

Health Effects of Climate Change

Environmental mechanisms and their human health consequences

Greenhouse gases → changing hazards → disease
A clinicopathologic framework

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Learning outcomes

- Explain how greenhouse gases alter climate and environmental exposures.
- Trace direct and indirect pathways from climatic hazards to human disease.
- Compare heat-, water-, vector-, air-, and food-related health effects.
- Explain displacement, vulnerability and the rationale for mitigation.

Environmental disease has multiple origins

Personal environment

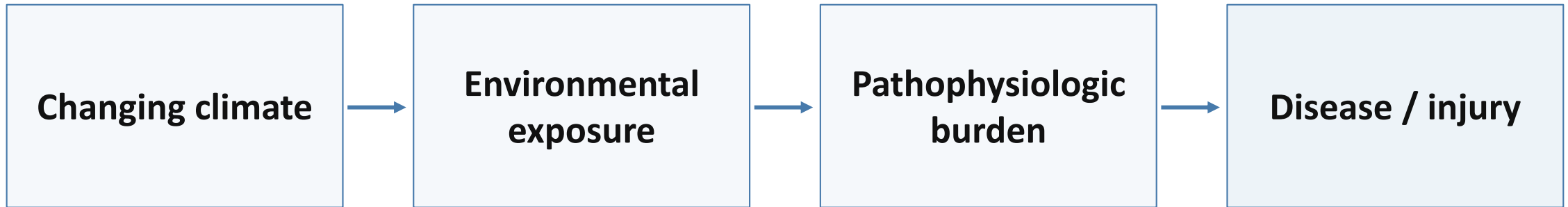
1. Behavior-related exposures
2. Diet and substance use
3. Factors acting on individuals

Ambient environment

1. Air, water and surrounding climate
2. Physical and chemical hazards
3. Exposures shared across populations

Climate change shifts the ambient conditions in which many diseases develop.

Climate hazards become health outcomes



A climate signal becomes a health effect through a specific exposure pathway.

Causal sequence (schematic)

Three levels of climate–health causation

Drivers

Greenhouse-gas accumulation and reduced plant carbon fixation.

Hazards

Extreme heat, severe weather, air pollution and water disruption.

Outcomes

Injury, infection, cardiopulmonary disease and malnutrition.

Documenting warming in the reference period

1.18°C

2023 global land–ocean anomaly

A 2023 temperature 1.18°C above the twentieth-century average.

Historical textbook measurement; Not a current-year figure.

Climate and weather are different scales

- Climate change concerns sustained shifts in conditions, not a single event.
- Extreme weather represents one pathway through which altered climate affects health.
- Warming trends, changing precipitation extremes and ice loss.

Physical consequences of a warming planet

Heat

More severe thermal exposure

Storms

Changing frequency and severity

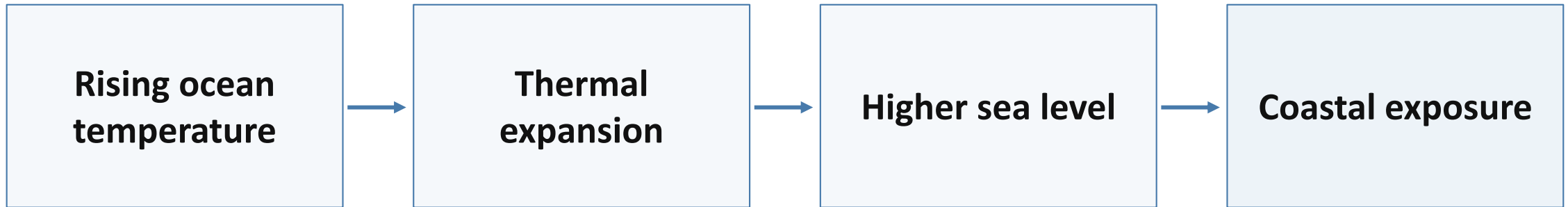
Water

Drought and flooding

Ice

Loss of land and sea ice

A warming ocean affects coastal risk



Thermal expansion operates alongside meltwater from land-based ice.

