PARMA SUMMER SCHOOL

26 – 28 SEPTEMBER 2023

Innovative food products

Risks-Benefits assessment of the substitution of beef by insects in burgers in Europe

Dr. Géraldine Boué, Associate professor at ONIRIS / INRAE, France

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Content

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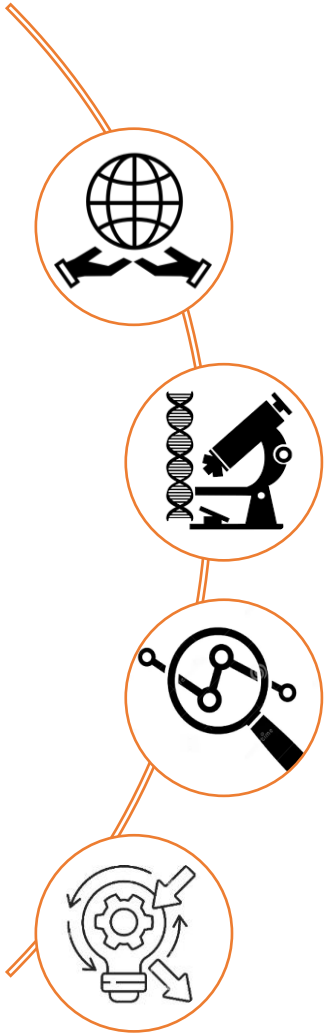

- Introduction
- Model structure and simulation
- Food intake estimates
- Individual Risks and benefits assessments:
  - Nutrition
  - Toxicology
  - Microbiology
- Health impact estimate and scenarios comparison
- Main limitations and conclusions

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Introduction

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NovRBA Risk Benefit Assessment

- **NovRBA Project, 2019-2022, Novel foods as red meat replacers -** an insight using Risk Benefit Assessment methods
- **Knowledge exchange grant, EFSA-Q-2022-00244**
- **Partnairs:Coordinated by Prof. Androniki Naska (NKUA)**
  - **NKUA (Greece),** School of Medicine of the National and Kapodistrian University of Athens, including Ermolaos Ververisis as part of his PhD thesis
  - **INRAE (France)** National Research Institute for Agriculture, Food and the Environment
  - **DTU (Denmark)** National Food Institute
  - **BfR (Germany)** German Federal Institute for Risk Assessment

HELLENIC REPUBLIC
National and Kapodistrian University of Athens
EST. 1837

INRAE

DTU

BfR
Bundesinstitut für Risikobewertung

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Introduction

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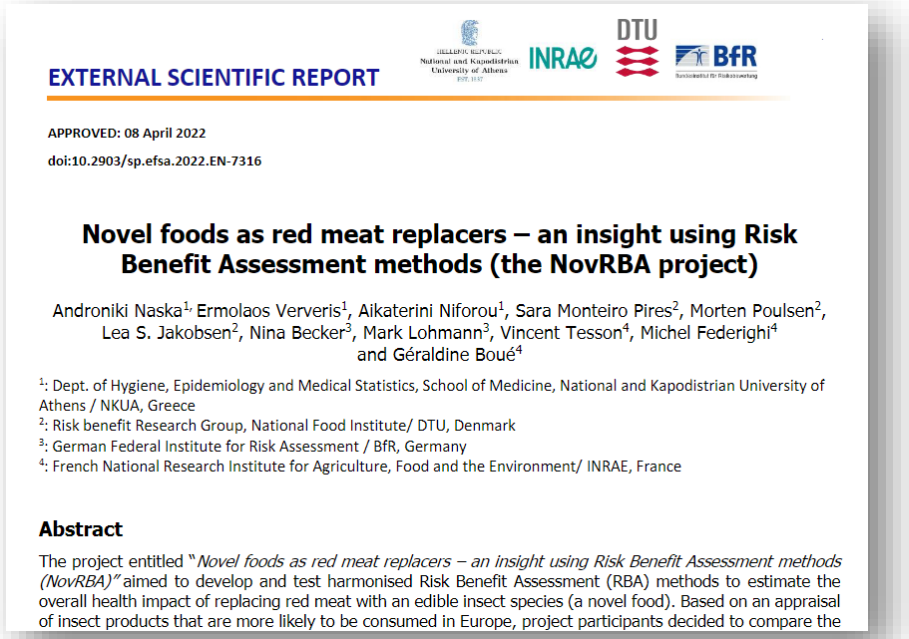
- **Report available – EFSA Journal 2022;19(5):EN-7316**
- **Main content:**
  - The RBA case study on Insect burger
  - Methodological improvements in RBA
  - RBA communication



EXTERNAL SCIENTIFIC REPORT

APPROVED: 08 April 2022

doi:10.2903/sp.efsa.2022.EN-7316

Novel foods as red meat replacers – an insight using Risk Benefit Assessment methods (the NovRBA project)

Androniki Naska[1], Ermolaos Ververis[1], Aikaterini Niforou[1], Sara Monteiro Pires[2], Morten Poulsen[2], Lea S. Jakobsen[2], Nina Becker[3], Mark Lohmann[3], Vincent Tesson[4], Michel Federighi[4] and Géraldine Boué[4]

[1]: Dept. of Hygiene, Epidemiology and Medical Statistics, School of Medicine, National and Kapodistrian University of Athens / NKUA, Greece
[2]: Risk benefit Research Group, National Food Institute/ DTU, Denmark
[3]: German Federal Institute for Risk Assessment / BfR, Germany
[4]: French National Research Institute for Agriculture, Food and the Environment/ INRAE, France

Abstract

The project entitled "*Novel foods as red meat replacers – an insight using Risk Benefit Assessment methods (NovRBA)*" aimed to develop and test harmonised Risk Benefit Assessment (RBA) methods to estimate the overall health impact of replacing red meat with an edible insect species (a novel food). Based on an appraisal of insect products that are more likely to be consumed in Europe, project participants decided to compare the

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Introduction

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Objective:

To design and implement RBA models to estimate the overall health impact of red meat replacement by the identified insect species

- **Assess the consumers' exposure** to the selected components (nutrients + microbial and toxicological hazards) for reference (beef patty) and alternative (*Acheta domesticus* powder) scenarios
- **Develop and implement a RBA model** to estimate the overall health impact of this substitution to compare scenarios

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MODEL STRUCTURE AND SIMULATION

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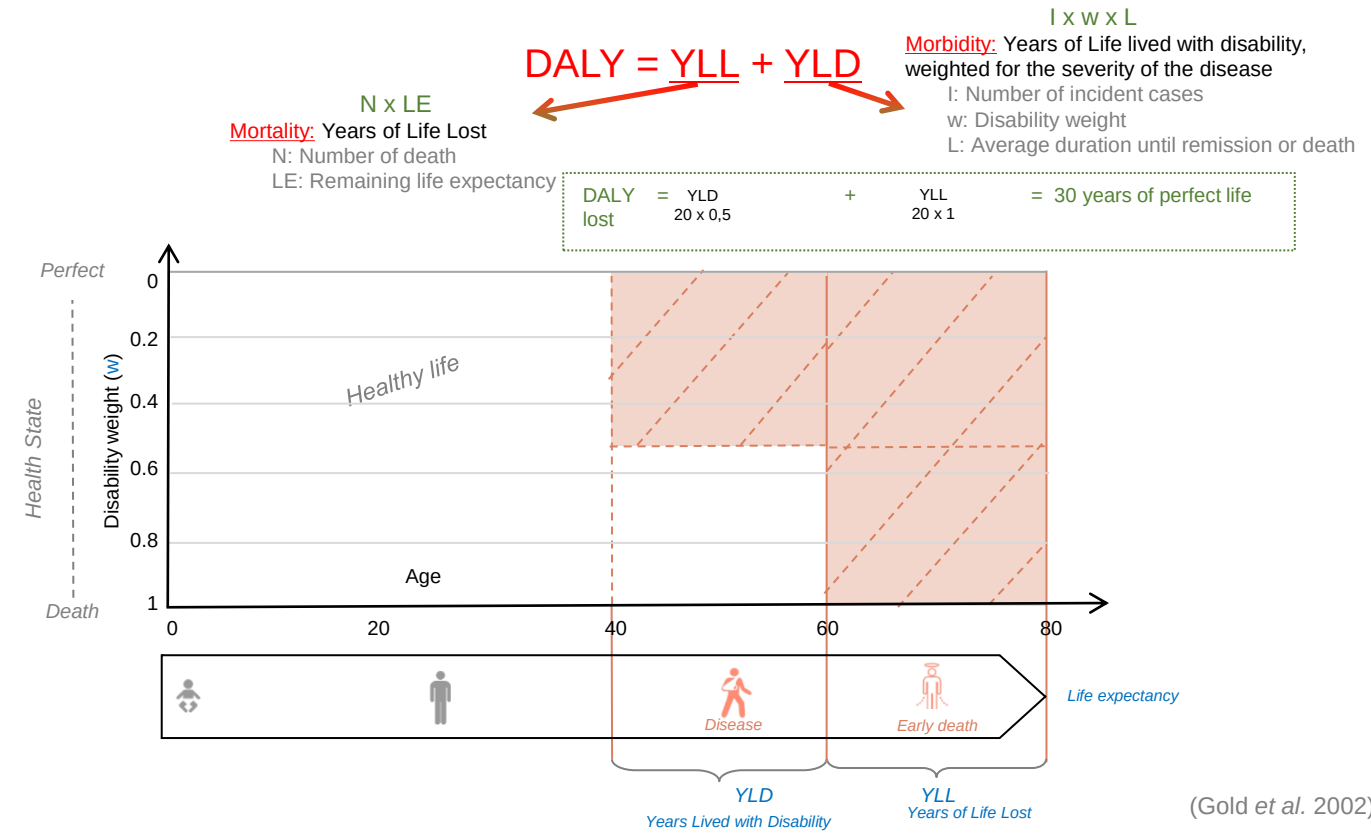
- **Main output = Number of cases per disease and DALY** when moving from reference to alternative scenarios, due to health outcomes associated to the following components, in Greece, France and Denmark

