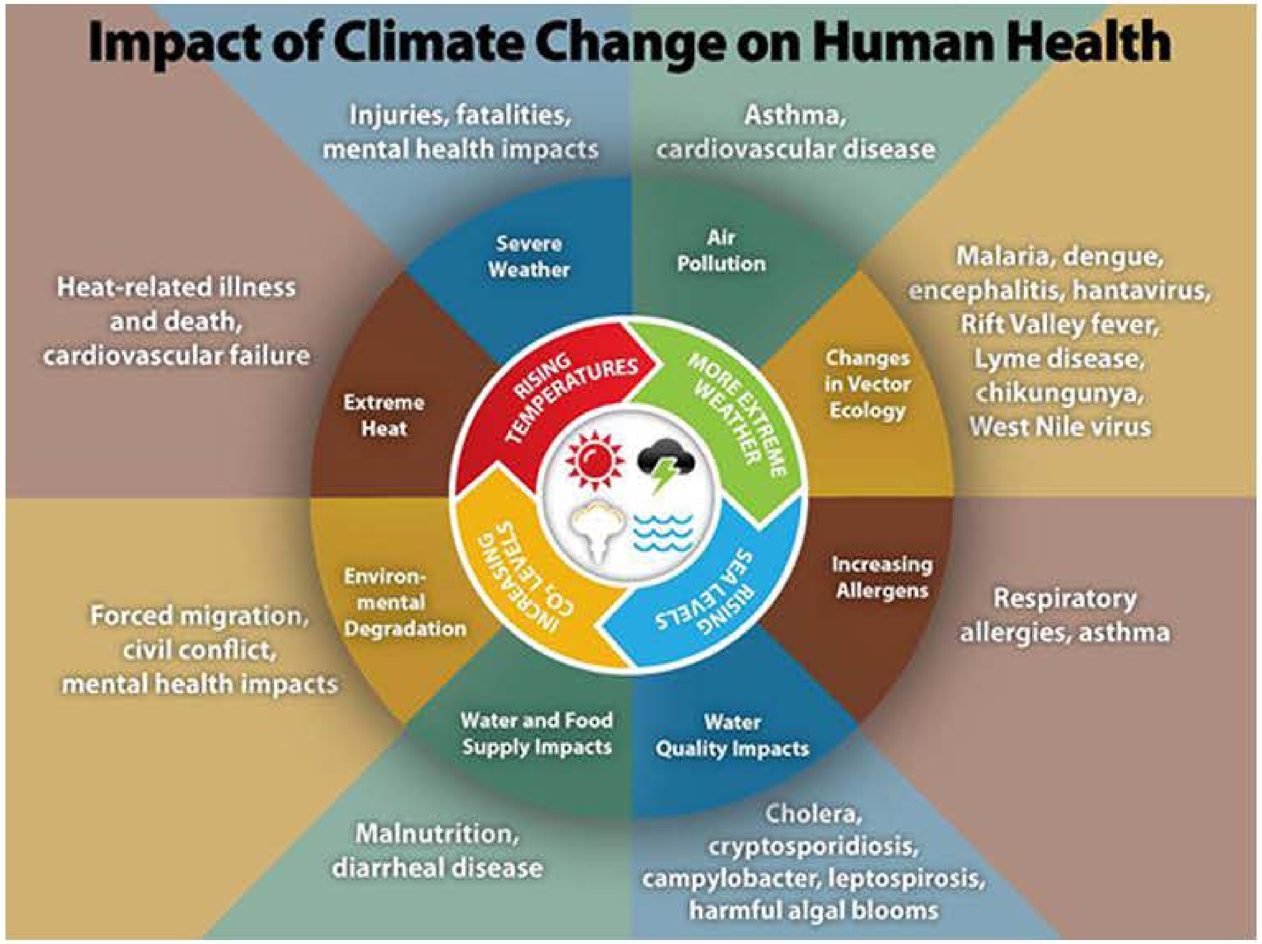
Climate Change and CVD

Climate change (CC) is the greatest existential challenge to planetary and human health.

Among many effects, **climate change impacts the CVD** and overall health, and this represents a multifaceted problem that needs to be urgently addressed at various levels.



Impact of Climate Change on Human Health.
Source:
https://www.cdc.gov/climateandhealth/images/climate_change_health_impacts600w.jpg?_=06389

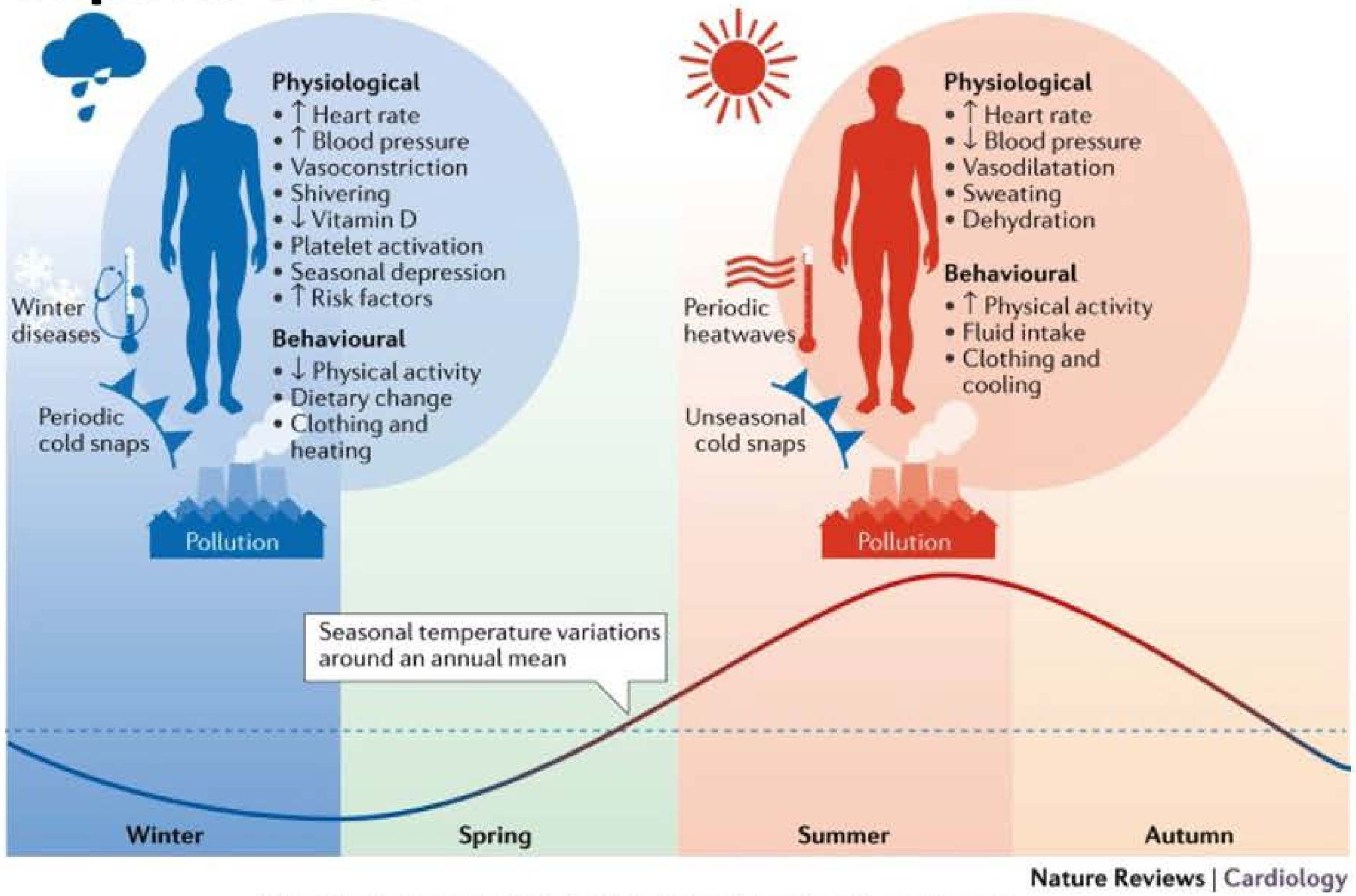
→ Climate change (CC) is the greatest existential challenge to planetary and human health.

→ Among many effects, climate change impacts the CVD and overall health, and this represents a multifaceted problem that needs to be urgently addressed at various levels.

→ For example, in 2019, approximately 18.6 million people died from CVD worldwide and the CVD remains the leading cause of death globally.

→ Accordingly, it is necessary to uncover the connections that exist between CC and other stressors and CVD in order to develop mitigation and prevention strategies.

Air temperature impacts on CVD



Model of seasonal variation in cardiovascular disease: individual–environmental interactions

Source: from Stewart et al., 2017

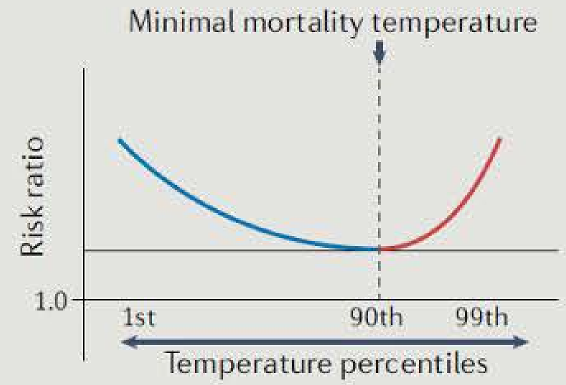
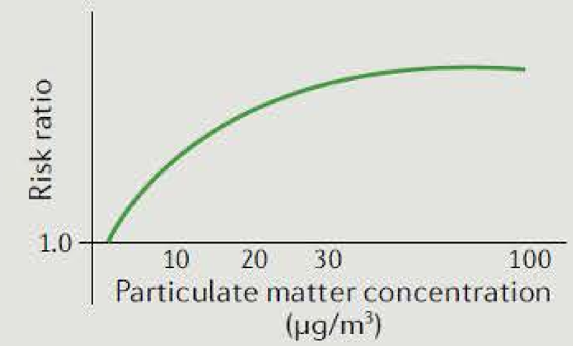
Both low and high temperatures contribute to cardiovascular morbidity and mortality.

In 2019, the Global Burden of Disease Study introduced non-optimal temperatures as a risk factor for death worldwide, with the greatest mortality burden associated with low rather than high temperatures.

A 2021 global analysis estimated that >5 million deaths annually are associated with non-optimal temperatures.

These trends are expected to worsen in the coming years given continual global warming and greater vulnerability of patients with multiple risk factors for CVD61.

Air temperature impacts on CVD

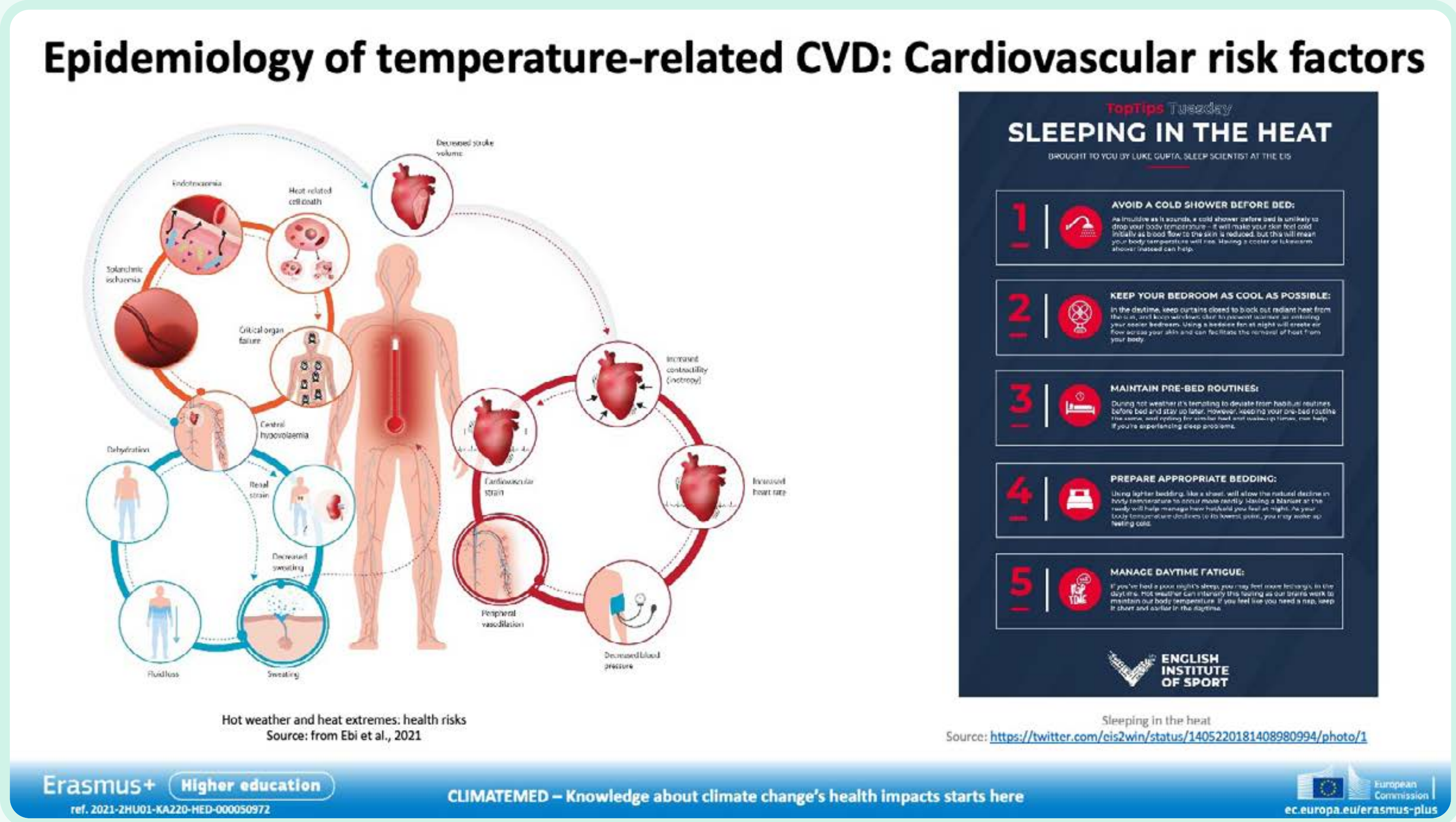
Feature	Ambient temperature	Particulate matter
Unit of measurement	Degrees Fahrenheit or Celsius	Micrograms per cubic metre
Exposure assessment	Average daily outdoor air temperature, usually measured from meteorological stations	Average daily particulate matter ($PM_{2.5}$ and PM_{10}) levels, usually measured by regulatory monitoring networks or estimated from models with fine spatiotemporal resolution
Study design	Time-series and case–crossover studies for short-term effects; longitudinal cohort studies for long-term effects	Time-series and case–crossover studies for short-term effects in time-series and case–crossover studies; longitudinal cohort studies for long-term effects
Lag effect	Cold temperatures up to 3 weeks; hot temperatures up to 1 week	Up to 5 days (short-term effects)
Exposure–response curve		

$PM_{2.5}$, fine particulate matter ≤2.5 μm in diameter; PM_{10}, particulate matter ≤10 μm in diameter.

Temperature and particulate matter as climate change-related health exposures

Source: from Khraishah et al., 2022

- → The effect of short-term exposure to temperature fluctuations on mortality showed that the exposure–response relationship is inherently non-linear and might produce U-shaped, V-shaped or J-shaped curves.
- → Optimum temperature (which refers to the mean daily temperature at which the lowest mortality occurs and is also known as the minimum mortality temperature) is the demarcation or the inflexion point of the curves and can vary according to climate zone, geographical location and population vulnerabilities.
- → Another actor to consider is the delayed or 'lagged' effect over time of environmental stressors, such as extreme temperature or air pollution.
- → The health effects of exposure to extreme cold temperature usually persist longer (up to 2 weeks or more) than the effects of exposure to extreme heat events, which normally last for 2–3 days.



→ In addition, increases in mean ambient temperature were associated with lower plasma HDL and higher plasma LDL levels.

→ Higher temperatures are associated with less time spent exercising, which can potentially increase the risk of CVD in the long term.

→ Temperature extremes might have an influence on the risk of developing diabetes and might also be associated with poor glycaemic control in patients with underlying diabetes.

→ Short-term fluctuations in temperature have also been linked with blood pressure levels.

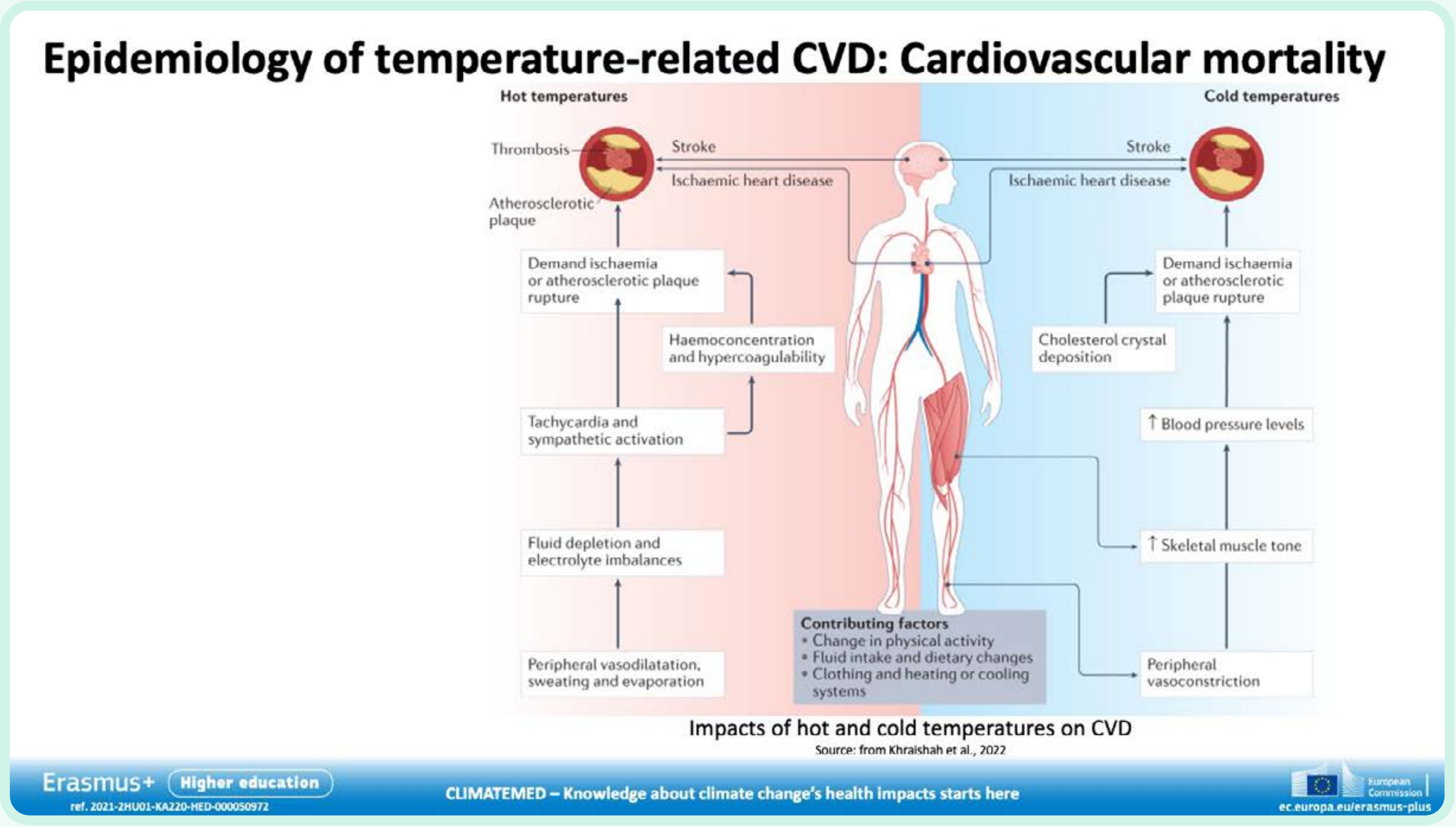
> → Studies across a range of climates and populations have demonstrated an inverse association between temperature and blood pressure levels on the same and/or preceding days.

