Harnessing Cereal Crop Diversity for Improved Health

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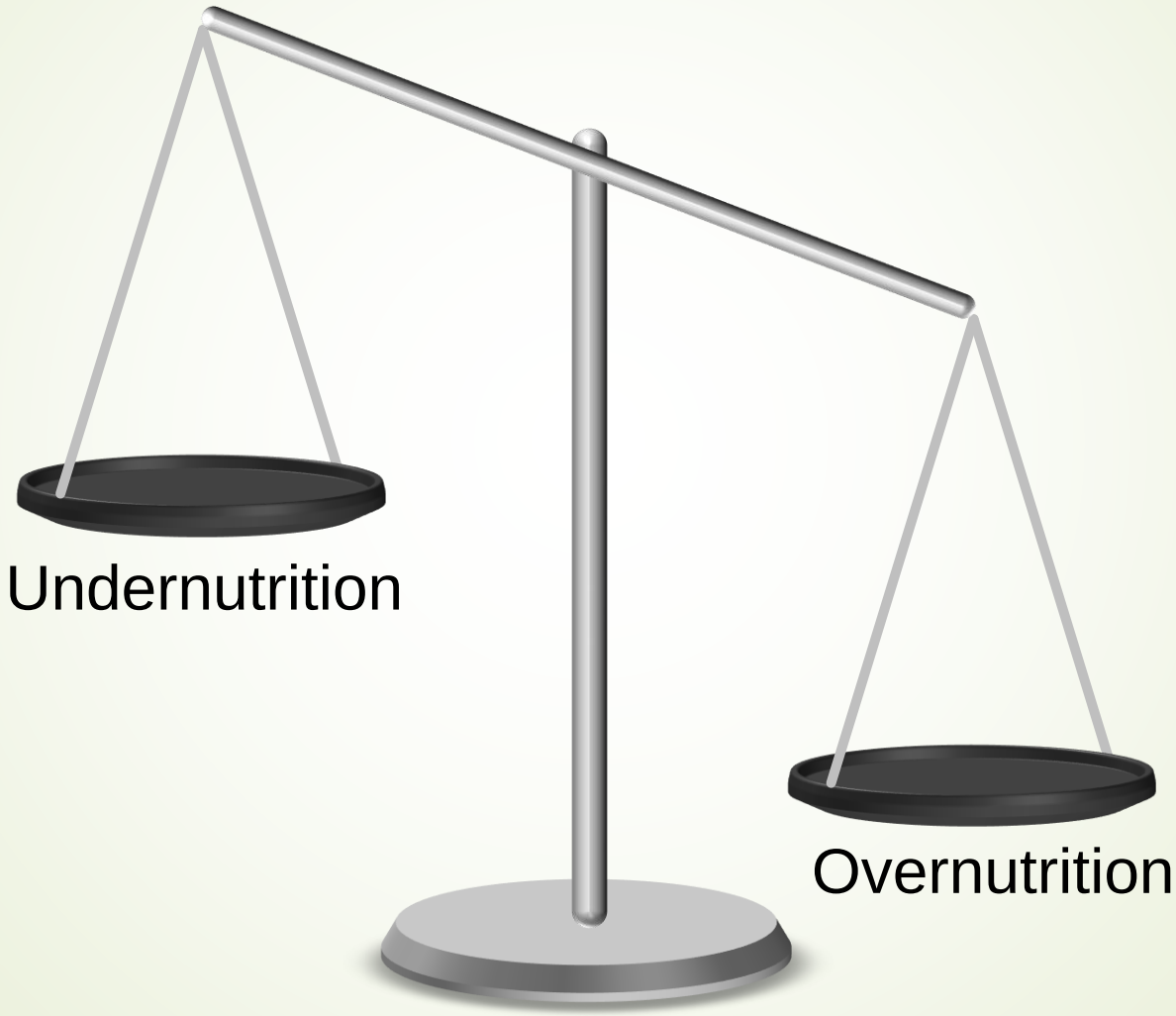
Overview

1. Nutrition-Related Disorders
2. Health Benefits of Cereal Grains
3. Nutritional Improvement Strategies
4. Contribution of Crop Diversity
5. Next Steps