Causal sequence (schematic)

Ice loss has two distinct implications

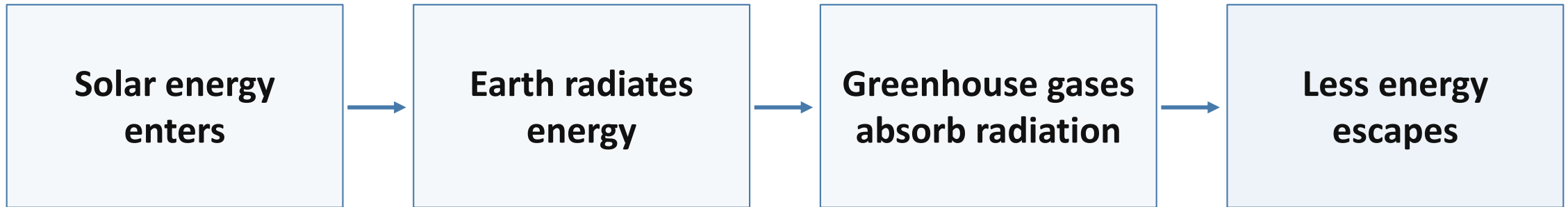
Land-based glacial ice

1. Melting contributes water to the oceans.
2. Greenland and Antarctica are cited as major ice-loss regions.

Arctic Ocean sea ice

1. The source describes dramatic thinning and disappearance.
2. Its loss documents climatic change;
Distinguish from land-ice addition to sea level.

Greenhouse gases alter energy balance



Atmospheric heat retention underlies the greenhouse effect.

Causal sequence (schematic)

Principal greenhouse constituents named by Robbins

Carbon dioxide

Emissions from fossil fuels

Methane

A greenhouse gas

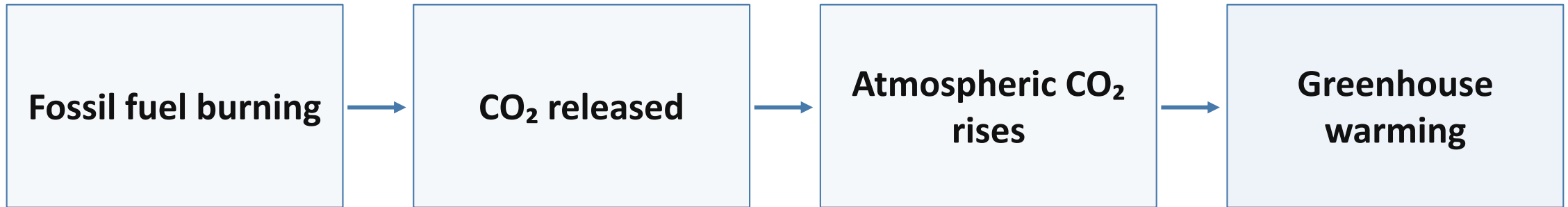
Ozone

Also a clinically important air pollutant

Water vapor

Participates in heat trapping

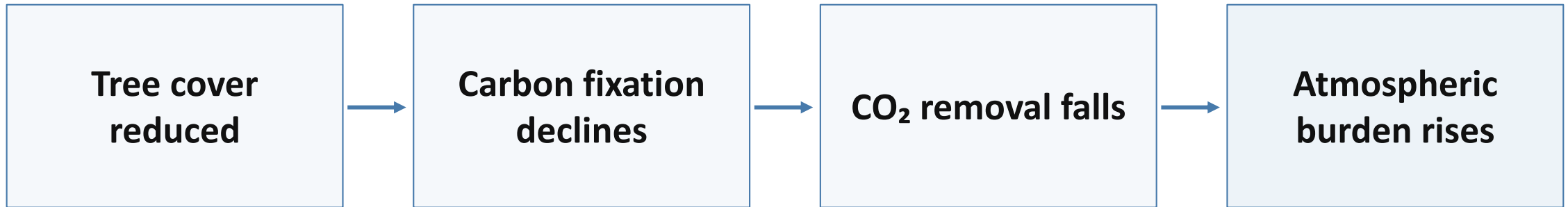
Fossil fuel combustion increases CO₂



Combustion-derived carbon dioxide as a central driver.

Causal sequence (schematic)

Deforestation amplifies atmospheric CO₂



Atmospheric concentration reflects both emissions and biological removal.

Causal sequence (schematic)

Two complementary routes to higher CO₂

Increased source

1. Burning fossil fuels releases CO₂.
2. Higher emissions add carbon to the atmosphere.

Reduced sink

1. Deforestation reduces plant uptake.
2. Lower carbon fixation leaves more CO₂ in the atmosphere.

Climate intervention may address sources and sinks through different mechanisms.

Atmospheric CO₂: Reference values

419.3 ppm

Annual average reported for 2023

The section contrasts this concentration with an approximately 280 ppm preindustrial level.

Both figures are reported by the textbook; No updated measurement is implied.