DALY = Disability adjusted life year

1 DALY ≈ 1 year of perfect health lost



(Gold *et al.* 2002)

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MODEL STRUCTURE AND SIMULATION

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❑ Components identification:

- Insects (Novel Food): systematic literature search
- Beef (Traditional food): Key reviews, databases and reports for beef

Journal of Food Composition and Analysis 114 (2022) 104859

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

A systematic review of the nutrient composition, microbiological and toxicological profile of *Acheta domesticus* (house cricket)

Ermolaos Ververis [a,b,*], Géraldine Boué [c,d], Morten Poulsen [e], Sara Monteiro Pires [e], Aikaterini Niforou [a], Sofie Theresa Thomsen [e], Vincent Tesson [c,d], Michel Federighi [c,d],

Nutrients			Microbiological hazards		Chemical hazards	
Crickets and beef			Crickets	Beef	Crickets	Beef
Macronutrients:	**Vitamins:**	**Sterols:**	**Bacteria:**	**Bacteria:**	**POPs:**	**POPs:**
Carbohydrates	Folate	Cholesterol	*B. Cereus*	*B. Cereus*	Total PCB (organochlorine	Total PCB
Fiber	Niacin	**Amino acids:**	*Campylobacter spp.*	*Campylobacter spp.*	compounds)	Dioxin + dl-
Fiber IDF (insoluble)	Pantothenic acid	Alanine	*C. Botulinum*	*C. botulinum*	Phosphorous flame	
Fiber SDF (soluble)	Retinol	Cystine/cysteine	*C. perfringens*	*Escherichia coli*	retardants (PFR,	
Minerals:		Histidine*		*sakazakii*	organochlorine	
Aluminum		Lysine*		*EHEC*		ene, dieldrin,
Calcium		Methionine*		*Listeria monocytogenes*		ane, DDT)
Chloride	Pyridoxine	Phenylalanine*		*Salmonella*		**Metals:**
Chromium	Vitamin C	Tryptophan*		*S. aureus (rare, human origin)*		(Methyl)mercury
Copper	Vitamin D3 (Cholecalciferol)			*Yersinia enterocolitica*		Cadmium
Iodine	Vitamin E			**Virus:**		Lead
Iron	(alpha-Tocopherol)			*Hepatitis E*		Inorganic arsenic
Magnesium	**Fatty acids:**			*Norovirus (human origin)*		Aluminum
Manganese	Total MUFAs			*Rotavirus (human origin)*		Nickel
Potassium	Total PUFAs			**Parasites:**		Chromium
Selenium	Total n-3 fatty acids			Cryptosporidium spp. (veals)		**Pesticides:**
Sodium	Total n-6 fatty acids			Toxoplasma gondii		[organochlorine compounds
Sulfur	Total SFA					listed above]
Zinc						**Neoformed compounds or process contaminants:**
					(presence of 10 pesticides)	PAH

41 Nutrients

18 Microorganims

14 Chemicals

MODEL STRUCTURE AND SIMULATION

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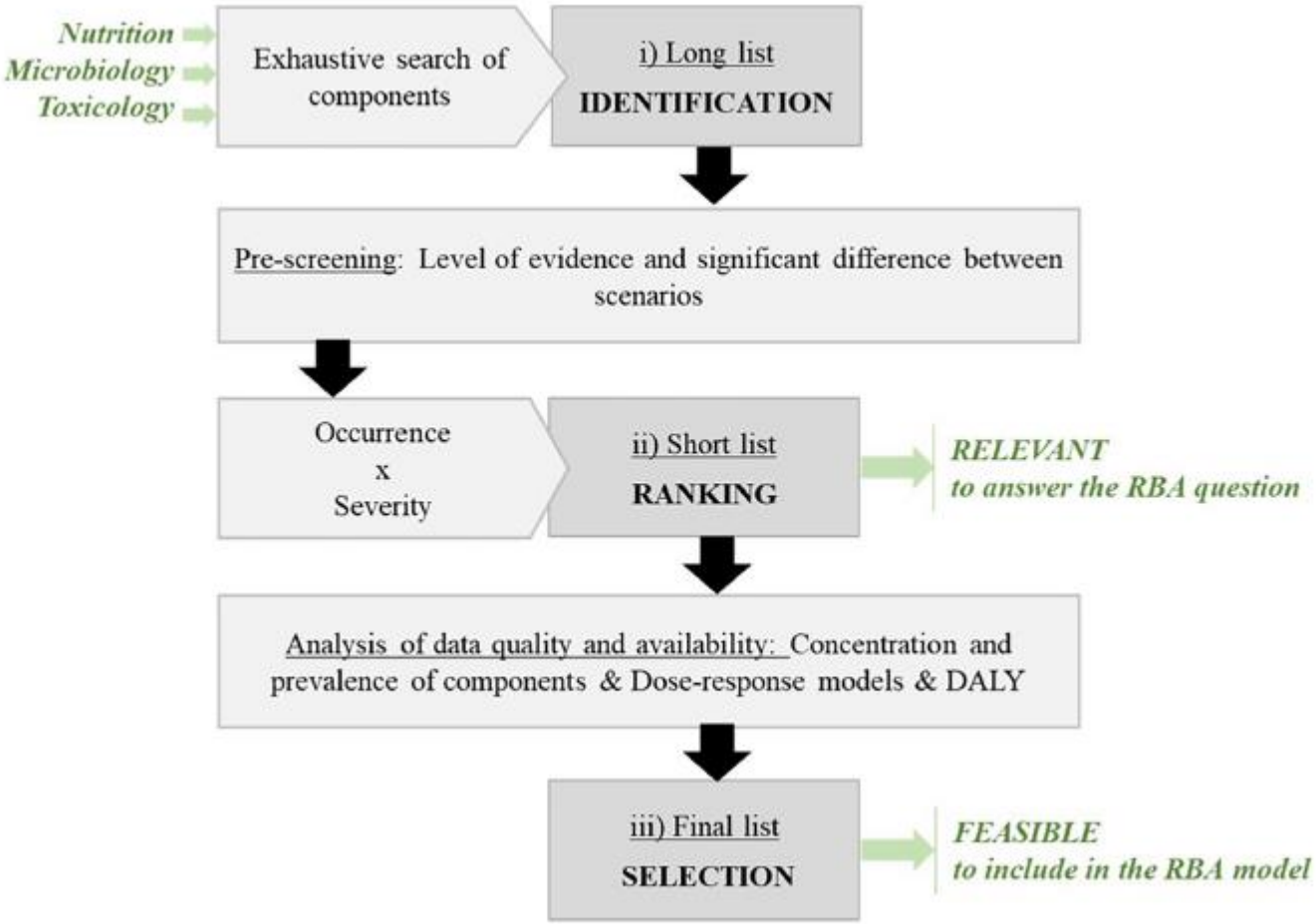
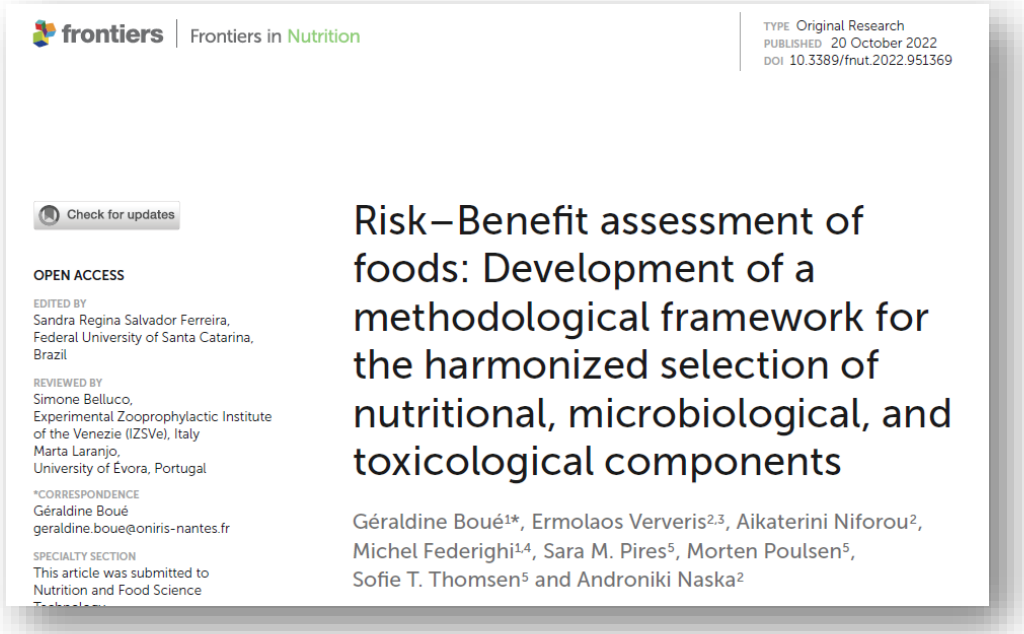
NovRBA Risk Benefit Assessment

❑ **Components selection**:




frontiers | Frontiers in Nutrition

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SPECIALTY SECTION
This article was submitted to Nutrition and Food Science

Risk–Benefit assessment of foods: Development of a methodological framework for the harmonized selection of nutritional, microbiological, and toxicological components

Géraldine Boué[1]*, Ermolaos Ververis[2,3], Aikaterini Niforou[2], Michel Federighi[1,4], Sara M. Pires[5], Morten Poulsen[5], Sofie T. Thomsen[5] and Androniki Naska[2]

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MODEL STRUCTURE AND SIMULATION

NovRBA Risk Benefit Assessment

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❑Final list of components to be included in the RBA