Nutrition Disorders

Infectious disease
Stunted growth
Wasting



Heart Disease
Cancer
Type 2 diabetes

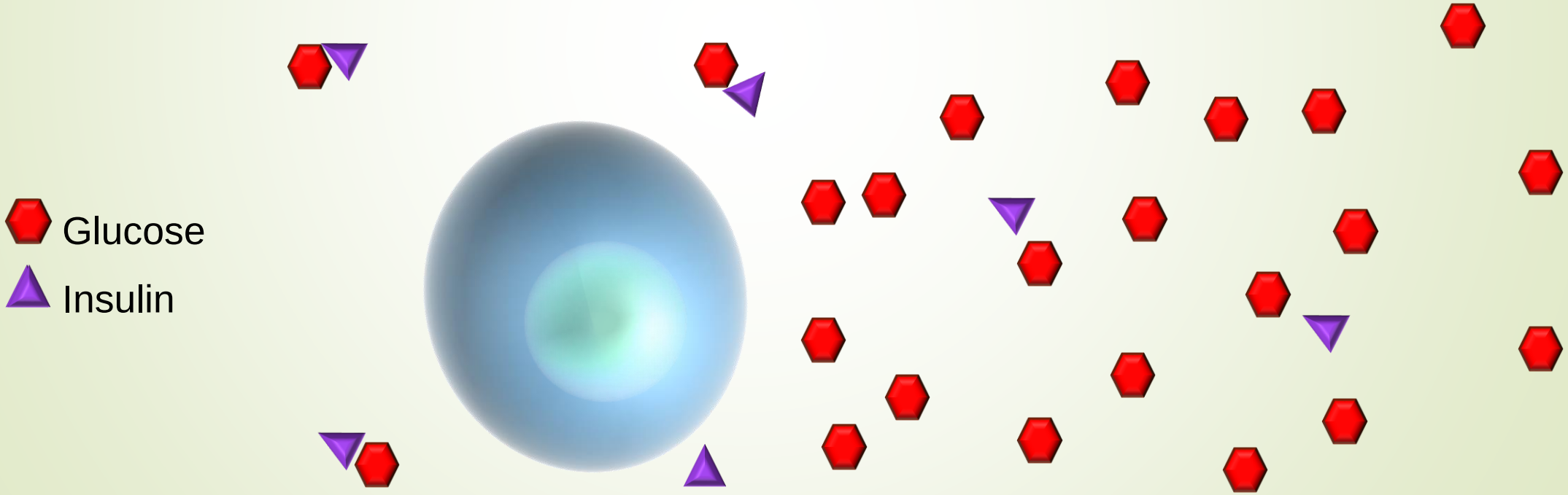
Obesity

Humans (37%)	Cats (31%)	Dogs (20%)
• **Insulin resistance** • Type 2 diabetes • Cancer • Osteoarthritis • CHD • Fatty liver	• **Insulin resistance** • Type 2 diabetes • Cancer • Skin disorders • UTI's	• **Insulin resistance** • Cancer • Osteoarthritis • Hip dysplasia • Immune functions • UTI's

cdc.gov; petobesityprevention.org

Insulin Resistance

- Insulin delivers glucose from our food to our cells
- Cells use glucose for energy
- Insulin resistance – the body doesn't properly respond to insulin



Inflammation Connects Obesity and Insulin Resistance

Chronic overnutrition

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Increased fat and immune cells

↓

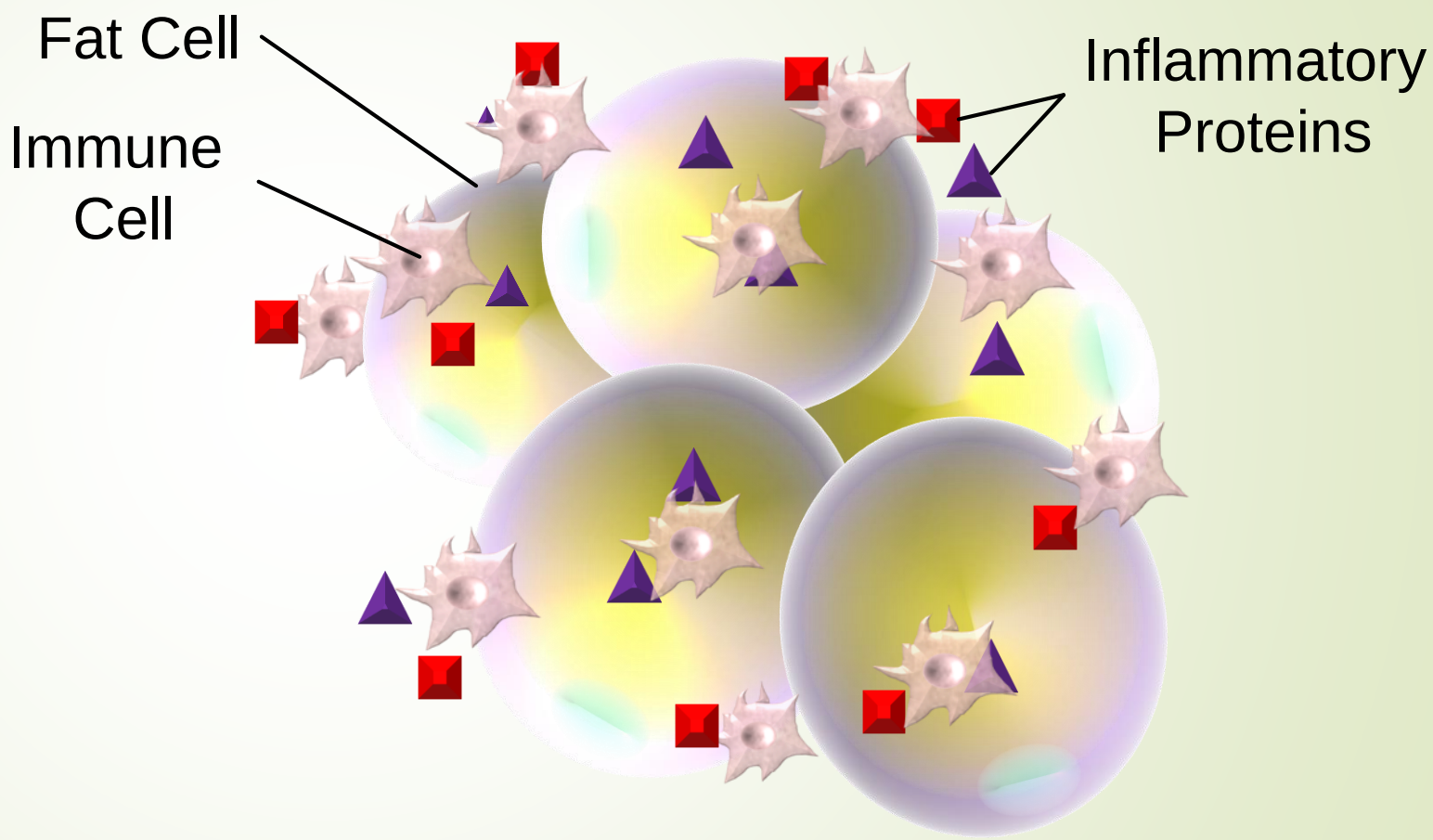
Inflammatory proteins

↓

Chronic low-grade inflammation

↓

Insulin resistance



What is a Cereal Grain?