Observation is not the same as projection

Observed / reported

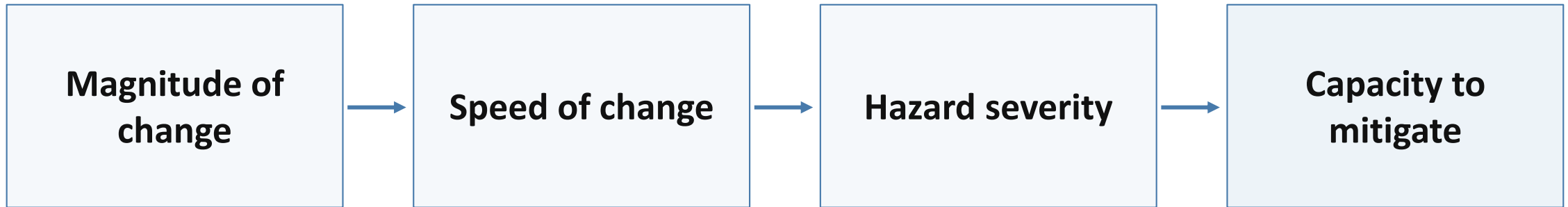
1. 2023 temperature anomaly
2. 2023 atmospheric CO₂ concentration
3. Reported sea-level change since 1900

Projected / conditional

1. Future warming under model assumptions
2. Future crop losses in some settings
3. Future sea-level and health burdens

Future estimates depend on the emission pathway, exposure and adaptation.

Why health outcomes vary



Robbins frames health consequences as conditional rather than fixed.

Causal sequence (schematic)

The principal exposure pathways

Thermal

Heat and severe weather

Air

Pollution and allergens

Biologic

Vectors and microbes

Systems

Water, crops and displacement

Direct, ecological and societal impacts

Direct exposure

Heat illness; Injuries during severe weather.

Ecologic change

Vector ranges, contaminants, allergens and food supply.

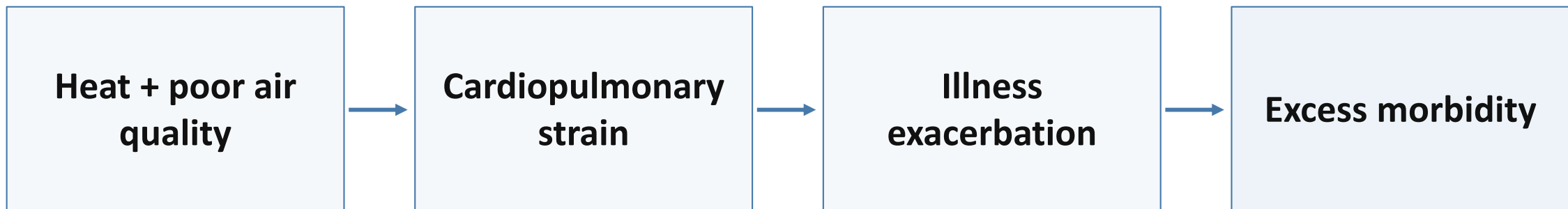
Societal cascade

Migration, disrupted livelihoods and poverty.

From environmental factor to clinical consequence

Environmental change	Health pathway	Examples
Extreme heat	Thermal / circulatory stress	Heat illness, cardiovascular failure
Air pollution	Respiratory / cardiovascular burden	Asthma, cardiovascular disease
Water contamination	Enteric infection	Cholera, diarrheal disease
Food disruption	Reduced dietary access	Malnutrition

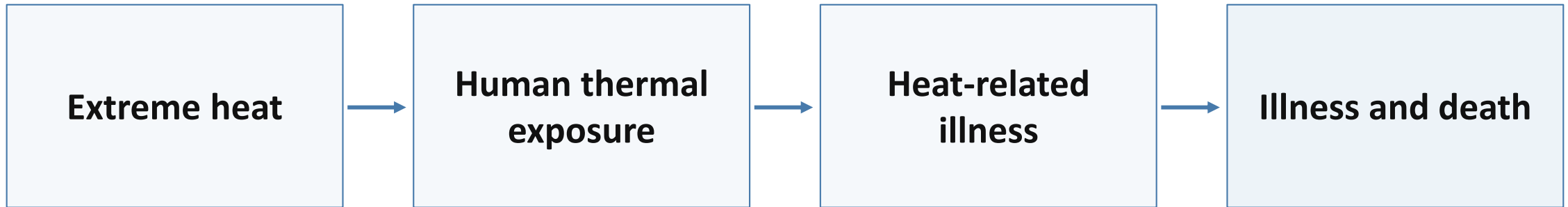
Multiple hazards may converge in one patient



The pathways are not independent: Co-exposure can occur during one climate event.

Causal sequence (schematic)

Direct pathway: Extreme heat



The source explicitly identifies heat-related illness and mortality.

Causal sequence (schematic)

Heat exacerbates vascular and cardiac disease

- Heat waves to increased cardiovascular and cerebrovascular disease burden.
- The accompanying climate–health figure includes cardiovascular failure among heat-associated outcomes.
- Existing disease burden matters when evaluating vulnerability to a heat event.