Nutrients			Microbiological hazards		Chemical hazards	
Crickets and beef			Crickets	Beef	Crickets	Beef
Macronutrients:	**Vitamins:**	**Sterols:**	**Bacteria:**	**Bacteria:**	**POPs:**	**POPs:**
Carbohydrates	Folate	Cholesterol	*B. Cereus*	*B. Cereus*	Total PCB (organochlorine	Total PCB
Fiber	Niacin	**Amino acids:**	*Campylobacter spp.*	*Campylobacter spp.*	compounds)	Dioxin + dl-PCBs
Fiber IDF (insoluble)	Pantothenic acid	Alanine	*C. Botulinum*	*C. perfringens*	Phosphorous flame	Organochlorine compounds
Fiber SDF (soluble)						
Minerals:						
Aluminum						
Calcium						
Chloride						
Chromium						
Copper						
Iodine						
Iron						
Magnesium						
Manganese						
Potassium						
Selenium						
Sodium						
Sulfur						
Zinc						

SHORT LIST

Nutrients		Microbiological hazards		Chemical hazards	
AD	Beef	AD	Beef	AD	Beef
Calcium	Iron	*Bacillus Cereus*	*Clostridium perfringens*	Inorganic arsenic	PAH
Copper	Niacin,	*Clostridium Botulinum*	*Campylobacter* spp.		
Fiber (including chitin)	Selenium	*Clostridium perfringens*	*Listeria monocytogenes*		
Iron	Sodium	*Cronobacter sakazakii*	*Salmonella* spp.		
Magnesium	Total saturated fatty acids	*Listeria monocytogenes*	*S. aureus* (enterotox		
Selenium	Thiamin Cyanocobalamin	*Salmonella* spp.	*Toxoplasma gondii*		
Sodium	Vitamin D3	*S. aureus* (enterotoxin)			
Total n-3 fatty acids	Zinc				
Total n-6 fatty acids					
Zinc					

FINAL LIST

Nutrients	Microbiological hazards		Chemical hazards	
AD and beef	AD	Beef	AD	Beef
Calcium	*Bacillus Cereus*	*Clostridium*	/	Inorganic
Fiber, insoluble	*Clostridium*	*perfringens*		arsenic
fiber	*perfringens*	*Salmonella* spp.		
Iron	*Cronobacter*	*Toxoplasma*		
Magnesium	*sakazakii*	*gondii*		
Sodium	*Listeria*			
Vitamin B12	*monocytogenes*			
Zinc	*Salmonella* spp.			

(From Boué, G., Ververis, ... & Naska, A. (2022). Risk–Benefit assessment of foods: Development of a methodological framework for the harmonized selection of nutritional, microbiological, and toxicological components. Frontiers in Nutrition, 9.)

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MODEL STRUCTURE AND SIMULATION

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❑Model split as a modular process

Level of components in beef patty and AD powder
- Nutrition: [mg/g]
- Toxicology: [µg/g]
- Microbiology: [cfu/g]

X

Beef patties intake and estimate of substitution by AD patty
[g/day]

Exposure assessment
- Nutrition: [mg/day]
- Toxicology: [µg/kg bw day]
- Microbiology: [cfu/day]

Dose-response
- Nutrition: epidemiological DR
- Toxicology: epidemiologal DR
- Microbiology: source attribution and using predictive microbiology

Risk Characterization
[+/- number of case/year]

Health Impact
[+/-DALY per year per country]

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MODEL STRUCTURE AND SIMULATION

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- **Monte Carlo simulations on @Risk, Version 7.6**

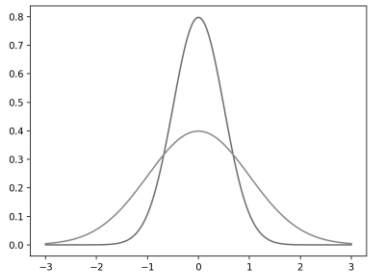
- **Main sources of variations considered in calculations:**

1st

EXPOSURE ASSESSMENT

VARIABILITY

- Percentage of pure beef in patty
- Individual food intake
- Food nutritional composition
- Concentration of hazards in food when contaminated



2nd

DALY ESTIMATE

UNCERTAINTY

- Dose-responses
- Incidence of disease
- DALY/case

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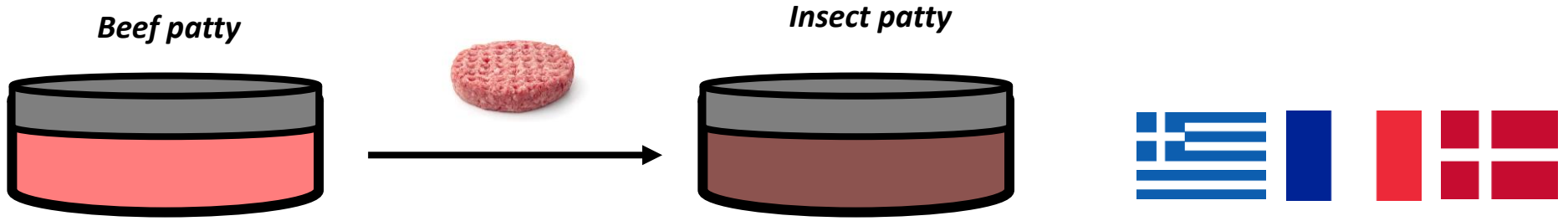
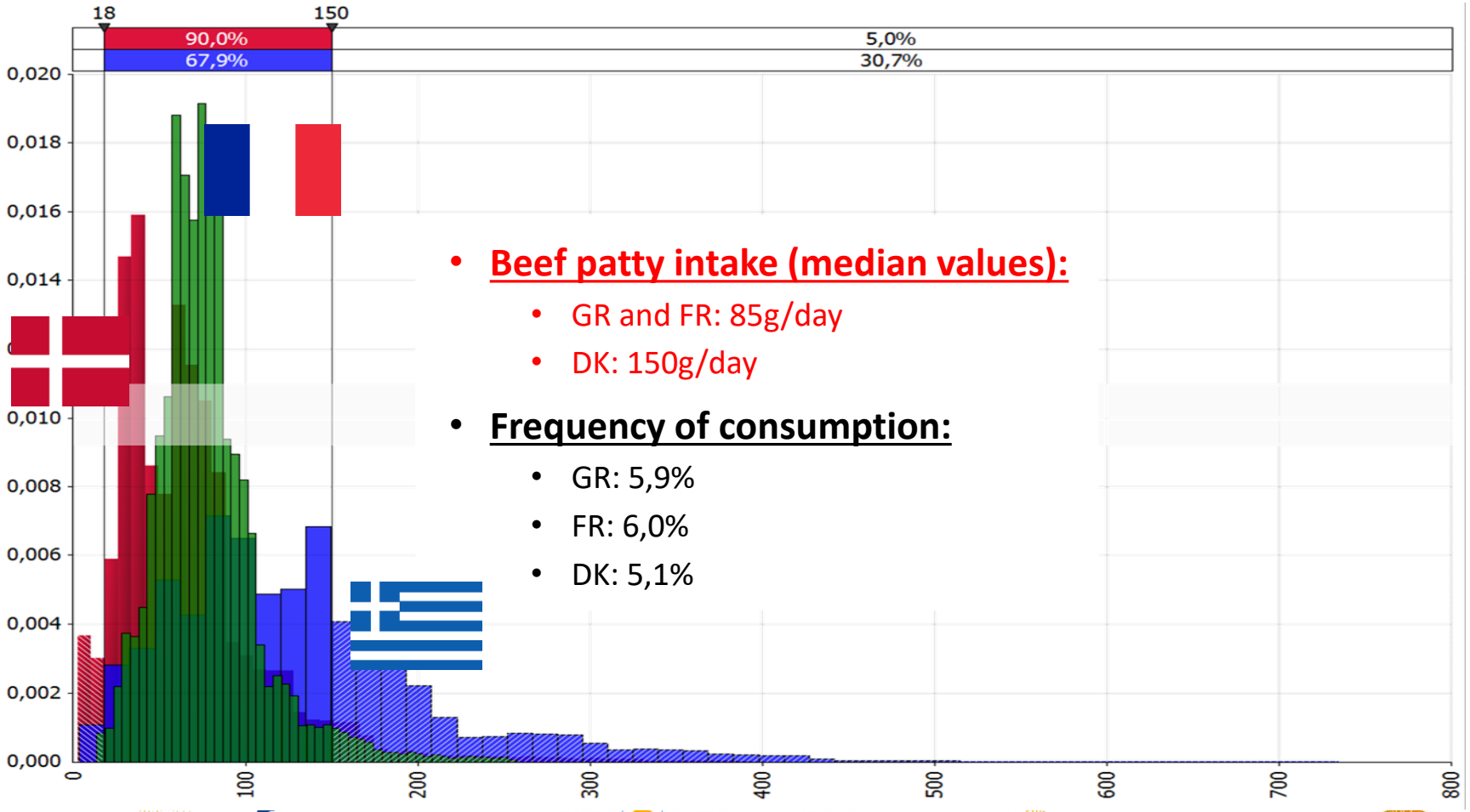
FOOD INTAKE ESTIMATE

- **Reference scenario:** Beef patty consumption data from national dietary surveys of each country
  - Assumption that 150g of beef patty contains between 100 and 150g of pure beef
- **Alternative scenario:** Insect powder consumption estimations
  - Iso-weight substitution with rehydrated insect powder
  - Ratio of rehydration assumed to be 35:65 powder to water, to provide a suitable texture for replacement
  - The powders used derive from a process including a boiling step for 5 minutes at 100°C