Cereal Grains

- Maize
- Rice
- Wheat
- Rye
- Triticale
- Barley
- Sorghum
- Millet
- Oats
- Teff

Pseudocereals

- Amaranth
- Buckwheat
- Chia
- Quinoa

Ancient Grains

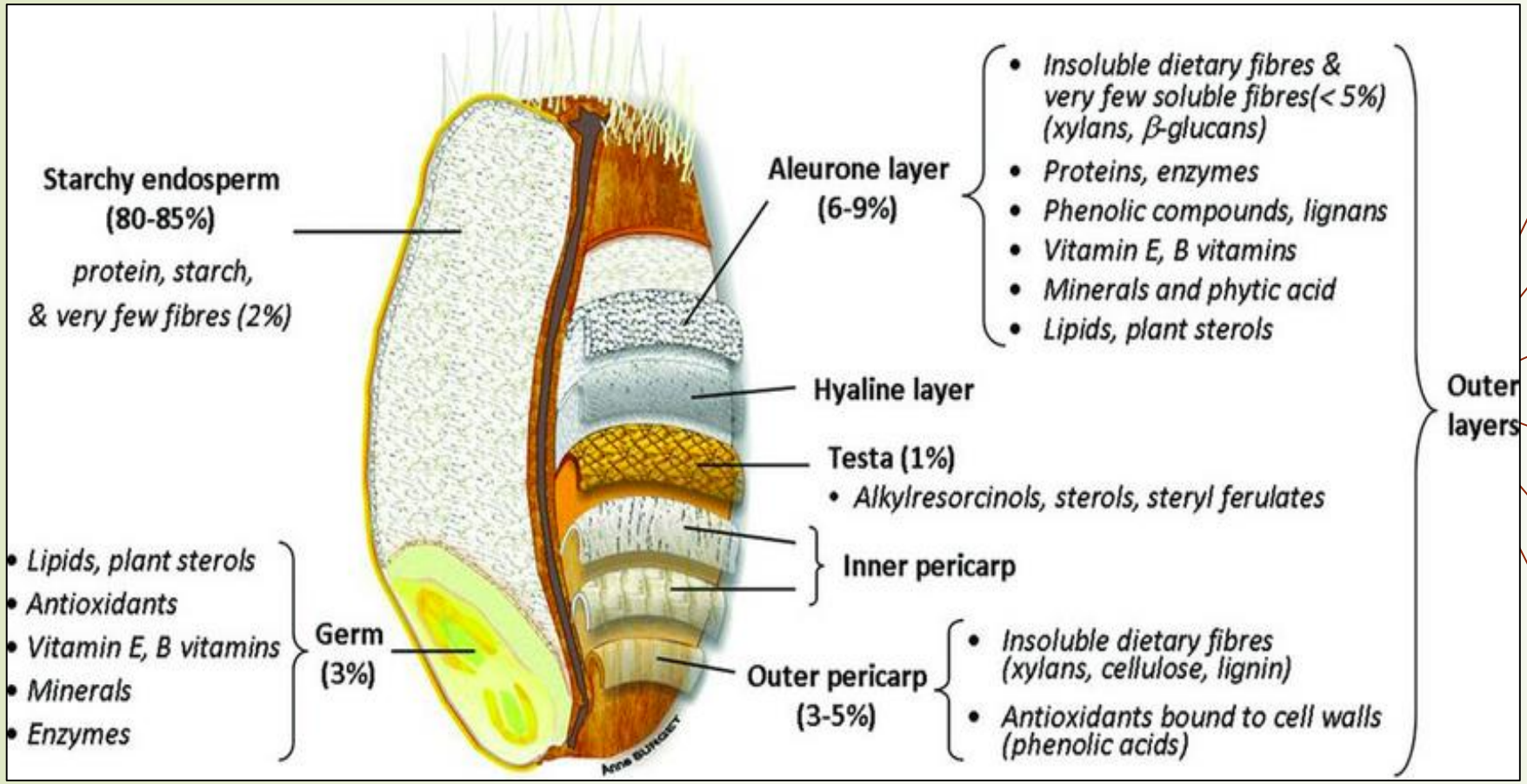
- Amaranth
- Buckwheat
- Einkorn
- Emmer
- Freekah
- Kamut
- Millet
- Quinoa
- Sorghum

Health Benefits of Cereal Grains

Cereal Grain Intake Decreases Risk

- Overweight/obesity
- Cardiovascular disease
- Type 2 diabetes
- Cancer
- All-cause mortality