Cardiovascular vs cerebrovascular effects

Cardiovascular

1. Exacerbation of cardiac disease during heat waves.
2. Cardiovascular failure appears among the described consequences.

Cerebrovascular

1. Heat waves are described as worsening cerebrovascular disease.
2. Interpret as a reported health association, not a disease-specific diagnostic criterion.

These are related but distinct disease categories.

Heat and respiratory illness can coexist

Thermal exposure

1. Extreme heat has direct physiologic consequences.
2. Heat-related illness and death are explicitly listed.

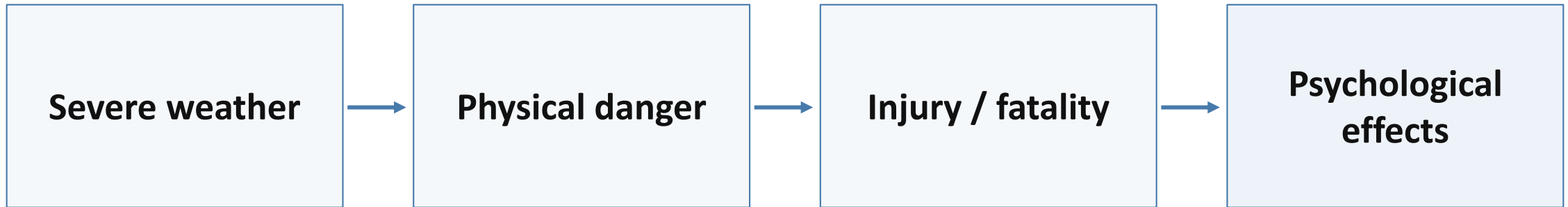
Respiratory co-exposure

1. Heat waves may occur alongside air pollution.
2. Aggravated respiratory disease as a major outcome.

Clinical consequences of heat exposure

Pathway	Outcomes named in Robbins	Interpretive point
Direct heat	Heat-related illness; death	Potentially life-threatening exposure
Cardiac	Cardiovascular disease / failure	Exacerbation during heat waves
Cerebral vascular	Cerebrovascular disease	Heat-associated disease burden
Respiratory co-exposure	Respiratory disease	Pollution may add risk

Storms produce immediate and delayed harms



Robbins Fig. 9.2 includes injuries, fatalities and mental-health impacts.

Causal sequence (schematic)

Disaster pathways are clinically distinct

Immediate

Trauma, injury and deaths linked to storms.

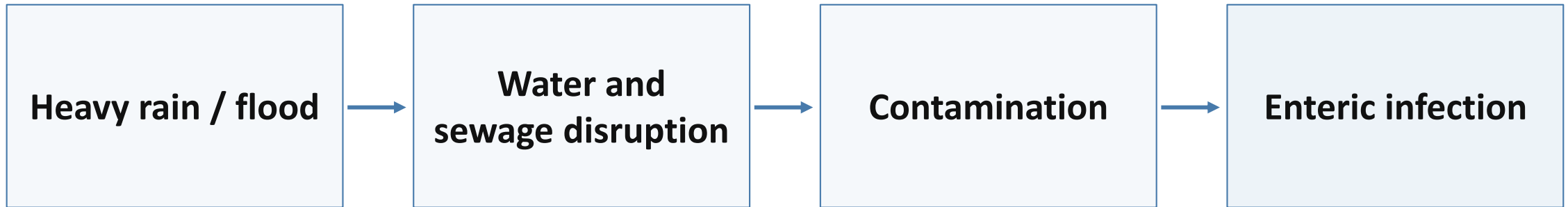
Infrastructure

Damage to safe water and sewage systems.

Longer-term

Displacement and mental-health impacts.

Flooding disrupts sanitation barriers



A flood need not infect directly: Damaged sanitation enables transmission.

Causal sequence (schematic)

Hazard versus secondary disease

Primary hazard

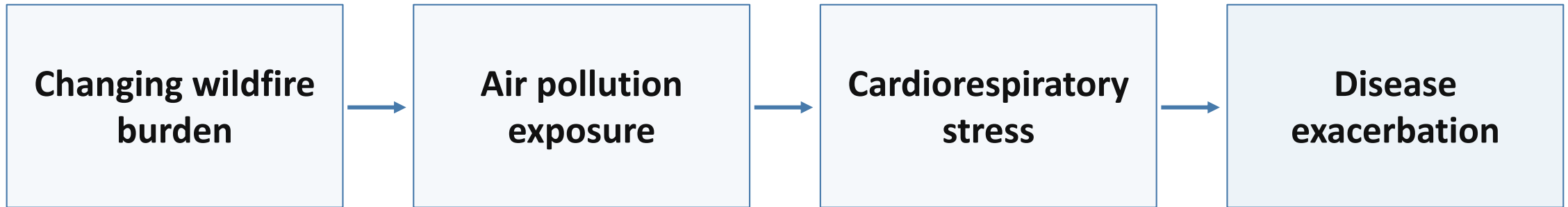
1. Flooding, storms and physical damage.
2. Injuries and immediate mortality.