FOOD INTAKE ESTIMATE

NovRBA Risk Benefit Assessment



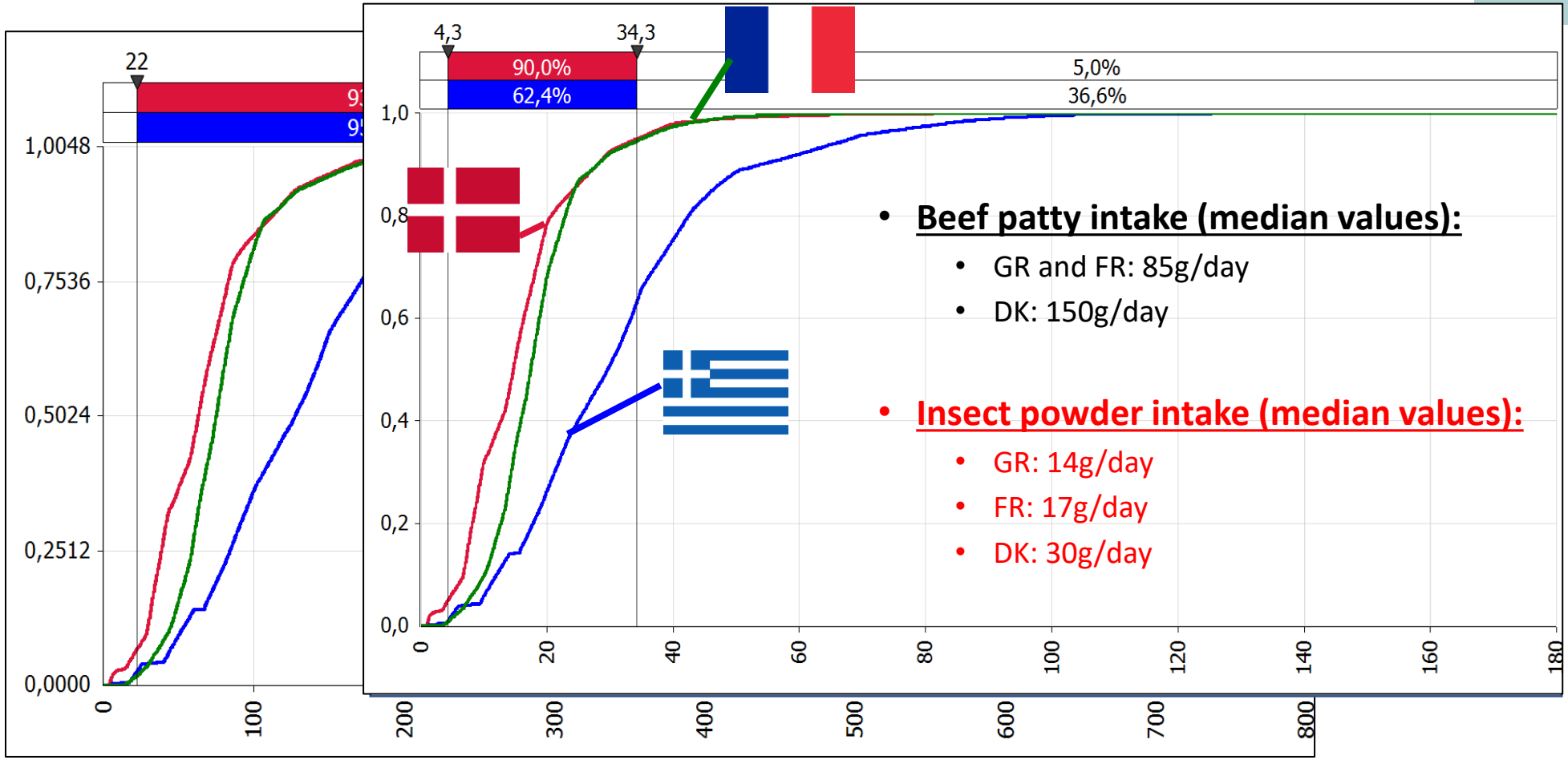
- **Beef patty intake (median values):**
  - GR and FR: 85g/day
  - DK: 150g/day
- **Frequency of consumption:**
  - GR: 5,9%
  - FR: 6,0%
  - DK: 5,1%

Figure: Beef patty intake (g/day)

Greece in red, France in green and Denmark in blue

FOOD INTAKE ESTIMATE

NovRBA Risk Benefit Assessment



- **Beef patty intake (median values):**
  - GR and FR: 85g/day
  - DK: 150g/day
- **Insect powder intake (median values):**
  - GR: 14g/day
  - FR: 17g/day
  - DK: 30g/day

Figure: Cumulative distribution of beef and AD patty intake (g/day)

Greece in red, France in green and Denmark in blue

INDIVIDUAL RISKS AND BENEFITS ASSESSMENTS

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NovRBA Risk Benefit Assessment

Nutrition

- **Exposure assessment** = Food intake x Nutrient concentration

INCREASE		GREECE		DENMARK		FRANCE	
		Ref scenario	Alt scenario	Ref scenario	Alt scenario	Ref scenario	Alt scenario
Calcium	mg/day	7.38	28.22	14.85	56.75	8.62	32.95
Copper	mg/day	0.05	0.57	0.09	1.14	0.05	0.66
Crude fiber	g/day	0.00	1.15	0.00	2.32	0.00	1.35
Iron	mg/day	1.71	1.02	3.45	2.05	2.00	1.19
Magnesium	mg/day	13.66	17.61	27.46	35.38	15.94	20.55
Selenium	mg/day	0.01	0.01	0.01	0.02	0.01	0.01
Sodium	mg/day	40.96	36.01	82.30	72.41	47.77	42.03
Total n-3 fatty acids	g/day	0.06	0.01	0.12	0.02	0.07	0.01
Total n-6 fatty acids	g/day	0.16	0.18	0.33	0.36	0.19	0.21
Total polyunsaturated fatty acids	g/day	0.30	0.64	0.61	1.28	0.35	0.74
Total saturated fatty acids	g/day	3.08	1.01	6.19	2.03	3.60	1.18
Vitamin B12 (Cyanocobalamin)	mg/day	0.001	0.000	0.003	0.000	0.002	0.000
Zinc	mg/day	3.04	2.74	6.11	5.50	3.54	3.19

Uniform distributions between MIN and MAX collected for:

- Raw minced beef: FR and DK composition databases
- AD powder: International scientific literature

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INDIVIDUAL RISKS AND BENEFITS ASSESSMENTS

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Nutrition

- **Exposure assessment** = Food intake x Nutrient concentration

DECREASE		GREECE		DENMARK		FRANCE	
		Ref scenario	Alt scenario	Ref scenario	Alt scenario	Ref scenario	Alt scenario
Calcium	mg/day	7.38	28.22	14.85	56.75	8.62	32.95
Copper	mg/day	0.05	0.57	0.09	1.14	0.05	0.66
Crude fiber	g/day	0.00	1.15	0.00	2.32	0.00	1.35
Iron	mg/day	1.71	1.02	3.45	2.05	2.00	1.19
Magnesium	mg/day	13.66	17.61	27.46	35.38	15.94	20.55
Selenium	mg/day	0.01	0.01	0.01	0.02	0.01	0.01
Sodium	mg/day	40.96	36.01	82.30	72.41	47.77	42.03
Total n-3 fatty acids	g/day	0.06	0.01	0.12	0.02	0.07	0.01
Total n-6 fatty acids	g/day	0.16	0.18	0.33	0.36	0.19	0.21
Total polyunsaturated fatty acids	g/day	0.30	0.64	0.61	1.28	0.35	0.74
Total saturated fatty acids	g/day	3.08	1.01	6.19	2.03	3.60	1.18
Vitamin B12 (Cyanocobalamin)	mg/day	0.001	0.000	0.003	0.000	0.002	0.000
Zinc	mg/day	3.04	2.74	6.11	5.50	3.54	3.19

Uniform distributions between MIN and MAX collected for:

- Raw minced beef: FR and DK composition databases
- AD powder: International scientific literature

ITÀ A

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INDIVIDUAL RISKS AND BENEFITS ASSESSMENTS

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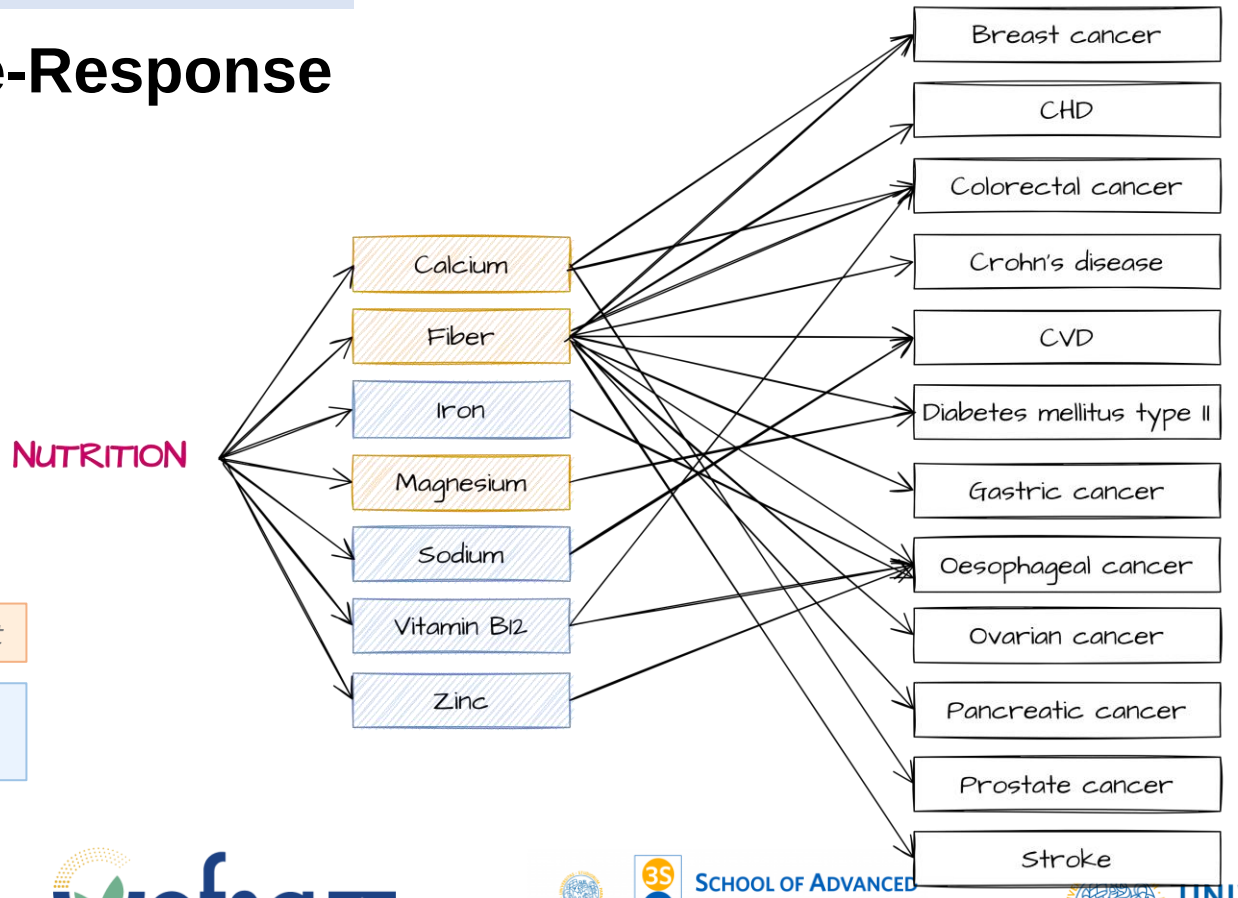
Nutrition