Cereal Grain Composition and Physiological Action

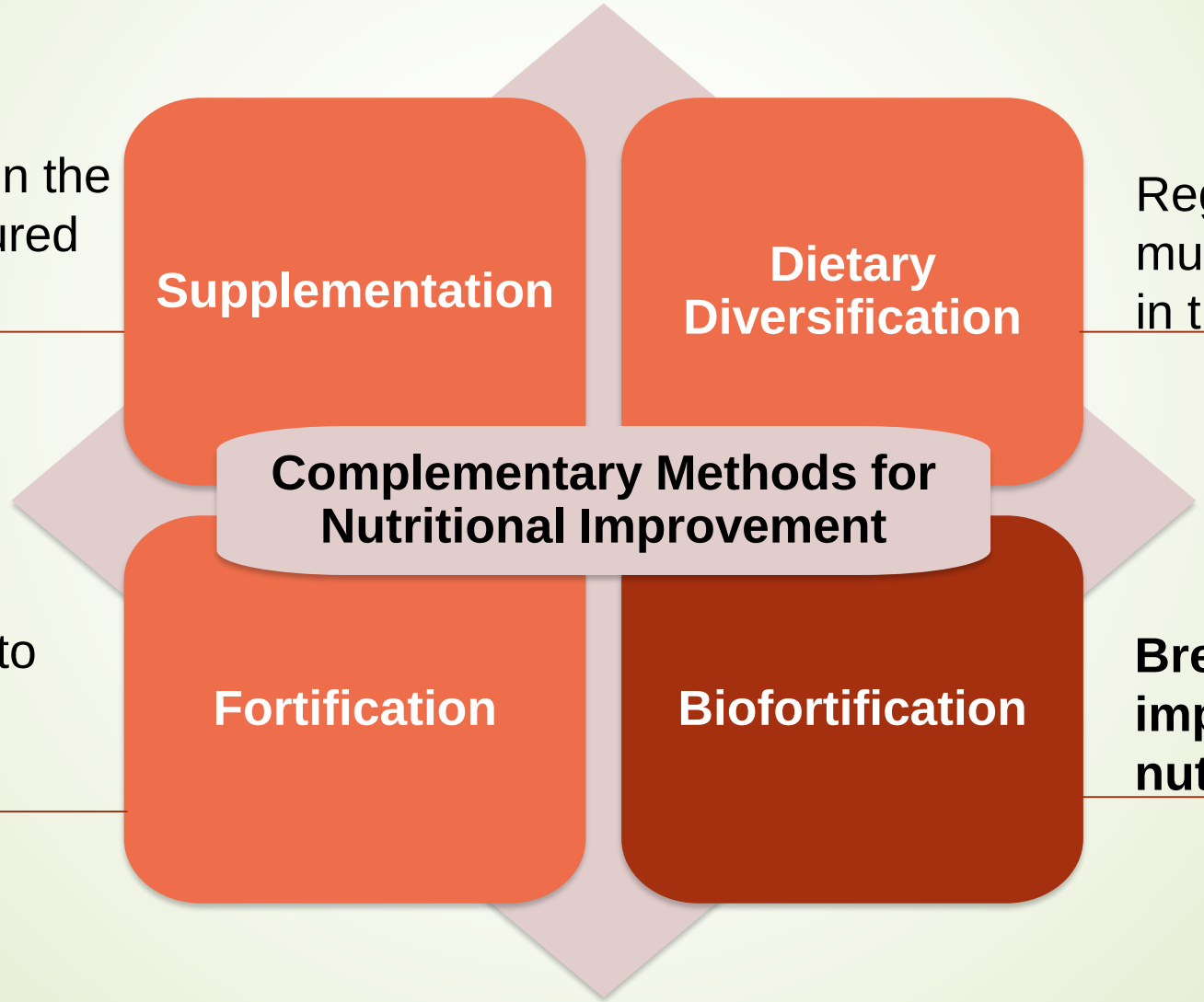


- ↑ Fullness
- ↓ Hunger
- ↓ Fat mass
- ↓ Inflammation
- ↑ Insulin sensitivity
- ↓ Insulin resistance

Nutritional Improvement Strategies

Intake of a nutrient in the form of a manufactured drug

Regularly including multiple food species in the diet



Adding a nutrient into a food during processing

Breeding crops to improve their nutritional value

What is Crop Diversity?

Genetic diversity within a crop

Moving Genes from One Variety to Another (Introgression)

Donor Variety

Elite Variety

Specialty Variety

Maize Carotenoid Biofortification

High Carotenoid Content → Adequate Vitamin A → Normal health

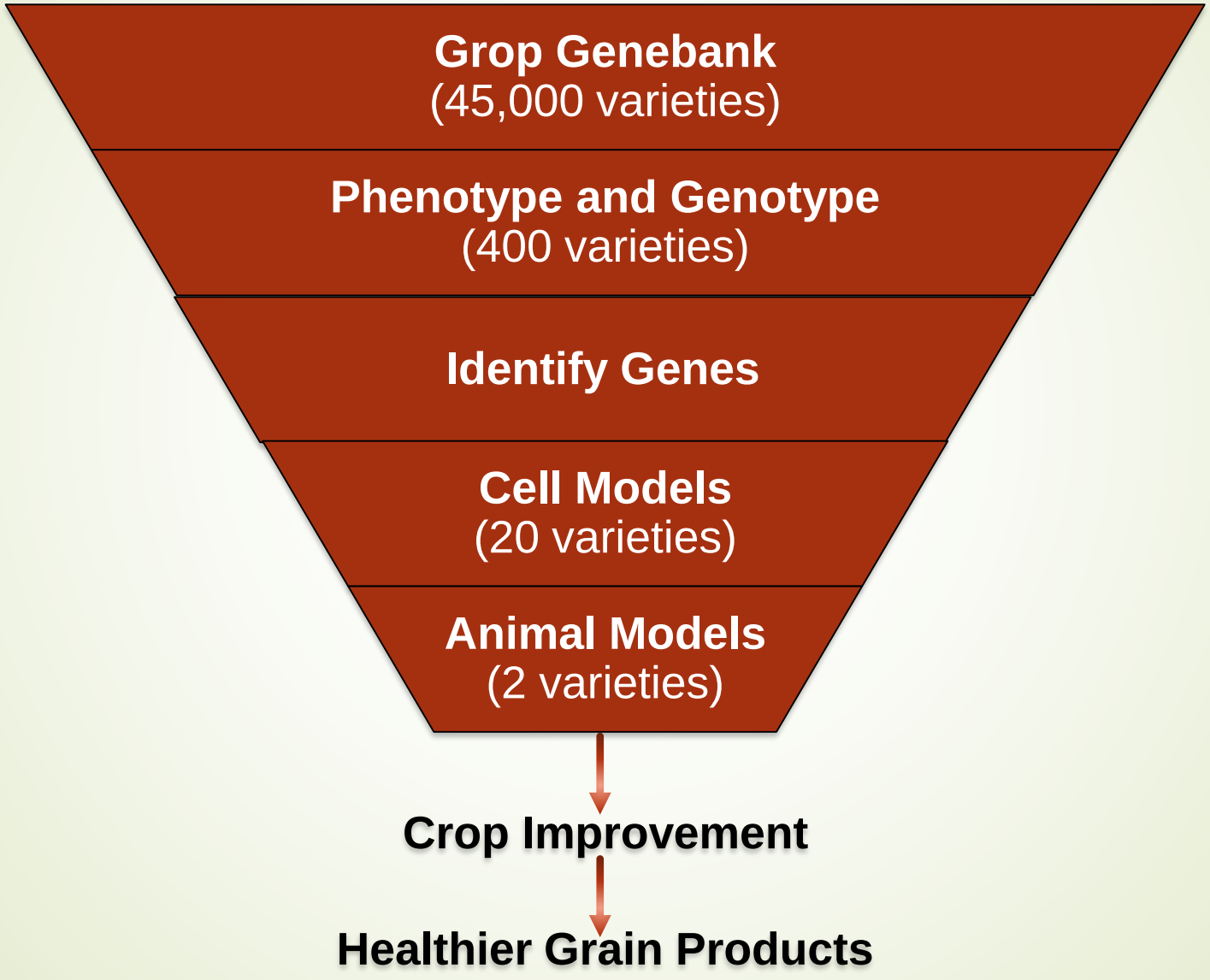
Low Carotenoid Content → Vitamin A deficiency → -Blindness -Disease -Death

Impact of Wheat Variety on Autoimmune Diseases

- Wheat proteins implicated in autoimmune diseases
- Underutilized wheat varieties have different proteins
- Genetic diversity decreases incidence of autoimmune disease

