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FOODBORNE DISEASES FROM DAIRY PRODUCTS IN DEVELOPING COUNTRIES: HAZARDS AND HEALTH IMPLICATIONS

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BURDEN OF FOODBORNE DISEASE

Illnesses, deaths

Disability-Adjusted Life Years (DALYs)

1 DALY = 1 healthy life year lost

Summary measure of population health

Morbidity + mortality

Disease occurrence + disease severity

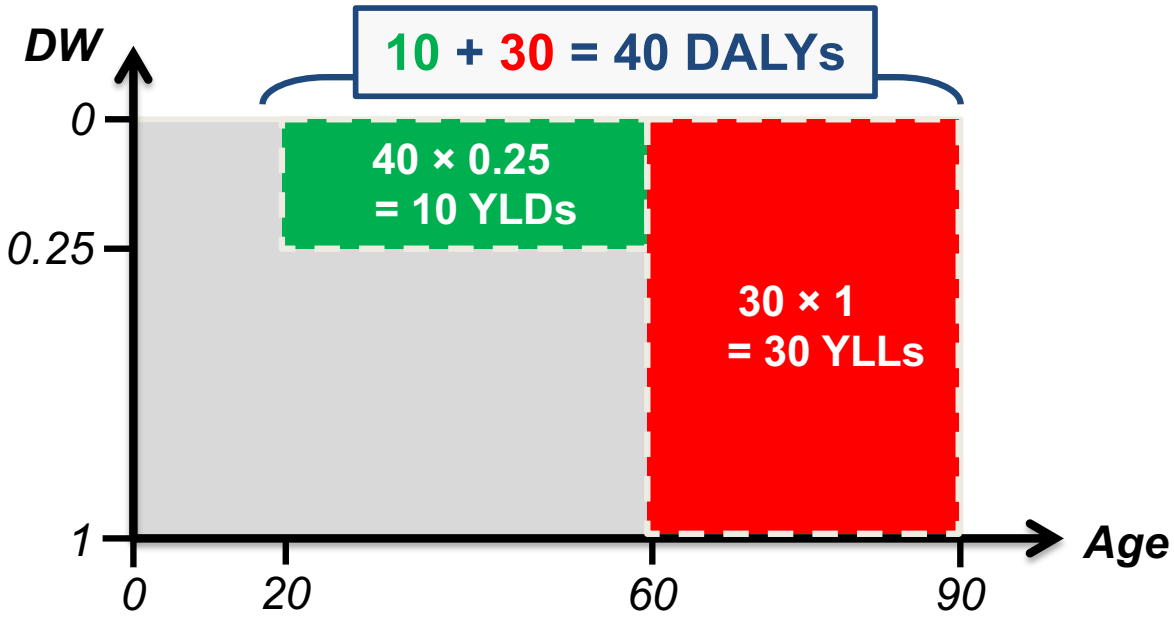
DALY = YLD + YLL

YLD = Years Lived with Disability

= Number of incident cases (N) × Duration (D) × Disability Weight (DW)

YLL = Years of Life Lost

= Number of deaths (M) × Residual Life Expectancy



DALY = YLD + YLL

- YLD = Years Lived with Disability = N×D×DW
- YLL = Years of Life Lost = M×RLE

GLOBAL BURDEN OF FOODBORNE DISEASE, 2010

Hazard group	Foodborne illnesses (millions)	Foodborne deaths (thousands)	Foodborne DALYs (millions)
All	600	420	33
Diarrheal	549	230	18
Invasive	36	117	8
Helminths	13	45	6
Chemicals	0.2	19	0.9

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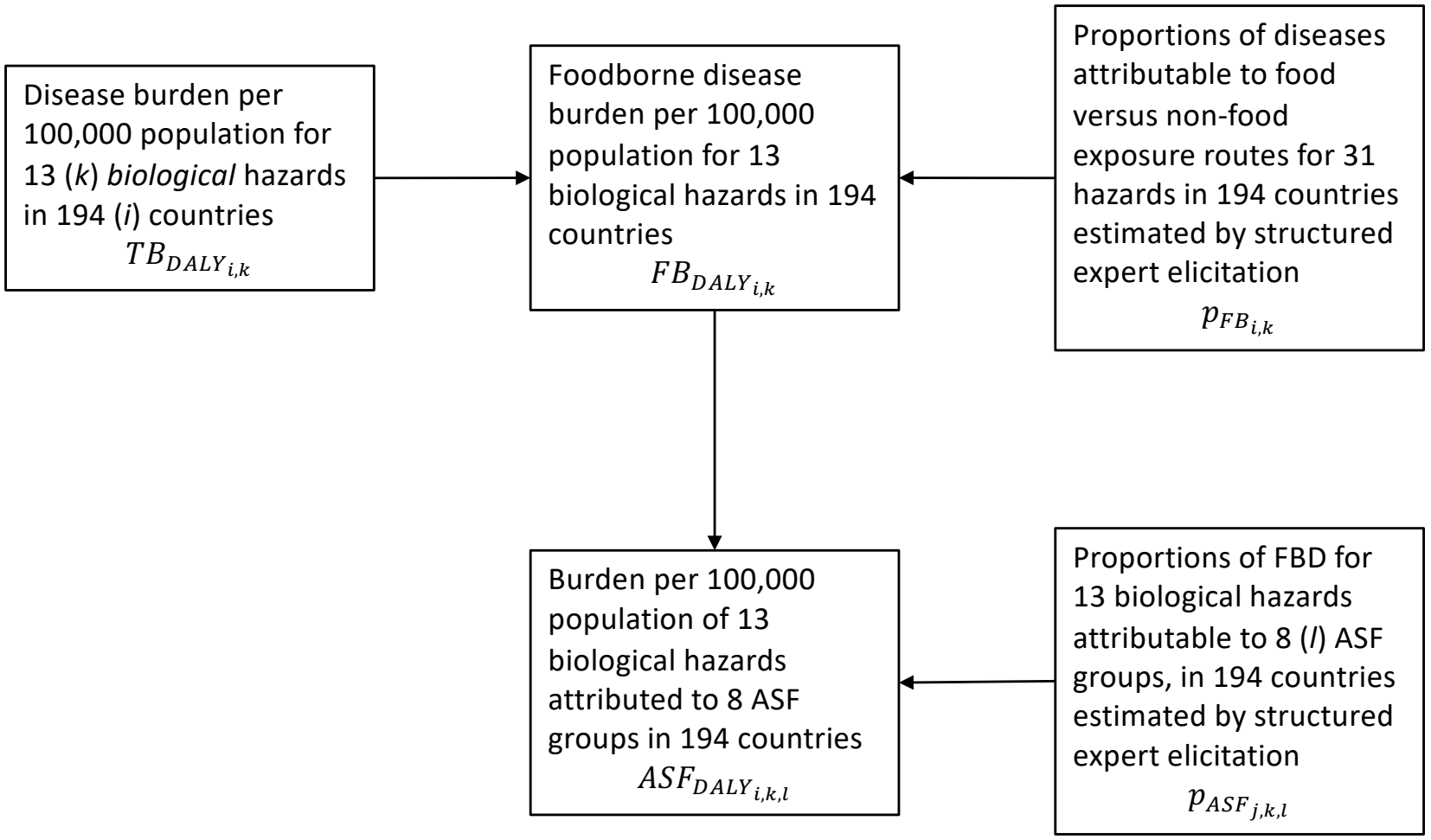
ESTIMATING THE GLOBAL BURDEN OF ASF