→ Studies showed that a decrease in mean outdoor temperature of 1 °C was associated with an increase in systolic blood pressure of 0.26 mmHg and in diastolic blood pressure of 0.13 mmHg.

→ Interestingly, night-time blood pressure has been shown to be higher during the summer months than in the winter months, suggesting that a warming climate might have opposing effects and counteract traditional mechanisms of cardio protection.

→ Warmer nights might lead to increased blood pressure levels several hours later during the following afternoon.

→ Reduced sleep duration or quality has also been suggested as a potential mechanism for the seemingly paradoxical elevation in night-time blood pressure levels during warmer weather.



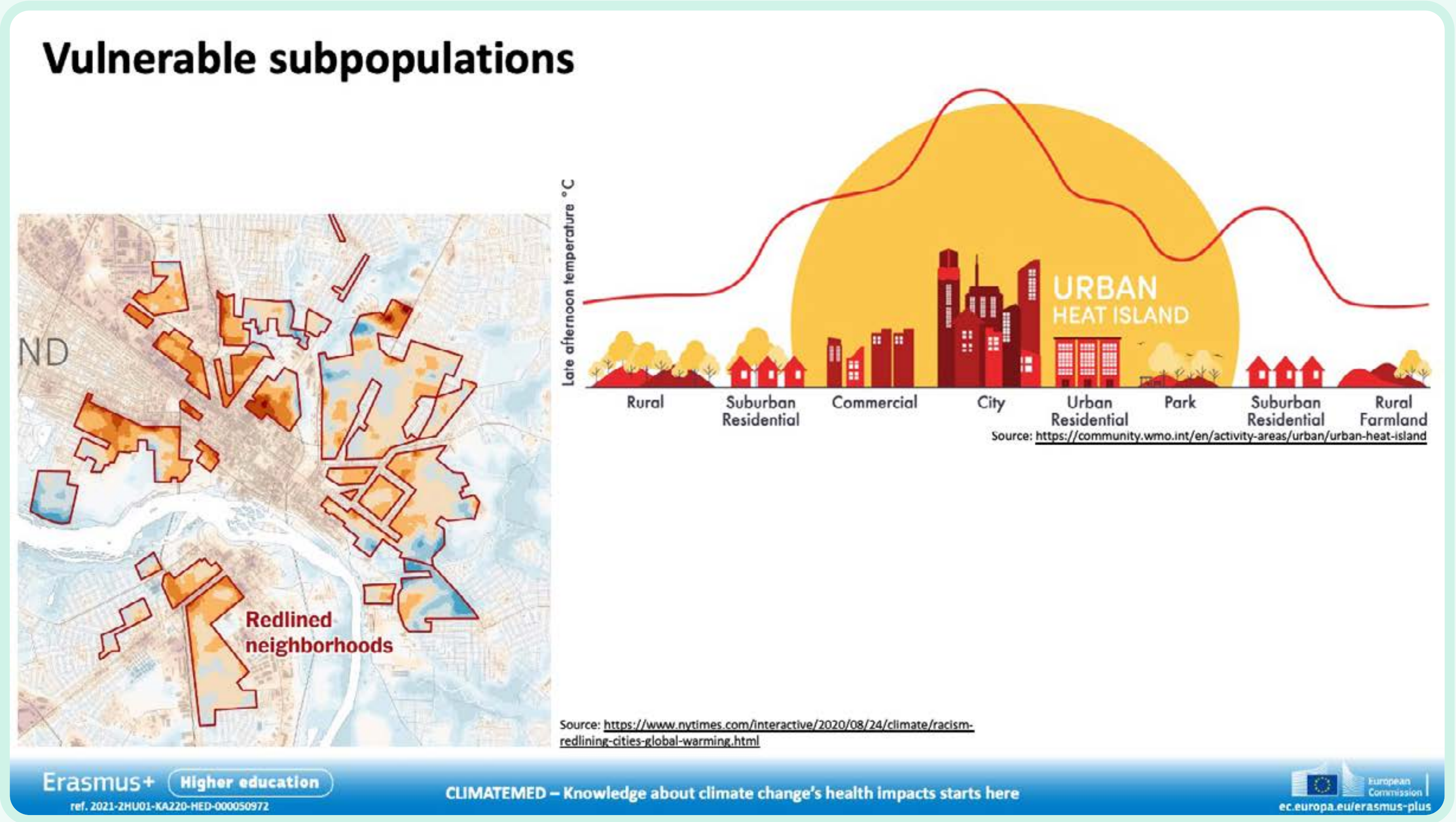
→ The relative risk of all-cause death and cardiovascular death increases sharply if the mean daily temperature goes above or below the optimum temperature.

→ A 1 °C increase or decrease in ambient temperature above or below the optimal temperature threshold was associated with an increase in cardiovascular mortality of 3.44% and 1.66%, respectively.

> → A time-series analysis in England and Wales during the summer months for the period 1993–2006 demonstrated an increase in cardiovascular mortality by 1.8% for every 1 °C increase above the regional heat threshold.

→ A time-series analysis of individuals from >270 Chinese cities assessed during 2013–2015 demonstrated that cold temperatures had a greater association with cardiovascular mortality than high ambient temperatures.

> → Compared with the optimum temperature, extreme cold temperatures were associated with an increase in cardiovascular mortality of 92%, with sustained effects lasting >14 days.
>
> → Conversely, extreme hot temperatures were associated with an increase in cardiovascular mortality of 22%.



Individuals from ethnic minority groups might also be more susceptible to the adverse health effects mediated by temperature-related events.

For example, African American individuals have an increased all-cause mortality during both heat-related and cold-related extreme weather events compared with white individuals, an effect that is driven by lower socioeconomic resources and numerous other socially disadvantageous circumstances among the African American population.

Climate change vulnerability is defined as the propensity to be adversely affected by climate change.

Coastal and low-lying geographical areas, as well as densely packed cities with poor infrastructural amenities, offer less protection from the potential health risks associated with extreme climate change-related events

Other factors such as homelessness, type of housing and lack of green spaces contribute to climate change vulnerability.

For example, during the heatwave in the summer months of 2003 in Europe, residents in old buildings with a lack of thermal insulation had a twofold increased risk of death compared with residents living in well-insulated buildings.

Climate change has differential effect across various demographic and socioeconomic subgroups living in different geographical areas.

Age is the most consistent individual-level effect modifier of temperature-related cardiovascular mortality, with older individuals being more vulnerable to the adverse health effects mediated by temperature extremes.

During the heatwaves in 1995 in Chicago, USA, and in 2003 in Paris, France, mortality was the highest in bed-bound, older patients with comorbidities, such as obesity, CVD, and mental and neurological disorders.

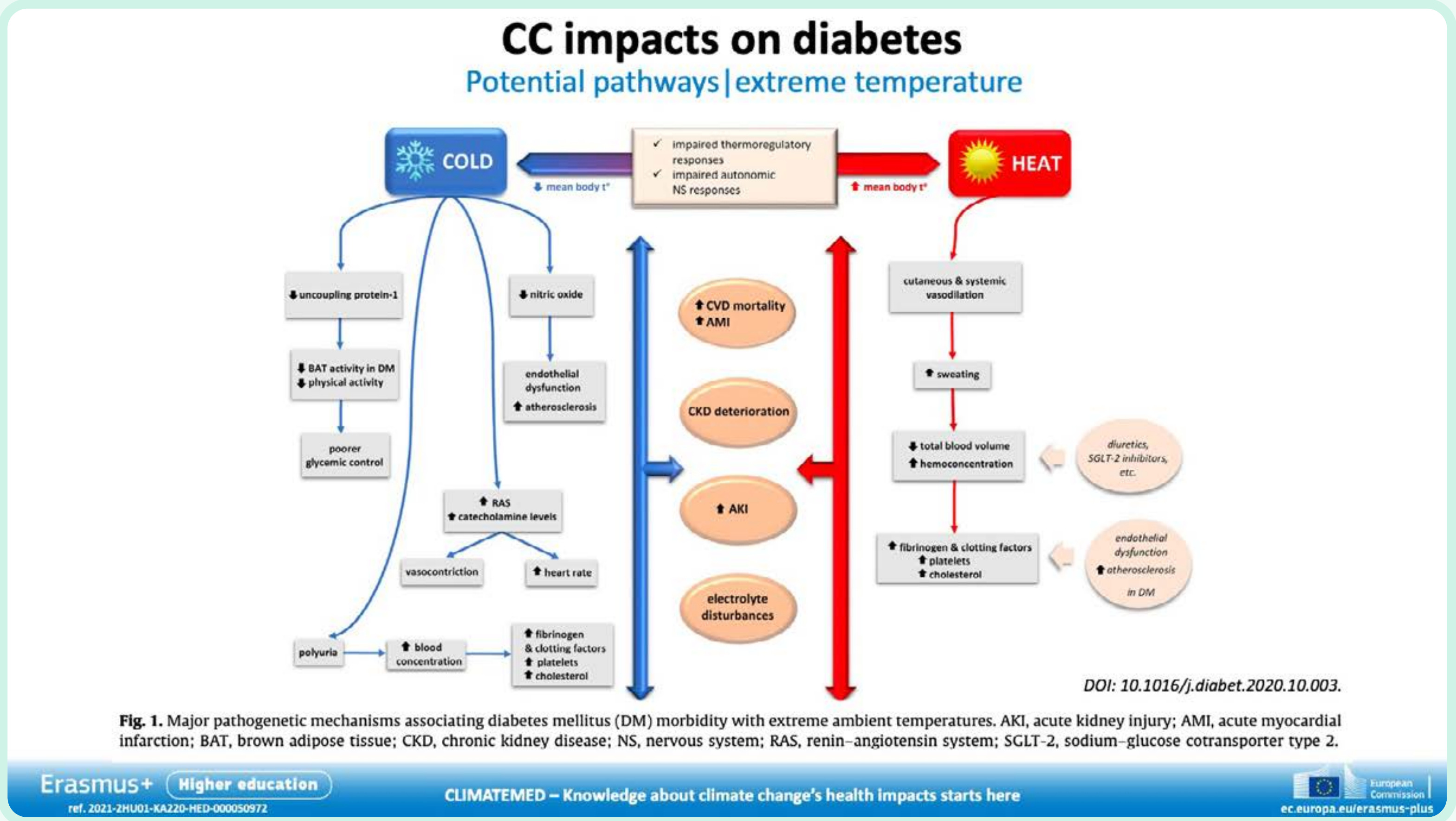


Fig. 1. Major pathogenetic mechanisms associating diabetes mellitus (DM) morbidity with extreme ambient temperatures. AKI, acute kidney injury; AMI, acute myocardial infarction; BAT, brown adipose tissue; CKD, chronic kidney disease; NS, nervous system; RAS, renin–angiotensin system; SGLT-2, sodium–glucose cotransporter type 2.

The magnitude of the global diabetes burden is large and on the rise, according to the GBD 2015 study.

Mortality from diabetes and chronic kidney diseases due to diabetes increased worldwide at a rate more than 10-fold greater than cardiovascular diseases and almost 4-fold faster than cancers.

Could it be due to climate change?

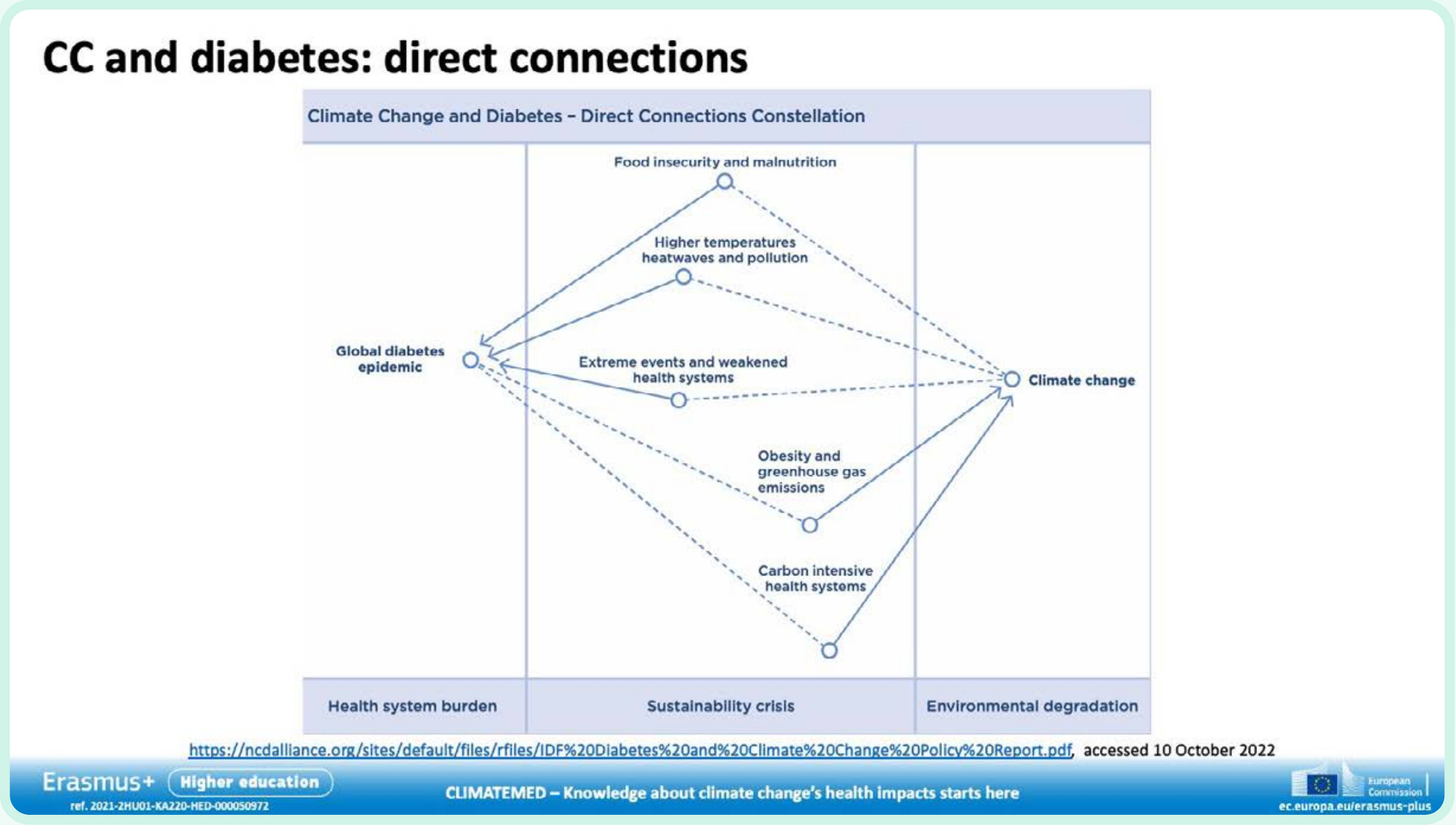
→ doi: 10.1093/advances/nmz035.

→ Exposure to extreme heat exacerbate diabetes-related dysfunctions (cardiovascular, metabolic, and neurological): impair thermoregulatory response, reduce capacity to dissipate heat and/or increase the risk of heat stress and hyperthermia.

- → Microvascular complications ➔ reduce skin blood flow ➔ decrease vasodilatation ability ➔ reduce capacity for dry heat exchange
- → Peripheral neuropathy and autonomic dysfunction, poor glycemic control ➔ disrupt the sweating response ➔ reduce capacity for evaporative heat loss
- → Prolonged exposure to extreme heat or heatwave increase the risk for life-threatening exacerbations of disease: abnormalities of the thermoregulatory capacity, effects on glucose tolerance and dehydration predisposes T1D patients to diabetic ketoacidosis (DKA) state and T2D patients to hyperosmolar hyperglycemic (HHS) state.
- → Prolonged heat exposure ➔ dehydration ➔ hyperthermia
- → Increased insulin absorption ➔ hypoglycemia
- → Hyperglycemia ➔ exaggerated dehydration ➔ cardiovascular (CV) events, acute kidney injury (AKI)
- → Polypharmacy ➔ exaggerated renal impairment ➔ AKI

→ doi: 10.1016/j.envres.2021.110762.

→ doi: 10.1016/j.diabet.2020.10.003.