- **Dose-Response**



Epidemiological dose-responses

Increase: Ref->Alt

Decrease: Ref->Alt

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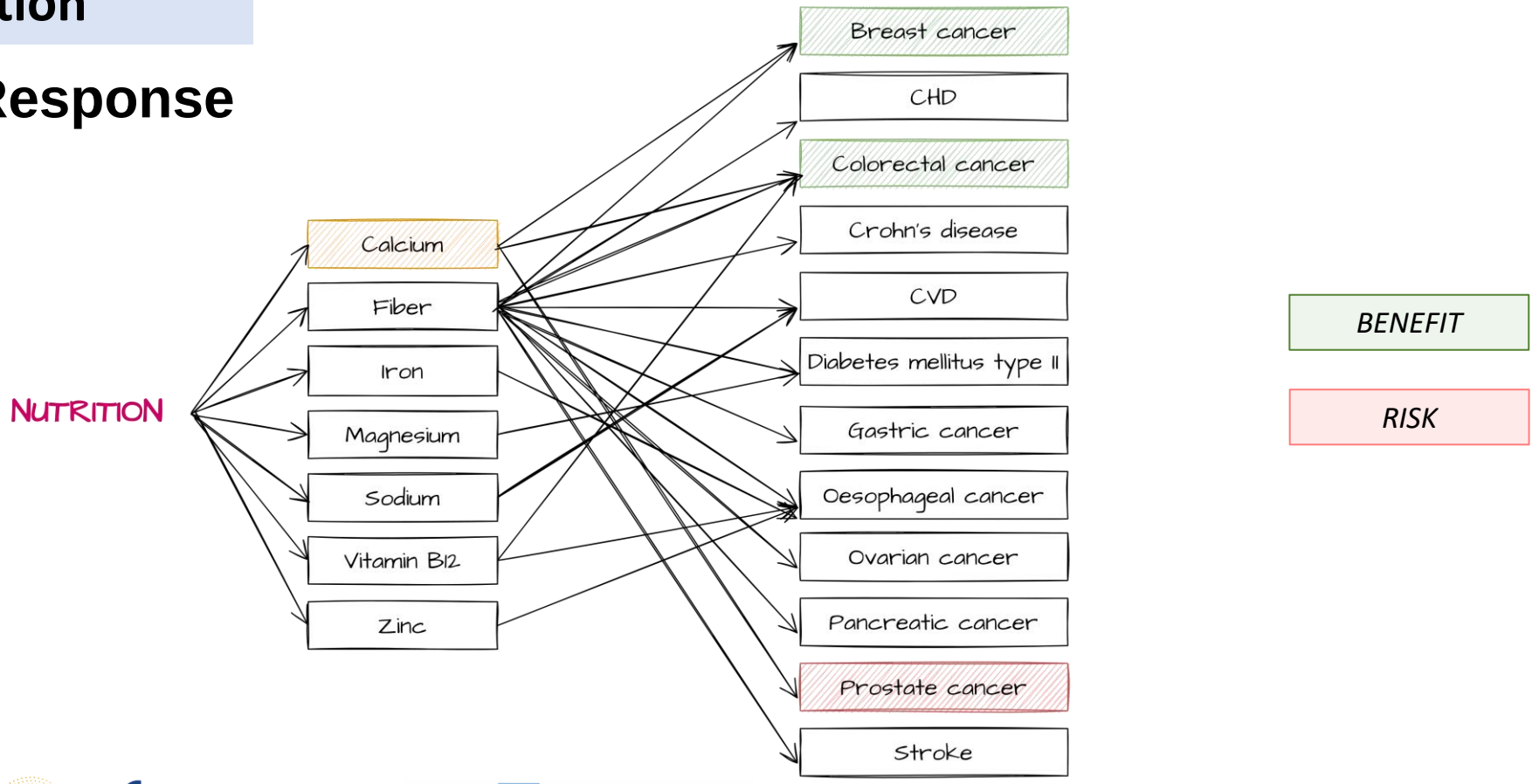
Nutrition

- **Dose-Response**



BENEFIT

RISK

Increase: Ref->Alt

Decrease: Ref->Alt

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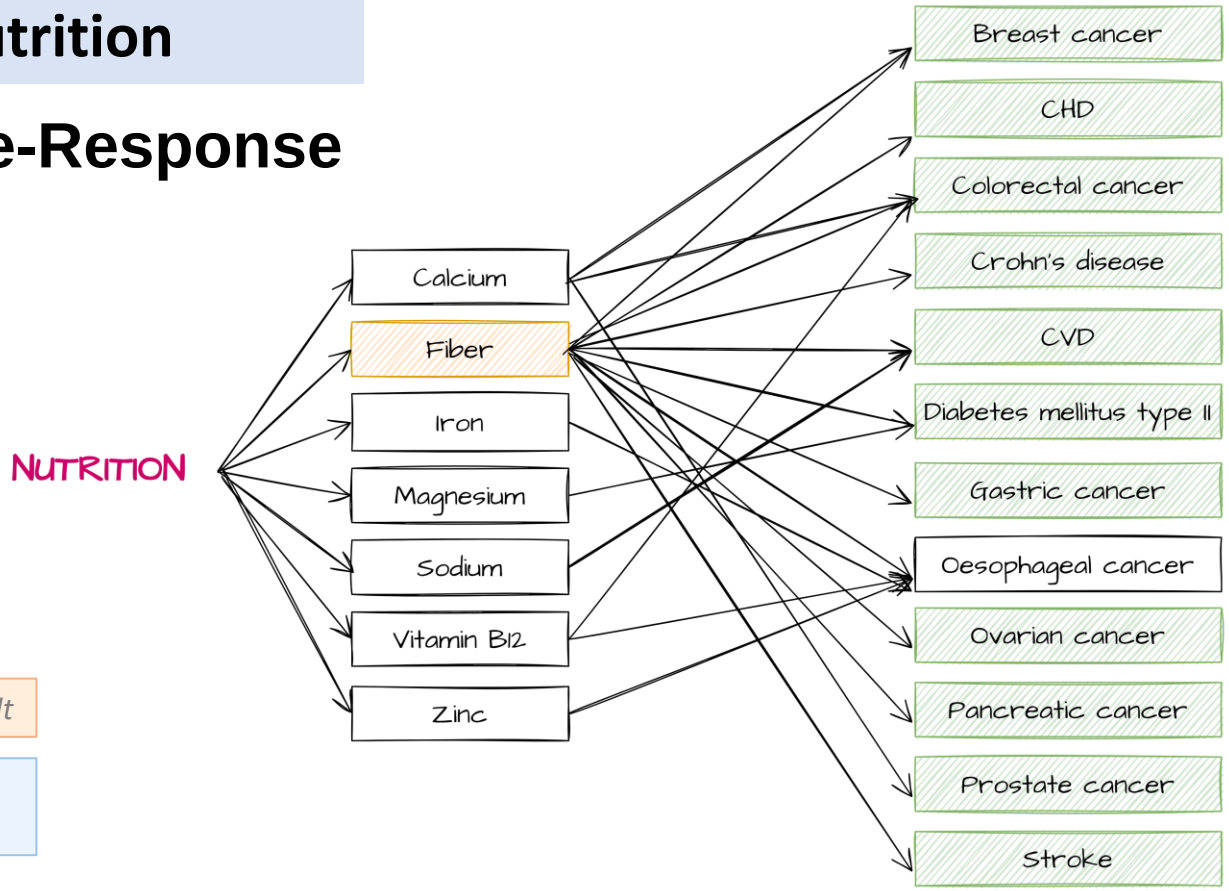
Risk Benefit Assessment

