



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

Biological mechanisms linking agriculture to nutrition: Role of food safety in achieving optimal health and well being in developing countries

Date/Title/Additional Information

Photo credit: Name/Organization



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



INTRODUCTION

- Within the context of the SDGs, food based approaches are an important programmatic strategy in improving nutrition and reducing mortality.
- Conversely, food-borne diseases account for 33 million DALYs and 420,000 deaths.
- Poor food safety reduces agricultural output, affects prices and trade in a global market.
- Emerging evidence on mycotoxins and environmental contamination and their relationship with nutritional status- stunting





- Poor food safety: Implications for nutrition, food security, food policy and trade- Patrick Webb
- Food safety along the value chain: potential intervention strategies- Ahmed Kablan
- Environmental Enteropathy, Microbiome, Mycotoxins and Stunting- Shibani Ghosh
- Biological Markers for Mycotoxins and Selecting an Appropriate Study Design- Johanna Andrews-Trevino
- Group Discussion
- Assignment of Case study (Lunch)
- Post lunch discussion





FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

ASSIGNMENT QUESTIONS

- Select your own group, select a rapporteur
- Review the methodology paper – any key issues or disagreements?
- In-group discussion to determine 1 top food safety priority needing research
- What research appropriate/method would you use?
- If planning an intervention study, how would you plan it to study efficacy/ impact
- Based on your discussion, present what you'd research, why, and how.



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

www.feedthefuture.gov



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

Poor food safety: Implications for nutrition, food security, food policy and trade

Patrick Webb

Nutrition Innovation Lab
July 2017



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

1. *Opportunity*: Food safety **new focus** of food/nutrition security.
2. *Challenge*: Nutrient-rich foods most valuable (for nutrition, as well as for nutrition), but **most perishable!**
3. *Policy implications*: **Actions needed across sectors**, with large private sector responsibility.
4. *Research needs*: Scale, nature, mechanisms, solutions.



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

“Food safety is a hidden, and often overlooked, problem. The pool of those people at greatest risk of disease is expanding.”

We must align “policies in agriculture, trade, health, education, and social protection to provide a safe and healthy diet for all.”

Margaret Chan, former DG of WHO – *Lancet* 2014 (Nov 29 issue)



USAID
FROM THE AMERICAN PEOPLE



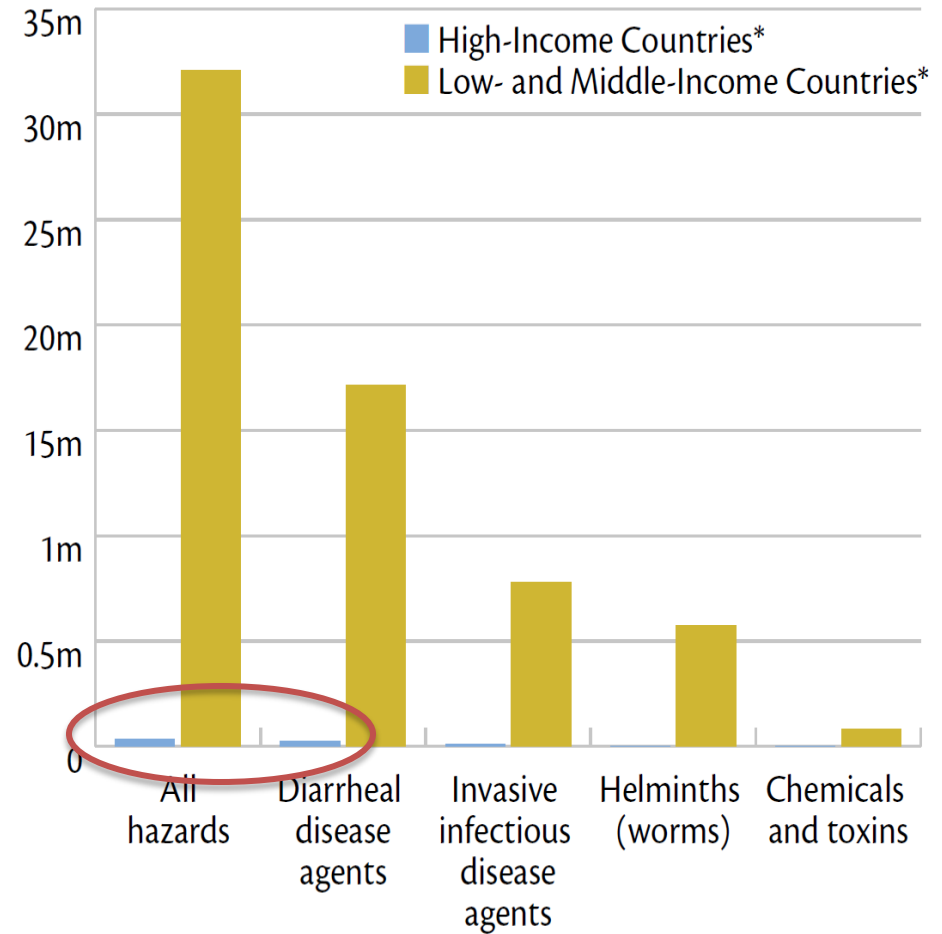
GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

Figure 1: Global Burden of Foodborne Disease (DALYs)



Source: Global Panel 2016

GERALD J. AND DOROTHY R.



Friedman School of
Nutrition Science and Policy



USAID
FROM THE AMERICAN PEOPLE



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative



Diarrhoeal disease agents

Invasive infectious disease agents

Helminths (parasites)

Naturally-occurring toxins

Intestinal damage

Inflammatory response

Increased metabolic rate

Redistribution of nutrients

Inhibition of protein synthesis

Oxidative stress

Nutrient malabsorption

Diarrhoea

Increased nutrient requirement

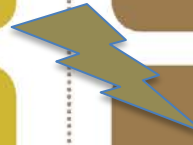
Impaired immune response

Growth retardation (stunting)

Nutrient imbalance, lean mass loss (obesity)

Vitamin and mineral deficiencies

Weight loss/lean mass loss (wasting)



>2 million diarrhoea deaths/p.a.



USAID
FROM THE AMERICAN PEOPLE

Source: Global Panel 2016



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



Documented food-based hazards

- Milk, kale – East Africa (bacterial contamination)
- Fish products – Bangladesh (formaldehyde)
- Peppers, maize – Nepal (aflatoxins)
- Groundnuts – Uganda (mycotoxins)
- Green leafy veg – India (toxic herbicides)
- Street foods – SE Asia (e-coli)





FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

Global food trade: access to nutrient-rich foods

TPP would **benefit trade in fresh fruits, vegetables and nuts**, currently hampered by sanitary and phytosanitary restrictions.



United States
International Trade Commission

Trans-Pacific Partnership
Agreement: Likely Impact

May 2016
Publication Number: 4607
Investigation Number: TPA-105-001



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



Recommendations

- **Strengthen evidence-base** on hazard risk to vulnerable consumers to define appropriate economic actions.
- Food trade regulations **focus on nutrition**, not only income.
- Establish **context-appropriate regulations** (not blanket prescriptions than may hurt nutrition)
- Much to be gained via new technologies to reduce **perishability** in storage, marketing, retail.
- Promote 'safe' **diet diversification** (via consumer knowledge).





FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

“ Food systems are evolving, giving rise to new food safety challenges. Assuring a safe food supply requires the highest level of political commitment to strengthen national systems. This is especially important for Africa and other developing countries. ”

**Akinwumi Adesina, President,
African Development Bank**



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



FEED^{THE}**FUTURE**

The U.S. Government's Global Hunger & Food Security Initiative

Food safety along the value chain: potential intervention strategies

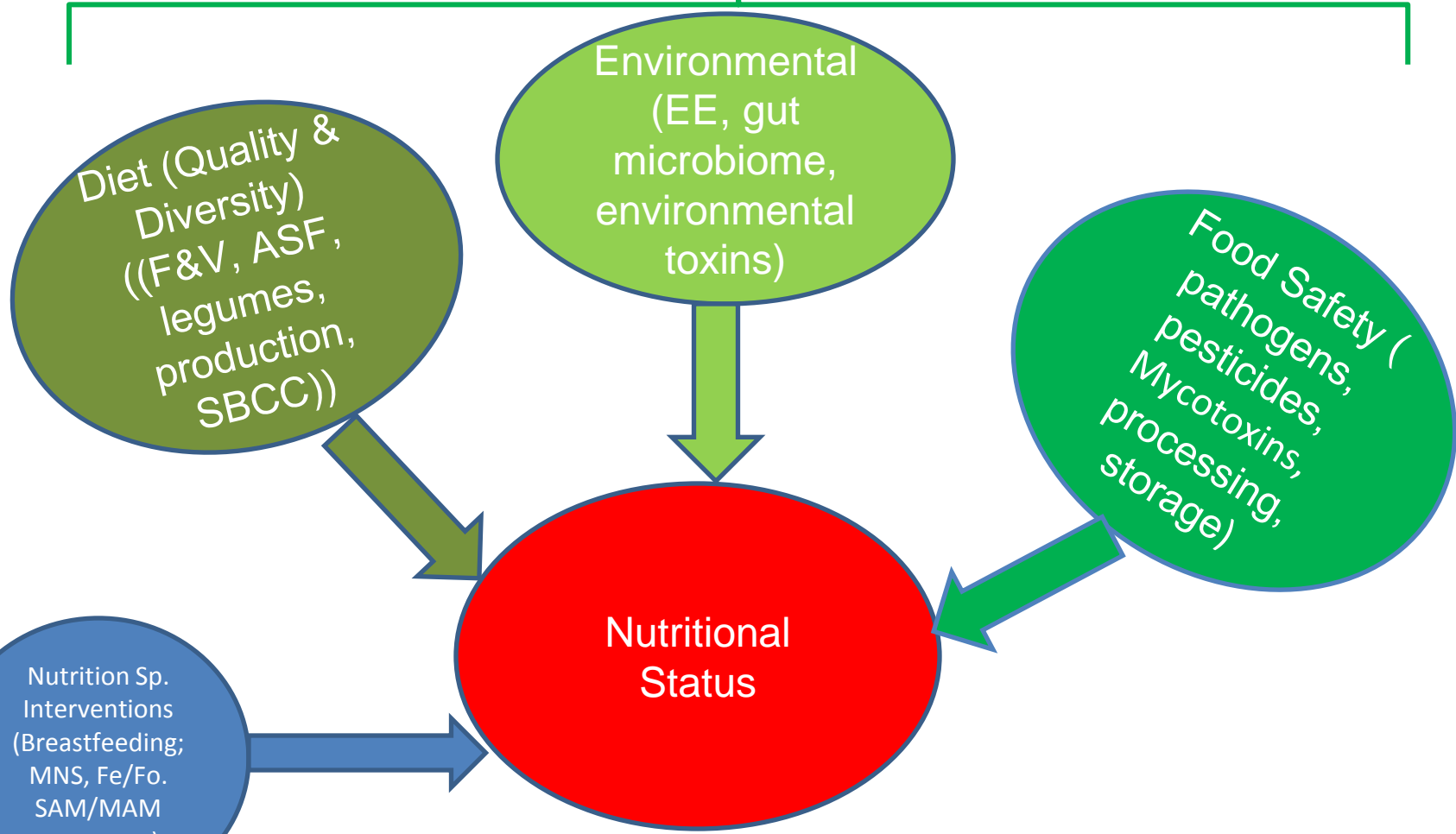
Ahmed Kablan, PharmD, PhD.

Senior Nutrition and Public Health Research Adviser

Bureau for Food Security/
Office of Agriculture Research and Policy
USAID



Agriculture Influenced



Key factors affecting Nutritional Status



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

The Goal!



Improve
Diet
Diversity



Better Nutrition

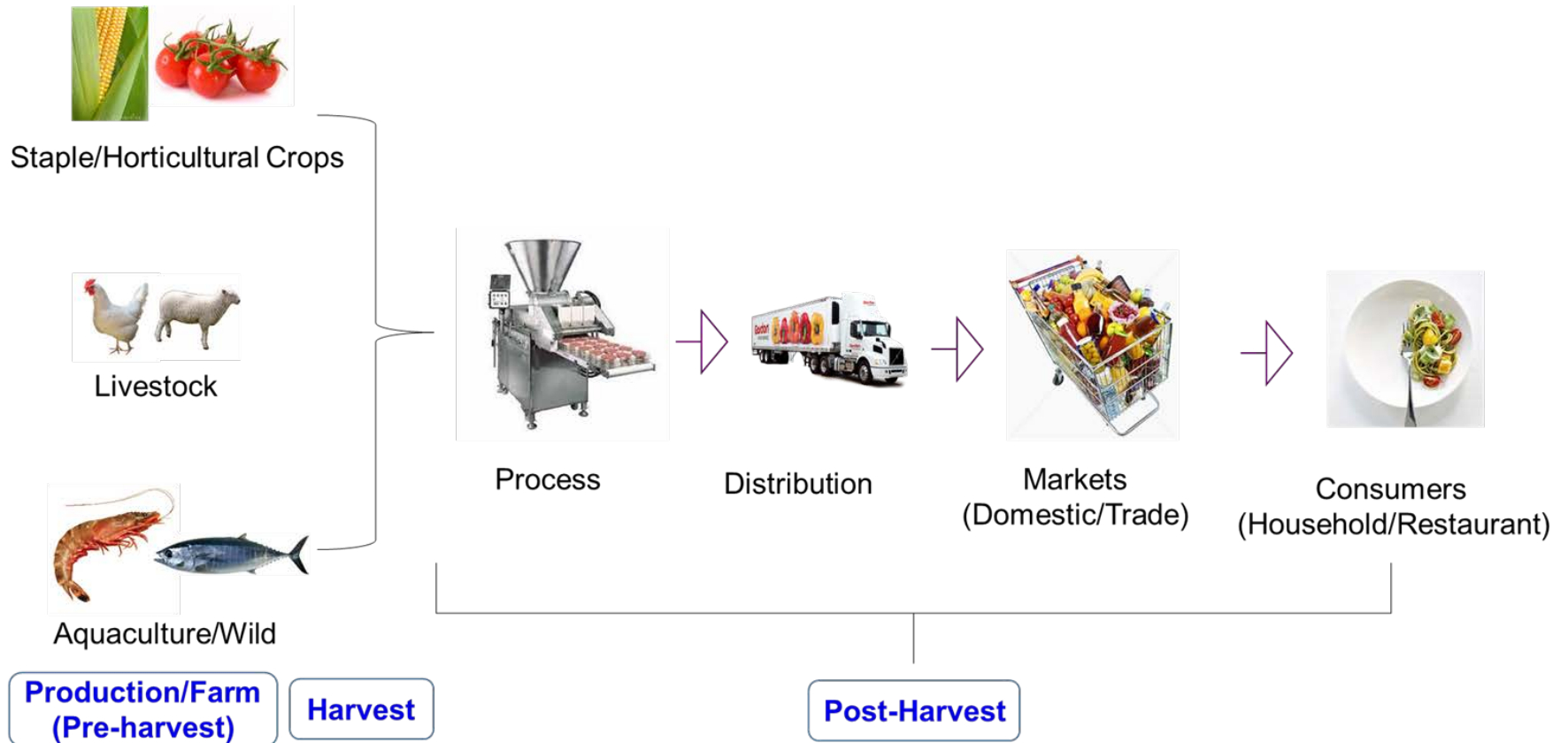




FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

Food Safety System Across the Value Chain





Pre-Harvest & Harvest

- **System biology:**

Identify /know the risk (e.g. toxigenic Asp. Spp in soil; type of microbes of potential risk to meat/diary products..etc)

- Understand the basic genetic component of pathogens
- Expression



Pre-Harvest & Harvest

- **Detection & Dx. of contaminants (DX)**
 - In soil
 - In raw materials
 - During processing
 - Should be sensitive & Specific
 - Can detect as early as possible (avoid future recalls, passing of harmful food to consumer...etc)



Pre-Harvest & Harvest

- **Intervention & Control methods and strategies**
 - Biocontrol /Afasafe
 - GAP (irrigation, mulching, fertilizers..etc)
 - Clean slaughter houses
 - Methods to dispose of by products after harvest (blood, hair..etc)
 - Clean/appropriate collection containers



Pre-Harvest & Harvest

- **Population Systems**

- Movement, dynamics, structure & characteristics of the population throughout the food production system
- Food processing and storage
- Interaction with food including epidemiology, ecology, host-pathogens relationships



Post-Harvest

- **Drying /moisture: grains mainly**
 - Relative humidity (RH) <65% no mold./fungal growth , <35% no pest growth
 - Speed & rate of drying is important to stop potential mold growth and production of toxins