Secondary consequences

1. Contaminated drinking water or food.
2. Subsequent gastroenteritis or cholera.

The causal sequence determines prevention priorities.

Wildfire-related pollution affects health



The section connects wildfire-related pollution with cardiovascular and respiratory harm.

Causal sequence (schematic)

Air pollution reaches several disease systems

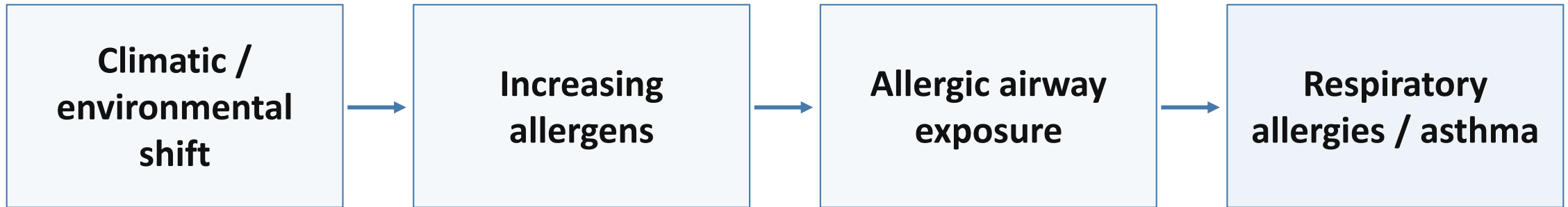
Pulmonary effects

1. Asthma and respiratory disease are named outcomes.
2. Air pollution is one component of the broader climate–health chain.

Cardiovascular effects

1. Cardiovascular disease is also associated with climate-related air pollution.
2. Do not restrict the health effect of poor air quality to the lungs.

Climate-linked allergens: A separate pathway



The source figure identifies respiratory allergies and asthma as downstream outcomes.

Causal sequence (schematic)

Pollutants and allergens are not synonyms

Air pollution pathway

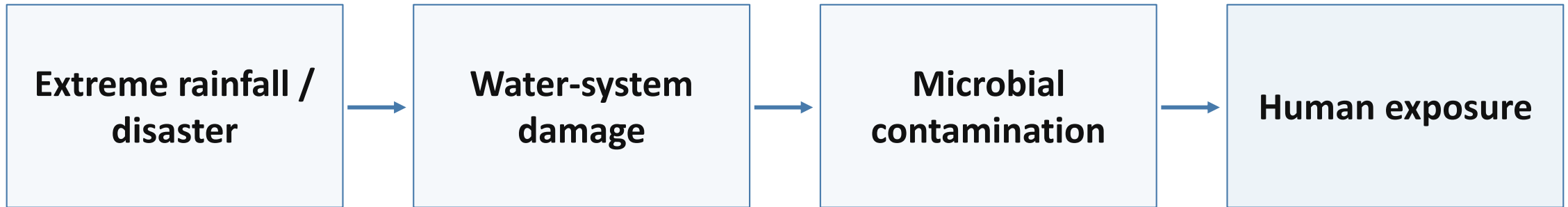
1. Ozone and wildfire-related pollution are emphasized.
2. Cardiovascular and respiratory outcomes.

Increasing allergen pathway

1. Allergic exposures are separately displayed.
2. Respiratory allergy and asthma outcomes.

Both can affect asthma; Their upstream exposures differ.

Climate affects safe water access



The infectious consequence depends on breakdown of clean water and sanitation.

Causal sequence (schematic)

Water-related conditions Fig. 9.2

Condition / agent	Category	Common exposure link
Cholera	Named water-quality outcome	Contaminated water
Cryptosporidiosis	Named water-quality outcome	Contaminated water
Campylobacter infection	Named water-quality outcome	Food / water
Leptospirosis	Named water-quality outcome	Water-quality disruption
Harmful algal blooms	Environmental water hazard	Water quality degradation