It is estimated that half the world will experience food shortages by the end of the 21st Century

Food insecurity ➔ malnutrition /over- and under- nutrition ➔ exacerbating T2D and related NCDs risk

Maternal under-nutrition in pregnancy increases the risk of the infant obesity and T2D in later life

Disrupted traditional food supplies ➔ fresh produce expensive and scarce ➔ increases consumption of imported and processed food ➔ exacerbating T2D risk

Low-income populations and indigenous people, who follow traditional diets are particularly at risk

Impact of CC on health of people with diabetes / risk of diabetes

Exposure to extreme heat ➔ increased morbidity and mortality from heatstroke

Exposure to heat waves with high air pollution ➔increased mortality from heart attack

Extreme weather conditions and natural disasters (e.g., heatwaves, hurricanes, floods, fires, drought etc.):

devastation of living conditions and the resource scarcity ➔ urban slum growth and increase resource scarcity ➔ increased obesity and diabetes risk

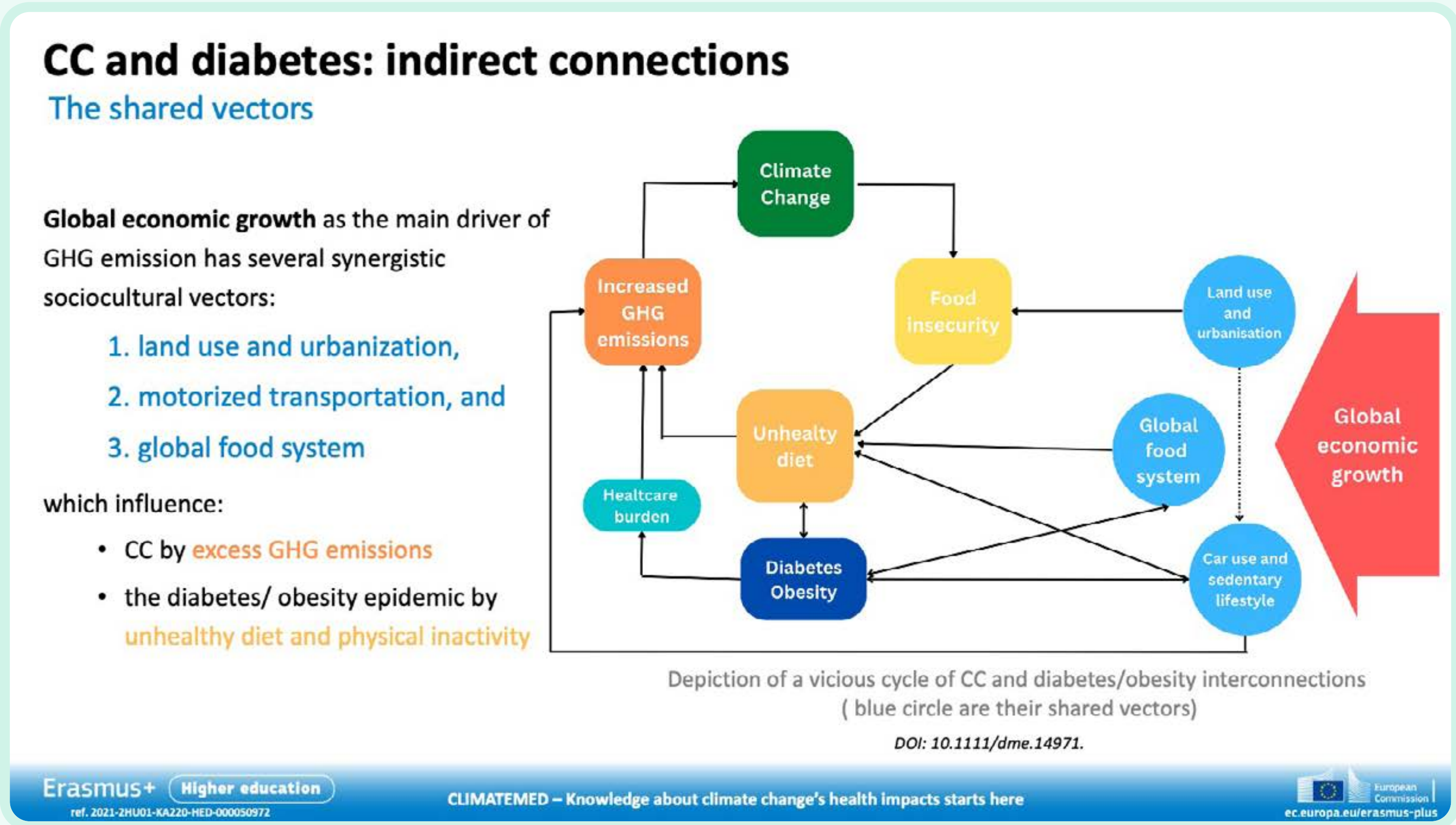
destruction of healthcare infrastructure and delivery of care ➔ life-threatening exacerbating of disease

Geo-environmental diabetology - describes how geophysical phenomena affect people with diabetes

→ doi: 10.4158/EP09344

Impact of CC on food security and T2D risk

Climate extremes and natural disasters ➔ water scarcity and the destruction of crops agricultural production and the food supply ➔ food shortage, rising prices ➔ food insecurity



The shared vectors | urbanisation and transport

Rapid and unplanned urbanization ➔ more carbon-intensive transports, slum growth, an urban heat island (UHI) effect, increased air pollution and resource degradation ➔ sedentary lifestyle: physical inactivity and unhealthy diet ➔ increasing transport emissions and diabetes risk.

Urban cities are responsible for:

70% of GHG emissions, with cars contributing to 30% of the air pollution

every extra hour spent in a car each day increases the risk of obesity by 6%

increased energy costs (e.g., for air conditioning), air pollution, heat-related illness and mortality

enhanced physical inactivity

increased demand for meat and cheap processed foods

→ DOI: 10.1111/dme.14971

The shared vectors | the global food system

Changing in the global food system (GFS) ➔ nutrition transition ➔ increasing diabetes risk and threatens the environment.

Multiple pathways for that impact: soil fertility, mass monocultural production, water availability, reduced food yield, reduced food nutrient concentration and bioavailability, mass livestock production etc.

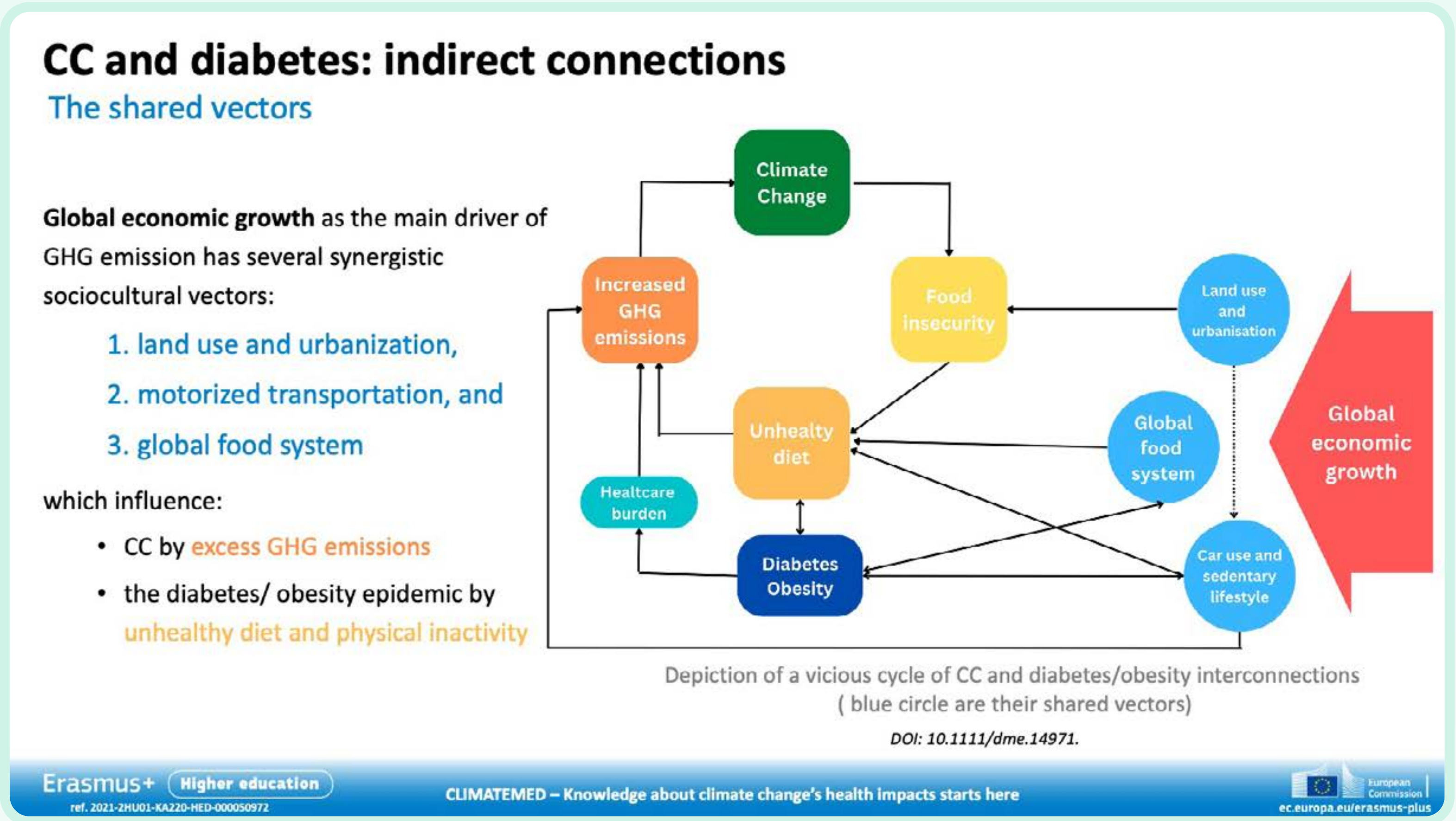
Accounts for ~ 30% of global GHGs and contribute to environmental and biodiversity degradation; reduces people's access to healthy diets, increasing their risk of poor health and diet-related diseases.

In 2020, two billion people were food insecure, and three billion people could not afford a healthy diet.

Considerable inequalities in the global consumption: developed countries consuming nearly ten times the amount of red meat and contribute 41% more emissions compared with developing countries. These inequalities are exacerbated by the extremely high cost of a plant-based diet that is much more affordable in higher-income countries.

Unsustainable the global food system includes:

Unsustainable agriculture produces up to a third of GHG emissions worldwide, due to increasing demand for animal products while the carbon cost of meat is seven times higher that of vegetables. Animal products are nutritionally important, but red meat and processed meats are associated with obesity, T2D and NCDs.



Increasing of ocean temperatures by CC, reduce marine phytoplankton - the primary producers of omega-3 polyunsaturated fatty acids (PUFAs).

Human diet deficient in omega-3 PUFAs are associated with an increased risk for the development of T2D.

→ DOI: 10.1111/dme.14971

Rapid development of food production increases the availability and affordability processed and energy-dense foods; carbon intensive production, transport and storage; forming of urban slums; harmful land clearing and deforestation etc.

Shifting of dietary pattern-nutrition transition from traditional diets based on grains, locally grown vegetables and fruits towards diets high in processed foods, saturated fats and sugar, and low in fibers

High levels of obesity, diabetes and other NCDs

Over-nutrition correlates with socio-economic inequality

Under and over-nutrition can co-exist in the same countries, communities and even households.

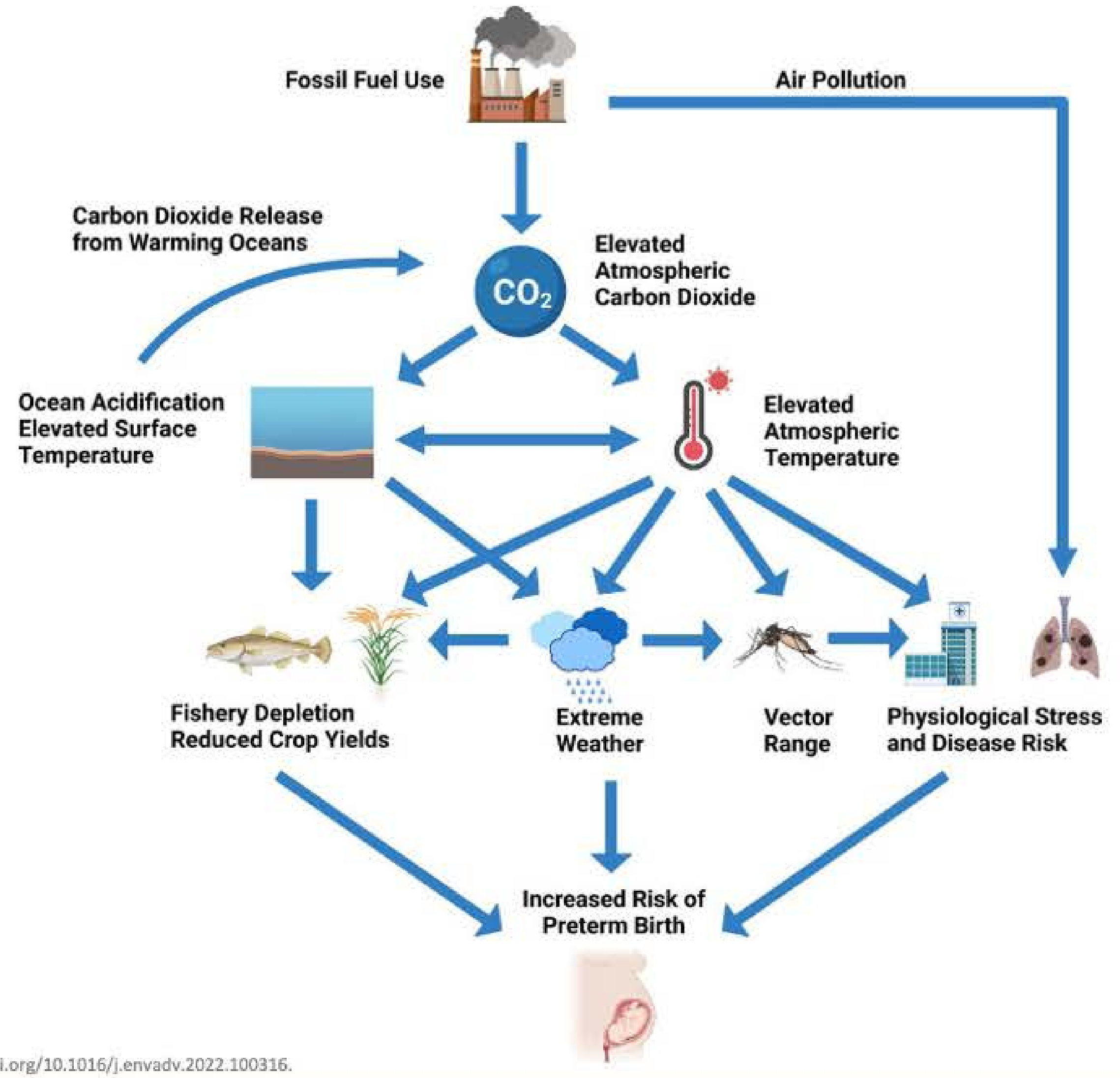
→ doi: 10.1038/s41572-021-00329-3

How changes in food quality impact diabetes risk?

Intensive agriculture affects food quality reducing micronutrients in plant-based foods

Reduced dietary micronutrients: zinc, magnesium, chromium, copper, manganese, iron, selenium, vanadium, B-group vitamins and antioxidants reduce insulin sensitivity or secretion and contribute to an increased risk of T2D.

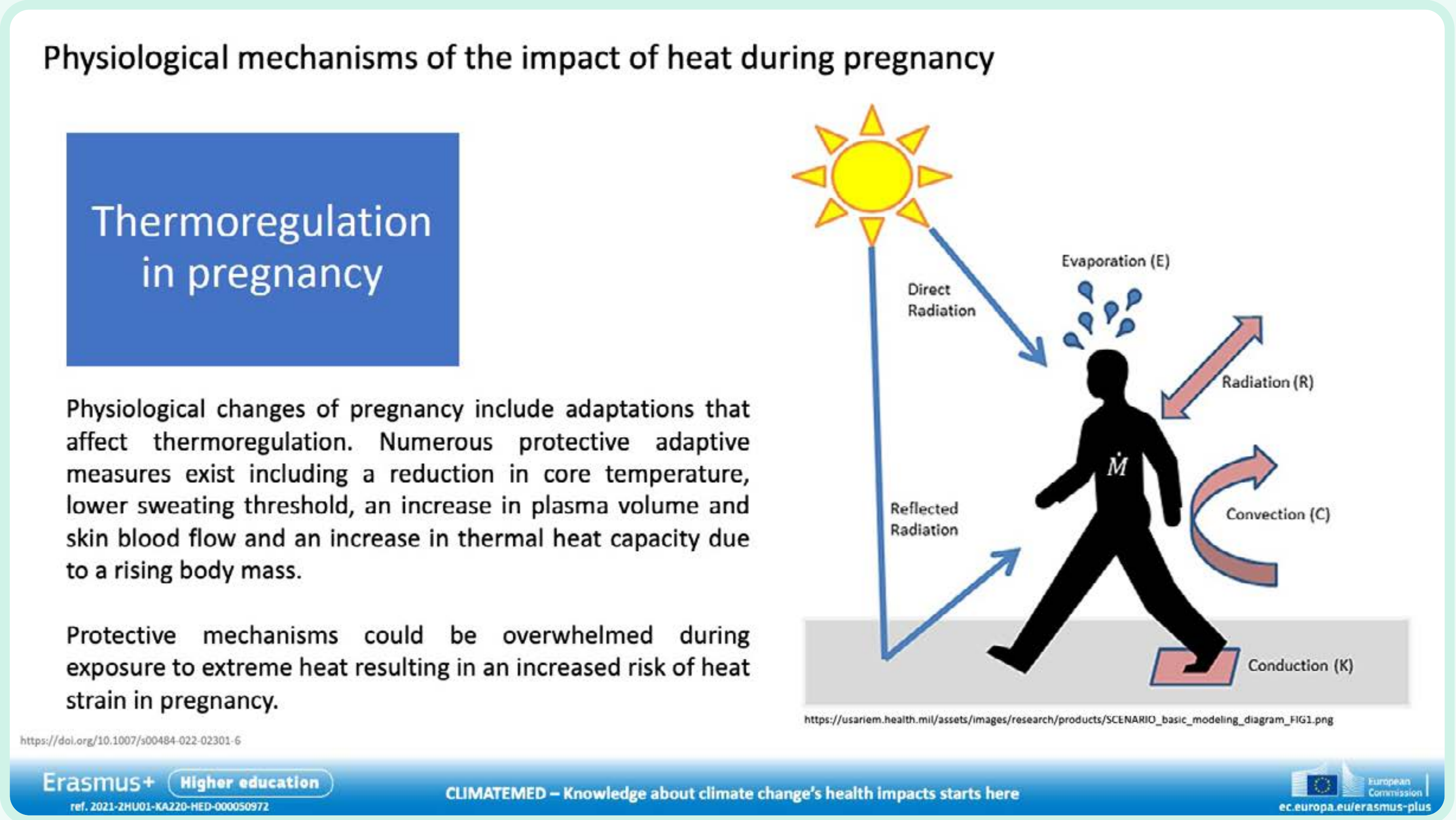
Schematic model of interacting direct and indirect effects of climate change on pregnancy outcomes



https://doi.org/10.1016/j.envadv.2022.100316.

Extreme weather events in turn, along with elevated temperatures, alter disease vector range and risk of exposure, exert maternal physiological stress and increase disease risk.

Each of these factors, individually and in concert act to increase the risk of preterm birth.



However, whether there are adverse effects of prolonged exercise or physical labour in a hot environment is not yet known and the temperature thresholds at which adverse effects may occur are not well described.