Gorelick, et al. “The Impact of Diet Wheat Source on the Onset of Type 1 Diabetes Mellitus—Lessons Learned from the Non-Obese Diabetic (NOD) Mouse Model.” *Nutrients*

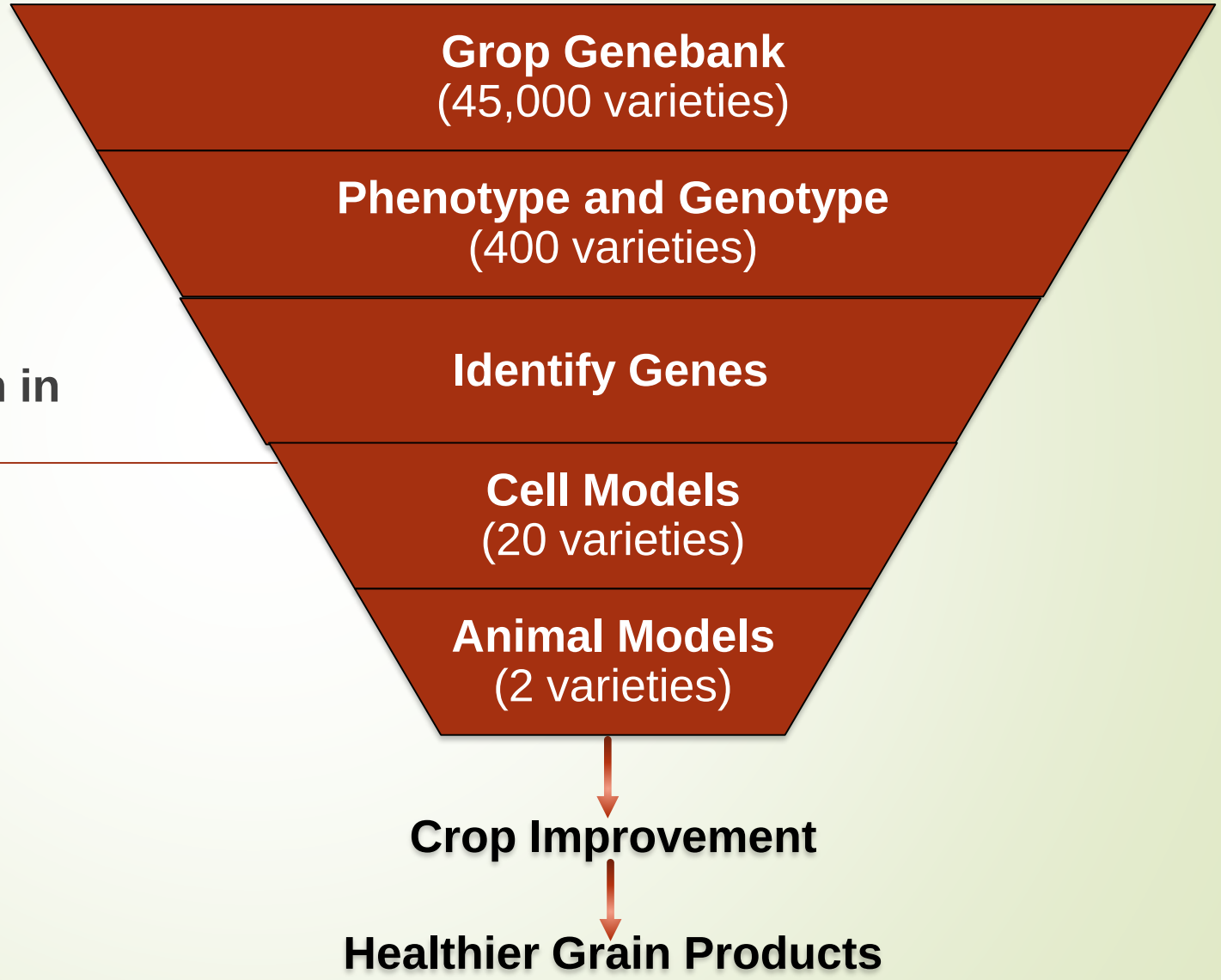
Leveraging Crop Diversity for Improved Health



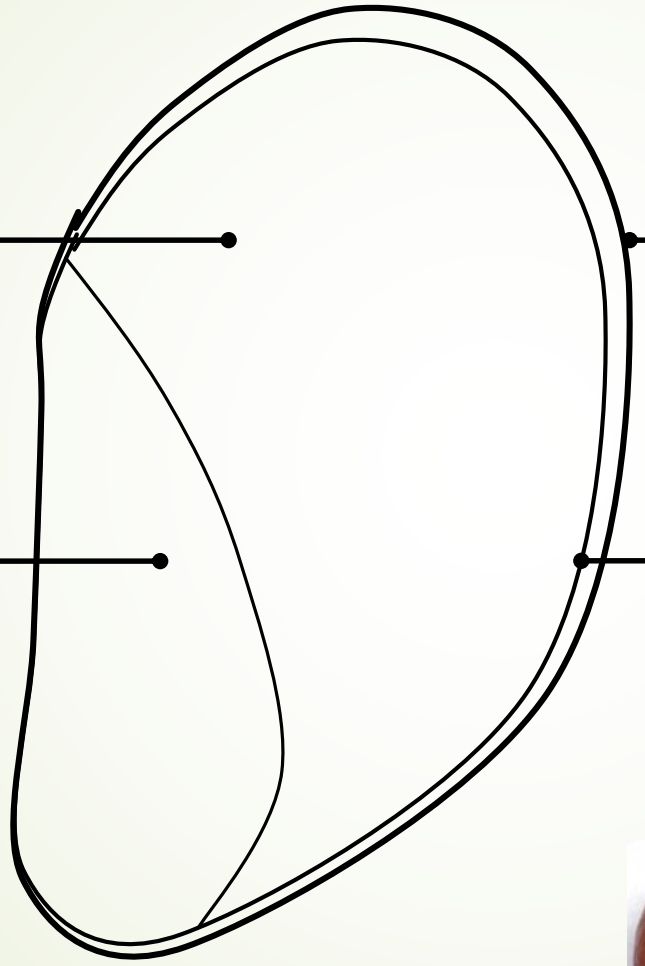
Developing Resources to Increase Sorghum Flavonoids

- **Objective 1**

  Measure grain flavonoid concentrations and identify genes controlling the variation in concentrations.