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WHO REGIONS AND SUBREGIONS

Subregions[1]	WHO member states
SEAR B	Indonesia; Sri Lanka; Thailand.
SEAR D	Bangladesh; Bhutan; Democratic People's Republic of Korea; India; Maldives; Myanmar; Nepal; Timor-Leste.
WPR A	Australia; Brunei Darussalam; Japan; New Zealand; Singapore.
WPR B	Cambodia; China; Cook Islands; Fiji; Kiribati; Lao People's Democratic Republic; Malaysia; Marshall Islands; Micronesia (Federated States of); Mongolia; Nauru; Niue; Palau; Papua New Guinea; Philippines; Republic of Korea; Samoa; Solomon Islands; Tonga; Tuvalu; Vanuatu; Viet Nam.

[1] The subregions are defined on the basis of child and adult mortality as described by Ezzati et al. [15]. Stratum A: very low child and adult mortality, Stratum B: low child mortality and very low adult mortality, Stratum C: low child mortality and high adult mortality, Stratum D: high child and adult mortality, and Stratum E: high child mortality and very high adult mortality. The use of the term 'subregion' here and throughout the text does not identify an official grouping of WHO Member States, and the "subregions" are not related to the six official regions. AFR = African Region; AMR = Region of the Americas; EMR = Eastern Mediterranean Region; EUR = European Region; SEAR = South-East Asia Region; WPR = Western Pacific Region.

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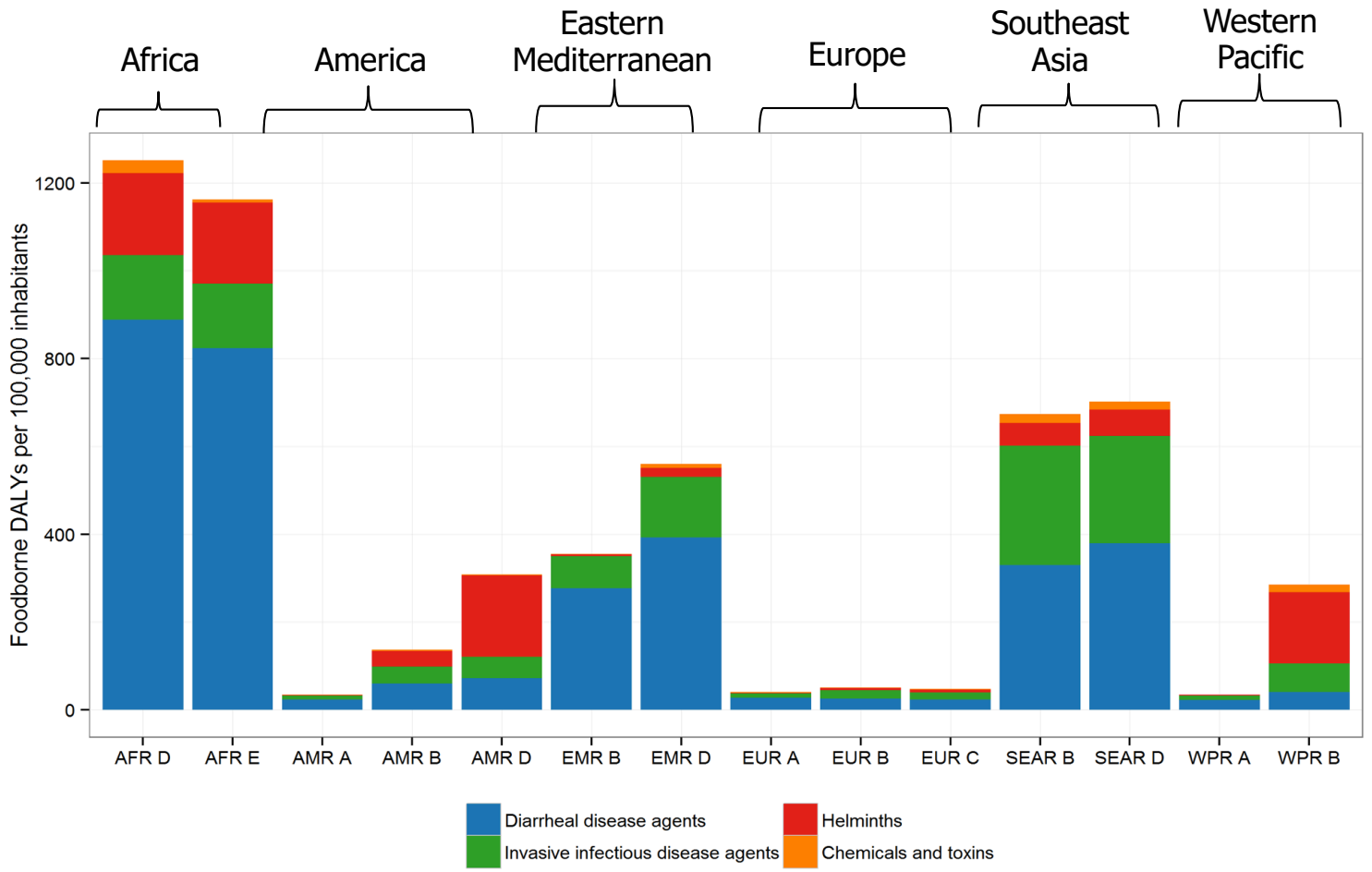
REGIONAL DIFFERENCES



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GLOBAL BURDEN OF ASF

	Burden (DALYs / 100,000)
All foods	477
Animal source foods	168 (35%)
Non-typhoidal *S. enterica*	49
Taenia solium	41
Campylobacter spp.	27
Paragonimus spp.	15
Toxoplasma gondii	9
Clonorchis sinensis	9
Other hazards	< 5