→ | **https://doi.org/10.1007/s00484-022-02301-6**

Pregnancy induces numerous physiological changes in women in addition to changes in body mass. Cardiovascular changes occur gradually throughout pregnancy so that by the third trimester, plasma volume and cardiac output increase by almost 50%.

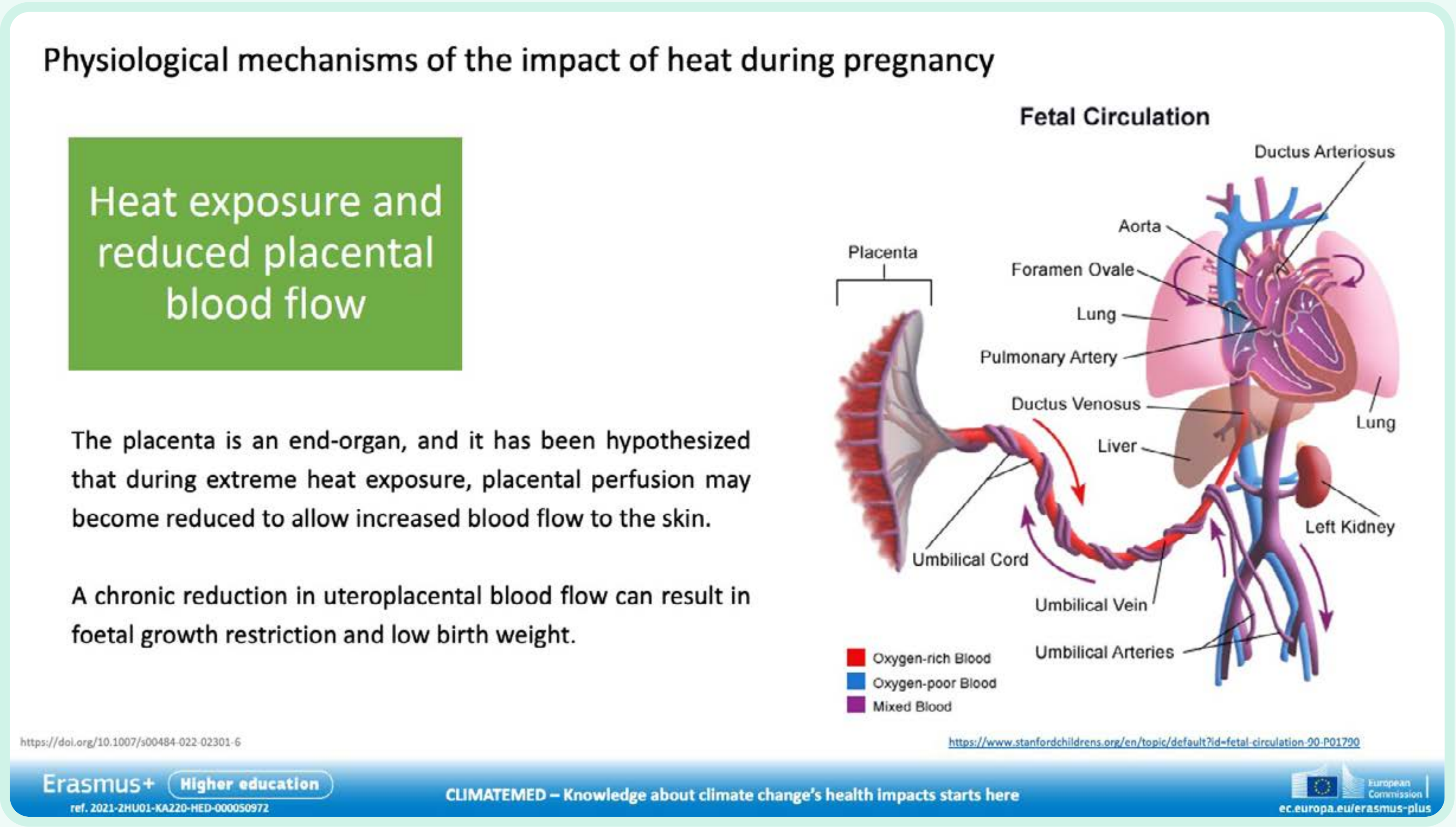
Physiological changes of pregnancy include adaptations that affect thermoregulation. Numerous protective adaptive measures exist including a reduction in core temperature, lower sweating threshold, an increase in plasma volume and skin blood flow and an increase in thermal heat capacity due to a rising body mass. These enable pregnant women to maintain their core temperature within normal limits.

These protective mechanisms could be overwhelmed during exposure to extreme heat resulting in an increased risk of heat strain in pregnancy.

Fetal core temperature is maintained at approximately 0.5 °C above maternal core temperature.

An increase in maternal core temperature will affect the fetal-maternal temperature gradient and influence the transfer of heat to the fetus.

Studies have shown that short-term exposure to heat through exercise or in a sauna or hot bath does not raise a pregnant woman's temperature over the teratogenic threshold of an increase in 1.5 °C.



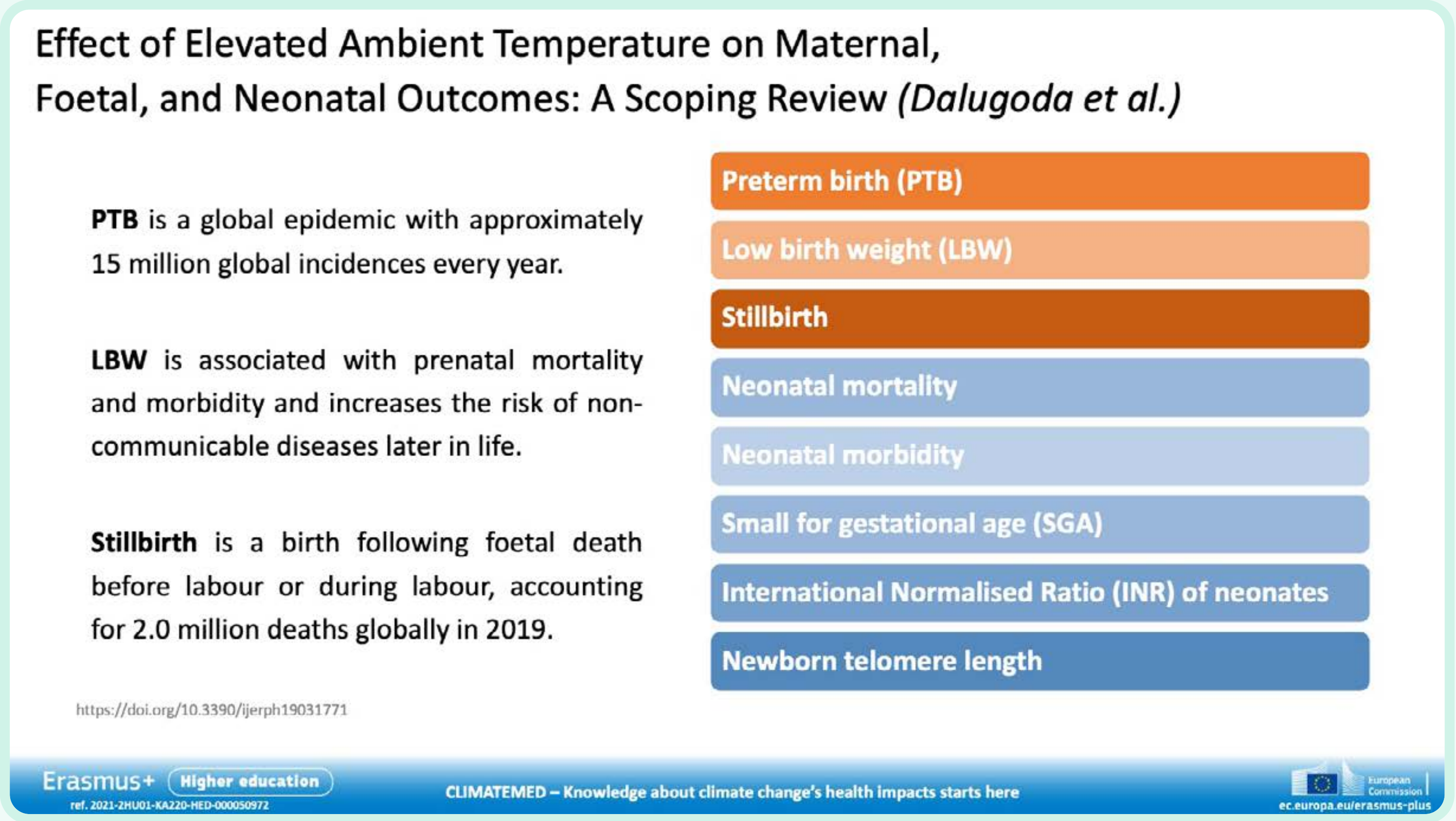
Adults maintain normothermia during heat exposure or exercise by sweating and increasing blood flow to the skin. The resulting rise in skin temperature increases heat loss via convection and radiation and also enhances evaporative capacity of the skin wetted by sweat. Part of this blood flow is redirected from the visceral organs to the skin.

Under extreme heat stress, this results in competition for available cardiac output which may have adverse effects for example, non-pregnant athletes have been shown to risk kidney damage during high workloads in the heat as a result of low renal perfusion rates

The placenta is an end-organ, and it has been hypothesised that during extreme heat exposure, placental perfusion may become reduced to allow increased blood flow to the skin.

A chronic reduction in uteroplacental blood flow can result in foetal growth restriction and low birth weight.

→ | https://doi.org/10.1007/s00484-022-02301-6



PTB (a baby being born before 37 weeks of gestation) is a global epidemic with approximately 15 million global incidences every year. PTB is a leading cause of childhood mortality and morbidity under five years and the direct cause of neonatal mortality (death within 28 days of births).

LBW (live births under 2500 g) is associated with prenatal mortality and morbidity and increases the risk of non-communicable diseases later in life.

Stillbirth is a birth following foetal death before labour or during labour, accounting for 2.0 million deaths globally in 2019.

→ **PTB** (75 studies)

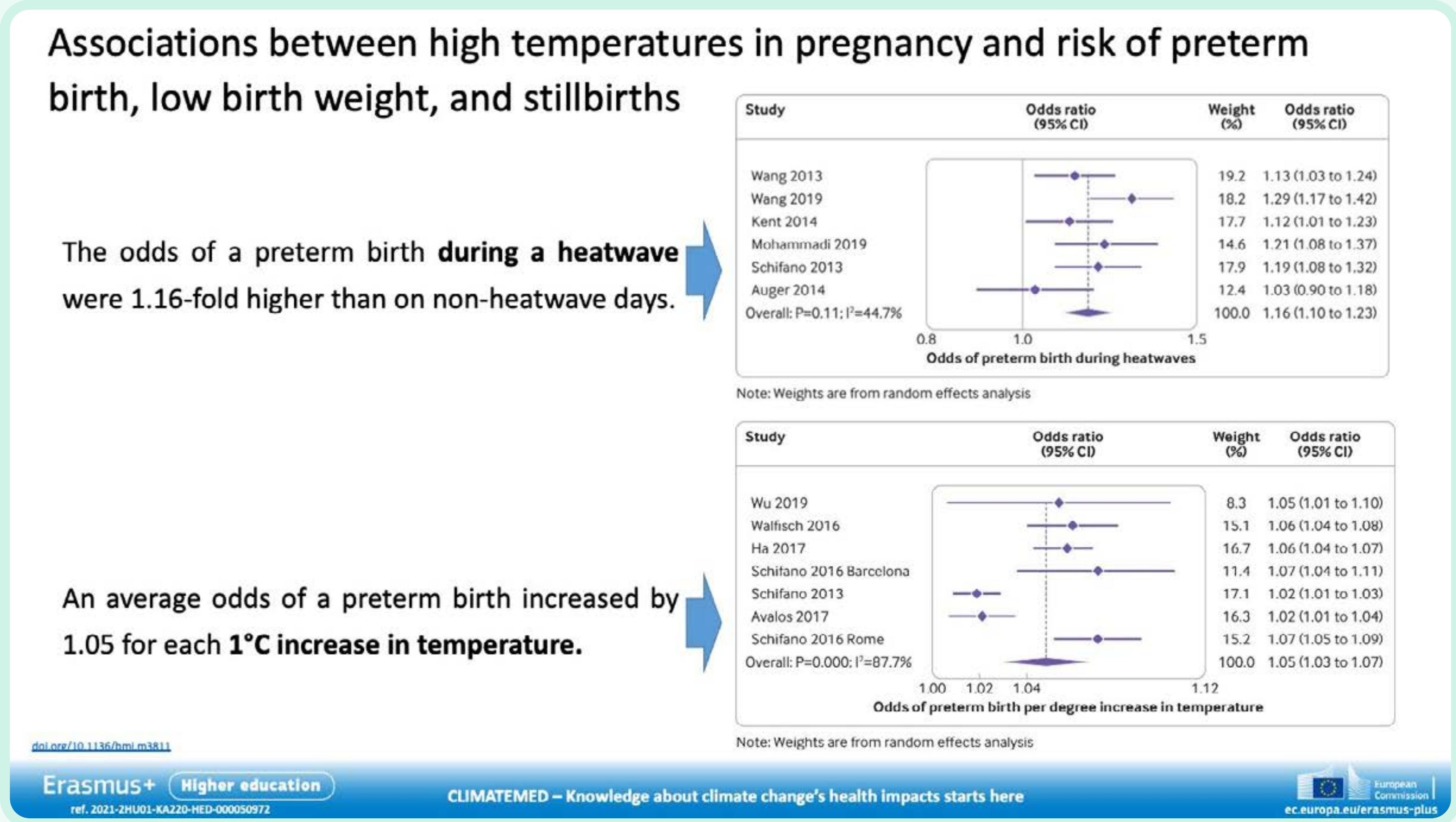
- → PTB was the most common adverse outcome
- → 23 studies reported that elevated temperatures significantly correlate with an increased risk or rate of preterm birth

→ **LBW** (11 studies)

- → Five found that elevated temperatures significantly reduce birth weight
- → no statistically significant effect of ambient temperature on low birth weight.

→ **Stillbirth** (9 studies)

- → all reported an increased risk for stillbirth with elevated temperatures



Meta-analysis of 70 studies (13 presented data on more than one review outcome)

Most studies covered impacts of heat exposure on preterm birth (n=47), 28 presented data on birth weight, and eight on stillbirth

Introduction:

Pregnant women included among the groups most vulnerable to heat stress.

Pregnancy raises the vulnerability of women to environmental hazards, including exogenous heat.

The physiological and anatomical changes that occur during pregnancy pose particular challenges to thermoregulation.

Internal heat production rises with fetal and placental metabolism, and with increased body mass and the resulting physical strain.

Pregnancy could bring social vulnerabilities to the fore, especially in low and middle income countries

Women continue to perform household chores during pregnancy (e.g., fetching wood and water, and subsistence farming).

Exposure to high temperatures in agricultural and other outdoor work, could occur before the pregnancy is recognized, and, even late in pregnancy

Preterm birth analysis

In meta-analysis of six studies, the odds of a preterm birth during a heatwave were 1.16-fold higher than on non-heatwave days (95% confidence interval 1.10 to 1.23; I2=44.7%)

In meta-analysis of seven studies, an average odds of a preterm birth increased by 1.05 for each 1°C increase in temperature (95% confidence interval 1.03 to 1.07) Although there was considerable heterogeneity in estimates (87.7%), all estimates showed significant effects in the same direction.

Birth weight

The median rate of low birth weights in the included studies was 3.0% (interquartile range 1.8-6.4). Of the 16 studies that provided data on the association of temperature with low birth weight, 10 reported that risk increased at higher temperatures, and only one reported the converse (five had null findings). The median of the observed effects of high temperatures on odds of low birth weight was 1.09 (interquartile range 1.04-1.47)

3.2 Major vector-borne diseases

Disease	Pathogen	Vector(s)	Non-human reservoir hosts	Clinical Features in Untreated Cases
Babesiosis	*Babesia microti* parasite	*Ixodes scapularis* (Deer ticks)	White-footed mouse, other small mammals.	Flu-like symptoms, destruction of red blood cells, jaundice, blood clots/bleeding, vital organ malfunction, death.
Bubonic plague	*Yersinia pestis* bacteria	Fleas	Rodents	Inflamed lymph nodes, infection of lungs giving pneumonic plague, death.
Chagas disease (American trypanosomiasis)	*Trypanosoma cruzi* parasite	*Triatomine* bug	Mammals	Skin lesions, cardiac, digestive or neurological disorders, heart failure, death.
Chikungunya	*Alphavirus*	*Aedes* mosquitoes	None of concern	Fever, rash, joint swelling, muscle pain, premature death in newborns and older people with underlying heath conditions.
Crimean-Congo haemorrhagic fever	*Bunyaviridae* nairovirus	Ticks	Wild and domestic animals, ostriches.	Kidney, liver or pulmonary failure.
Dengue fever	*Dengue* flavivirus	*Aedes* mosquitoes	None of concern	Internal bleeding, shock, death.
Hookworm infection	Bulinus globosus	Snail	Dogs, cats.	Rash, anaemia, abdominal pain, diarrhoea.
Japanese encephalitis	*Japanese encephalitis* flavivirus	*Culex* mosquitoes	Pigs, birds.	Fever, disorientation, coma, seizures, spastic paralysis, death.
Leishmaniasis	*Leishmania* parasite	Sand fly	Rodents, dogs, other mammals.	Skin lesions, destruction of mucous membranes, spleen/liver enlargement, death.
Lyme disease	*Borellia spirochete* bacteria	*Ixodes* ticks	White-footed mouse, other small mammals, birds.	Fever, facial palsy, arthritis, inflammation of brain/spinal cord, nerve pain.
Lymphatic filariasis	Various filarial nematodes (roundworms)	Various mosquito genera	None of concern	Lymphatic, kidney and immune system damage, tissue swelling, elephantiasis.
Malaria	*Plasmodium* parasite	*Anopheles* mosquito	None of concern	Organ failure, blood, metabolism or neurologic abnormalities, acute respiratory distress, kidney injury, cardiovascular collapse, relapses, death.

Major vector-borne diseases (contd.)