Sorghum Grain Structure and Composition



Endosperm
- Starch
- Protein
- Carotenoids

Germ (embryo)
- Fatty acids
- Iron
- Zinc

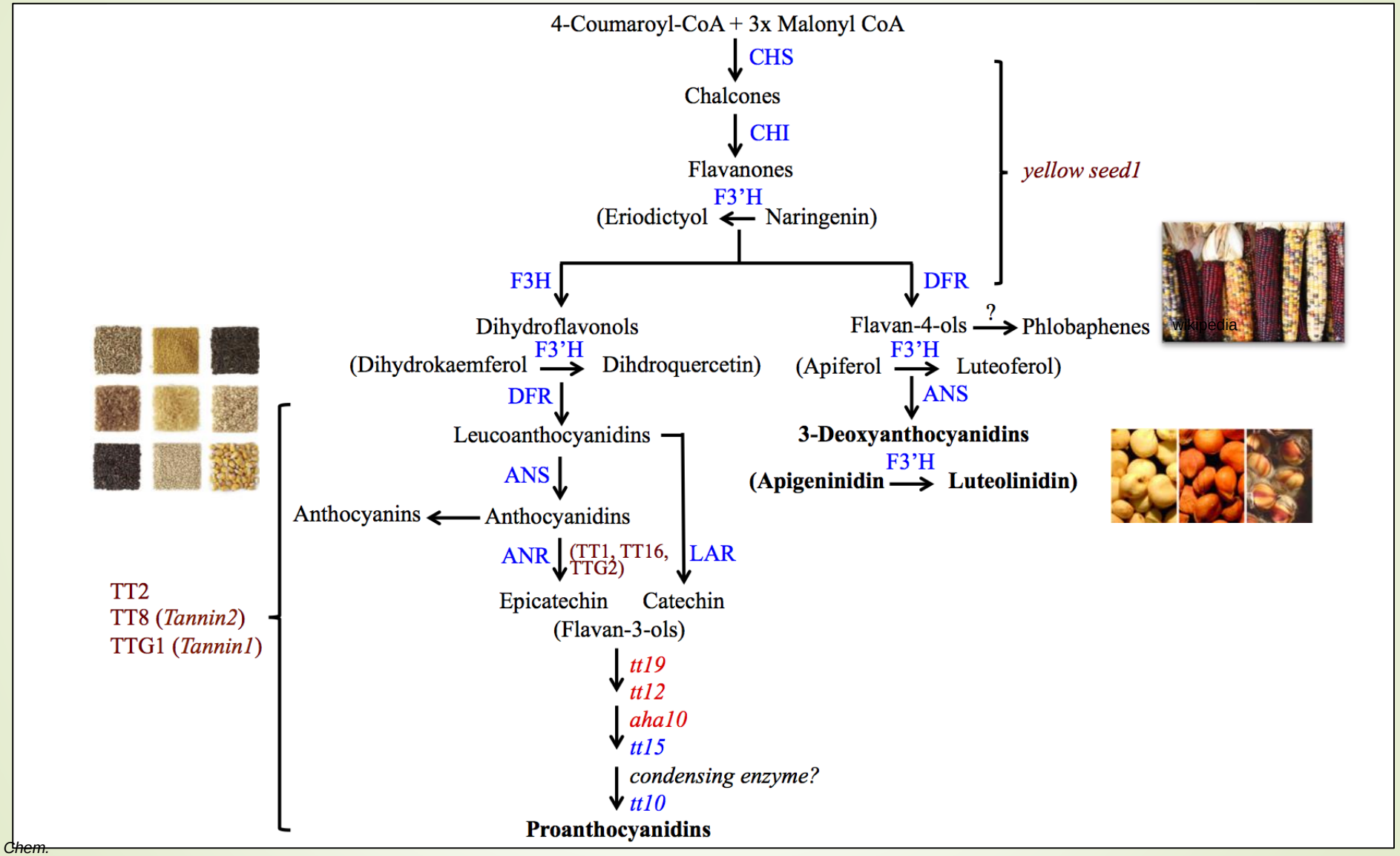
Pericarp (Outer seed coat)
- Tannins (Proanthocyanidins)
- 3-Deoxyanthocyanidins (3-DA's)
- Carotenoids

Testa (Inner seed coat)
- Tannins (Proanthocyanidins)

Sorghum Flavonoids

- Tannins
  - Concentrated in outer seed coat…the bran
  - Found in most wild relatives of cereals, but rare in domesticated cereals
- 3-Deoxyanthocyanidins (3-DAs)
  - Concentrated in outer seed coat and in entire plant
  - Only food source is sorghum