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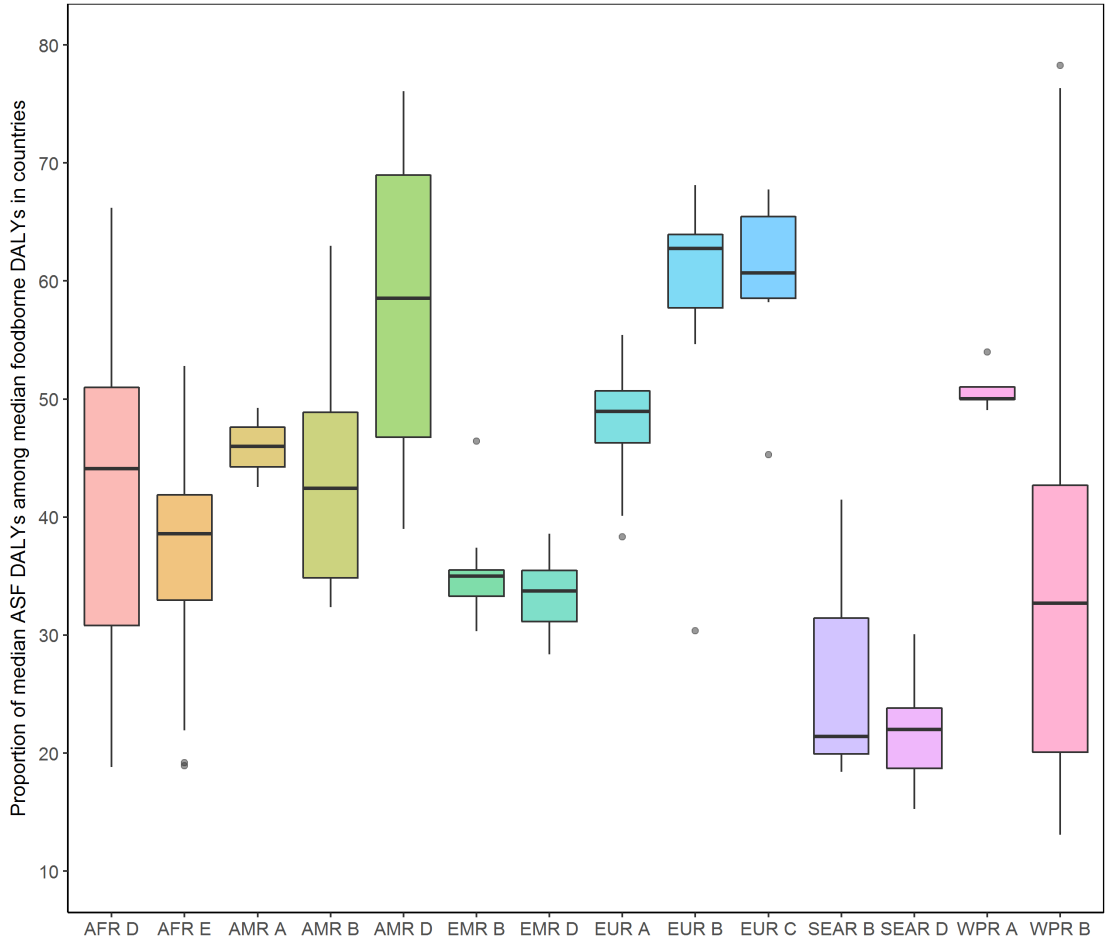
ASF PROPORTION OF FBD IS HIGHLY VARIABLE



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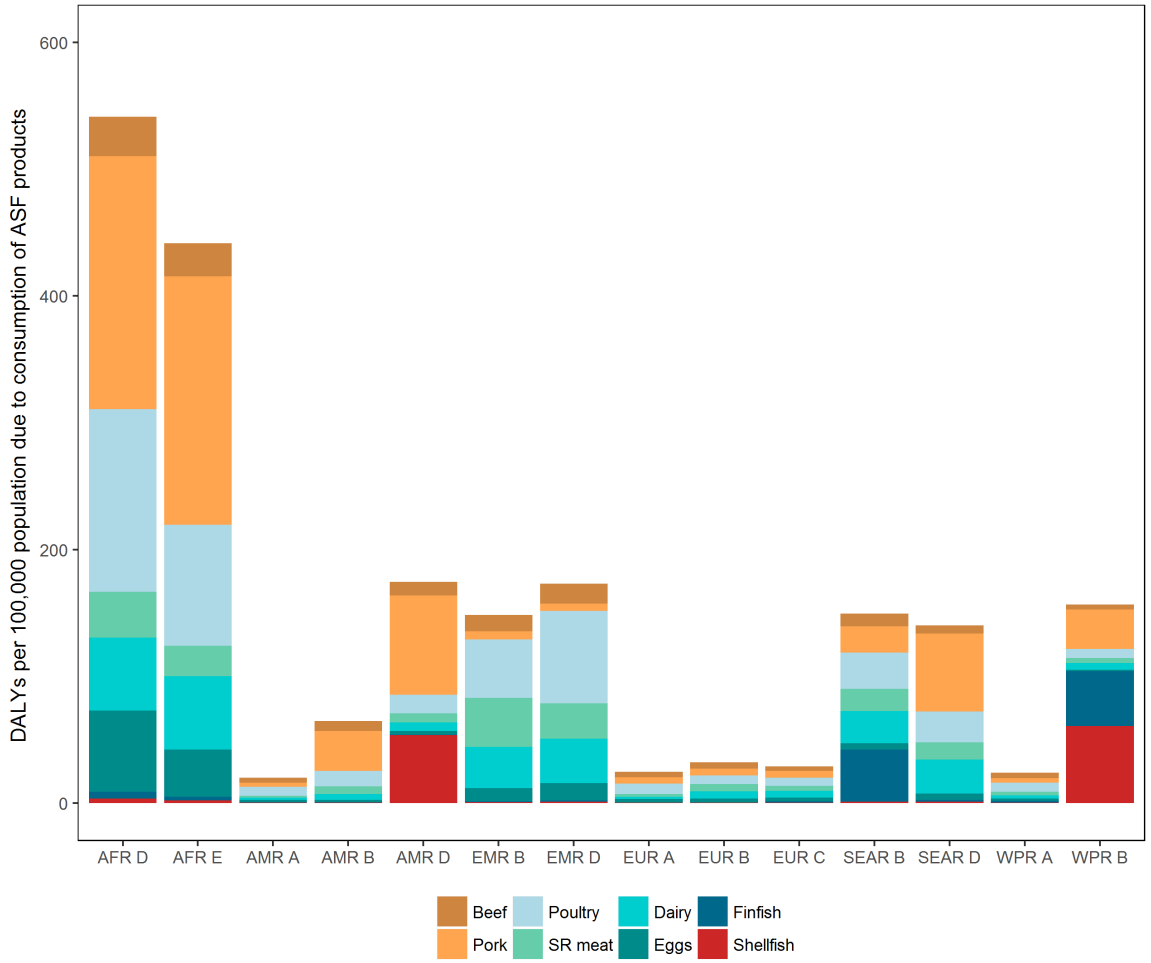
DIFFERENT ASF GROUPS CONTRIBUTE TO THE BURDEN IN DIFFERENT REGIONS