Disease	Pathogen	Vector(s)	Non-human reservoir hosts	Clinical Features in Untreated Cases
Onchocerciasis (river blindness)	*Onchocerca volvulus* nematode	*Simulium* (blackfly)	None	Eye lesions, severe skin inflammation, blindness.
Rift Valley fever	*RVF* virus	*Aedes* and *Culex* mosquitoes	Sheep, goats, other domesticated animals.	Eye disease, meningoencephalitis, haemorrhagic fever.
Schistosomiasis (bilharziasis)	*Schistosoma trematode* flukes (flatworms)	Snail	None of concern	Intestinal/urogenital pathologies, liver or spleen enlargement, infertility, kidney failure, bladder cancer, ectopic pregnancies, death.
Sleeping sickness (African trypanosomiasis)	*Trypanosoma brucei* parasite	*Glossina* (tsetse fly)	Wild and domestic animals	Fever, joint pains, central nervous system disorders, death.
Tick-borne encephalitis	*Flavivirus*	*Ixodes* ticks	Small rodents	Fever, central nervous system disorders, paralysis, permanent sequelae, death.
Toscana virus infection/sand fly fever	*Toscana* phlebovirus and papataci fever virus	Sand flies	None known at present	Fever, headache, rash, vomiting, fatal encephalitis in rare cases.
Tungiasis	*Tunga penetrans* (sand flea)	Sand flea	Pigs, bovines, dogs, cats, rats.	Abscesses, bacterial superinfection, disfigurement.
Typhus	*Rickettsial* bacteria	Fleas, mites, ticks, lice	Rodents, opossums, feral cats	Fever, headache, rapid breathing, body & muscle pain, cough, vomiting.
West Nile fever	*Flavivirus*	*Culex* mosquitoes	Birds	Fever, coma, tremors, convulsions, paralysis.
Yellow fever	*Flavivirus*	*Aedes* mosquitoes	Non-human primates	Fever, jaundice, bleeding, organ failure, death.
Zika	*Flavivirus*	*Aedes* mosquitoes	None of concern	Fever, rash, joint & muscle pain, conjunctivitis.

Table 1. Environmental effects of global change drivers pertinent to vector-borne diseases.

Global change driver	Potential effects on vector, pathogen, and host environments	Potential effects on vectors, pathogens, and hosts
Higher CO_2 concn	Increased ambient temperature and plant biomass; range expansion of woody vegetation; longer plant growth season with humid microclimates	Increased vector longevity for the same rainfall and temperature through more humide microclimates, with possible range expansion of humid-zone vectors
Temperature increase (regional/temporal variation)	Expansion of warm climatic zones, with longer growth seasons, less extreme low temperatures, and more frequent extreme high temperatures	Faster vector and pathogen development, with more generations per year; shorter life spans of vectors at high temperatures, reduced low-temperature mortality of vectors, and range expansion of warm-climate vectors and pathogens
Rainfall	Too uncertain and regionally variable to estimate, but increased frequency of extreme rainfall events	Altered patterns of breeding of mosquitoes, with more flushing of mosquito breeding with increased flooding
Urbanization	Increased density of human hosts, with poorer sanitation and water supply in developing countries Increased outer urban development in or near forests in developed countries	Higher rate of disease transmission at same vector density; more vector-breeding sites Increased contact between humans and vectors in periurban forested areas
Deforestation	Increased human entry into forests and increased surface water from soils exposed by logging or new agriculture	More vector-breeding sites and more contact between humans and vectors
Irrigation and water storage	Increased surface water, prevention of seasonal flooding	More vector-breeding sites; reduced flushing of snails and mosquitoes
Intensification of agriculture	Increased disturbance of land and vegetation and increased surface water; reduced biodiversity	More diversity of vector breeding sites, with reduced predation of vectors
Chemical pollution	Fertilizer, pesticide, herbicide and industrial toxins and endocrine-disrupting chemicals	Impaired human immune systems
Increased trade	Increased volume of shipped goods	Increased transport of vectors, leading to "homogenization" of vectors in receptive areas
Increased travel	Increased movement of people between North and South and East and West	Increased transfer of pathogens between regions of endemicity and disease-free regions, and increased exposure of visitors to regions of endemicity

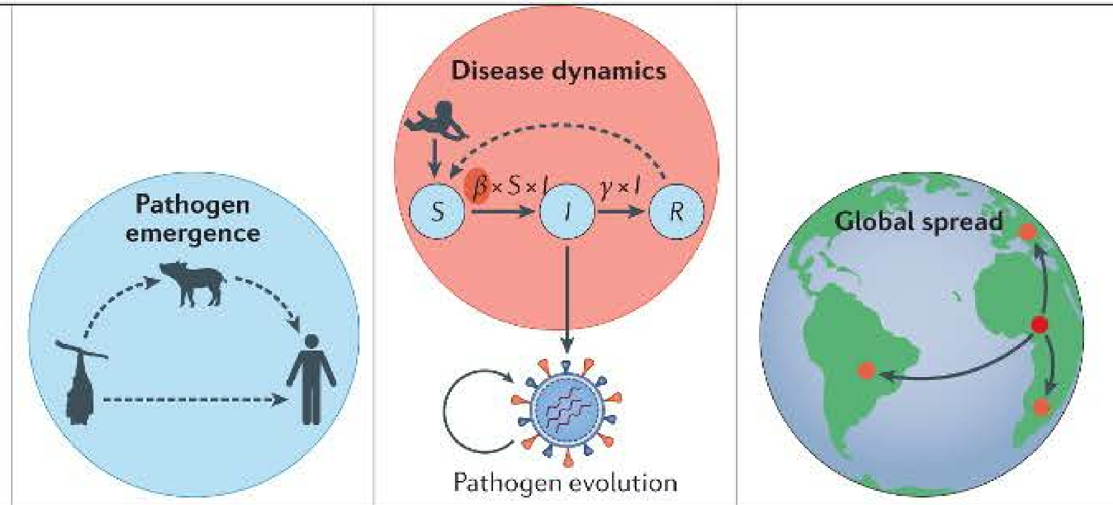
From: R.W. Sutherst, Clinical Microbiology Reviews, Jan. 2004, 17, (1), 136–173.
https://doi.org/10.1128%2FCMR.17.1.136-173.2004

4.5 Summary

Figure 6. Effects of climatic, technological and demographic change on disease emergence, dynamics and spread.

The table summarizes select recent global changes (rows) and their impacts on disease emergence, local-scale dynamics and global spread (columns).

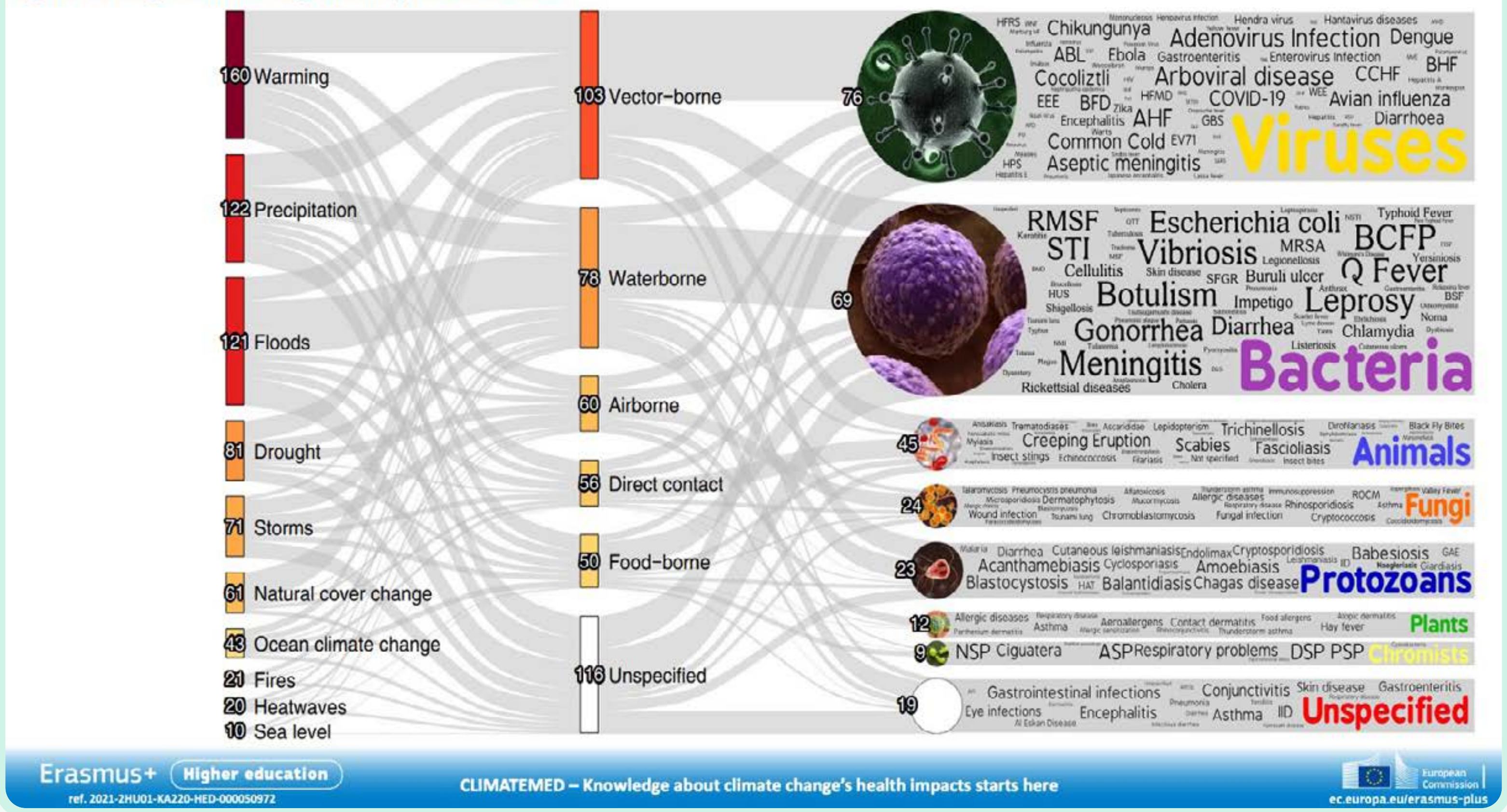
An example susceptible (*S*), infected (*I*), recovered (*R*) model is shown, where β represents the transmission rate and γ is the recovery rate.



	Pathogen emergence	Disease dynamics	Global spread
Climatic change	Drives range shifts for reservoir species	Affects transmission and susceptibility	Affects the geographical range of vectors
Technological change			
Transportation	Improved global surveillance		Air transit and high-speed rail affect pace and range of spread
Health care		Vaccination affects dynamics	Improved care reduces burden
Demographic change			
Population growth and land use	Increased contact with reservoir species	Population numbers affect evolution, birth rates affect dynamics	Larger population travelling
Urbanization	Depends on species	Density affects contact rate	Urban population more connected
Ageing	Imunosenescence affects spillover risk	Ageing population increases transmission	Possible larger burden

From: R.E. Baker *et al.*, Nature Reviews Microbiology, April 2022, 20, 193-205.
https://doi.org/10.1038/s41579-021-00639-z

Figure 8. Pathogenic diseases aggravated by climatic hazards.



Mora et al. have also presented a useful summary visualisation (figure 8 below) of their results, also available on-line for detailed interactive interrogation at

→ | **https://camilo-mora.github.io/Diseases/**

Displayed here are the pathways in which climatic hazards, via specific transmission types, result in the aggravation of specific pathogenic diseases. The thickness of the lines is proportional to the number of unique pathogenic diseases. The colour gradient indicates the proportional quantity of diseases, with darker colours representing larger quantities and lighter colours representing fewer. Numbers at each node are indicative of the number of unique pathogenic diseases.

Some general observations can be made from figure 8:

→ In terms of climatic hazards, warming, precipitation, floods, drought and storms account for the majority, 555 out of 710, (78%) of published cases of pathogenic disease aggravation.

→ Of the aggravated disease types, we see that VBDs represent the largest single group of published aggravated disease cases, followed by water-borne, air-borne, direct contact and food-borne, in all accounting for 347 out of 463 cases (75%).

→ Viruses and bacteria account for by far the largest pathogen groups.

In the following sections, we will examine the current state of knowledge on specific VBDs, according to vector(s) and with reference to these effects in the European context. In most cases we have filtered the data to show only cases where disease aggravation (negative effects) has been found to occur due to climate change factors.

Short selected summaries of some of the relevant publications will then be presented in each section.

Note: Many of the publications on this topic refer to RCP climate change models. The Intergovernmental Panel on Climate Change (IPCC) has developed four Representative Concentration Pathway (RCP) scenarios for greenhouse gas emissions, ranging from a high-emission 'business-as-usual' scenario (RCP8.5), to a low-emission, aggressive mitigation scenario (RCP2.6).

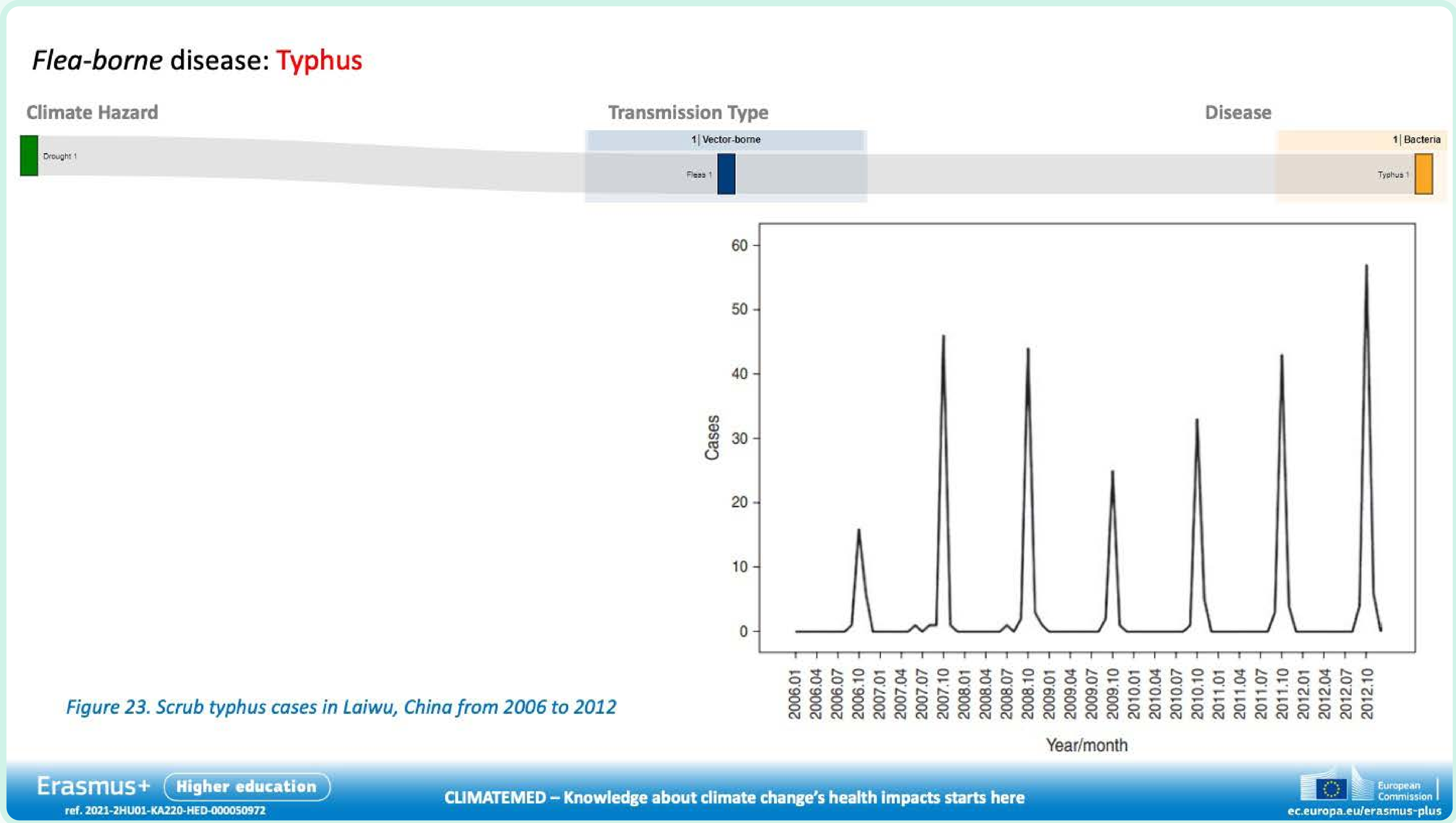


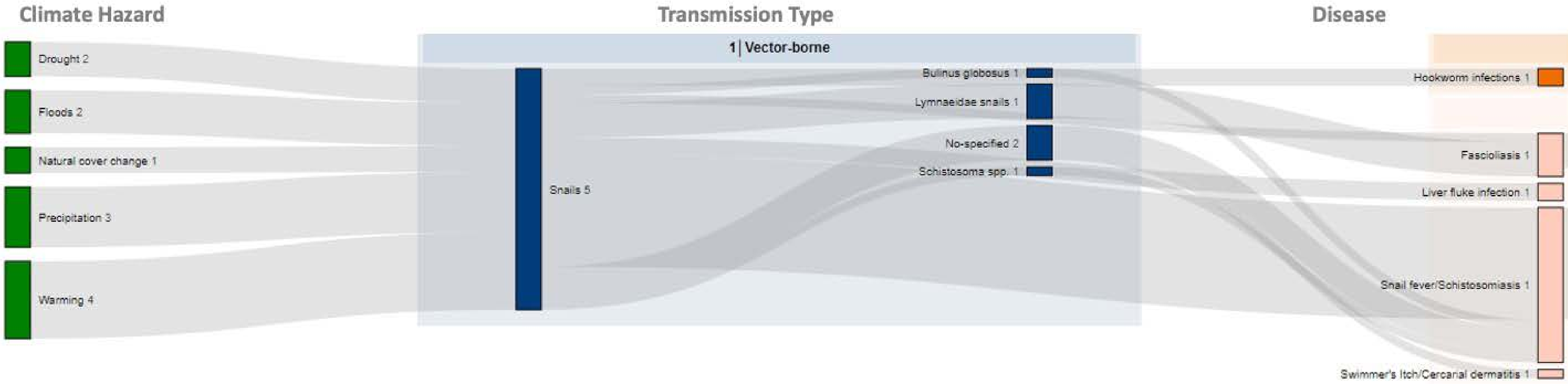
Figure 23. Scrub typhus cases in Laiwu, China from 2006 to 2012

"….the occurrence of scrub typhus is positively correlated with temperature in the previous 3 months, humidity in the previous 2 months and precipitation in the previous 3 months in Laiwu, China. Climate change, particularly global warming, coupled with the positive correlation between temperature and scrub typhus may increase the prevalence of scrub typhus in temperate regions."

L. P. Yang, J. Liu, X. J. Wang, W. MA, C. X. Jia, and B. F. Jiang, "Effects of meteorological factors on scrub typhus in a temperate region of China", Epidemiol. Infect., 2014, 142, 2217–2226.

→ | https://doi.org/10.1017/S0950268813003208

5.5 Climate change effects according to vector: Snails



Here we can see that various species of snails are responsible for 5 VBDs, and that these diseases are aggravated by 5 of the climate change effects discussed above, with global warming and precipitation responsible for 4 of the diseases.

Summary (contd.)