Waterborne and foodborne disease pathways

Waterborne

1. Drinking water becomes contaminated.
2. Water infrastructure is disrupted by flooding.

Foodborne

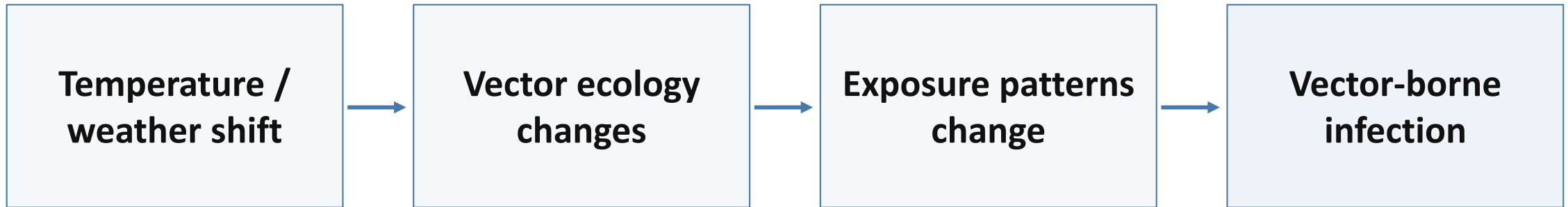
1. Contaminated food transmits enteric pathogens.
2. Disasters can compromise safe food handling and supply.

Robbins groups both pathways as infectious consequences of altered climate.

Gastroenteritis is a population-level outcome

- Floods and heavy rains can disrupt clean water supplies.
- Sewage-treatment disruption increases the opportunity for contamination.
- The downstream disease burden includes gastroenteritis and cholera.

Vector ecology translates climate into infection



Vector number and geographic distribution are explicit mediators.

Causal sequence (schematic)

Vector number and vector range are distinct

Vector abundance

1. Changes in vector number can alter opportunities for transmission.
2. Transmission risk is not determined by climate alone.

Geographic distribution

1. Changes in where vectors occur can expose different populations.
2. Location of risk may change even without a uniform global increase.

Vector-associated diseases named

Examples explicitly listed	Grouping for teaching
Malaria; dengue	Core examples in the chapter narrative
Chikungunya; West Nile virus	Additional arthropod-borne examples from Fig. 9.2
Lyme disease; encephalitis	Illustrative vector-associated outcomes
Rift Valley fever	Additional outcome shown in the source figure

Weather variability alters vector risk

- Temperature changes and extreme weather variation among drivers.
- The section cites El Niño events as an example of climatic variability.
- It is inappropriate to presume one uniform response across all pathogens or vectors.

Climate suitability is not a clinical diagnosis

Environmental inference

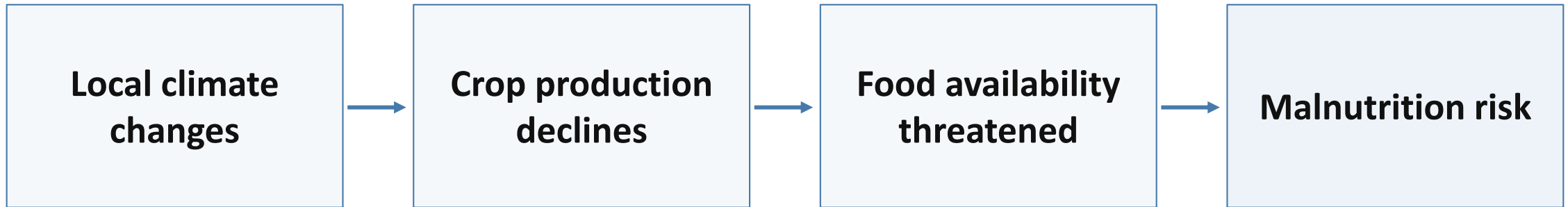
1. Vector abundance and habitat may change.
2. Geographic exposure may become more plausible.

Clinical confirmation

1. The source does not provide diagnostic tests or criteria.
2. Specific infection still requires ordinary disease-specific evaluation.

Ecologic hazard should not be mistaken for confirmed disease.

Crop disruption contributes to malnutrition



This pathway operates through the food system rather than direct heat injury.

Causal sequence (schematic)

Why tropical cropping systems may be vulnerable

Thermal context

1. Some tropical average temperatures are already near crop tolerance levels.
2. Additional warming may worsen growing conditions.

Health implication

1. Crop disruption threatens the local food supply.
2. Reduced nutritional security can increase malnutrition.

Illustrative agricultural projection

10–25%

Possible productivity decline by 2080

This projected range for some low-resource countries—not a worldwide observed loss.

Conditional projection; Not a measurement.