Post-Harvest

- **Storage**

- Cold storage

- F&V, Meat, Poultry , fish
 - Timing and speed and temp is critical
 - Food spoilage could happen at 1-2 degrees above recommended temp
 - Long term should be frozen

- **Ambient Temp storage**

- Hermetic storage , avoid increase in RH, protect from pest infestation , prevent the diffusion in humidity



Post-Harvest

- **Sorting** : to remove any contaminated /infected crops
- E.g. hand sorting of moldy peanuts is highly effective at reducing aflatoxin exposure



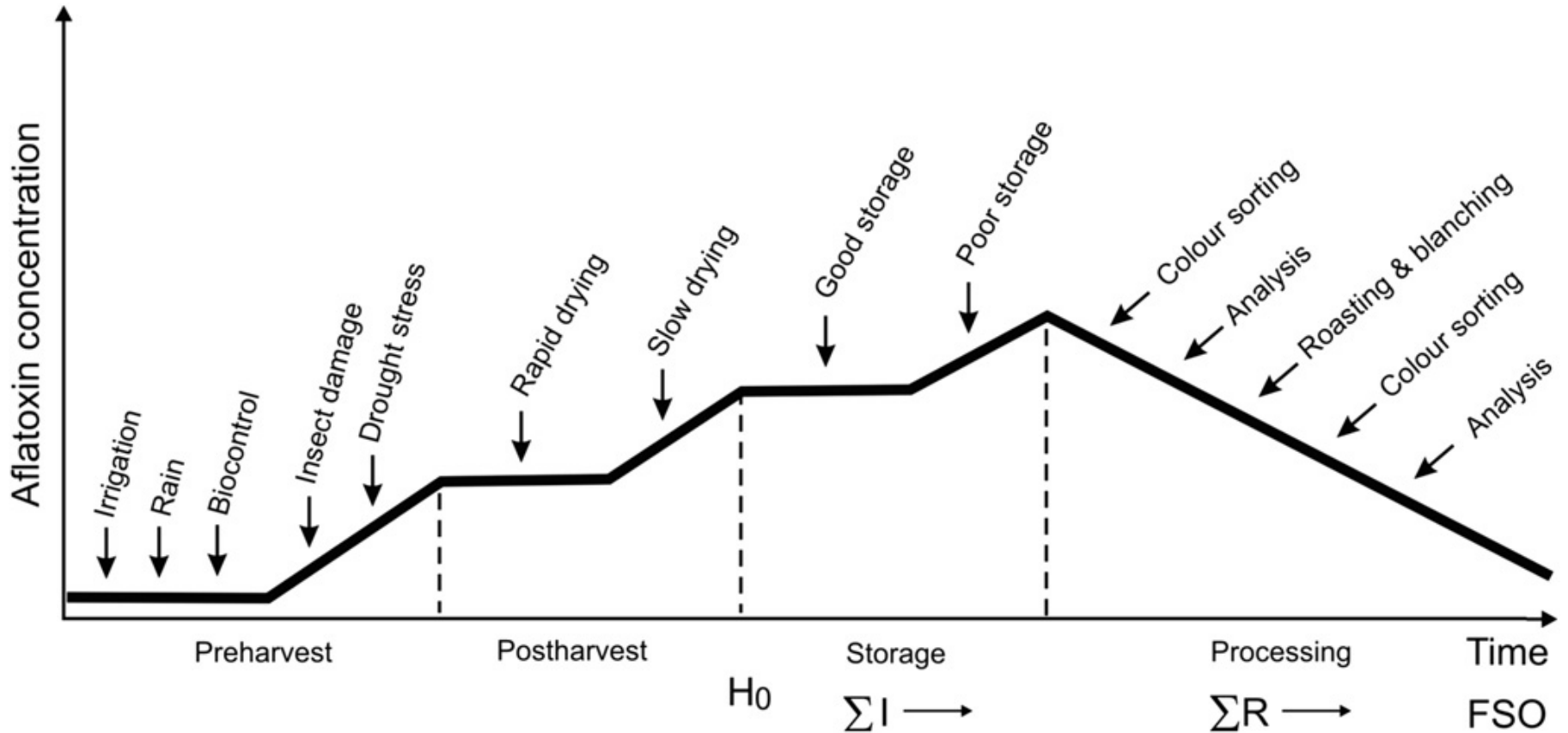
Shipping/transport

- Appropriate temperature control during transport
- Sanitation & hygiene (Pest, Personal,
- Appropriate packaging/packing of food products
- Good communications between shipper, transporter and receiver
- Employee awareness and training.



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative



The time course of aflatoxin formation and reduction in peanuts, with reference to the Food Safety Objective.



Processing/Preparation (HH, Commercial)

- Final & important step esp. in LMIC
- Proper hygiene during food preparation & Serving is critical to prevent cross contamination
- Proper preparation and cooking temp





FEED^{THE}**FUTURE**

The U.S. Government's Global Hunger & Food Security Initiative

Thank you



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

Environmental Enteropathy, Microbiome, Mycotoxins and Stunting

Shibani Ghosh

July 9, 2017



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

GLOBAL NUTRITION TARGETS FOR 2025



CHILD STUNTING

Cut the number of stunted children by 40%



CHILD WASTING

Reduce and maintain child wasting to less than 5%



CHILD OVERWEIGHT

No increase in childhood overweight



ANEMIA

Cut anemia in women of reproductive age by 50%



EXCLUSIVE BREASTFEEDING

Increase to at least 50%



LOW BIRTH WEIGHT

Cut low birth weight by 30%

HALT THE RISE IN PREVALENCE OF:



ADULT OVERWEIGHT



ADULT DIABETES (high blood sugar)



ADULT OBESITY

World Health Assembly Global Nutrition Targets- 2025 and Global Monitoring Framework for Prevention and Control of NCDs

<http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/130354/filename/130565.pdf>