Genes Involved in Flavonoid Production



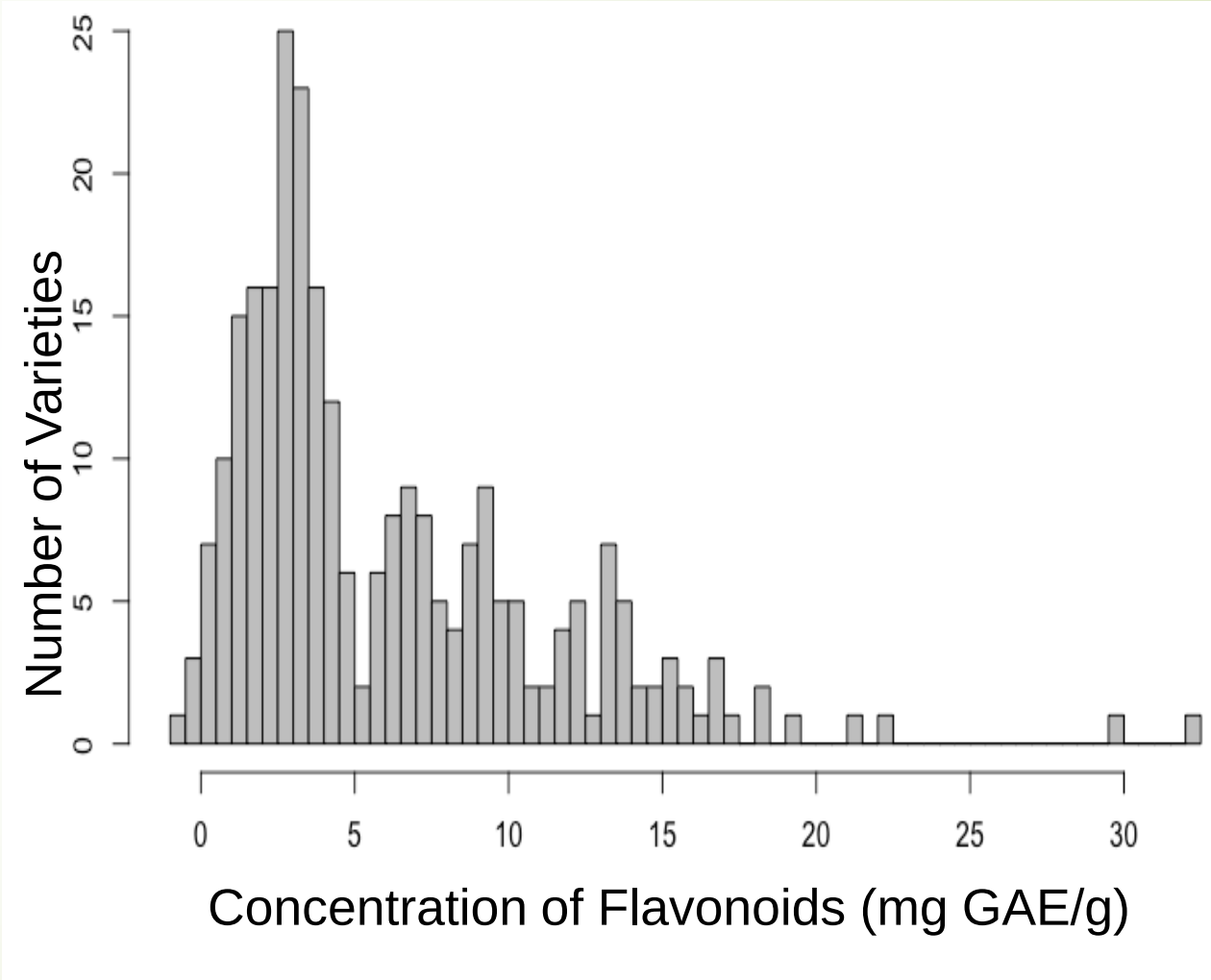
Rhodes *et al*, 2014. *J. Agric. Food Chem.*
Ibraheem et al, 2010, Genetics
Glover and Martin, 2012. *J. Current Biology*
Kawahigashi *et al*, 2016. *G3*

Plant Material

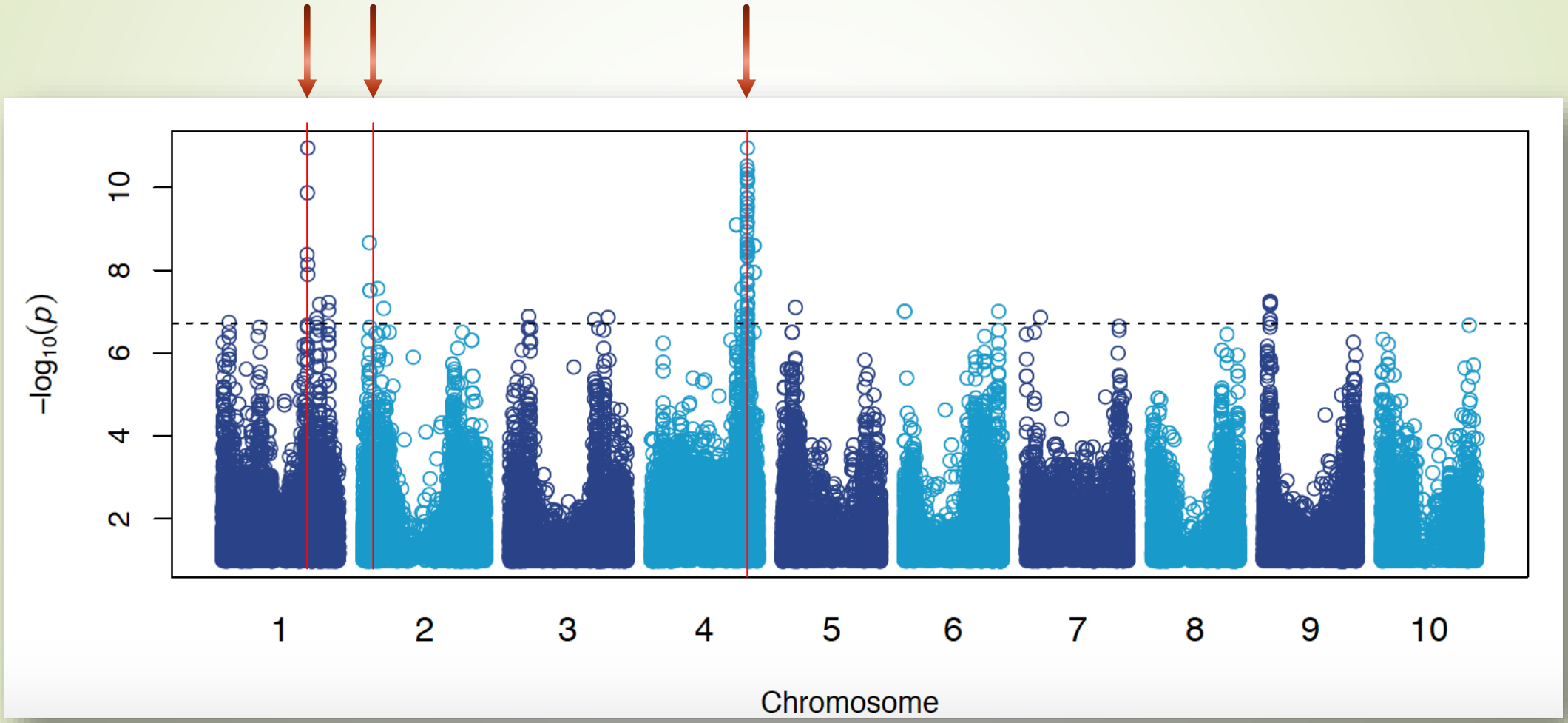
- Global diversity from crop gene bank
  - 400 varieties and breeding lines
- Planted 2012, 2013, 2014 in Florence, SC
- Harvested at grain maturity
- Genotyped each variety