Nutrition

- **Dose-Response**



BENEFIT

RISK

Increase: Ref->Alt

Decrease: Ref->Alt

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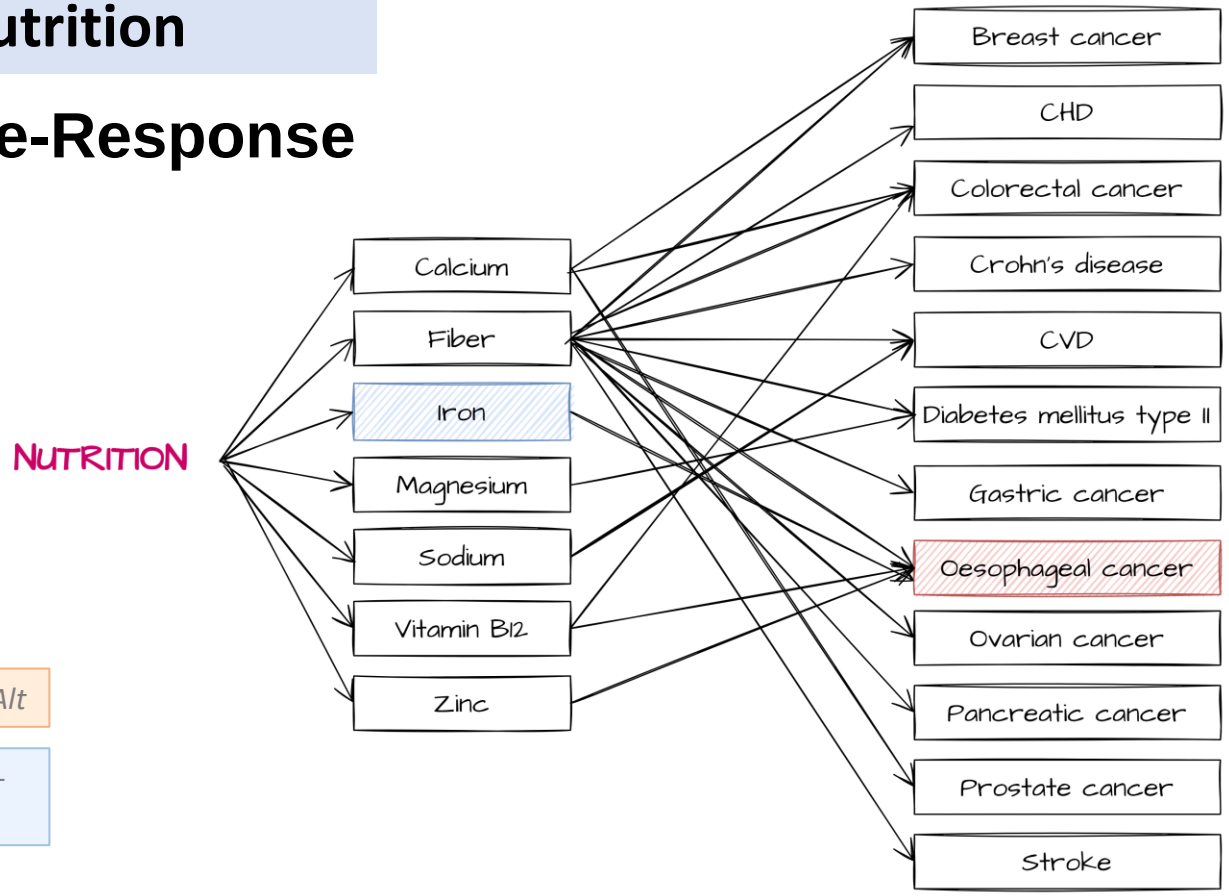
Risk Benefit Assessment

Nutrition

- **Dose-Response**



BENEFIT

RISK

Increase: Ref->Alt

Decrease: Ref->Alt

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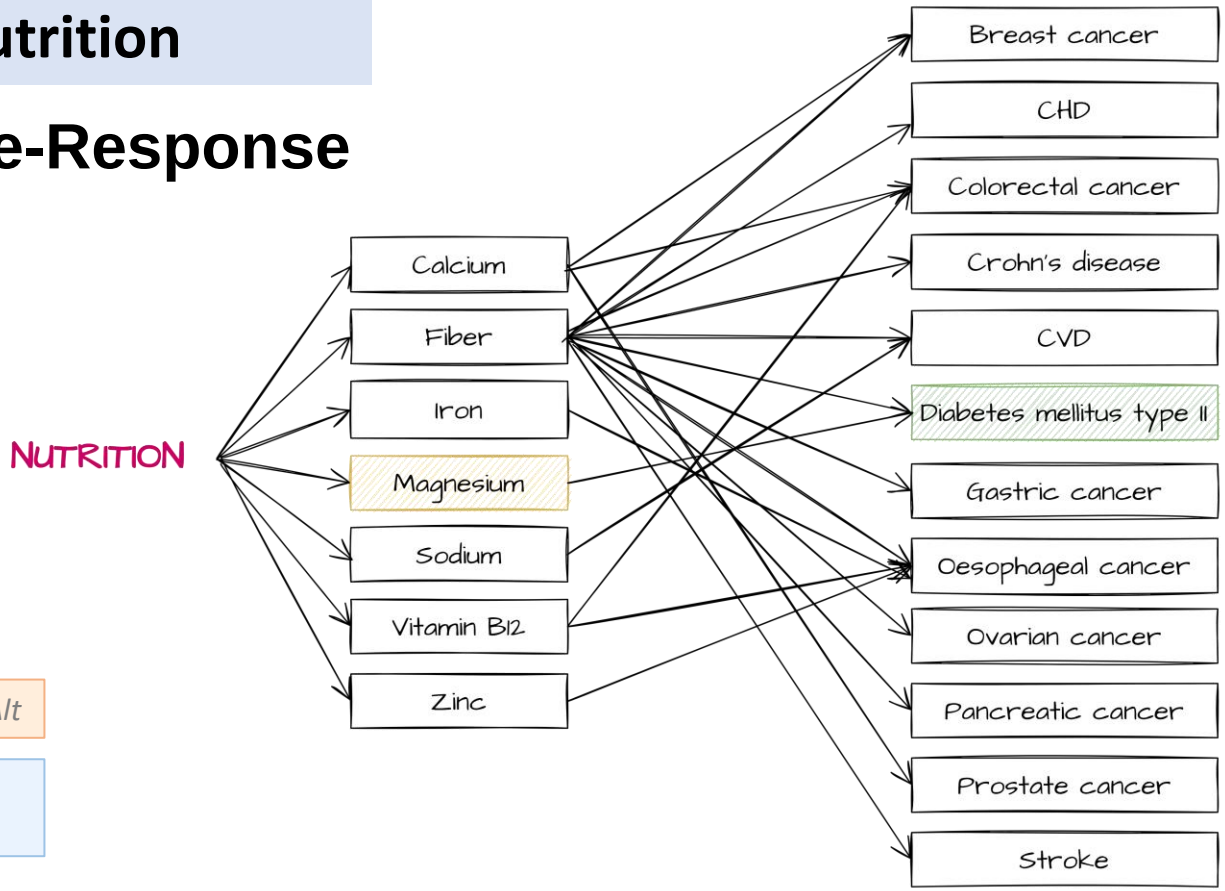
NovRBA Risk Benefit Assessment

Nutrition

- **Dose-Response**



BENEFIT

RISK

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INDIVIDUAL RISKS AND BENEFITS ASSESSMENTS

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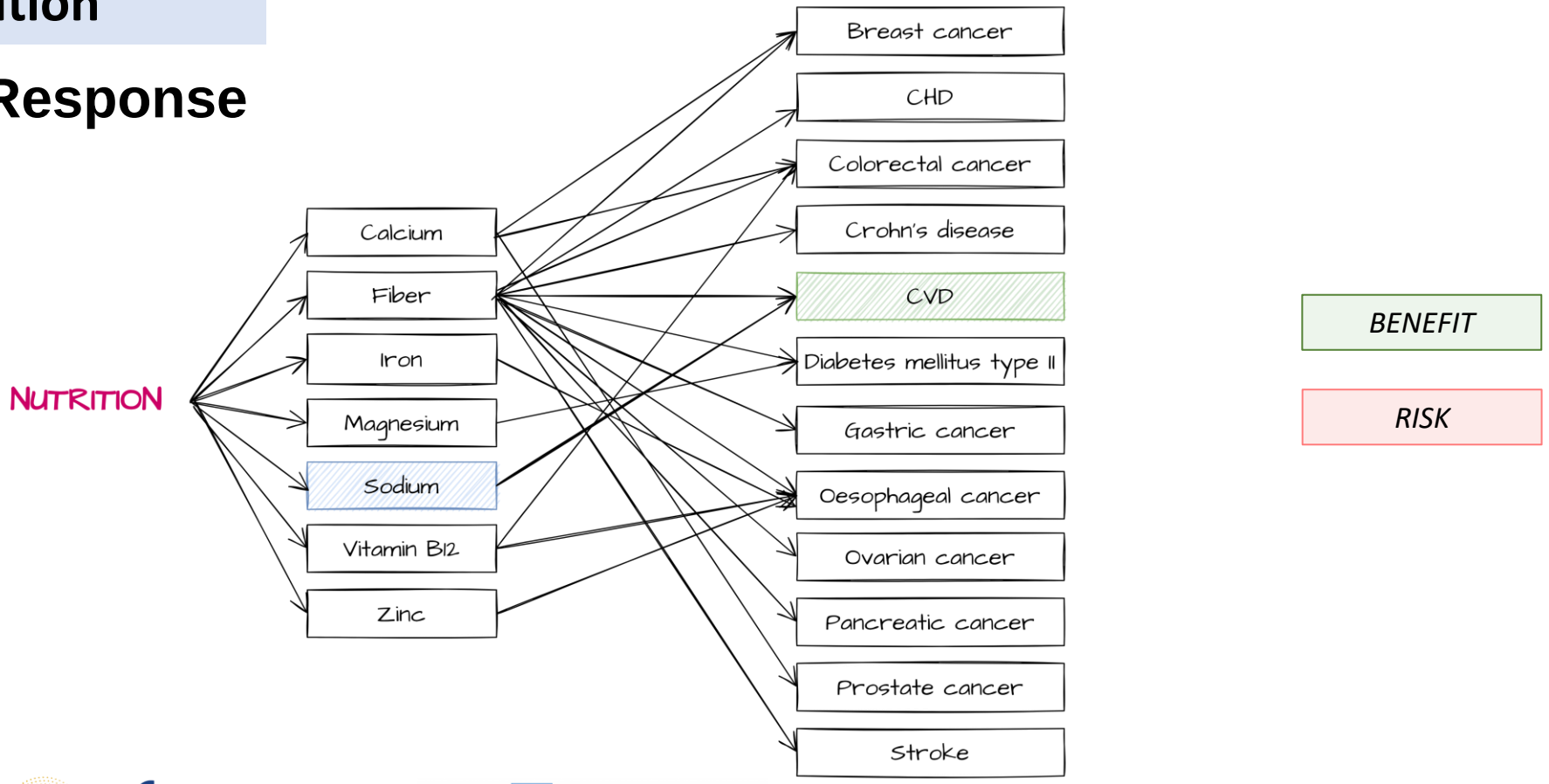
Risk Benefit Assessment