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy

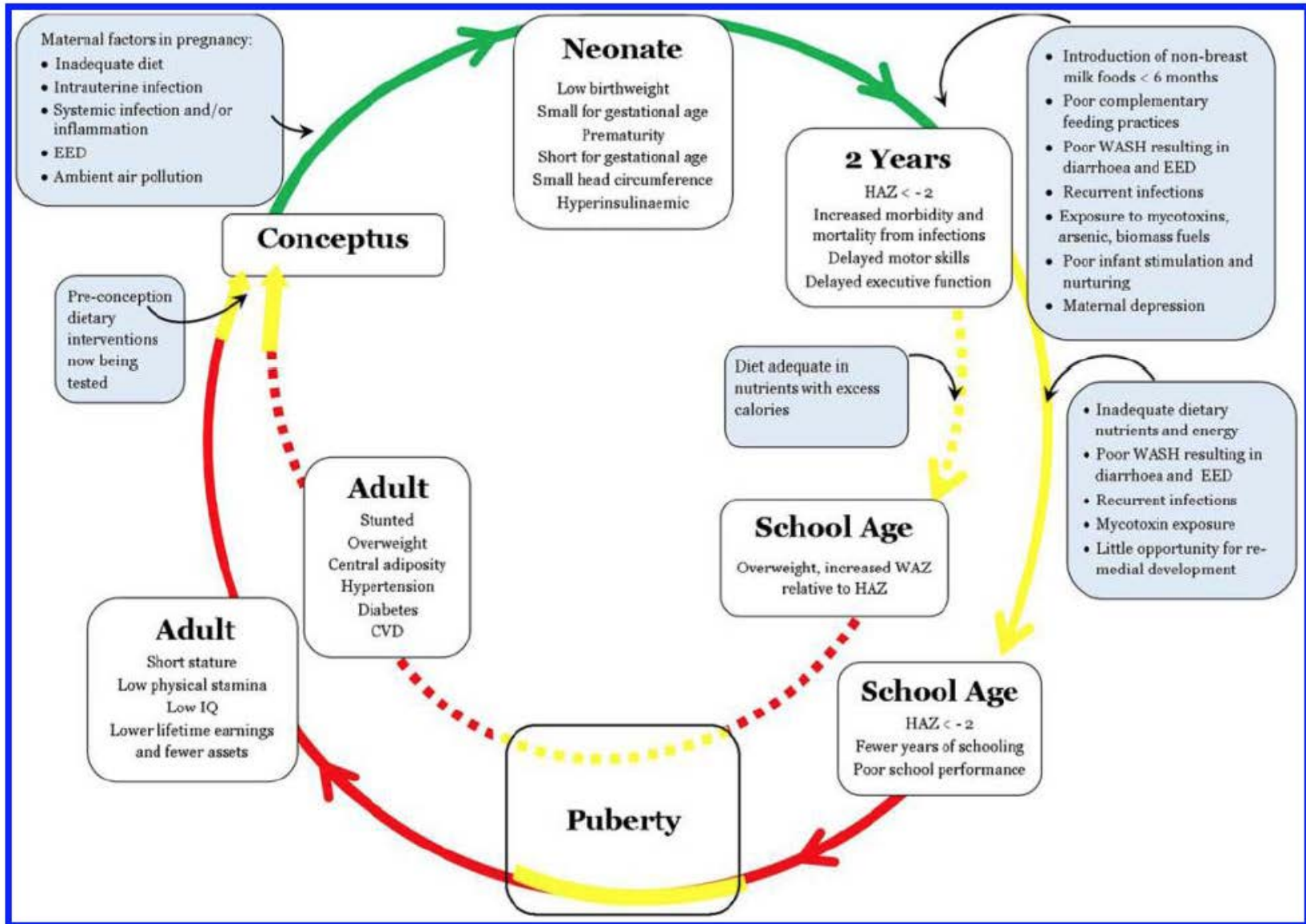


Figure 1 The stunting syndrome. The green pathway denotes the period between conception and 2 years (*'the first 1000 days'*)



ENVIRONMENTAL ENTEROPATHY

- Sub-clinical disorder of the small intestine
- Phenomenon of impaired intestinal function rather than a clinical condition
- Environmental exposure to infections and enteric pathogens- early in life- gut in perpetual state of low level inflammatory immune stimulation
- Over time- disruption of normal intestinal function, alterations in mucosal lumen surface structure, compromise in gut capacity to absorb nutrients





MICROBIOME

- The intestinal microbiota is an ecosystem of gut microbes
- helps to modulate nutrient harvesting from the diet, mucosal inflammation, and the immune response in the gut



Preventing environmental enteric dysfunction through improved water, sanitation and hygiene: an opportunity for stunting reduction in developing countries

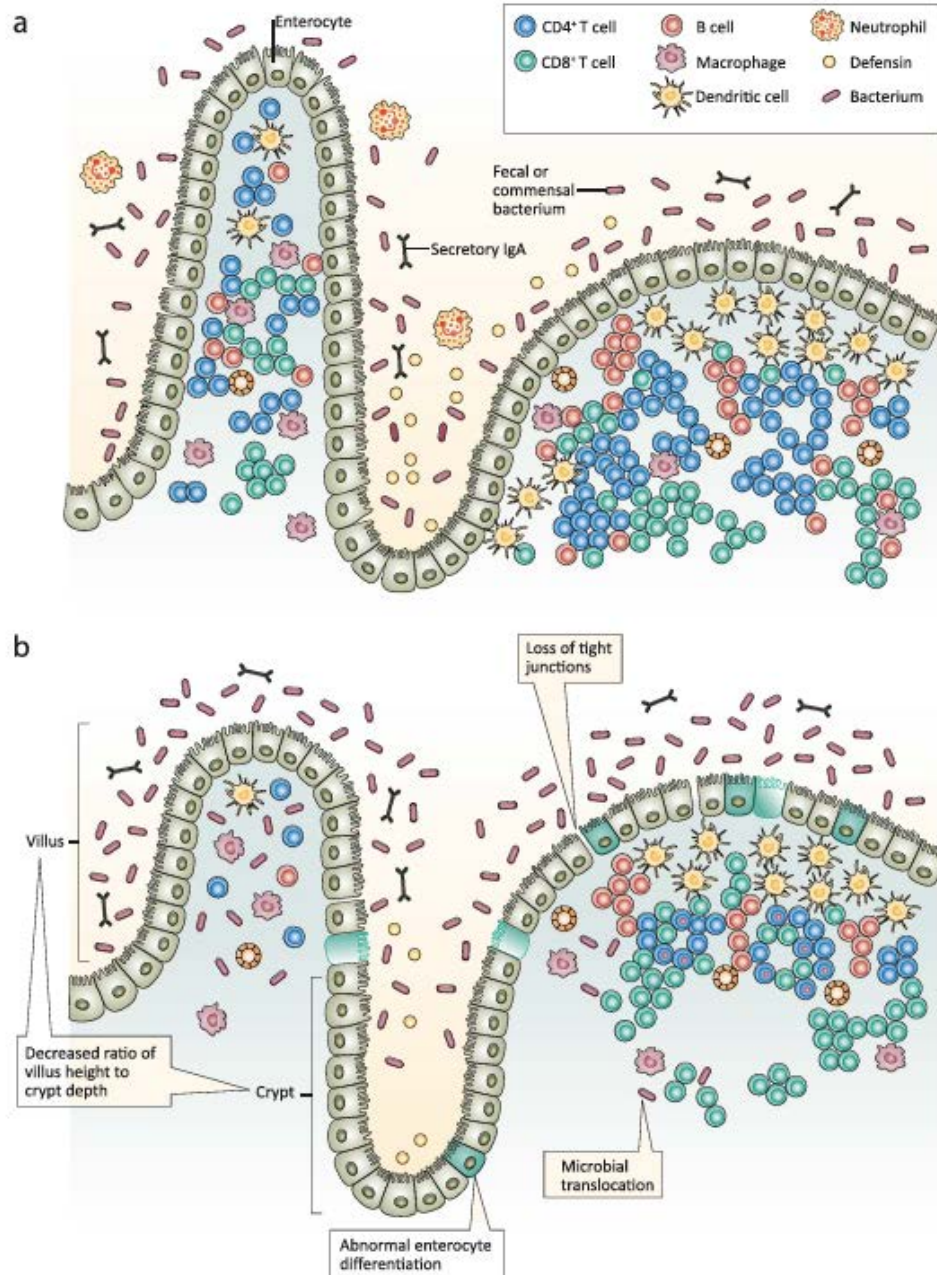
Mduduzi N. N. Mbuya^{*,†} and Jean H. Humphrey^{*,†}^{*}Zimbabwe Institute for Maternal and Child Health Research, Harare, Zimbabwe, and [†]Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland 21205, USA

Fig. 1. The intestinal epithelium in health (a) and with environmental enteric dysfunction (b). Adapted and reprinted with permission from Macmillan Publishers Ltd. *Nature Reviews Microbiology*: Sander and Douek (2012).



ENVIRONMENTAL ENTEROPATHY (EED)

- LM Test (Lactulose mannitol dose and excretion in urine)
- EED testing in Uganda (lactulose:mannitol): **385 children 12-16 m.**
 - Median L:M score 0.27: 21% no EED, **58% moderate, 22% severe.**
 - Infants with **clean water** better L:M scores ($P < 0.050$).
 - If **goats/sheep inside home**, significantly worse L:M ($P < 0.050$).
 - **L:M significantly higher if infants stunted or wasted at 6-9m** (i.e. prior to L:M test).
- Fecal markers- myeloperoxidase, npeoterin, AAT (alpha 1- antitrypsin), inflammatory markers- cytokines, interleukins, immunoglobulins, calprotectin, zonulin
- Blood markers- serum flagellin, serum citrulline, serum lipopolysaccharide
- Fecal MRNA