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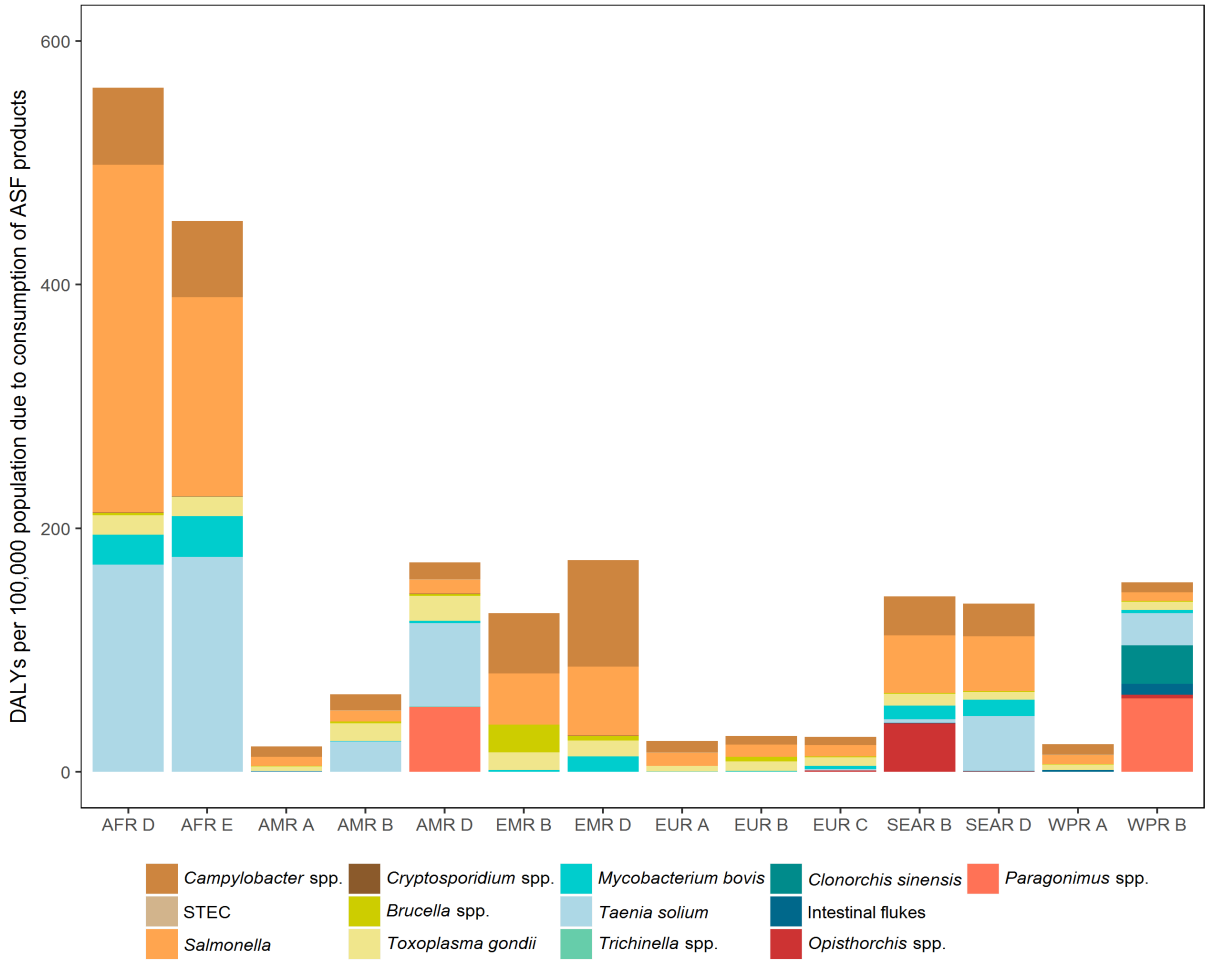
DIFFERENT PATHOGENS CONTRIBUTE TO ASF BURDEN IN DIFFERENT REGIONS



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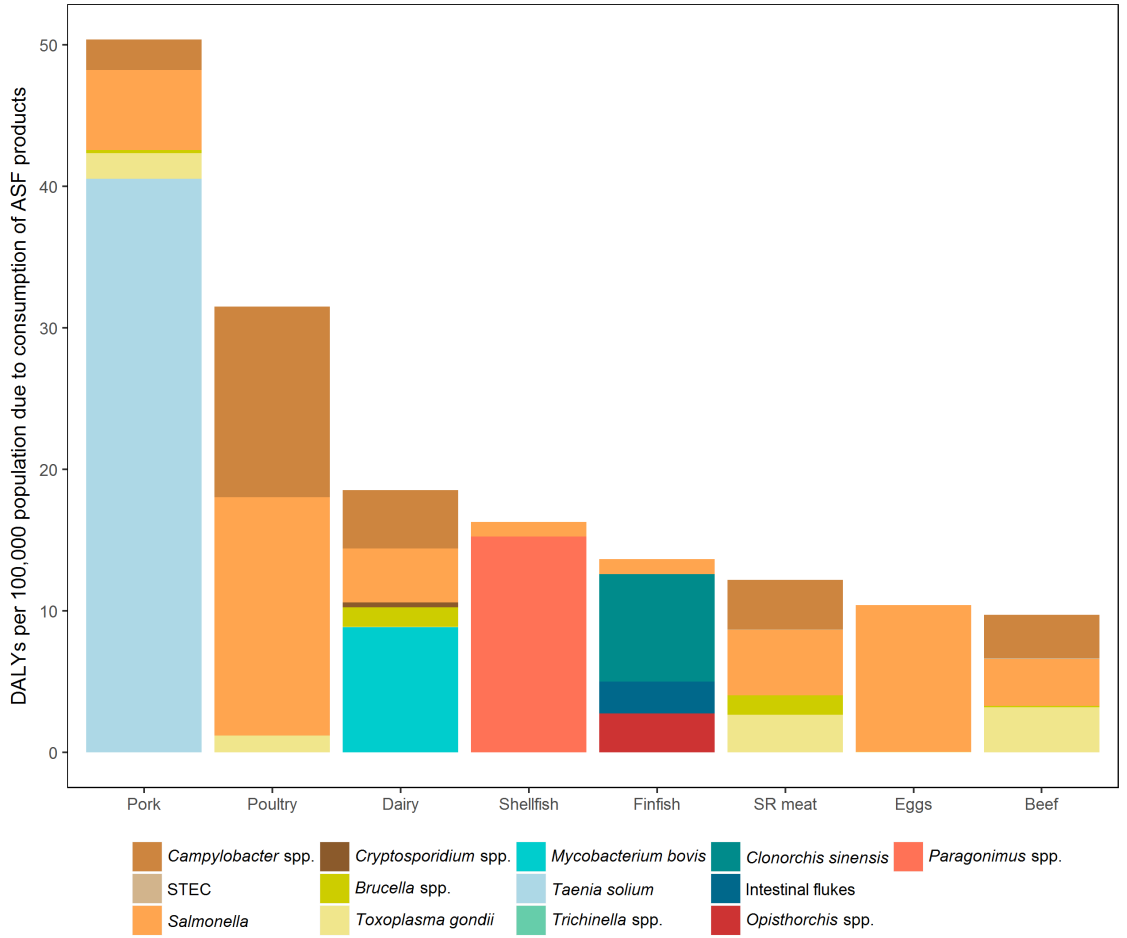
DIFFERENT PATHOGENS CONTRIBUTE TO THE BURDEN OF ASF GROUPS