Disease	Change in geographical range/occurrence frequency/seasonal duration?	Main mechanism of disease spread over large distances	Areas affected
Onchocerciasis (river blindness)/blackflies	Possible increased occurrence frequency	Human travel	Africa
Rift Valley fever/mosquitoes	Yes	Trade in domestic animals	Mediterranean basin, central Europe, and Middle East
Schistosomiasis (bilharziasis)/snails	Range shifts to less hot areas	Human travel	Southern Europe, Africa and Middle East
Sleeping sickness (African trypanosomiasis)/tsetse flies	Range shifts	Reservoir hosts	Sub-Saharan Africa
Tick-borne encephalitis/ticks	Northwest range shift	Reservoir hosts	Brittany, southwest England, Ireland
Toscana virus infection/sand fly fever/sand flies	Yes	Reservoir hosts Human travel	Britain, northern and eastern Europe
Tungiasis/fleas	Yes	Human travel	Developed countries
Typhus/fleas	Increased occurrence frequency	Reservoir hosts	Temperate regions
West Nile fever/mosquitoes	Yes	Reservoir hosts	Western Europe
Yellow fever/mosquitoes	Yes	Reservoir hosts	Southern Europe
Zika/mosquitoes	Yes	Human travel	Areas suitable for *Aedes* and *Culex* mosquitoes in Europe and North America

Table 5 (contd.)

Table 6. Current status of VBD vaccine development

Disease	Vaccine available?	Vaccine under development?
Babesiosis	No	No
Bubonic plague	Yes	-
Chagas disease (American trypanosomiasis)	No	Yes
Chikungunya	No	Yes
Crimean-Congo haemorrhagic fever	No	Yes
Dengue fever	Yes	-
Hookworm infection	No	Yes
Japanese encephalitis	Yes	-
Leishmaniasis	No	Yes
Lyme disease	No	Yes
Lymphatic filariasis	No	Yes
Malaria	Yes	-

Disease	Vaccine available?	Vaccine under development?
Onchocerciasis (river blindness)	No	Yes
Rift Valley fever	No	Yes
Schistosomiasis (bilharziasis)	No	Yes
Sleeping sickness (African trypanosomiasis)	No	Yes
Tick-borne encephalitis	Yes	-
Toscana virus infection/sand fly fever	No	No
Tungiasis	No	*N/a
Typhus	No	Yes
West Nile fever	No	Yes
Yellow fever	Yes	-
Zika	No	Yes

*Not applicable: pathogen is an insect

Only 26% (6/23) have a vaccine currently available.

→ This mosquito species is a known vector of chikungunya virus, dengue virus and dirofilariasis. A number of other viruses affecting human health have also been isolated from field-collected Ae. albopictus in different countries. Moreover, its recent involvement in the localised transmission of chikungunya virus in Italy and France and dengue virus in France and Croatia highlights the importance of monitoring this invasive species.

Other water-related, mosquito-borne viruses:

→ Chikungunya Virus

→ Eastern Equine Encephalitis Virus

→ Japanese Encephalitis Virus

→ La Crosse Encephalitis

→ St. Louis Encephalitis

→ Yellow Fever

→ Etc.

It is now possible to relate vector-borne infectious disease patterns directly to climate. (Rita Corwell, Johns Hopkins Univ.)

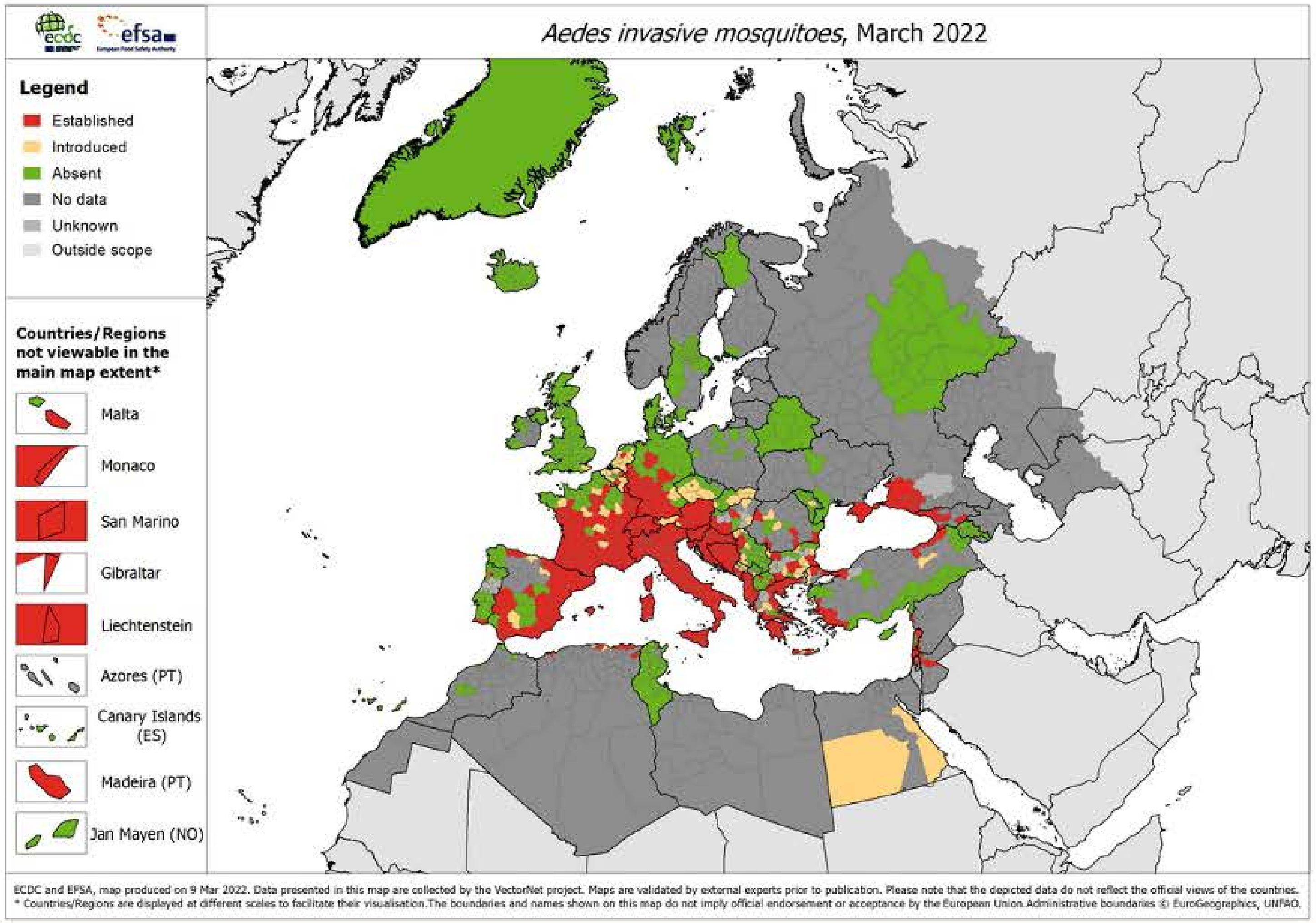
Aedes albopictus

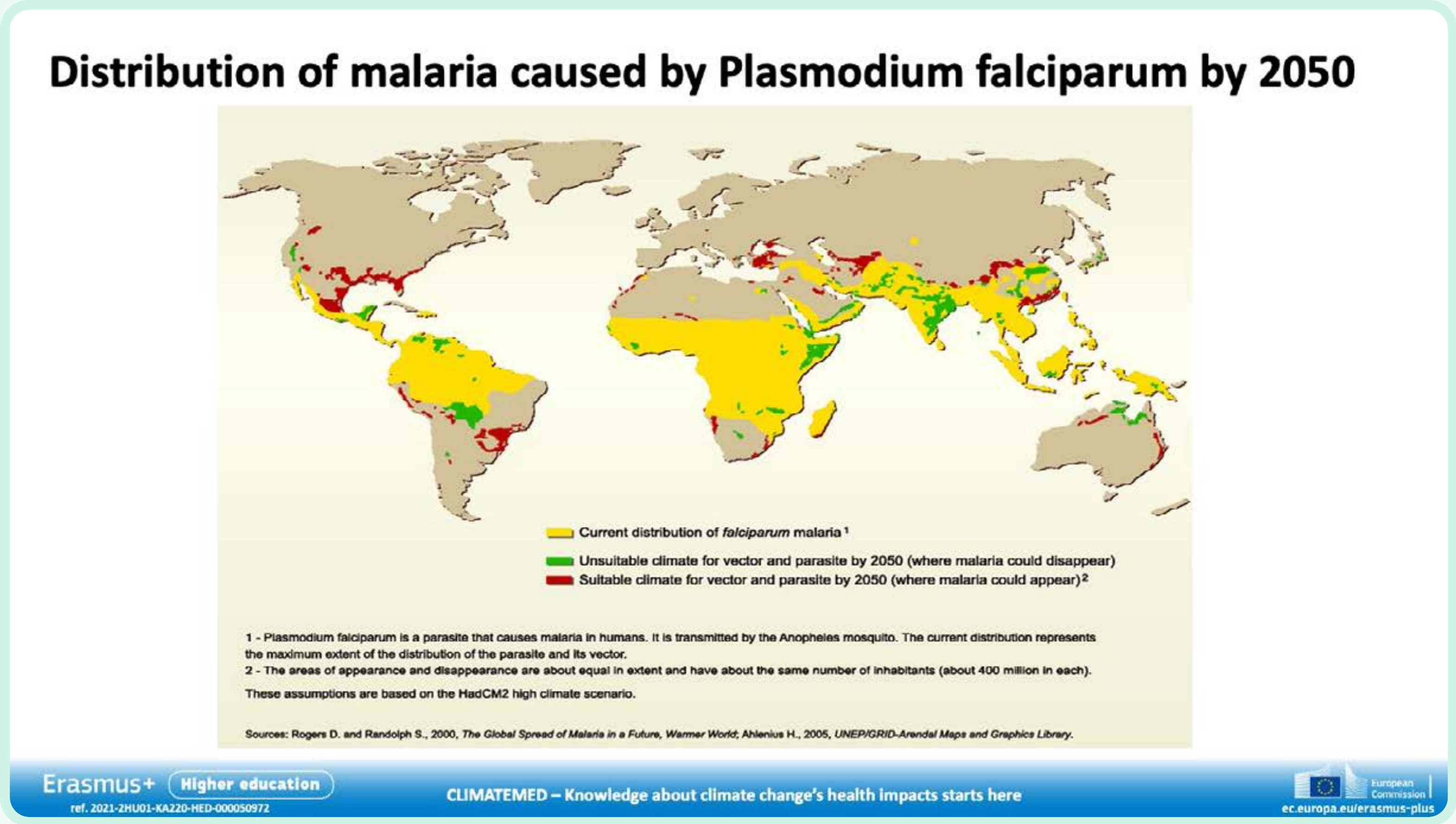
→ Aedes albopictus has undergone a dramatic global expansion facilitated by human activities

→ It is now listed as one of the top 100 invasive species by the Invasive Species Specialist Group

→ Climate change predictions suggest Ae. albopictus will continue to be a successful invasive species that will spread beyond its current geographical boundaries

The map shows the current known distribution of Aedes invasive mosquitoes (Ae. aegypti, Ae. albopictus, Ae. atropalpus, Ae. japonicus and Ae. koreicus) in Europe as of March 2022.





There are vaccines that can prevent malaria, a mosquito-borne infectious disease which annually affects an estimated 247 million people worldwide and causes 619,000 deaths. The first approved vaccine for malaria is RTS,S, known by the brand name Mosquirix. As of April 2023, the vaccine has been given to 1.5 million children living in areas with moderate-to-high malaria transmission. It requires at least three doses in infants by age 2, and a fourth dose extends the protection for another 1–2 years. The vaccine reduces hospital admissions from severe malaria by around 30%.

Malaria

The most abundant infectious parasitic disease on Earth (some 200 million patients each year, killing more than 600,000).

Its distribution area is continuously increasing with the global warming, both vertically (higher altitudes) and horizontally (more new countries are involved).

Malaria is caused by infection with parasites in the genus Plasmodium. Vector: Anopheles sp. mosquitoes

In humans, malaria is caused by six Plasmodium species: P. falciparum, P. malariae, P. ovale curtisi, P. ovale wallikeri, P. vivax and P. knowlesi.

Among those infected, P. falciparum is the most common species identified (~75%) followed by P. vivax (~20%). Although P. falciparum traditionally accounts for the majority of deaths, recent evidence suggests that P. vivax malaria is associated with potentially life-threatening conditions about as often as with a diagnosis of P. falciparum infection. P. vivax proportionally is more common outside Africa.

3.2 Major allergy diseases

Disease	Causes/triggers	Symptoms/clinical features	Affected by climate change?
Allergy	Genetic predisposition, drug/environmental/ food/latex/pet allergens	Runny nose, sneezing, pain/tenderness around cheeks, eyes or forehead, coughing, breathlessness, itchy skin, rash, diarrhoea, nausea/vomiting, swollen eyes, lips, mouth or throat.	Yes
Anaphylaxis	Certain allergens: foods, some medications, insect venom, latex.	Rapid, severe allergic reaction: rapid, weak pulse, skin rash, nausea, vomiting, death.	Yes
Angioedema	Animal dander, exposure to water, sunlight, cold or heat, foods, insect bites, pollen, autoimmune diseases such as lupus.	Swelling below the skin surface, abdominal cramping, breathing difficulty.	Yes
Aspergillosis	*Aspergillus* fungus	Wheezing, shortness of breath, cough, stuffiness, runny nose, headache.	Yes
Asthma	Dust mites, animal fur, pollen, smoke, exercise viral infections, inhalation of chemical or other allergens.	Coughing, wheezing, chest tightness, breathlessness, death.	Yes
Chronic granulomatous	Genetic predisposition	Fever, chest pain, swollen lymph glands, runny nose, rash, swelling/redness in the mouth, gastrointestinal problems, pneumonia.	No
Chronic rhinosinusitis	Allergens, pre-existing conditions such as cystic fibrosis.	Nasal obstruction, thick nasal discharge, facial pain/pressure, reduction/loss of sense of smell.	Yes
Churg-Strauss syndrome	Thought to be a combination of genetic predisposition and exposure to allergens.	Blood vessel inflammation, nasal allergies, sinus problems, rash, gastrointestinal bleeding, pain and numbness in the hands and feet, adult-onset asthma, death.	Yes
Cold urticaria	Exposure to cold and in some cases genetic predisposition.	Hives, swelling of hands, lips, tongue or throat, anaphylaxis, death.	No
Common variable immunodeficiency (CVID)	Genetic predisposition	Bronchitis, bacterial and viral infections of the upper airway, sinuses, and lungs, pneumonia.	No
Esophagitis	Food/medicine allergens	Difficult/painful swallowing, chest pain, heartburn, acid regurgitation.	Yes
Hay fever (allergic rhinitis)	Pollen	Sneezing, runny/blocked nose, conjunctivitis, itchy throat, mouth, nose and ears, cough.	Yes
Pneumonitis	Aeroallergens, certain drugs.	Shortness of breath, cough, fatigue, loss of appetite, weight loss.	Yes
Urticaria (hives)	Food/medicine allergens, insect venom.	Rash, hives, precursor to angioedema.	Yes

3.3 Major dermal diseases (excluding vector-borne dermal diseases[1])

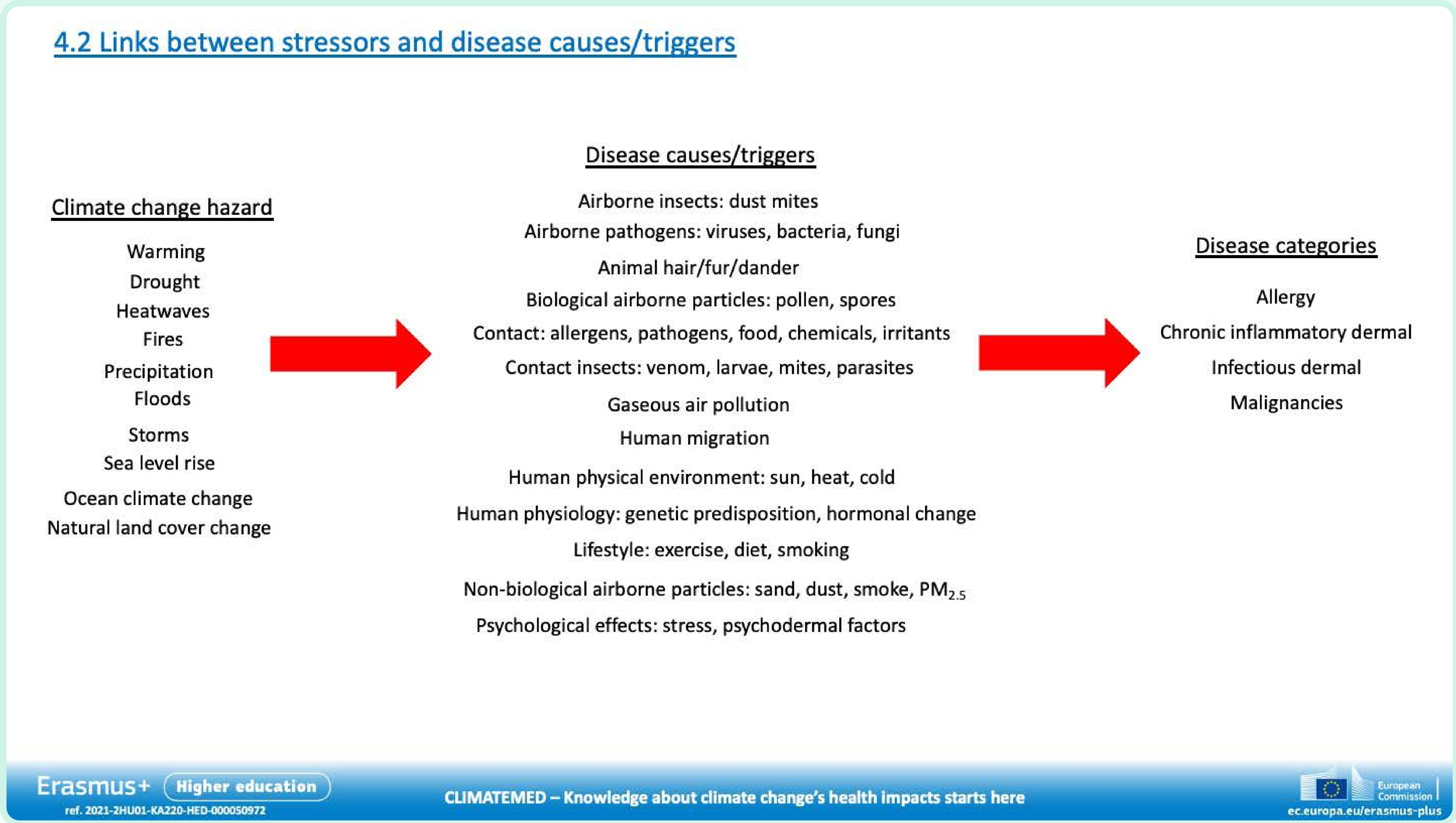
Disease	Causes/triggers[2]	Symptoms/clinical features	Affected by climate change?
Acne	Genetic predisposition, hormonal changes, certain medicines, cosmetics, smoking, high glycaemic diets.	Pimples, skin nodules, cystic lesions.	No
Actinic keratosis	Sun damage	Dry, scaly skin patches, possible precursor to skin cancer.	Yes
Alopecia areata	Genetic predisposition, certain medicines, hormonal changes, stress.	Hair loss	Yes
Cellulitis	Injuries/infections that allow bacteria to penetrate the skin.	Red, swollen, painful skin on feet or legs, fever.	Yes
Chickenpox	Contact or airborne *varicella-zoster* virus	Rash, fever, headache, pneumonia, encephalitis, sepsis, death.	Yes
Cutaneous larva migrans	Contact with hookworm larvae	Serpiginous skin lesions.	Yes
Cutaneous myiasis	Contact with larvae of the fly order Diptera	Painful larvae-containing ulcers/sores.	Yes
Diphtheria	Contact or airborne *corynebacterium diphtheriae* bacteria	Fever, respiratory system attack, skin sores/ulcers, myocarditis, nerve damage, kidney failure, death	Yes
Eczema (atopic/contact dermatitis)	Genetic predisposition, environmental allergens, chemicals.	Red, dry skin patches, rash, skin thickening, conjunctivitis.	Yes
Epidermolysis bullosa	Genetic predisposition	Skin fragility, tears, sores, blisters on skin.	No
Herpes simplex	Contact or bodily fluid *herpes simplex* virus.	Pain, itching and sores around the genitals, anus or mouth.	Yes
Gonorrhea	Contact *neisseria gonorrhoeae* bacterium	Fever, rash, skin sores, joint pain, swelling and stiffness.	Yes
Hand-foot-and-mouth disease	Contact or airborne *Coxsackievirus.*	Fever, sore throat, nausea, painful mouth lesions, rash.	Yes
Hidradenitis suppurativa	Hormonal changes, smoking, obesity.	Painful abscesses, scarring of the skin.	No
Ichthyosis	Genetic predisposition	Dry, scaly, itchy, red skin.	No
Impetigo	Contact *staphylococci* bacteria	Red sores on face.	Yes
Marburg	Contact *marburg* virus	Fever, headache, rash, vomiting, diarrhoea, jaundice, haemorrhaging, multi-organ failure, death.	Yes
Measles	Contact or airborne *measles morbillivirus.*	Fever, cough, conjunctivitis, Koplik spots, rash, pneumonia, encephalitis, death.	Yes
Monkeypox	Contact *mpox* virus	Rash, scabs, fever, headache, swollen lymph nodes, respiratory symptoms.	Yes