Bacteria Shared With Animals

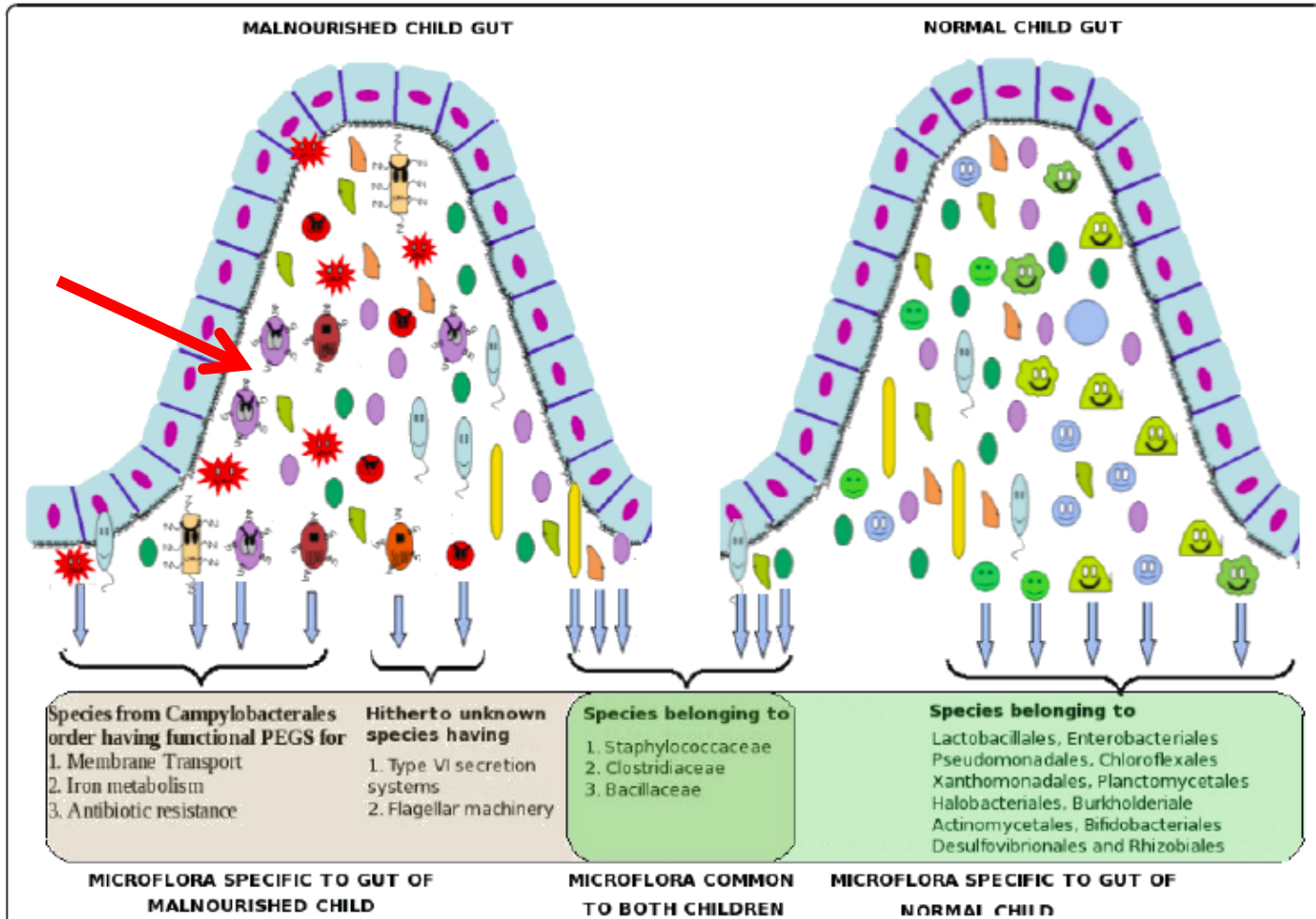


Figure 4 Schematic diagram indicating the overall differences between microbial communities residing in the gut of a malnourished and a healthy child.



US

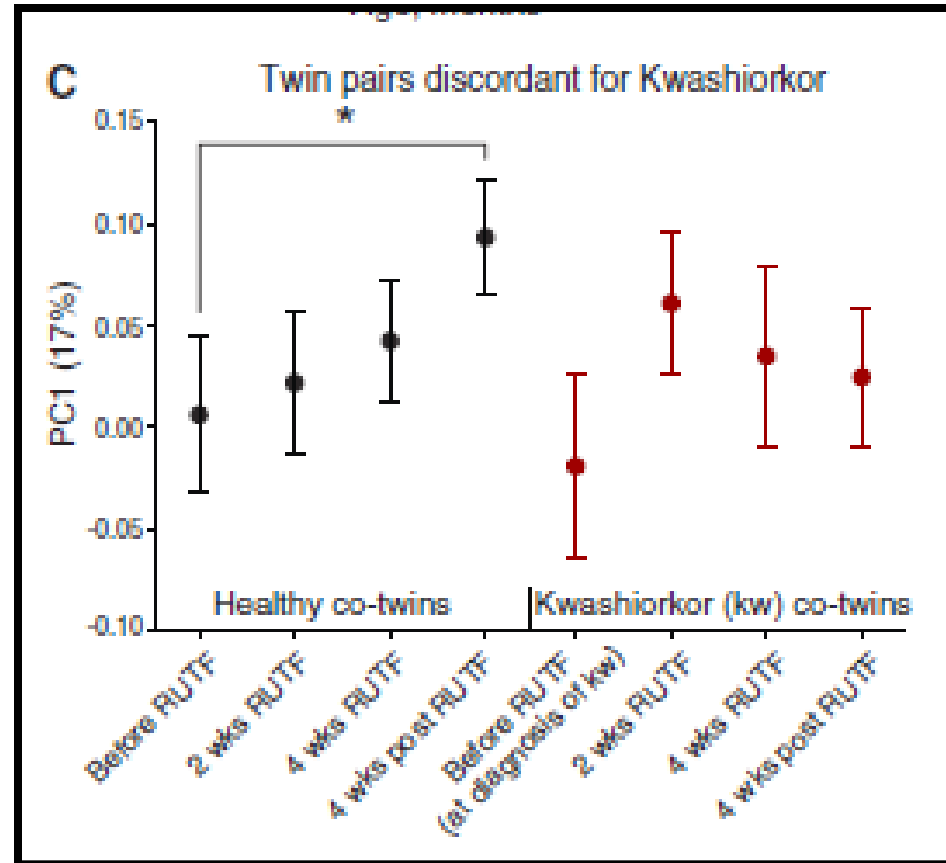
FROM THE AMERICAN PEOPLE

Gut Microbiomes of Malawian Twin Pairs Discordant for Kwashiorkor

Michelle I. Smith,^{1*} Tanya Yatsunenکو,^{1*} Mark J. Manary,^{2,3,4} Indi Trehan,^{2,3} Rajhab Mkakosya,⁵ Jiye Cheng,¹ Andrew L. Kau,¹ Stephen S. Rich,⁶ Patrick Concannon,⁶ Josyf C. Mychaleckyj,⁶ Jie Liu,⁷ Eric Houpt,⁷ Jia V. Li,⁸ Elaine Holmes,⁸ Jeremy Nicholson,⁸ Dan Knights,^{9,10†} Luke K. Ursell,¹¹ Rob Knight,^{9,10,11,12} Jeffrey I. Gordon^{1‡}

Science 339:548-554.
1 February 2013

- 317 Malawian twins studied first 3 years of life
- 50% both well nourished; 43% discordant (one well, one malnourished); 7% both were malnourished.
- Both twins in discordant pairs received RUTF, a therapeutic food. Gut microbiomes (MB) studied: RUTF → transient MB improvement.





MICROBIOME AND STUNTING

- Less diverse gut microbiota are associated with stunting severity
- Increase in the relative abundance of *Acidaminococcus* sp. associated with lower future linear growth in Malawi and Bangladesh



Preventing environmental enteric dysfunction through improved water, sanitation and hygiene: an opportunity for stunting reduction in developing countries