Nutrition

- **Dose-Response**



BENEFIT

RISK

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INDIVIDUAL RISKS AND BENEFITS ASSESSMENTS

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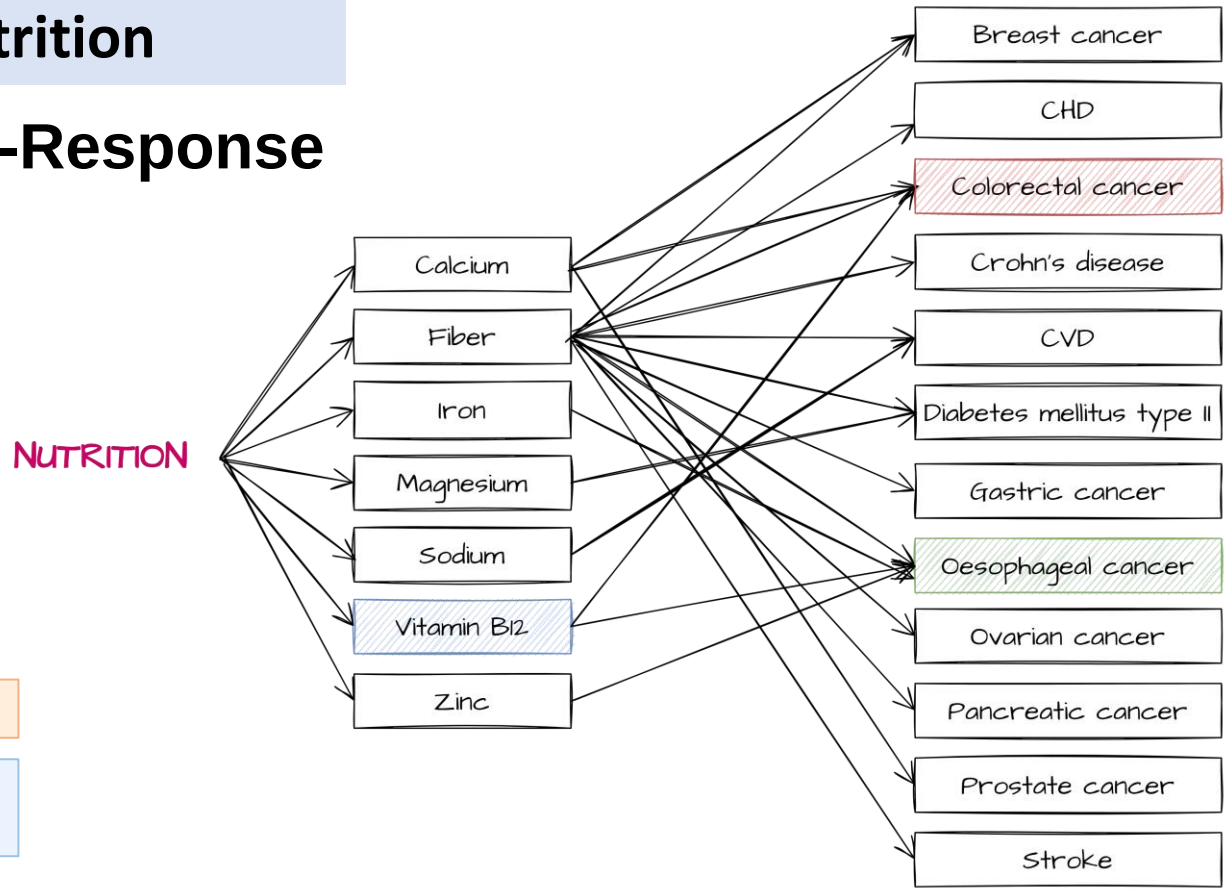
Nutrition

- **Dose-Response**



BENEFIT

RISK

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INDIVIDUAL RISKS AND BENEFITS ASSESSMENTS

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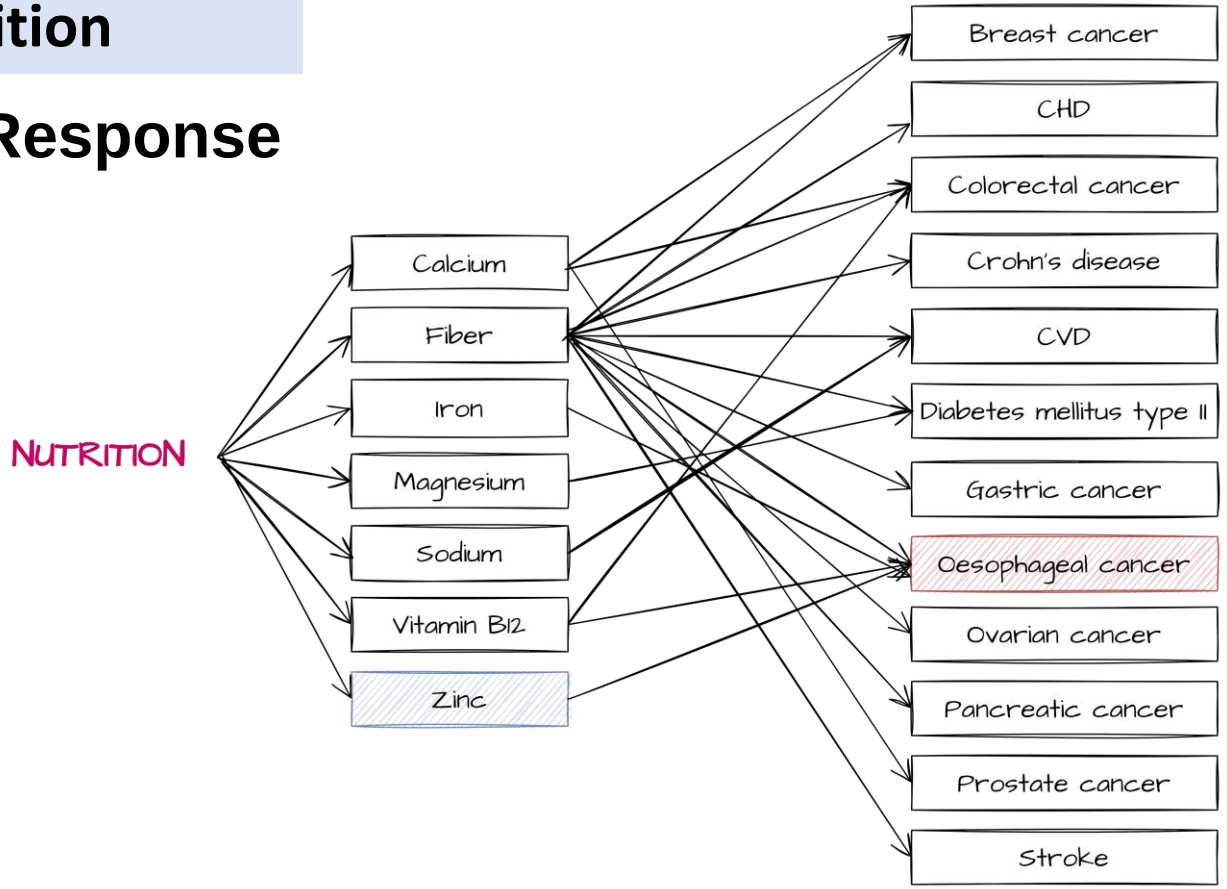
Nutrition

- **Dose-Response**



BENEFIT

RISK

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INDIVIDUAL RISKS AND BENEFITS ASSESSMENTS

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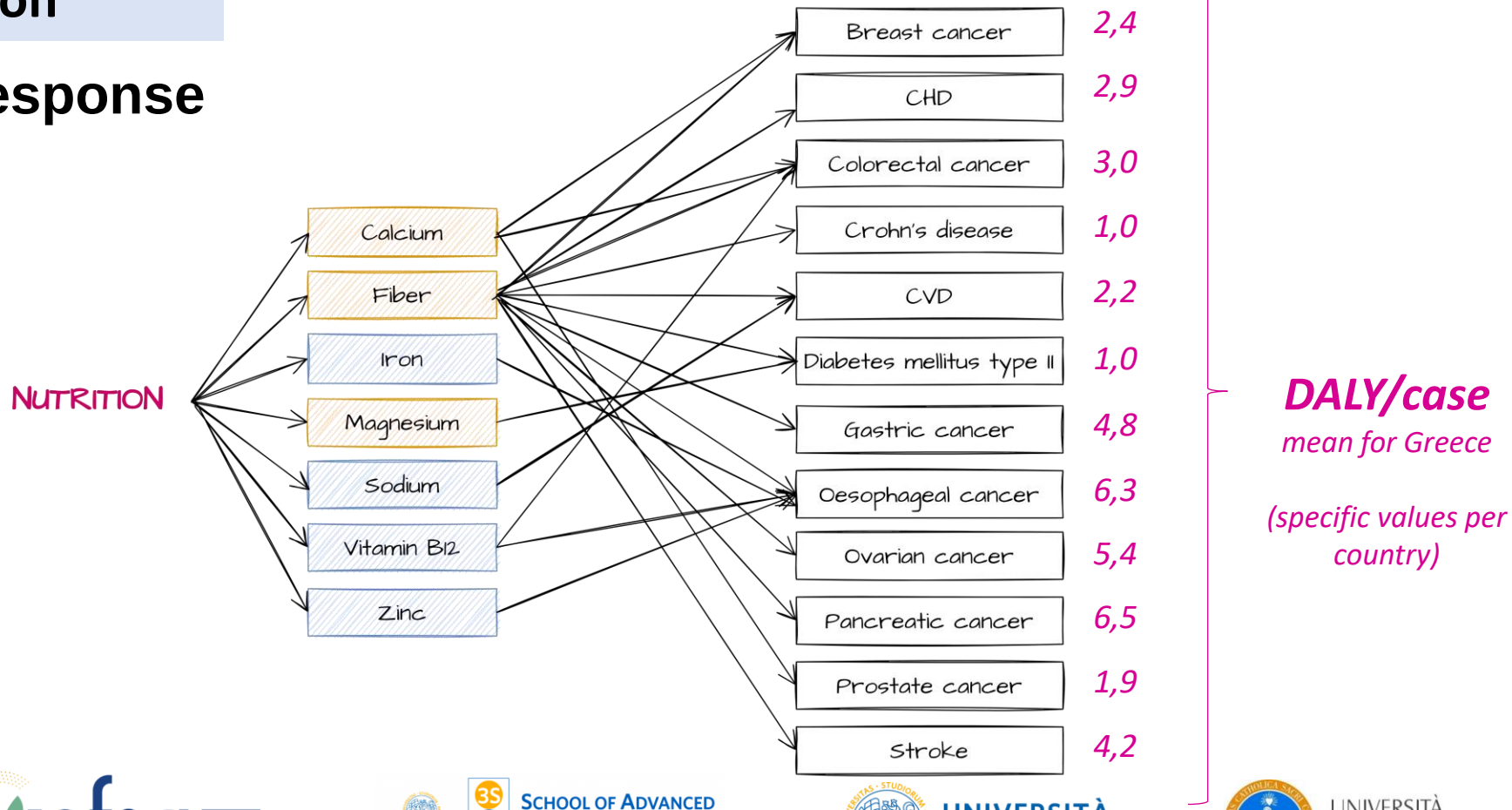
NovRBA Risk Benefit Assessment