[1] Dealt with in the lesson on "Effect of Climate Change on Vector-Born and Related Diseases"

[2] Here "contact" means physical contact with solids or fluids containing the pathogen

Major dermal diseases (contd.)

Disease	Causes/triggers	Symptoms/clinical features	Affected by climate change?
Prurigo nodularis	Not known. Among risk factors is atopic dermatitis.	Itchy skin nodules on arms, legs, abdomen, and/or back.	Possibly
Psoriasis	Genetic predisposition, skin injury, throat infections, certain medicines.	Flaking skin patches/scales	Yes
Reynaud's disease	Cold temperatures	Cold, numb, white/blue skin on fingers or toes	No
Ringworm (tinea corporis)	Contact *trichophyton*, *microsporum*, or *epidermophyton* fungi.	Itchy, red, circular rash.	Yes
Rosacea	Genetic predisposition, certain chemicals in food, alcohol, climatic conditions.	Red spots/rash on the face.	Yes
Rubella	Airborne or contact *rubella* virus	Red rash, red eyes, fever, headache, cough, arthritis (in women), miscarriage, birth defects and death (in newborn children)	Yes
Shingles	*Varicella-zoster* virus pre-acquired from chickenpox	Painful rash on one side of face or body.	Yes
Skin cancers (basal cell, squamous cell, melanoma)	Genetic predisposition, exposure to the sun, kidney dialysis, arsenic ingestion.	Lesions or lumps on the skin, in the case of squamous cell and melanoma: metastasis, death.	Yes
Scabies	Contact human itch mite (*sarcoptes scabiei var. hominis*)	Itchy, pimple-like rash.	Yes
Syphilis	Contact treponema pallidum bacterium	Single chancre (sore), rashes, lesions, fever, swollen lymph nodes, attack of vital organs, death.	Yes
Vibrio vulnificus	Open wound contact with fluids or ingestion of seafood containing *vibrio vulnificus* bacteria	Blistering skin lesions, fever, vomiting, diarrhoea, necrotizing fasciitis, death.	Yes
Viral warts	Contact *human papilloma* virus	Warts.	Yes
Vitiligo	Genetic predisposition, sunburn, injured skin, certain chemicals.	Symmetrical loss of skin pigment/colour on both sides of the body.	Yes



From the previous sections we can see that there are more than 40 allergy and dermal diseases that can be affected by one or more of 10 climate change stressors via many different disease causes or triggers. We can get an overall view of these inter-relationships for each of the four disease categories by considering the causal links between the climate change stressors and a generalised list of disease causes/triggers:

Transmission by contact with pathogens on/in solids or fluids only

Disease	Climate change factor(s) affecting the disease	Outcome/predicted effect on the disease	Reference
Herpes simplex	Sun exposure, stress from extreme weather events	Disease flare-up/aggravation	S.R. Cuddy *et al.*, eLife, 2020, 9, e58037. https://doi.org/10.7554/eLife.58037
Gonorrhoea	Temperature increase, human migration	Increase in number of cases	R. Suresh, 2021, USFCA Master's Theses, 1382. https://repository.usfca.edu/thes/1382. Accessed 11th June 2023
Impetigo	Flooding	Increase in number of cases	E. Parker, J. Climate Change and Health, 2022, 8, 10016. https://doi.org/10.1016/j.joclim.2022.100162
Marburg	Temperature increase leading to spread of host animals	Geographical spread of disease	F. Kritz, https://www.wbur.org/npr/1167093290/theres-a-second-outbreak-of-marburg-virus-in-africa-climate-change-could-be-a-fa Accessed 11th June 2023
Monkeypox	Natural land cover change and deforestation leading to increased human/animal host contact	Geographical spread of disease	B. Hugh et al., https://climateandsecurity.org/2022/09/monkeypox-and-the-convergence-of-climate-ecological-and-biological-security-risks/ Accessed 11th June 2023
Ringworm (tinea corporis)	Increased temperature and humidity, flooding	Increase in number of cases	A. Gadre *et al.*, J. Climate Change and Health, 2022, 6, 10015. https://doi.org/10.1016/j.joclim.2022.100156
Shingles	Increased temperature	Increase in number of cases	Y. Choi *et al.*, Nature Scientific Reports, 2019, 9, 12254. https://doi.org/10.1038/s41598-019-48673-5
Syphilis	Human migration due to climate change and war	Geographical spread of disease	J. F. Dayrit, Int. J. Dermatology 2022, 61, 127–138. https://doi.org/10.1111/ijd.15543
Vibrio vulnificus	Temperature increase and flooding-induced changes in estuarine salinity	Increased incidence and geographical distribution range	C. Baker-Austin *et al.*, Env. Microbio. Reports, 2010, (1), 2, 7–18. https://doi.org/10.1111/j.1758-2229.2009.00096.x
Viral warts	Increase in temperature due to El Niño, human migration	Increase in number of cases	E.L. Gutierrez *et al.*, An. Bras. Dermatol., 2010, (4), 85, 461-8. https://doi.org/10.1590/S0365-05962010000400007

Transmission by contact with both airborne pathogens and those on/in solids or fluids.

Disease	Climate change factor(s) affecting the disease	Outcome/predicted effect on the disease	Reference
Chickenpox	Temperature, sun exposure, and rainfall	Increasing incidence with decreasing temperature, increasing sun exposure and increasing rainfall	Y. Yang *et al.*, BMC Infectious Diseases, 2016, 16, 179. https://doi.org/10.1186/s12879-016-1507-1
Diphtheria	Human migration	Increasing incidence due to population displacement resulting from natural disasters	European Centre for Disease Prevention and Control, 6 Oct. 2022, Stockholm. https://www.ecdc.europa.eu/en/publications-data/increase-reported-diphtheria-cases-among-migrants-europe-due-corynebacterium Accessed 11th June 2023.
Hand-foot-and-mouth disease	Temperature increase	Increasing incidence and prolonged outbreak length	S.J. Coates *et al.*, Int. J. Dermatology, 2019, 58, 388–399. https://doi.org/10.1111/ijd.14188
Measles	Temperature, humidity and human migration/travel	Increasing incidence within the optimum temperature range 18°C to 20°C. Increasing incidence with decreasing humidity	Q. Yang *et al.*, Human Vaccines & Immunotherapeutics, April 2014, 10, (4), 1104–1110. http://dx.doi.org/10.4161/hv.27826
Rubella	Temperature and humidity/precipitation	Increasing incidence with decreasing temperature and decreasing humidity	Y. Ma *et al.*, Am. J. Trop. Med. Hyg., 2021, 104, (1), 166–174. https://doi.org/10.4269/ajtmh.20-0585

Transmission by contact with insects only

Disease	Climate change factor(s) affecting the disease	Outcome/predicted effect on the disease	Reference
Cutaneous larva migrans	Temperature increase and human migration	Increasing incidence	S.H. Choi *et al.*, International Journal of Dermatology, 2023, 62, 681–684. https://doi.org/10.1111/ijd.16636
Cutaneous myiasis	Temperature increase and human travel	Increased incidence and geographical distribution range due to expansion of climatic regions favourable for *Diptera* order flies	E. Andreattas and L. Bonavina, European Surgery, 2022, 54, 289–294. https://doi.org/10.1007/s10353-021-00730-y
Scabies	Temperature and humidity	Increased incidence with decreasing temperature and increasing humidity	J.M. Liu *et al.*, Parasite, 2016, 23, 54. http://dx.doi.org/10.1051/parasite/2016065

Mycotoxins

- Mycotoxins - naturally occurring toxins produced by certain molds (fungi)
- Fungi of the genus Aspergillus, Fusarium and Penicillium
- Aflatoxins (AF) - produced by Aspergillus flavus
- Aspergillus - grow in soil, decaying vegetation, hay, and grains
- Aflatoxin B1 (AFB1) - the most potent known natural carcinogen
- Other important mycotoxins: Fumonisin B1 (FB1) and Ochratoxin A (OTA)

Aspergillus flavus

www.efsa.europa.eu/en/topics/topic/mycotoxins; www.who.int/news-room/fact-sheets/detail/mycotoxins Accessed: 14.03.2023.

Crops frequently affected (Aspergillus spp.): cereals (corn, sorghum, wheat and rice), oilseeds (soybean, peanut, sunflower and cotton seeds), spices (chili peppers, black pepper, coriander, turmeric and ginger) and tree nuts (pistachio, almond, walnut, coconut and Brazil nut). The toxins can also be found in the milk of animals that are fed contaminated feed, in the form of aflatoxin M1.

FAO estimations: 25% of global samples contaminated

→ DOI: 10.3390/toxins13060399

→ www.who.int/news-room/fact-sheets/detail/mycotoxins
↘ Accessed: 25.02.2023.

→ DOI: 10.1080/10408398.2019.1658570

Climate (temperature, precipitation, and atmospheric CO2 concentration) represents the key driving force of agricultural ecosystems

Climate changes may significantly impact fungal colonization and mycotoxin production.

Climate changes could lead to unexpected increases/reductions in mycotoxin contamination of crops in the field and post-harvest.

Climate change could result in changes in the fungal biodiversity and emergence of new diseases.

→ DOI: 10.3390/microorganisms8101496

1960s - a new turkey disease with high mortality identified in England

The turkey “X” disease

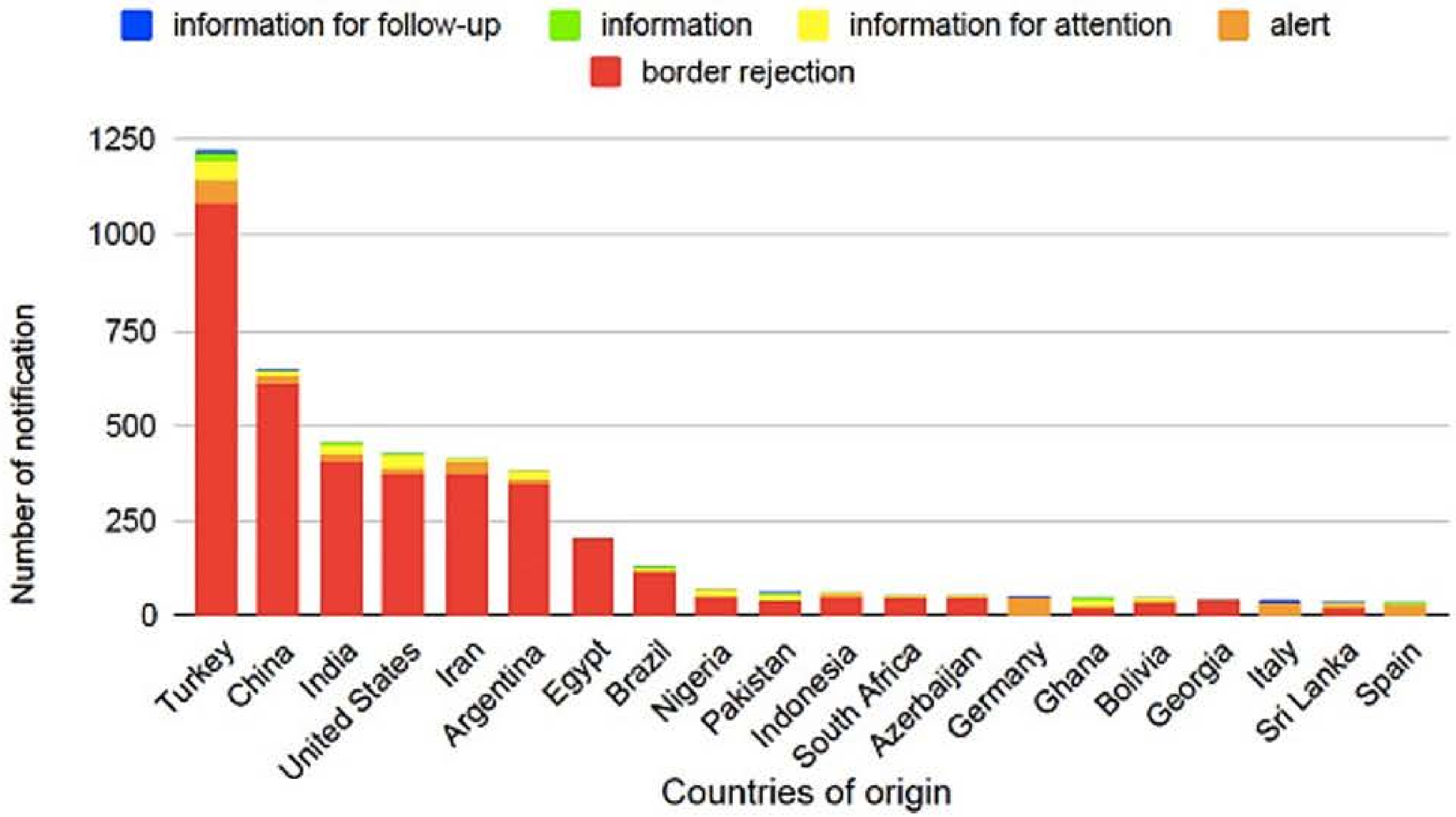
100,000 turkeys died after being fed with contaminated Brazilian groundnut meal on a poultry farm in London.

William Percy Blount - veterinary scientist developed an effective poultry disease diagnostic service

Mycotoxins enter the food chain as a result of infection of crops before or after harvest

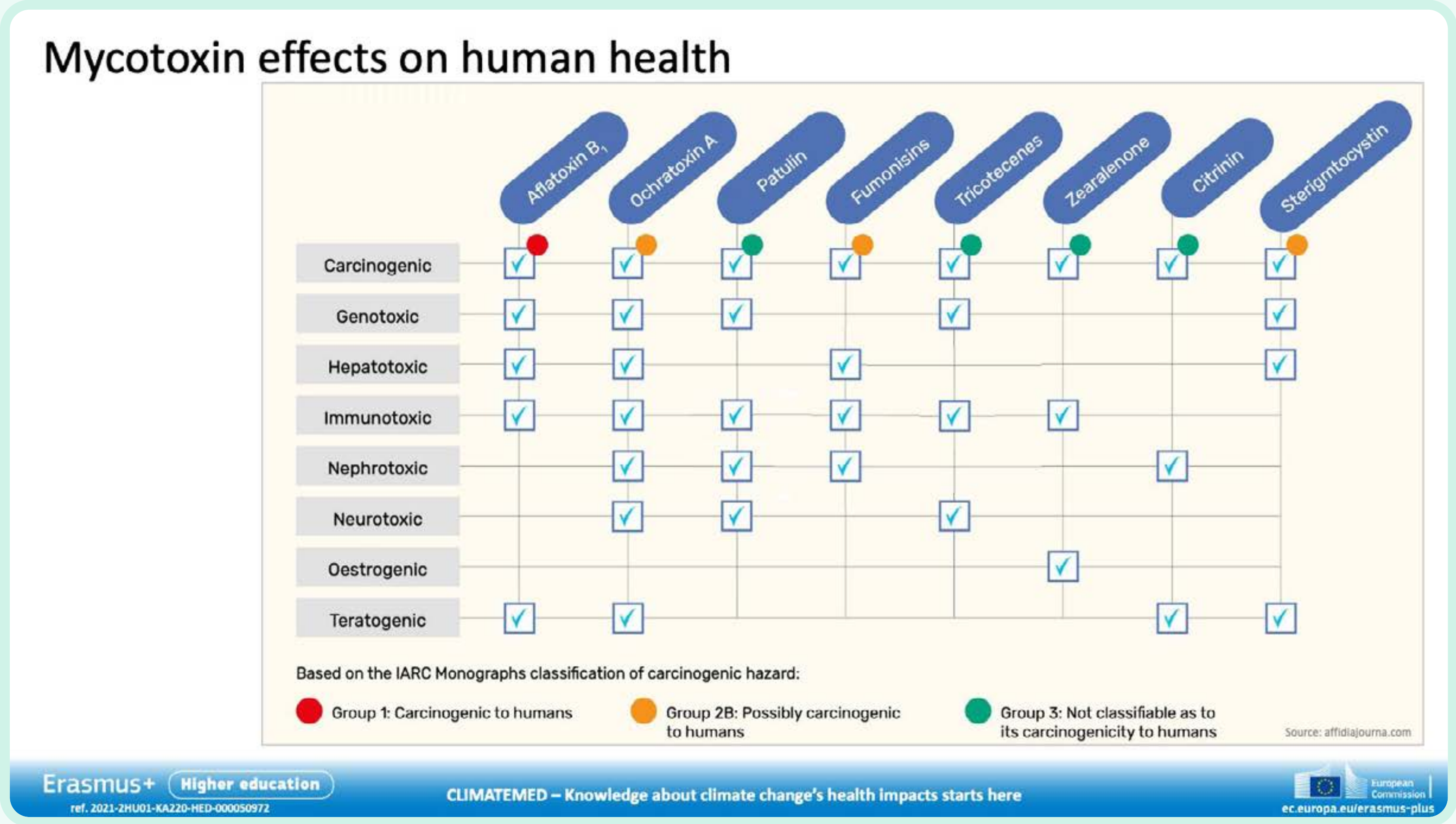
Exposure to mycotoxins typically by eating contaminated foods or from animals that are fed contaminated feed

Aflatoxin-related notifications - EU



Countries of origin for aflatoxin-related notifications in food based on the European Union Rapid Alert System for Food and Feed (RASFF) database from 1st January 2009 until 27th June 2019

DOI: 10.3389/fmicb.2019.02908



Effects: hepatotoxic, carcinogenic, teratogenic, immunosuppressive, nephrotoxic

Mycotoxicoses can manifest as acute or chronic intoxications

Acute mycotoxicoses caused by exposure to high amounts of mycotoxins

In the past - common even in moderate temperature zones, causing epidemics that devastated entire regions (during famines, moldy foods)

Nowadays, mostly in tropical countries (Africa, Asia) with equal severity and high mortality

Symptoms appear quickly and, if exposure continues, the outcome may be fatal.

