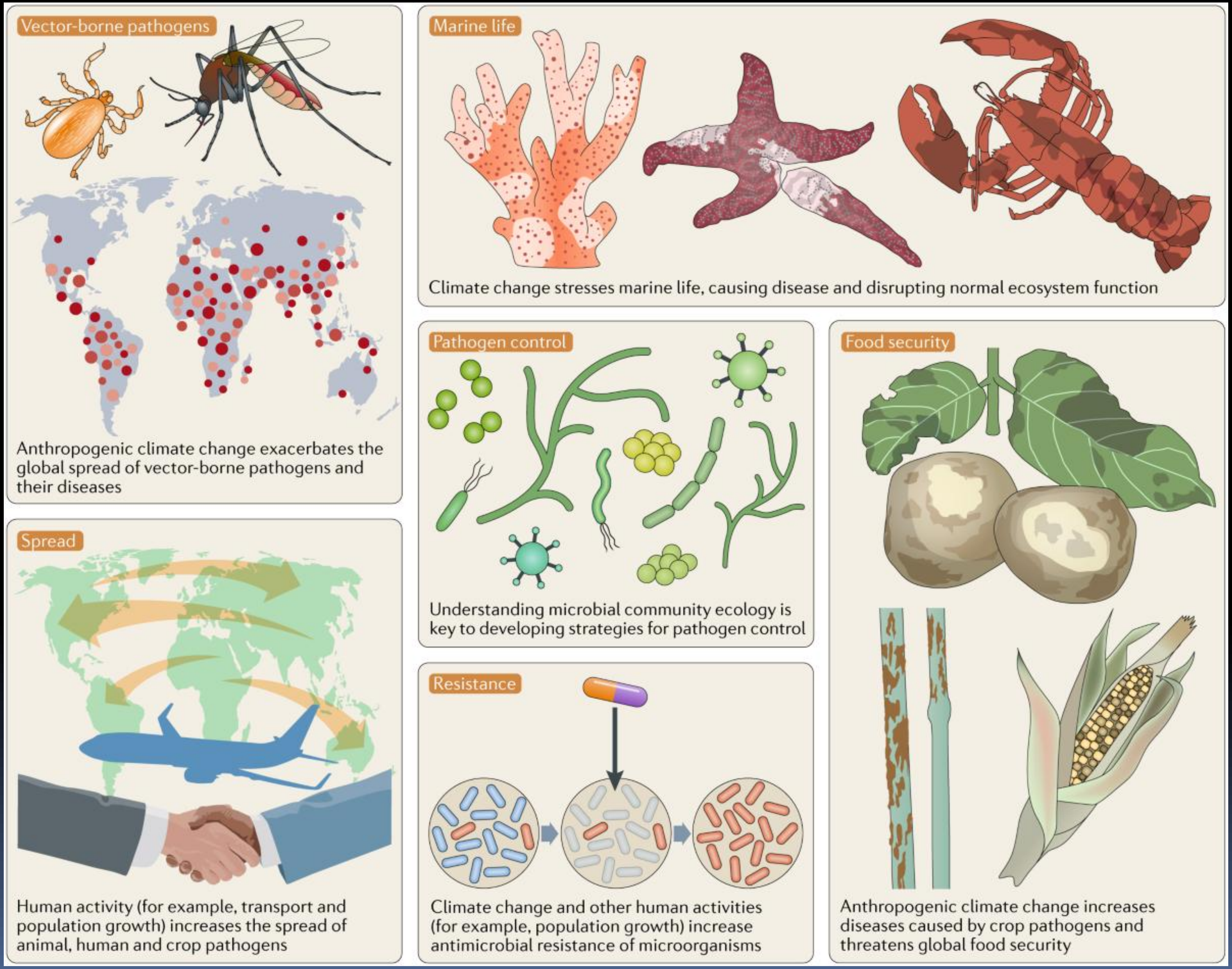
GLOBAL THREATS: spread of diseases



Source: Cavicchioli et al. *Nat Rev Microbiol* **17**, 569–586 (2019)