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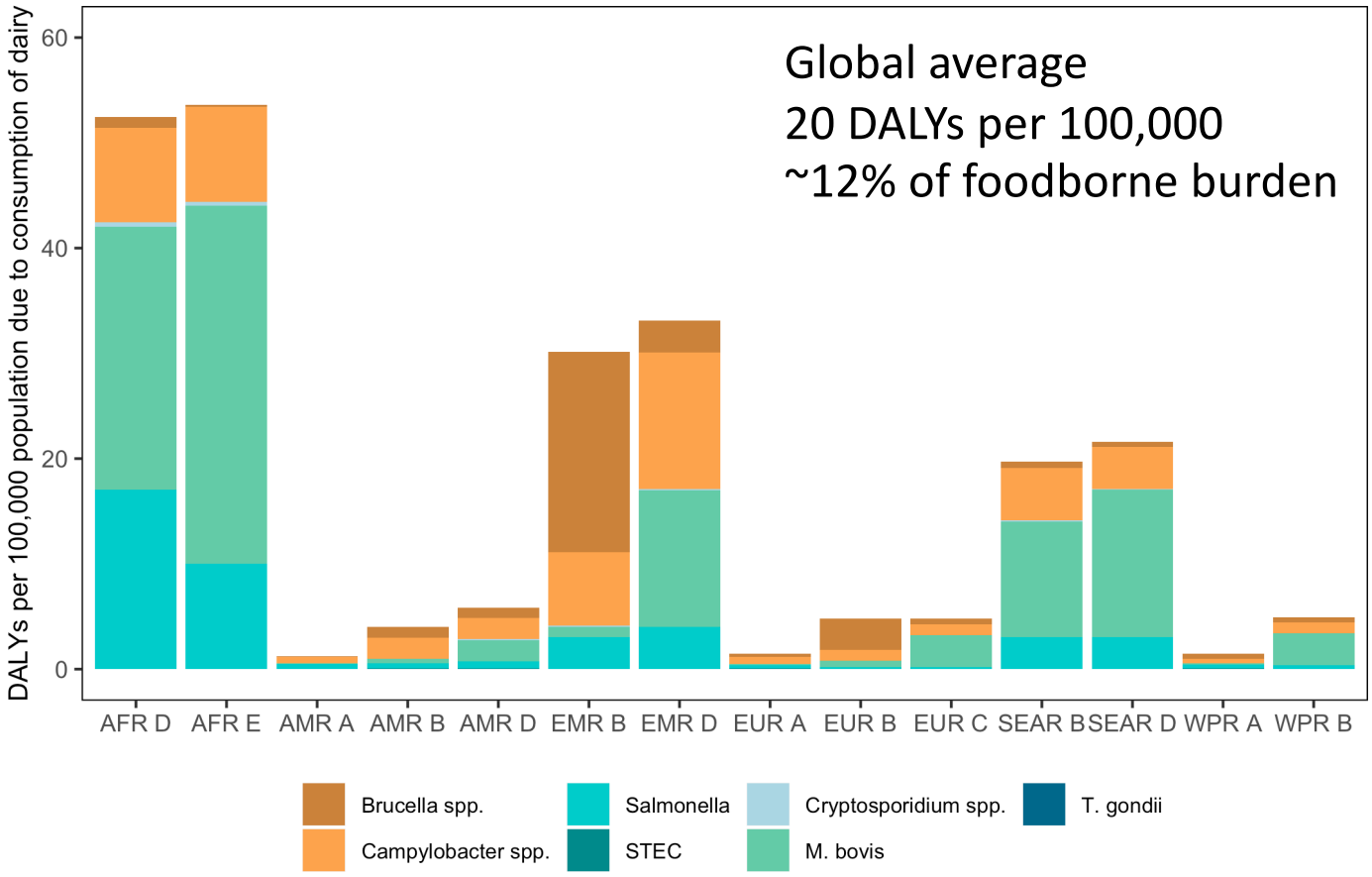
GLOBAL BURDEN OF DAIRY PRODUCTS



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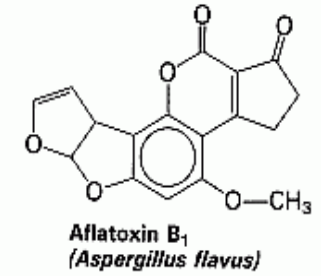
TOXIC CHEMICALS OF POTENTIAL CONCERN

- Dioxins
  - Global burden 3 DALYs/100,000
  - High disease burden in Southeast Asia (14 DALYs/100,000)
  - High levels found in dairy products, meat, fish and shellfish
  - Burden from dairy products not quantified
- Heavy metals
  - Lead, arsenic, methylmercury
  - Global burden of 20-70 DALYs/100,000
  - Contribution of dairy products to human exposure unknown.
- Adulteration (e.g. melamine in infant formula in China)
- Aflatoxin M_1

AFLATOXIN B_1

- Produced by *Aspergillus flavus, A. parasiticus*
  - Maize, peanuts, tree nuts, cottonseed
  - Exposure highest in warm regions where maize & peanuts are dietary staples (Africa, Asia)



Aflatoxin B_1
(Aspergillus flavus)

- Human health effects
  - Liver cancer
    - Synergizes with chronic hepatitis B virus (HBV) infection
    - **25,000-172,000 cases/yr** worldwide caused by aflatoxin (Liu & Wu 2010, Liu et al. 2012)
  - Childhood stunting
  - Acute aflatoxicosis: liver failure & death at high doses
  - Immune system dysfunction

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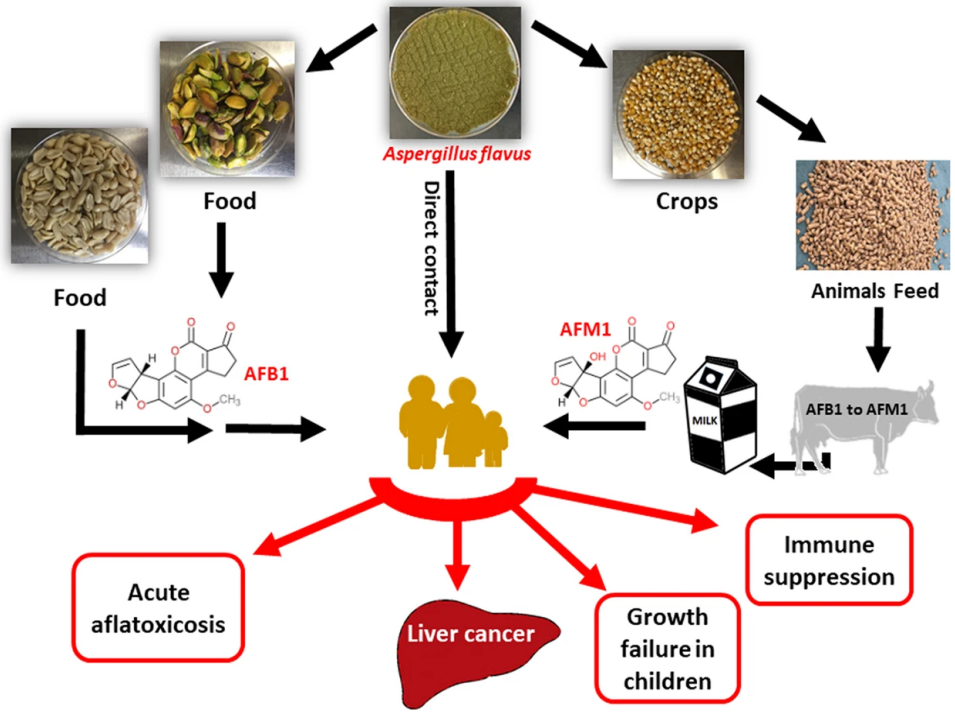
AFLATOXIN M_1 IN MILK