Direct heat injury differs from food insecurity

Direct / rapid

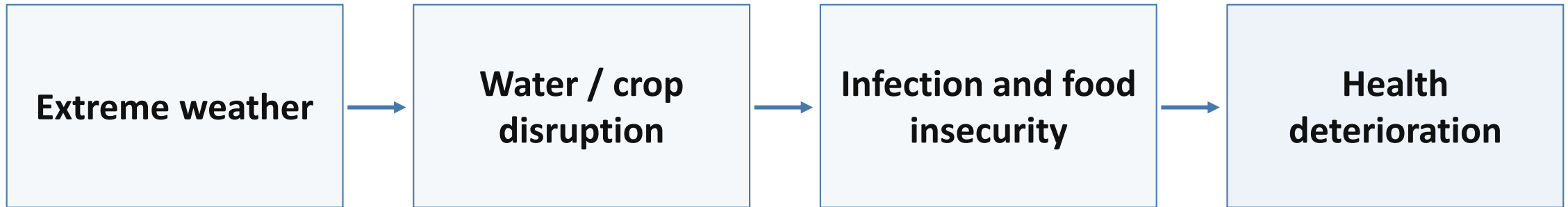
1. Exposure to an extreme temperature.
2. Heat-related illness develops through thermal stress.

Indirect / systemic

1. Changed climate affects crop yields.
2. Food-system disruption contributes to malnutrition.

Different latencies and intermediates require different health responses.

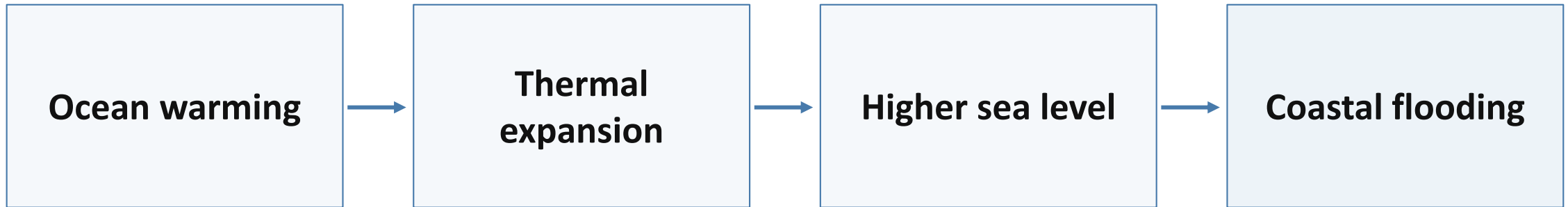
Water and food pathways interact



Multiple climate mechanisms can affect the same community.

Causal sequence (schematic)

Two processes raise mean sea level



Land-ice melt also adds ocean water: The processes act together.

Causal sequence (schematic)

Sea-level change: Observation vs forecast

Historical record in source

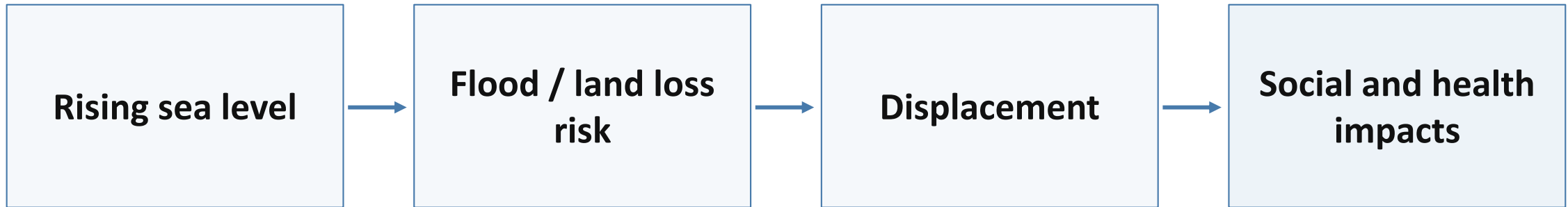
1. Approximately 13–20 cm of global mean rise since 1900.
2. Reported as a historical quantity, not an annual rate.

Future possibility in source

1. Substantial additional rise is projected by 2100.
2. Low-lying settlements face varying exposure.

Projection ranges should not be described as already observed.

Coastal flooding may trigger migration



The downstream impact extends beyond the initial physical hazard.

Causal sequence (schematic)

Displacement creates layered health risks

Material disruption

Homes, livelihoods and commerce may be lost or interrupted.

Social instability

Poverty, political unrest or conflict may follow.

Health consequences

Malnutrition, illness, death and psychological impacts may increase.

Low-lying communities face concentrated exposure

- People living in low-elevation coastal areas.
- Even smaller rises may worsen coastal flooding risks.
- The Maldives is used as an example of substantial exposure.
- Population vulnerability depends on the ability to adapt or relocate.