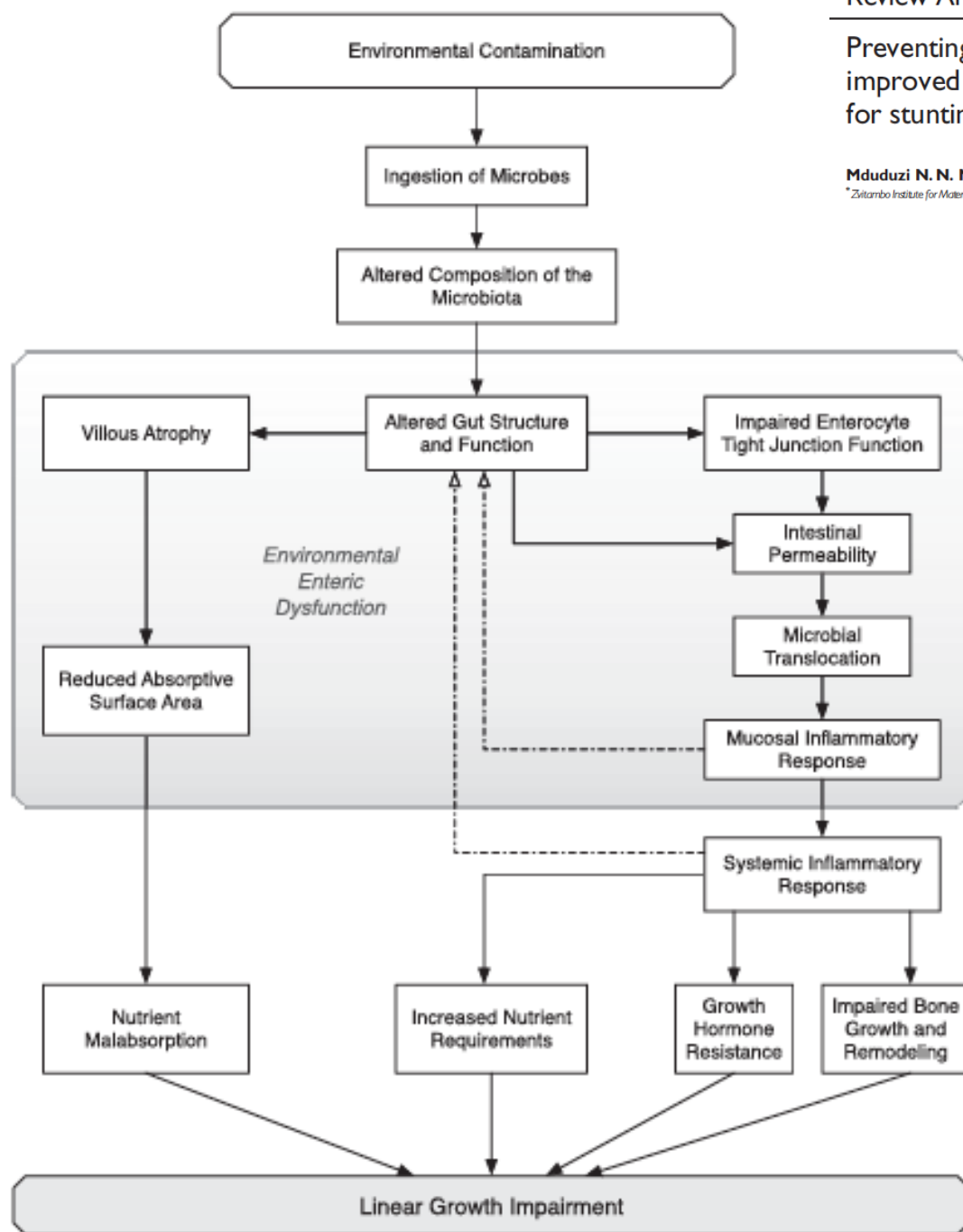
Mduuzi N. N. Mbuya^{*,†} and Jean H. Humphrey^{*,†}^{*}Zimbabwe Institute for Maternal and Child Health Research, Harare, Zimbabwe, and [†]Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland 21205, USA

Fig. 2. Biological mechanisms linking environmental contamination, environmental enteric dysfunction and linear growth impairment.



- In EED, reduced intestinal barrier function enables bacterial translocation to occur, leading to chronic systemic inflammation, which is associated with malnutrition (acute and chronic)
- Increase in glutamate fermentation
- Glutamate – important precursor for synthesis and metabolic recycling of other amino acids (e.g. arginine)
- Contributes to epithelium restitution, preserves barrier function, attenuates intestinal tissue damage



Gough et al. *Microbiome* (2015) 3:24
DOI: 10.1185/s41001-015-0087-2



RESEARCH

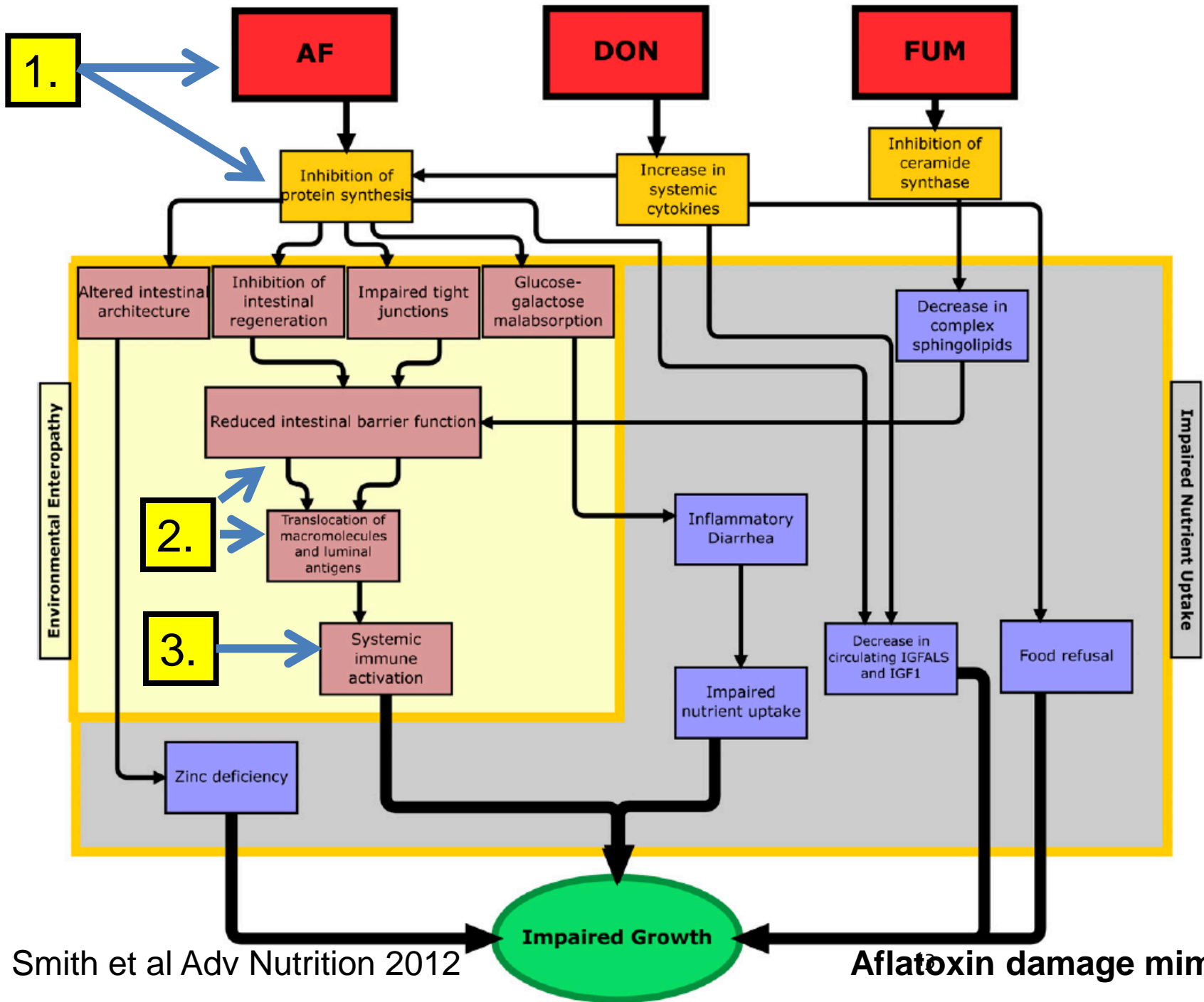
Open Access

Linear growth faltering in infants is associated with *Acidaminococcus* sp. and community-level changes in the gut microbiota

Ethan K. Gough¹, David A. Stephens², Erica E.M. Moodie¹, Andrew J. Prendergast^{1,3}, Rebecca J. Stotzfus⁴, Jean H. Humphrey^{1,5} and Aimee R. Mangis^{1*}



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy





CONCLUSION

- Mechanistic pathways from contamination/ingestion of contaminants such as aflatoxins, alterations in microbiome and recurrent infections leading to inflammation seem to be similar
- Implementing the 10 Lancet interventions at 90% coverage reduces stunting by only 20%
- Impacts of EED and poor microbiome could negate any gains made in program implementation





FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

U.S. GOVERNMENT PARTNERS





FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

www.feedthefuture.gov



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

Biological Markers for Mycotoxins and Selecting an Appropriate Study Design

Johanna Y. Andrews-Trevino

July 9, 2017



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



MYCOTOXINS

- Metabolites of fungi, cancer, growth faltering, neural tube defects, renal diseases and immune modulation/suppression
- Aflatoxin B1 (AFB1), fumonisin (FUM), deoxynivalenol (DON) and ochratoxin (OTA).
- Maize, (AFB1, FUM), groundnuts, wheat, oats, rice, barley, milk, chilies and spices, OTA has also been isolated in infant formula and baby foods
- Contamination - pre-harvest due to poor agricultural practices (soil contamination) or post-harvest at different points in the value chain due to poor storage and processing practices.