- AFM_1 appears in milk 2-3 days after animal eats AFB_1
- Conversion of AFB_1 in animal feed to AFM_1 in milk: 0.3%-6.2%
- AFM_1 has 10% cancer potency of AFB_1 (JECFA 2001)
- FDA regulates AFM_1 at **0.5 µg/kg** allowable in dairy (EU: 0.05 µg/kg)
- Causes cytotoxicity, & suggestive risk of genotoxicity → IARC classifies as Group 2B carcinogen (possible carcinogen), 2002



Major contamination/exposure routes of AF and health risks to humans (Alshannaq et al. 2018)

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HEALTH EFFECTS OF AFM_1

- **Human studies**
  - *Carcinogenic effect* - Dose-response relationship between serum/urinary AFM1 levels and risk of liver cancer in chronic hepatitis B virus patients in Asia & Africa

- **Animal studies**
  - *Immune effects* in T cells from spleens in the mice exposed to AFM_1
    - Reduced proliferation of splenocytes (lower spleen weight), decreased IFN-y , increased IL-10
  - *Intestinal function disorders* - Increase DNA fragmentation & change gene expression in mice

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OCCURRENCE OF AFM_1 IN DAIRY PRODUCTS WORLDWIDE

Country	Dairy food	Min–Max (µg/kg)
Brazil	Cheese	0.091–0.3
Burundi	Yogurt	**8.2–63.2**
Democratic Republic of Congo	Yogurt	**4.8-26**
	Cheese	**18.5-261.1**
Iran	White cheese	**0.052-0.75**
	Cream cheese	**0.058-0.79**
	Yogurt	n.d-0.087
Kuwait	White cheese	0.024–0.45
Lebanon	Cheese	n.d-0.32
	Yogurt	n.d.
Libya	Cheese	**0.11-0.52**
Pakistan	White cheese	**0.004-0.6**
	Cream cheese	0.004–0.46
	Butter	0.004–0.41
	Yogurt	**0.004-0.62**
Saudi Arabia	Cheese	0.024–0.452
Serbia	Milk products	**0.27-0.95**
Spain	Yogurt	n.d-0.051
	Cheese	n.d.
Turkey	Cheese	0.012–0.38
	Dairy dessert	0.0015–0.08
	Butter	**0.01-7.0**
	Cream cheese	**0-4.1**
	Yogurt	0.01–0.48

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AFM_1 CONTAMINATION IN DIFFERENT TYPES OF BOVINE MILK WORLDWIDE

Country	Type of milk	Min-Max
Brazil	Pasteurized milk	0.01-0.2 µg/L
China	Pasteurized milk	0.023-0.15 µg/L
Croatia	Raw milk	0.006-0.027 µg/L
Egypt	Raw milk	0.023-0.073 µg/L
India	Pasteurized milk	**0.063–1.01 µg/L**
Iran	Pasteurized milk	**0.0056-0.53 µg/L**
Italy	Pasteurized milk	0.005-0.03 µg/L
Japan	Raw milk	0.007–0.13 µg/L
Jordan	Buttermilk	**7.97–2027 ng/kg**
Lebanon	Pasteurized milk	0.001-0.12 µg/L
Morocco	Fresh milk	**0.407–0.95 µg/L**
Nigeria	Skimmed milk	**0.25–2.51 µg/L**
Pakistan	Fresh milk	**0.02-3.09 µg/L**
Portugal	Raw milk	n.d–0.069 µg/L
Saudi Arabia	Pasteurized milk	**0.06-1.2 µg/L**
Serbia	Raw milk	**0.08-1.2 µg/L**
Spain	Raw bulk milk	**0.009-1.36 µg/L**
South Africa	Raw milk	0.002-0.08 µg/L
South Korea	Raw milk	**0.22-6.9 µg/L**
Sudan	Pasteurized milk	**0.008-0.77 µg/L**
Syria	Raw milk	**0.026-2.007 µg/L**
Tanzania	UHT milk	**n.d – 0.544 µg/L**
Turkey	Raw milk	0.011-0.1 µg/L

Of interest: No AFM1 monitoring data publicly available in US dairy foods.

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IMPLICATIONS FOR HUMAN HEALTH FROM AFM_1 EXPOSURE

- AFM_1 in dairy products may cause human health risks, especially for children who consume large quantities of milk and have lower body weight
  - But risk is much lower than that of "parent" aflatoxin (AFB_1) in corn and nuts: not all aflatoxins are created equal!
  - Exposure to AFB1 from other foods much higher than AFM_1 from dairy
- High occurrence of AFM_1 demonstrates need for monitoring in dairy products to reduce risk of toxicity to humans
- Most effective way to prevent AFM_1 in dairy foods: reduce AFB_1 in animal feed
  - Monitor AFB_1 in corn, nuts, & cottonseed fed to dairy animals, or switch to other feed crops with low aflatoxin
- Communication challenge
  - Achieving strict Western standards end goal
  - Benefits of consuming milk far outweigh risks of AFM_1 so consumption should not be discouraged

CONCLUSIONS

- The global burden of unsafe foods is substantial
- Low- and middle-income countries have the highest burden
- Animal-source foods contribute ~ 35% to this burden and dairy products ~ 12%
- Priority ASF groups and pathogens vary by country
- The main pathogens in dairy are *Mycobacterium bovis*, non-typhoidal *Salmonella* spp. and *Campylobacter* spp.
- *Brucella* spp. are of concern in the Eastern Mediterranean region
- The burden of toxic chemicals in dairy products is unquantified
- Aflatoxin M_1 is frequently found in dairy products in low- and middle-income countries at levels exceeding US or EU standards
- The risk of liver cancer from current exposure levels to AFM_1 is likely to be extremely low and the benefits of consuming dairy outweigh these risks
- Managing contamination of animal feed with AFB_1 and pro-active risk communication are necessary

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Questions?