GLOBAL THREATS: pathogens susceptible to the effects of climate change

Example pathogens or diseases	Climatic and environmental factors	Transmission parameters
Vector-borne		
West Nile virus Malaria Dengue fever Lyme disease	Precipitation, relative humidity, temperature, El Niño Southern Oscillation	Vector abundance, longevity and biting rate, pathogen replication rate in vector
Waterborne		
Cholera Non-cholera *Vibrio* spp. *Cryptosporidium* spp. Rotavirus	Temperature, precipitation variability, salinity, El Niño Southern Oscillation	Pathogen survival, pathogen replication in environment, pathogen transport
Airborne		
Influenza Hantavirus Coccidioidomycosis	Relative humidity, temperature, wind	Pathogen survival, pathogen and/or host dispersal
Foodborne		
Salmonella spp. *Campylobacter* spp.	Temperature, precipitation	Pathogen replication, human behaviour

Sources: Cavicchioli et al. *Nat Rev Microbiol* 17, 569–586 (2019)
Ibanez et al. *Microbiol Res* 14, 918-947 (2023)

PUBLIC HEALTH THREATS

- Climate change is predicted to increase the rate of antibiotic resistance of some human pathogens – potential underlying mechanisms include elevated temperatures facilitating horizontal gene transfer of mobile genetic elements of resistance, and increased pathogen growth rates promoting environmental persistence, carriage and transmission

- Data suggest that an increase of the daily minimum temperature by 10°C will lead to an increase in antibiotic resistance rates of *Escherichia coli*, *Klebsiella pneumoniae* and *Staphylococcus aureus* by 2–4% (up to 10% for certain antibiotics); carbapenem resistance in *Pseudomonas aeruginosa* increases 1.02-fold for very 0.5°C rise

- Population growth, which amplifies climate change, is also an important factor in contributing to the development of resistance

- Climate change affects microbiome of the: gut (beneficial bacteria), respiratory tract (composintion and diversity), and skin (antimicrobial peptides, which act as a protective barrier) leading to deterioration of the immune system

Forecast for the near future: an increase in the infection transference and spread, as well as a change in the patterns of infectious pathologies

MICROBIAL STRATEGIES TO MITIGATE CLIMATE CHANGE: examples

- Introducing *Wolbachia* bacteria into the *Aedes aegypti* mosquito population and releasing them into the environment reduces the transmission of Zika, dengue, and chikungunya viruses

- The use of (both natural and genetically modified) bacterial strains with higher N_2O reductase activity provides opportunities to reduce emissions of this greenhouse gas

- Manipulating the rumen microbiota and breeding programs that target host genetic factors that change microbial community responses are possibilities for reducing methane emission from cattle. In this latter case, the aim would be to produce cattle lines that sustain microbial communities producing less methane without affecting the health and productivity of animals

- Fungal proteins can replace meat, lowering dietary carbon footprints (*Fusarium venenatum* – textural properties, mimicking meat, and rich content of essential amino acids, fibers, and vitamins; can be processed, e.g., being mixed with egg white, into various food products like burgers, nuggets, and pasta, offering a versatile protein source)

CLIMATE CHANGE: solutions

American Society of Microbiology & International Union of Microbiological Societies (2024)

3 microbe-based innovations to help humans adapt to and sustainably mitigate climate change in terms of its pace and deleterious consequences

INNOVATION	MITIGATION	ADAPTATION
Microbes for a non-fossil carbon economy	Reduces greenhouse gas emissions and reliance on fossil fuels	Reduces waste, frees up land and water resources and produces value-added products with a lower carbon output
Microbes for food security and ecosystem resilience	Supports rehabilitated ecosystems that reduce greenhouse gas emissions and increase carbon sequestration of agricultural soils	Prevents biodiversity loss and promotes enhanced ecosystem resilience and increased crop yields
Microbes for urgent methane mitigation	Reduces methane emissions and global warming potential from agricultural and freshwater ecosystems	Reduces waste and produces food and energy with a lower carbon output

- scientifically sound, economically sustainable, safe and scalable in a 5-to-15-year period
- promote social equity and societal well-being more generally
- can be tailored to the needs and capacities of local communities, countries and regions