Nutrition

- **Dose-Response**



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Nutrition

- **Health impact in DALY**

- **Total DALY saved (-) or lost (+) when moving from Reference to Alternative scenario (per 100.000 population)**

	Greece	Denmark	France
Nutrition	-5,206	-2,360	-17,400
Calcium	0,08%	0,19%	0,16%
Fiber	15%	18%	15%
Iron	0,06%	0,39%	0,36%
Magnesium	0,50%	0,24%	0,70%
Sodium	84%	80%	82%
Vit B12	0,71%	1,69%	1,28%
Zinc	0,03%	0,17%	0,16%

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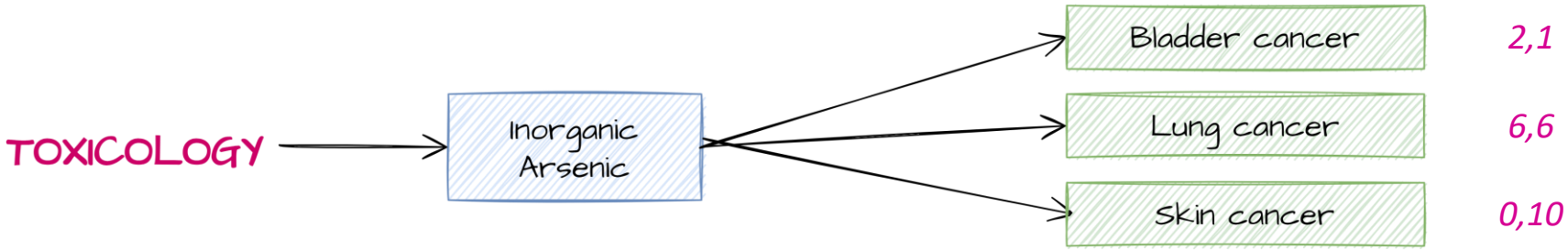
Toxicology

- **Health impact in DALY**

- Inorganic Arsenic was considered in beef patty only
- Same method of calculation using epidemiological dose-response



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BENEFIT

RISK

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Toxicology

- **Total DALY saved (-) or lost (+) when moving from Reference to Alternative scenario (per 100.000 population)**

	Greece	Denmark	France
Toxicology	**-0,10**	**-0,11**	**-0,69**
In Arsenic	**100%**	**100%**	**100%**

INDIVIDUAL RISKS AND BENEFITS ASSESSMENTS

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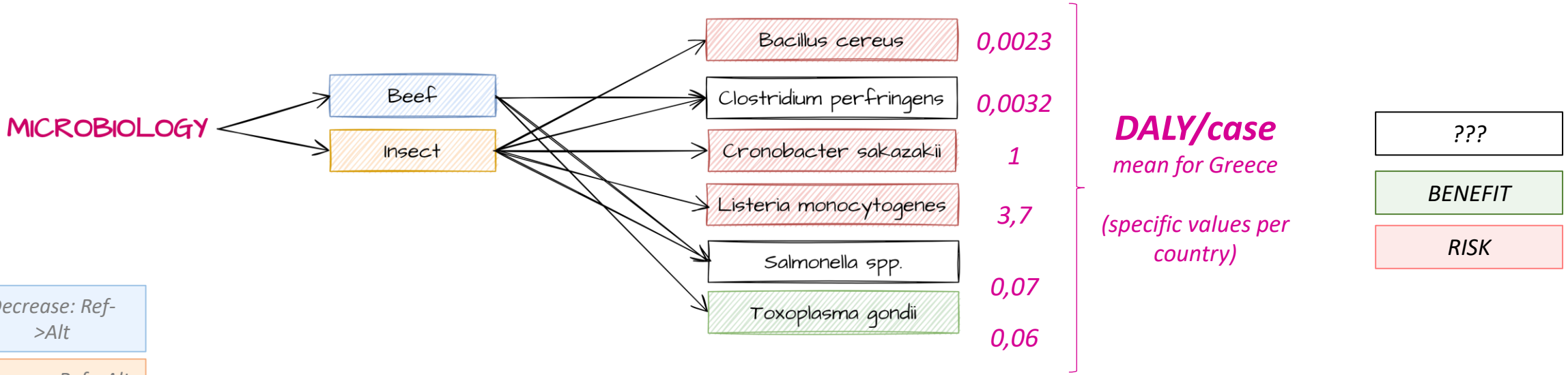
Microbiology

- Hazards selected and associated DALY



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Microbiology

- **Total DALY saved (-) or lost (+) when moving from Reference to Alternative scenario (per 100.000 population)**

		Greece	Denmark	France
	Microbiology	**-3,520**	**-4,225**	**-4,305**
Beef	*Clostridium perfringens*	0,4%	0,3%	0,3%
	Salmonella spp	2%	1%	1%
	Toxoplama gondii	**88%**	**92%**	**92%**
AD	*Bacillus cereus*	**10%**	**6%**	**6%**
	Clostridium perfringens	0,0000002%	0,0000003%	0,0000002%
	Cronobacter sakazakii	0%	0%	0%
	Listeria monocytogenes	0%	0%	0%
	Salmonella spp	0%	0%	0%

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HEALTH IMPACT ESTIMATE AND SCENARIOS COMPARISON

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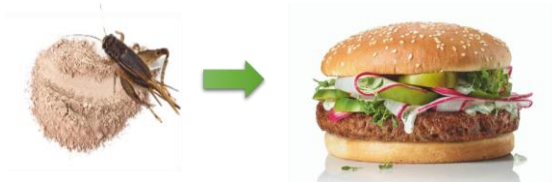
- **Change in DALY per 100 000 people**



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	Greece	Denmark	France
Sum of ΔDALY	-8,753 (-14,848 ; -4,595)	-6,572 (-13,444 ; -2,737)	-21,972 (-34,400 ; -12,613)
Nutrition	**-5,206**	**-2,360**	**-17,400**
Calcium	*0,08%*	*0,19%*	*0,16%*
Fiber	*15%*	*18%*	*15%*
Iron	*0,06%*	*0,39%*	*0,36%*
Magnesium	*0,50%*	*0,24%*	*0,70%*
Sodium	*84%*	*80%*	*82%*
Vit B12	*0,71%*	*1,69%*	*1,28%*
Zinc	*0,03%*	*0,17%*	*0,16%*
Toxicology	**-0,10**	**-0,11**	**-0,69**
Inorganic Arsenic	*100%*	*100%*	*100%*
Microbiology	**-3,520**	**-4,225**	**-4,305**
Beef - Clostridium perfringens	*0,4%*	*0,3%*	*0,3%*
Beef - Salmonella spp.	*2%*	*1%*	*1%*
Beef - Toxoplasma gondii	*88%*	*92%*	*92%*
AD – Bacillus cereus	*10%*	*6%*	*6%*
AD – Clostridium perfringens	*0,0000002%*	*0,0000003%*	*0,0000002%*
AD – Cronobacter sakazakii	*0%*	*0%*	*0%*
AD – Listeria monocytogenes	*0%*	*0%*	*0%*
AD – Salmonella spp.	*0%*	*0%*	*0%*

MAIN LIMITATIONS AND CONCLUSIONS

NovRBA Risk Benefit Assessment

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❑ Important limitations

- Significant components and **health outcomes that were not quantified** in this RBA

	Nutrition	Microbiology
Components (not prioritised because of lack of dose-response data)	Copper, Phosphorus	*Clostridium botulinum*
Health outcomes (not considered because of lack of information on DALYs)	Colorectal adenoma (calcium, fiber) Diverticular disease (fiber) Gestational diabetes mellitus (iron) Metabolic syndrome (calcium, magnesium)	

- **Lack of data** on Nutritional composition and prevalence of hazards in **Novel Food** (AD)
- Need to define **substitution recipes** of beef meat by AD powder in patty
- Incidence and DALY/case values of some health outcomes
- **Dose responses** for fatty acids

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MAIN LIMITATIONS AND CONCLUSIONS

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❑ Conclusions on the case study

- Overall health impact of the **substitution is positive**
- **High contribution of nutritional impacts**
- The **overall microbiological impact is beneficial** but risks associated with AD must be refined with data on occurrence and concentration and could be managed
- Conclusions must be read **considering model limitations**

❑ Challenges of Novel Foods

- **Lack of data -> systematic research** is needed for each input
- Need to integrate **data at the country scale**
- Consideration of **food substitutions in scenarios -> Survey**
- **RBA considering substitution are necessary for Risk Assessment of Novel Foods** to ensure safety and beneficial nutritional substitution

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Acknowledgement to the whole NovRBA team!

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National and Kapodistrian University of Athens
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Bundesinstitut für Risikobewertung

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September 27th 2023

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