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SOURCE ATTRIBUTION

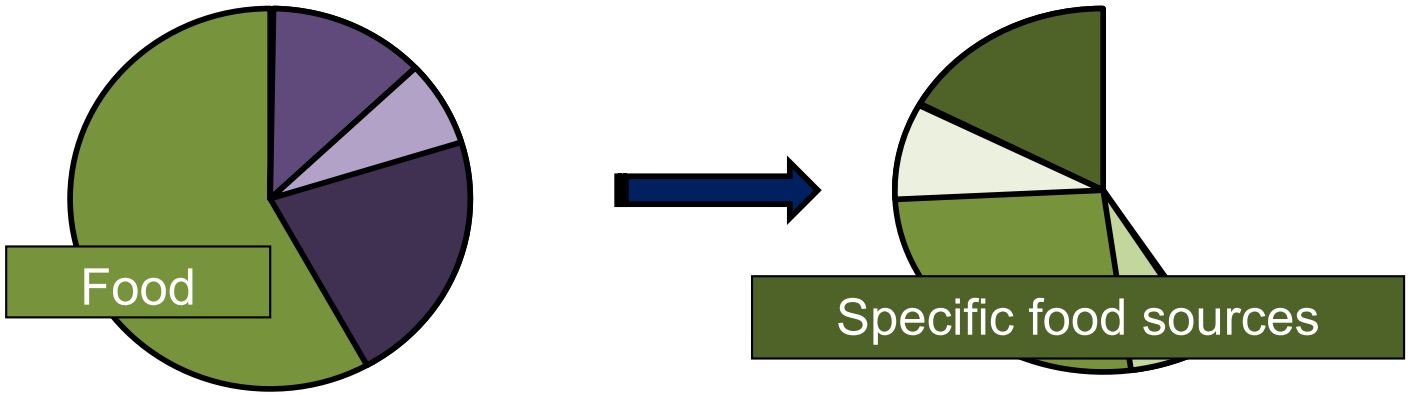
Determine for each hazard the proportion of the disease burden that is attributable to food

Identify – if possible quantify - the reservoirs and/or food commodities leading to illness

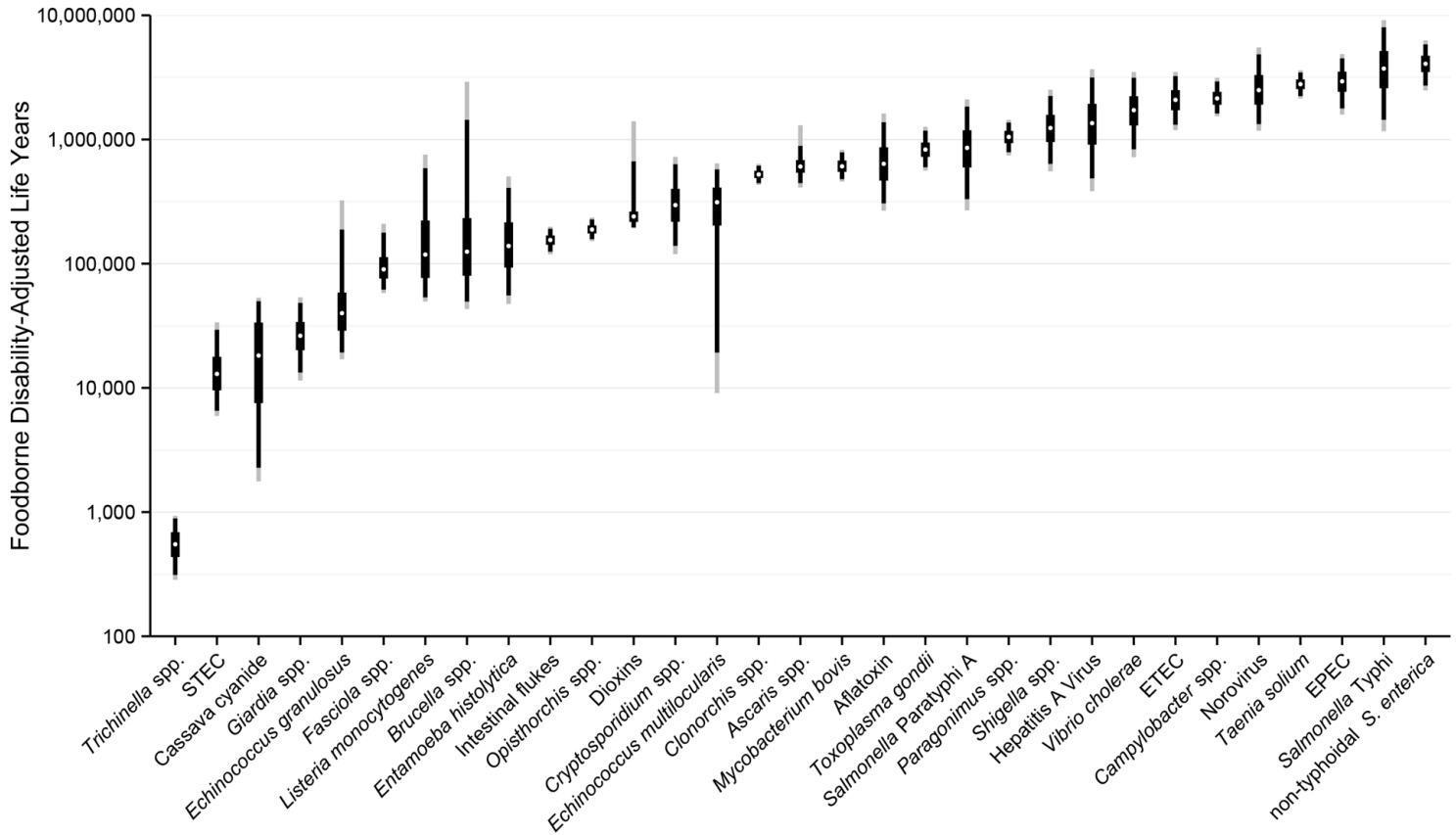
Expert elicitation was applied to all hazards that are not (almost) 100% originating from a single food source/reservoir

Hazards included were prioritised by the thematic task forces

Cooke's classical model (performance-based weights)