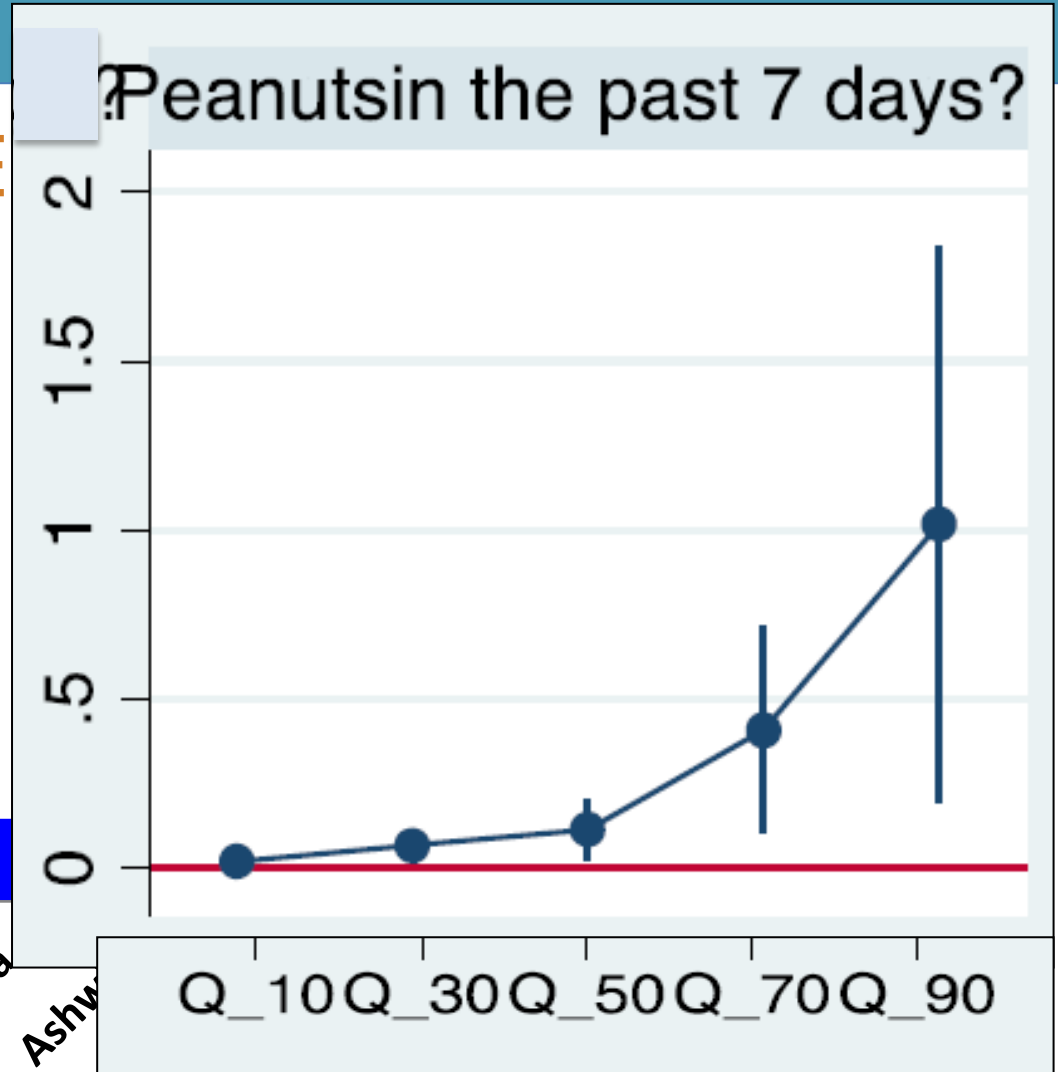
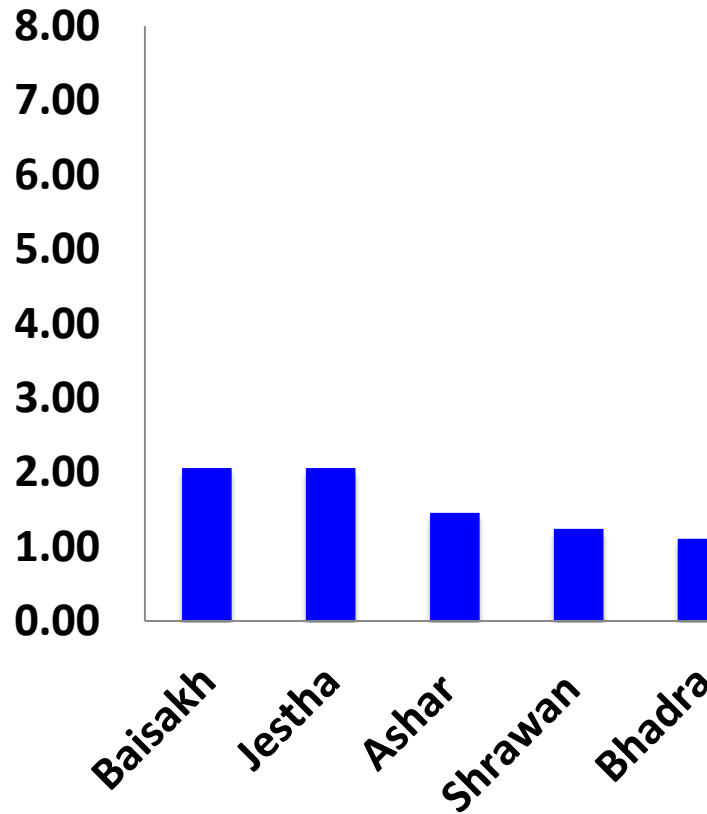




FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

MEAN AF LEVEL



USAID
FROM THE AMERICAN PEOPLE

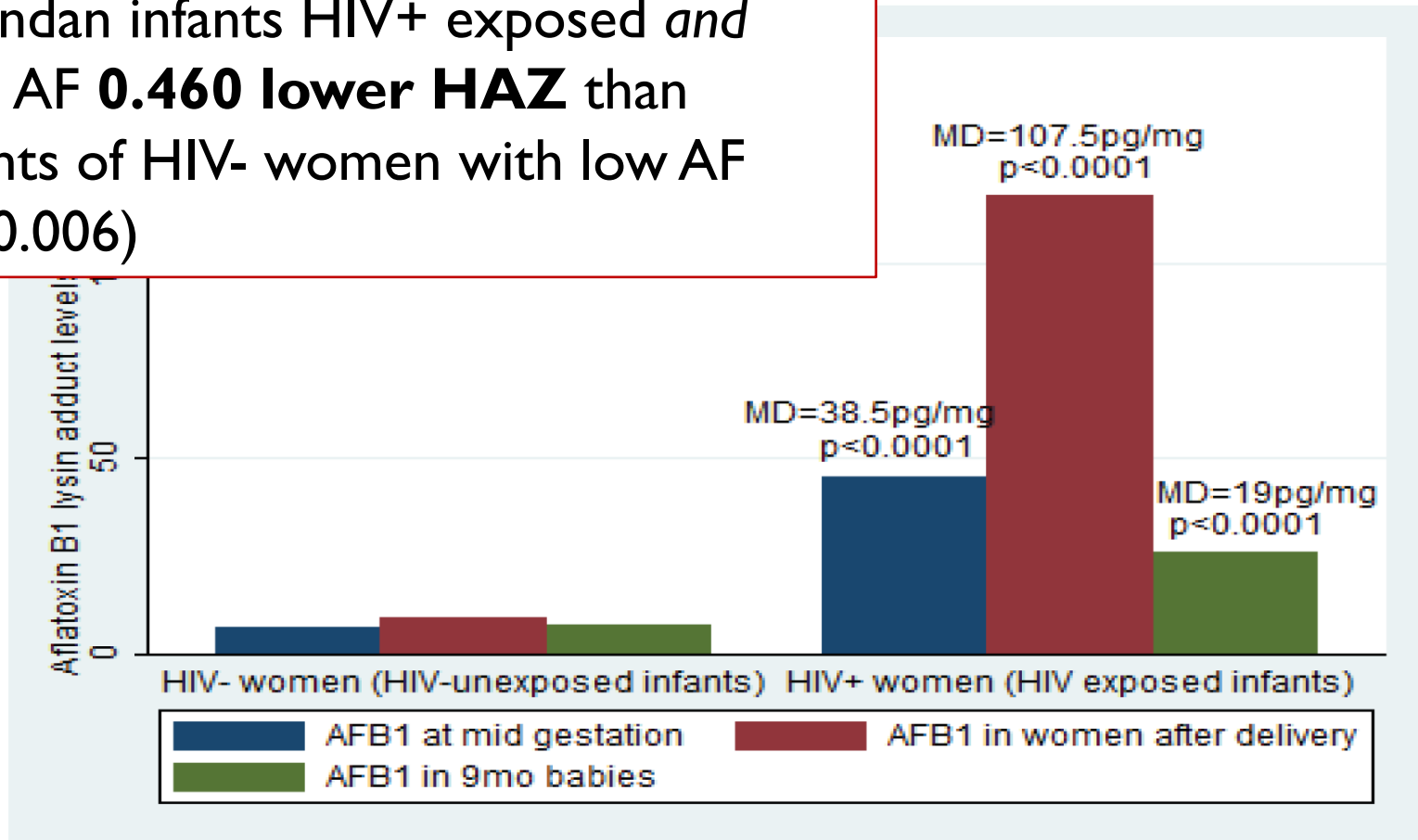


GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy



AFLATOXIN LEVELS HIGHER IN HIV (+) WOMEN AND THEIR INFANTS

Ugandan infants HIV+ exposed *and* high AF **0.460 lower HAZ** than infants of HIV- women with low AF ($p=0.006$)





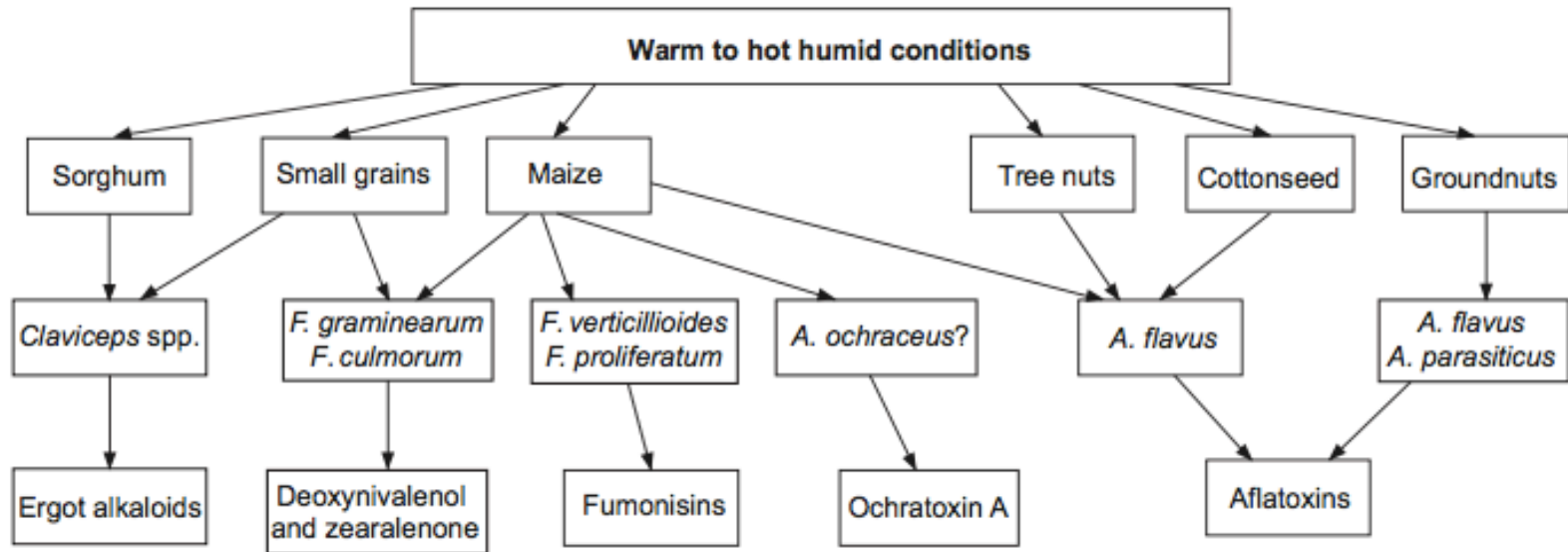
MYCOTOXINS – AGRICULTURAL OR PUBLIC HEALTH ISSUE?

- Mycotoxins - toxic secondary metabolites produced by species of fungi growing on grains before harvest and in storage.
- Contaminate staple foods consumed by many of the poorest and most vulnerable populations in the world.
- Aflatoxin is a type of mycotoxin, Class I human carcinogen, most frequently studied.
- Although animal studies over the past decades have repeatedly shown an association between aflatoxin exposure and growth impairment in many animals, the evidence is lacking in humans.



POTENTIAL SOURCES OF MYCOTOXINS

Fig. 1.10. Decision tree for directing risk management decisions or actions based on environmental considerations and probability of fungal contamination in warm climates. Expected toxic effects in susceptible animals are given for each group of mycotoxins.





CHALLENGES TO MYCOTOXIN RESEARCH

- Multiple strains and different food items (maize, groundnuts, wheat, rice, chilies) contaminated
- Food items are usually not contaminated with a single toxin
 - Bulk of the literature relating growth impairment to mycotoxin exposure focuses on aflatoxin-related stunting.
 - What about the co-occurrence with fumonisins? DON? OTA?
- No established bio threshold
- Biological pathways (e.g. compromised gut health, liver dysfunction, immunity)



CHALLENGES TO MYCOTOXIN RESEARCH

- Difficulty separating the effects of mycotoxins from poor diet quality
- Ethical considerations
 - Aflatoxins are carcinogens that have the potential to contribute to a diversity of adverse health effects in humans, even at low concentrations
 - No established threshold
 - Fear
- Difficulty measuring levels in food



BIOMARKERS

Table 2. Summary of the most prevalent mycotoxins in Africa

| | Mycotoxins | | | |
|-------------------------|---|---|---|--|
| | AF | FB | DON | ZEA |
| Origin | <i>Aspergillus flavus</i> and <i>Aspergillus parasiticus</i> [9] | <i>Fusarium verticillioides</i> [31] | <i>Fusarium culmorum</i> and <i>Fusarium graminearum</i> [31] | <i>Fusarium graminearum</i> and <i>Fusarium crookwellence</i> [30] |
| Types | B ₁ , B ₂ , G ₁ , G ₂ , M ₁ , M ₂ | FB ₁ , FB ₂ , FB ₃ | | |
| Accumulation | accumulate after harvest | location, climate, susceptibility of the plant to fungal invasion, insect damage, crop stress | | |
| Primary food sources | nuts, spices, maize (corn), cacao, coffee, rice, milk | maize (corn) | wheat, barley, maize (corn) | maize (corn), wheat, barley, sorghum |
| Solubility | fat soluble | water soluble [16] | partially water soluble | |
| TDI, µg/kg bw/day | none | 2 [32] | 100 [33] | |
| PMTDI, µg/kg bw/day | | 2 | 1 | 0.5 |
| ★ Urine biomarker | AF-guanine adduct, AFM ₁ , AFP ₁ , AFQ ₁ and AFB ₁ -mercapturic acid [34] | FB ₁ | DON glucuronide, DON + de-epoxydeoxynivalenol (DON-1) | ZEA + α-zearalenol (α-ZOL) + β-zearalenol (β-ZOL) |
| ★ Blood biomarker | Serum/plasma AF-alb adduct [34] | | | |
| ★ Breast milk biomarker | AFM ₁ [5] | | | |

TDI = Tolerable daily intake; bw = body weight.



STUDY DESIGN

Descriptive: tries to give a picture of what is happening, rather than trying to quantify a relationship.

- Qualitative
- Cross-sectional survey (incidence, prevalence, experience of a group)

Analytical: Try to quantify the relationship between two factors

- Experimental
 - Randomized (parallel or crossover)
- Observational analytical
 - Cohort, case control



STUDY DESIGN

Meet certain criteria for rigor

- Sample size
- Outcome measures
- Exposure or dose assessments – time dependent
- Appropriate analyses (controlling for confounders)



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

U.S. GOVERNMENT PARTNERS





FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

www.feedthefuture.gov



USAID
FROM THE AMERICAN PEOPLE



GERALD J. AND DOROTHY R.
Friedman School of
Nutrition Science and Policy