One hazard can affect multiple outcomes

Flood

Injury and waterborne infection

Heat

Cardiopulmonary disease

Drought

Food-system stress

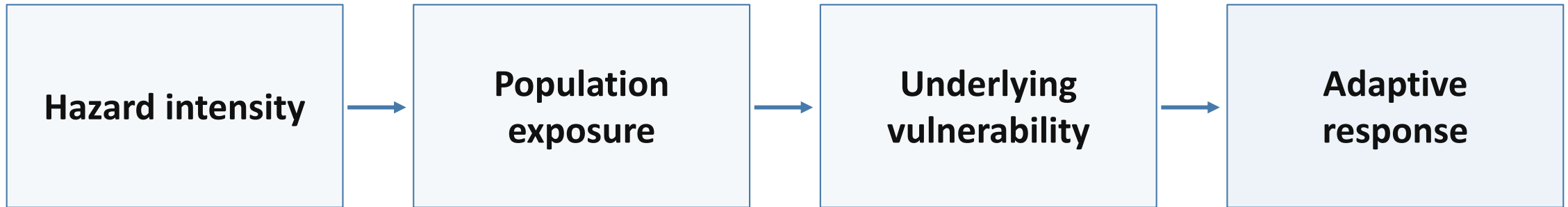
Coastal change

Displacement and poverty

Clinical outcomes versus transmission routes

Type of consequence	Representative outcome	Dominant pathway
Physical injury	Storm-related trauma	Direct hazard
Thermal illness	Heat-related disease	Direct heat
Infectious	Cholera; malaria	Water or vector ecology
Chronic exacerbation	Asthma; cardiovascular disease	Air / heat
Nutritional / social	Malnutrition; displacement	Food and coastal systems

Climate burden depends on adaptive capacity



Similar physical hazards may generate different consequences in different settings.

Causal sequence (schematic)

Risk is unevenly distributed

Higher vulnerability

1. Low-lying coastal populations.
2. Crop-dependent settings near climatic tolerance limits.
3. Populations lacking robust sanitation or water systems.

Potential buffering

1. Resilient water and food systems.
2. Capacity to prepare for severe weather.
3. Ability to prevent, treat and recover from disease.

WHO estimate quoted by Robbins

$\approx 250,000$

Additional annual deaths projected for 2030–2050

The textbook attributes this approximate projection to the WHO, reflecting multiple climate-associated disease pathways.

Historical estimate cited by the book, not an observed contemporary mortality count.

Interpret causal claims with care

Supported by the chapter

1. Climate change alters several environmental exposures.
2. Those exposures contribute to specified classes of disease.

Not established by this excerpt

1. Individual diagnostic criteria or causal attribution.
2. Updated estimates, pathogen-specific incidence or intervention effect sizes.

Population-level burden and patient-level diagnosis are different questions.

Health protection operates at several stages

Address drivers

Reduce accumulation of climate-warming gases.

Reduce exposure

Improve preparation for heat, flooding and air hazards.

Limit consequences

Protect clean water, food access and displaced populations.

Paris Agreement: Temperature goals

1.5°C

Effort to limit warming above preindustrial levels

The 2015 international agreement: Well below 2°C, while pursuing efforts toward 1.5°C.

This is an agreed temperature goal, not a forecast of achieved warming.

Mitigation and adaptation answer different questions

Mitigation

1. Addresses greenhouse-gas sources and sinks.
2. Acts upstream of future climate hazards.

Adaptation

1. Reduces exposure and vulnerability to hazards.
2. Protects infrastructure and health-system capacity.

Both climate magnitude and capacity to mitigate damage as determinants.

Case 1: Flooding followed by enteric illness

After unusually heavy rainfall, a community experiences flooding, damaged sewage infrastructure and a cluster of diarrheal illnesses.

Which environmental step most directly links the flood to infection?

A. Change in solar radiation

B. Contamination of drinking water

C. Melting of sea ice

Case 2: Heat and respiratory deterioration

During an extreme-heat episode with degraded air quality, local services report more cardiovascular and respiratory presentations.

What is the most defensible interpretation?

A. Only heat has a health effect

B. Only pollution has a health effect

C. Heat and pollution can operate together

Case 3: Altered vector range

A region with shifting temperature and seasonal weather conditions reports changes in the presence of disease-carrying vectors.

What changes may follow before a disease case is confirmed?

A. Vector number and geography

B. A fixed global increase in all infections

C. A new diagnostic cutoff

Synthesis: The four causal chains to retain

Thermal

Heat → illness / vascular burden

Environmental

Flood → contaminated water → infection

Ecologic

Climate → vectors → infection

Systemic

Crop / coast disruption → social harm

Questions to ask when interpreting a claim

- Is the statement an observation, estimate or conditional projection?
- What exposure links the climatic change to the clinical outcome?
- Is the outcome direct, ecologically mediated or socially mediated?
- Does the source provide a disease diagnosis, or only a population-level association?

Primary source and figure provenance

- Robbins, Cotran & Kumar. Pathologic Basis of Disease — Health Effects of Climate Change.
- The integrated climate–health outcome figure in the textbook credits CDC Foundation resources.
- Historical measurements and projections are presented as reported in the primary textbook; they are not current measurements.