RANKING OF FOODBORNE HAZARDS GLOBAL DALYS



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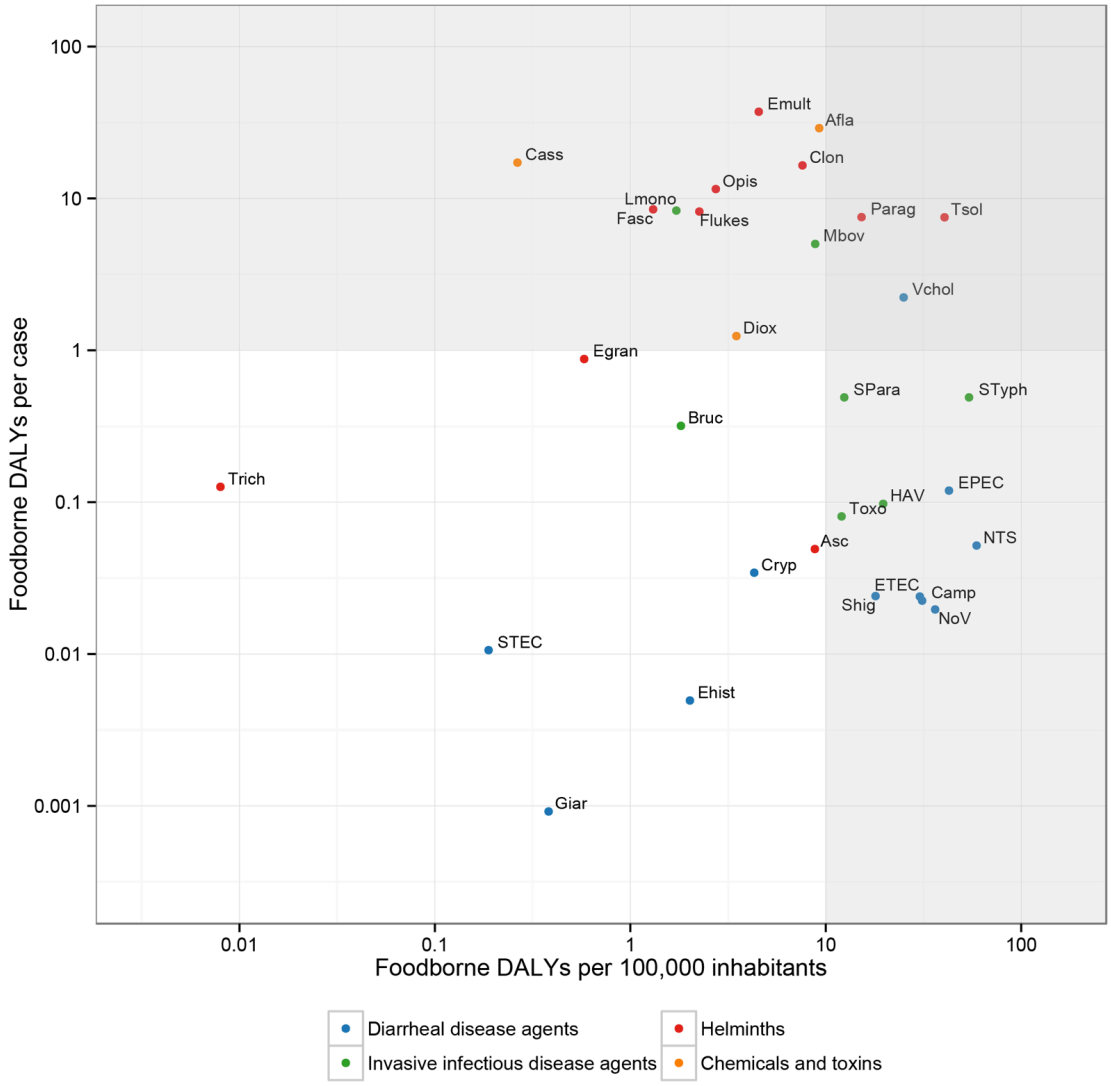
GLOBAL BURDEN AT POPULATION AND INDIVIDUAL LEVEL



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CHILDREN UNDER FIVE YEARS OF AGE …

- … make up 9% of the world population
- … suffer from 38% of all foodborne illnesses
- … succumb to 30% of foodborne deaths
- … bear 40% of global foodborne DALYs

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PEOPLE LIVING IN THE POOREST AREAS OF THE WORLD

…

- … make up 41% of the world population
- … suffer from 53% of all foodborne illnesses
- … succumb to 75% of foodborne deaths
- … bear 72% of global foodborne DALYs

- D and E subregions: high child and high – very high adult mortality

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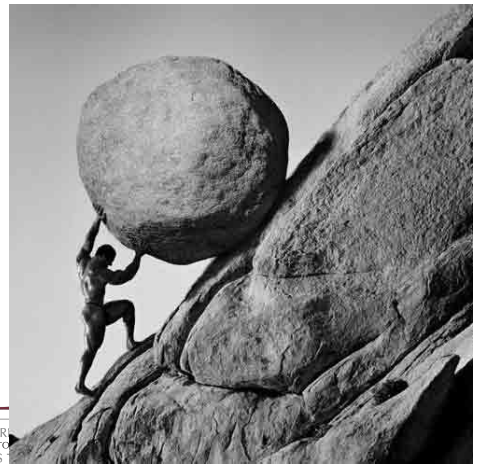
FOODBORNE DISEASE IN HIGH-INCOME COUNTRIES

- High-income countries have largely controlled foodborne deaths
- Foodborne disease incidence in these regions is only 3-4 fold lower than the global average
- Main causes of foodborne disease burden in these regions are non-typhoidal *S. enterica*, *Campylobacter* spp., *Toxoplasma gondii*, norovirus and *Listeria monocytogenes*
- Incidence of foodborne disease due to norovirus in these regions is similar to the global average, but incidence of deaths is much lower
- Safe food requires 100% commitment from all involved in production, distribution and preparation, every day!



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COMPARISON WITH OTHER ESTIMATES

- **FERG Foodborne diseases: 33 million DALYs**
- IHME Global Burden of Disease 2010
  - Dietary risk factors: 254 million DALYs
  - Unimproved water and sanitation: 211 million DALYs
  - HIV/AIDS: 82 million DALYs
  - Malaria: 82 million DALYs
  - Air pollution: 76 million DALYs
  - Tuberculosis 49 million DALYs
- WHO Global Health Observatory 2012
  - HIV/AIDS 92 million DALYs
  - Malaria: 55 million DALYs
  - Tuberculosis: 44 million DALYs

Methodological differences!!

EXPOSURE PATHWAYS

Pathway	*Campylobacter* spp.	Non-typhoidal *S. enterica*	*Mycobacterium bovis*	*Taenia solium*	*Clonorchis sinensis*	*Paragonimus* spp.
All pathways	54	122	9	41	8	15
All food	31	59	9	41	8	15
ASF	27	49	9	41	8	15
Beef	3	3	-	-	-	-
Pork	2	6	-	41	-	-
Poultry	13	17	-	-	-	-
SR meat	3	5	-	-	-	-
Dairy	4	4	9	-	-	-
Eggs	-	10	-	-	-	-
Finfish	-	1	-	-	8	
Shellfish	-	1	-	-	-	15

PATHOGEN – ASF ASSOCIATIONS

Hazards	Animal source foods							
	Beef	Pork	Poultry	SR meat*	Dairy	Eggs	Finfish	Shellfish[1]
Campylobacter spp.	×	×	×	×	×			
Shiga-toxin producing Escherichia coli	×	×		×	×			
Non-typhoidal Salmonella enterica	×	×	×	×	×	×	×	×
Cryptosporidium spp.					×			
Brucella spp.	×	×		×	×			
Mycobacterium bovis					u			
Toxoplasma gondii	×	×	×	×	×	×		
Taenia solium		u						
Trichinella spp.		u[2]						
Clonorchis sinensis							u	
Intestinal flukes							u[3]	
Opisthorchis spp.							u	
Paragonimus spp.								u