Chronic exposure to AF has been associated with an increased risk of cirrhosis and liver cancer.

About 25,000–150,000 cases of liver cancer are attributed annually worldwide to aflatoxin exposure.

Aflatoxin may play a causative role in up to 1/3 of all global liver cancer cases.

Most cases occur in sub-Saharan Africa, Southeast Asia, and China, where populations suffer from both high HBV prevalence and largely uncontrolled aflatoxin exposure in food.

Controlling and minimizing the risk from mycotoxins

Good agricultural practices effectively control A. flavus infection in the field:

→ Timely planting

→ Providing adequate plant nutrition

→ Controlling weeds

→ Crop rotation

Efficient drying of commodities and maintenance of the dry state

Proper storage - effective measure against mold growth and the production of mycotoxins (mold does not grow in properly dried and stored foods)

Disposal of contaminated stocks

ISBN: 9780124114715, 45-49.

Climate justice

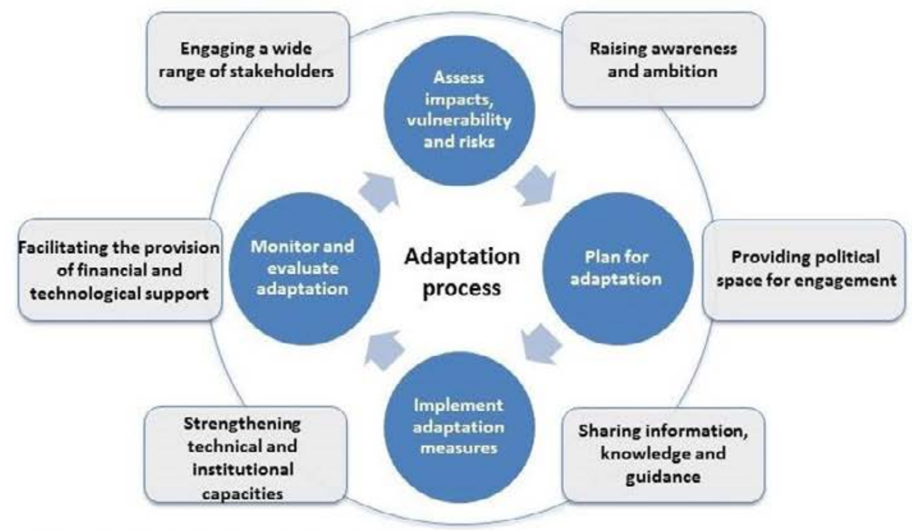
Addressing health inequalities related to climate change requires a focus on climate justice. This involves recognizing the disproportionate impacts of climate change on vulnerable communities and implementing equitable policies and strategies to mitigate and adapt to climate change.

Climate justice advocates for a transition to a low-carbon, sustainable future that prioritizes social and economic justice. It emphasizes the need for an equitable distribution of the costs and benefits of transitioning to renewable energy, green jobs, and sustainable development.

It aims to ensure that no one is left behind during this transition and that workers and communities dependent on high-carbon industries are supported in the shift to cleaner alternatives.

Adaptation

Adaptation refers to adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects. It refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change.



Source: https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction

Erasmus+ Higher education
ref. 2021-2HU01-KA220-HED-000050972
CLIMATEMED – Knowledge about climate change's health impacts starts here
European Commission
ec.europa.eu/erasmus-plus

The strategy of private preparedness and responsibility would emphasise public information campaigns and public health education to make people aware of the

→ health risks associated with climate change,

→ factors contributing to people's exposure and sensitivity,

→ alternatives for avoiding and mitigating adverse health outcomes, so that they can protect themselves.

Solutions such as advance warning systems would also support such strategies, signalling that people should deploy adaptation measures.

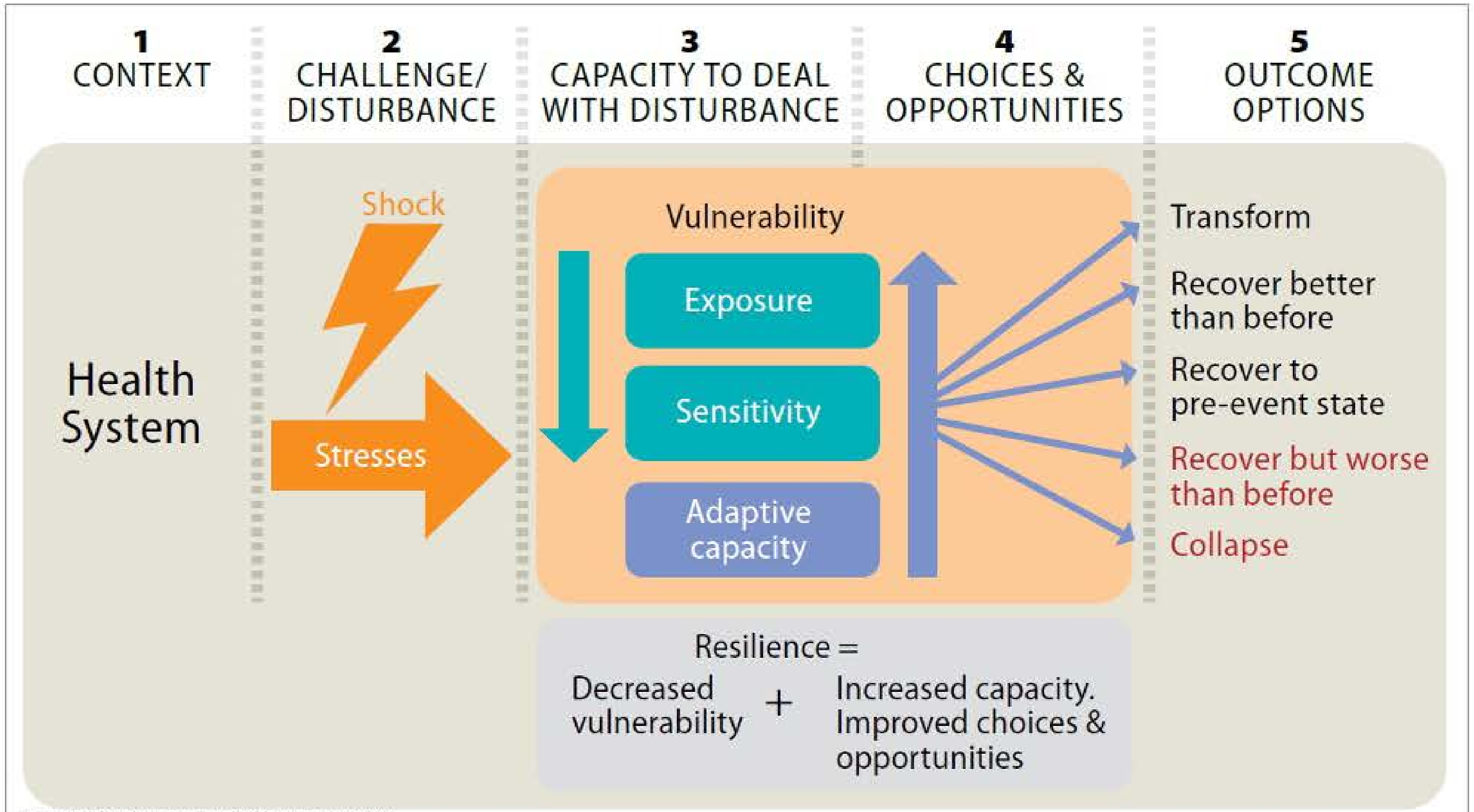
Adaptation to climate change's health impacts involves taking proactive measures to minimize the negative health consequences associated with changing climatic conditions.

Adaptation actions can take on many forms, depending on the unique context of a community, business, organization, country or region. There is no "one-size-fits-all-solution": it can range from building flood defences, setting up early warning systems for cyclones, switching to drought-resistant crops, to redesigning communication systems, business operations and government policies.

Countries and communities need to develop adaptation solutions and implement actions to respond to current and future climate change impacts.

Adaptation need to be based on and guided by the best available science and traditional knowledge, knowledge of indigenous peoples and local knowledge systems, with a view to integrating adaptation into socioeconomic and environmental policies and actions.

Resilience and climate change's healt impact



Source: Bulidnig climate resilient health system WHO, 2015

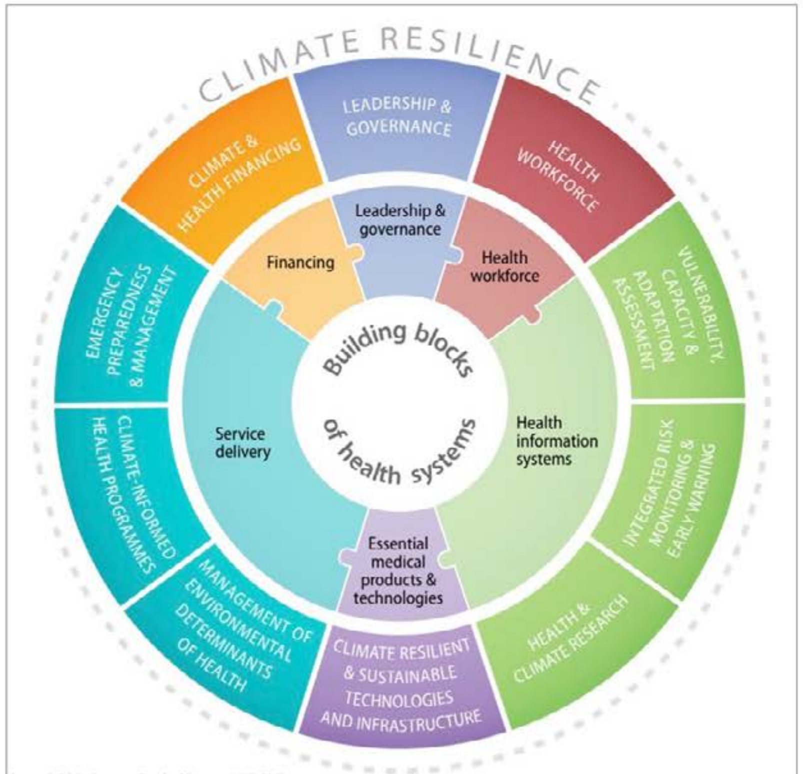
Resilience is intrinsically linked to adaptation.

A climate-resilient healthcare system is one that is capable to anticipate, respond to, cope with, recover from and adapt to climate-related shocks and stress, so as to bring sustained improvements in population health, despite an unstable climate.

Components for building climate resilient health systems

Building capacities and implementing strategies to minimize negative impacts and promote well-being in the face of climate-related challenges is a crucial aspect of resilience.

Whether it be in personal or professional situations, the resilience means being flexible and adaptable, and willing to make changes when necessary.



Source: Buildnig climate resilient health system WHO, 2015

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Key aspects of resilience in terms of climate change's health impacts

Adaptive capacity: includes taking proactive steps such as implementing early warning systems, preparedness plans, and infrastructure improvements to minimize vulnerability to climate-related health impacts. In addition, adaptive capacity also involves fostering flexibility and learning from past experiences to continually enhance responses to climate change.

Health system readiness: healthcare systems need to be prepared to handle climate-related health risks. Hence, the healthcare infrastructure must be strengthened:

→ ensuring access to essential health and social services;

→ training healthcare professionals on climate-related health issues;

→ developing response plans for emergencies and outbreaks exacerbated by climate change.

Health information systems that include

→ information on vulnerability to climate risks

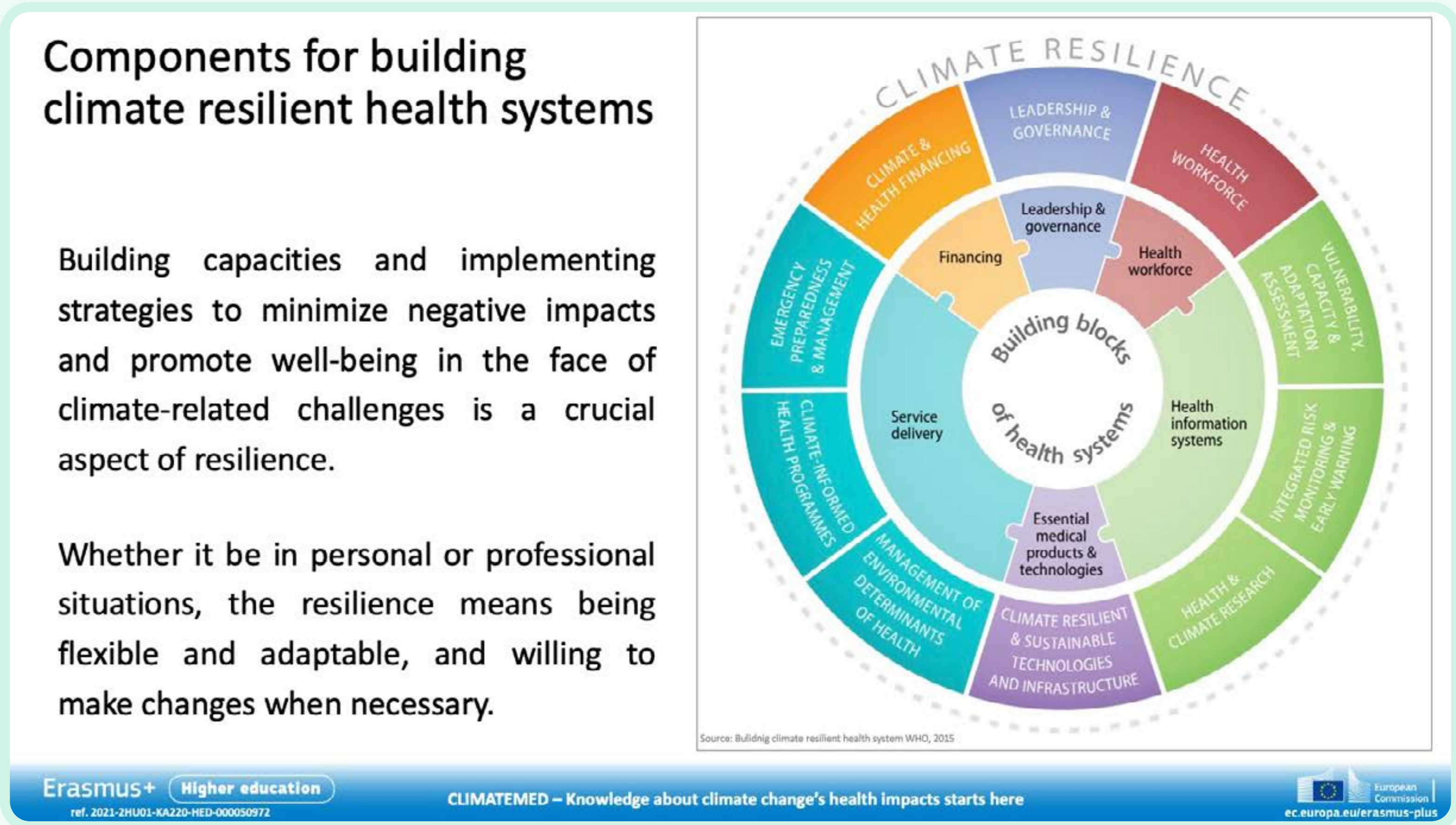
→ disease surveillance;

→ research programmes to monitor health-related progress against persistent and emerging threats;

→ existing and expected future capacity of the system to respond, and identification of adaptations;

→ integration of climate information into disease surveillance providing an opportunity to develop early warning systems and more accurate target interventions.

Community engagement and empowerment: resilience is enhanced when communities are engaged and empowered to actively participate in decision-making processes and take actions to protect their health in the face of climate change.



Achieving these goals, the following activities would be more than beneficial both for individuals and neighbourhoods:

→ raising awareness about climate-related health risks;

→ providing education and resources for individuals and communities to develop health literacy and make informed decisions;

→ supporting community-led initiatives to adapt and build resilience.

Multi-sectoral collaboration: is essential for building resilience to climate change and its impacts. Bringing together various sectors, and expertise to address complex challenges and develop comprehensive solutions is cricical.

Engaging stakeholders from different sectors, including businesses, civil society organizations, community groups, academia, and vulnerable populations, is crucial.

Addressing climate change health impacts involves integrating climate considerations into sectoral policies and practices across these sectors to ensure a coordinated and comprehensive response.

Addressing underlying vulnerabilities: to develop resilient and inclusive communities it is crucial addressing the underlying social, economic, and environmental determinants of health.

Related initiatives should address issues such as

→ poverty;

→ social exclusion and inequality;

→ inadequate housing;

→ limited access to healthcare.

These determinants can exacerbate the health impacts of climate change, particularly for vulnerable populations.

Long-term thinking and planning: resilience involves adopting a long-term perspective in assessing and addressing climate change health impacts.

On an operational level, long-term thinking and planning include:

→ considering future climate scenarios;

→ conducting risk assessments;

→ incorporating climate projections into health planning and policy development;

→ integrating climate change considerations into development plans to prioritise health and well-being.