Diversity of Sorghum Grain Flavonoid

- Large range of flavonoid concentrations
  - 0 – 30 mg GAE/g



Identifying the Genes Controlling Flavonoid Concentrations



Rhodes *et al*, 2014. *J. Agric. Food Chem.*

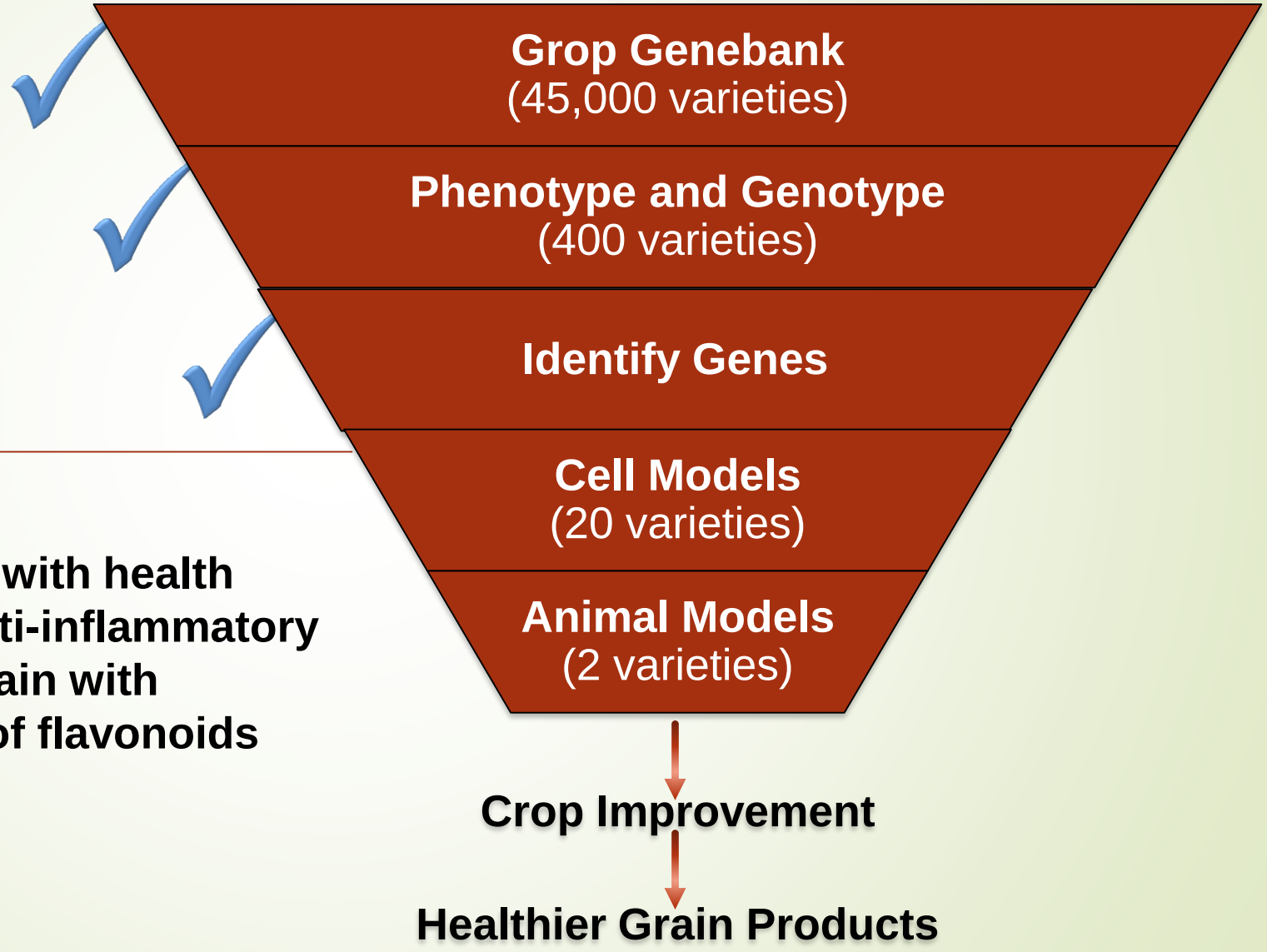
Developing Resources to Increase Sorghum Flavonoids

- Objective 1

  Quantify grain flavonoids and identify genes controlling their variation

- **Objective 2**

  Identify specific varieties with health benefits by identifying anti-inflammatory properties of sorghum grain with different concentrations of flavonoids



Identifying Related Sorghum Varieties

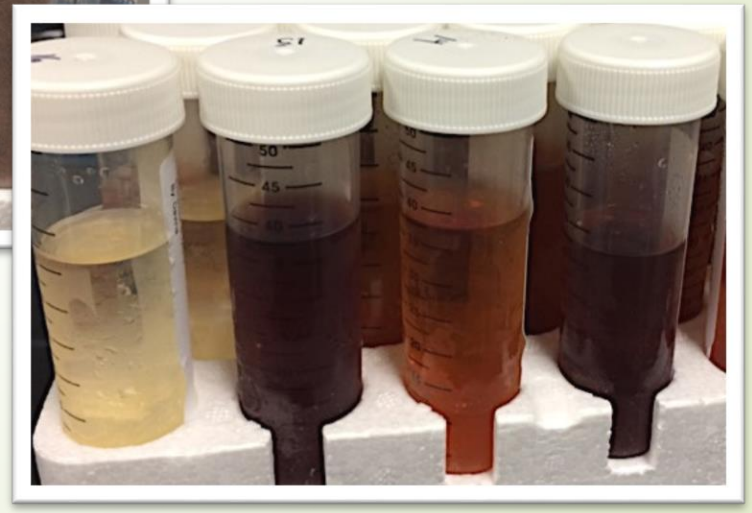
- 400 varieties to 20 varieties
- Subsets of contrasting flavonoids

Decortication and Extraction

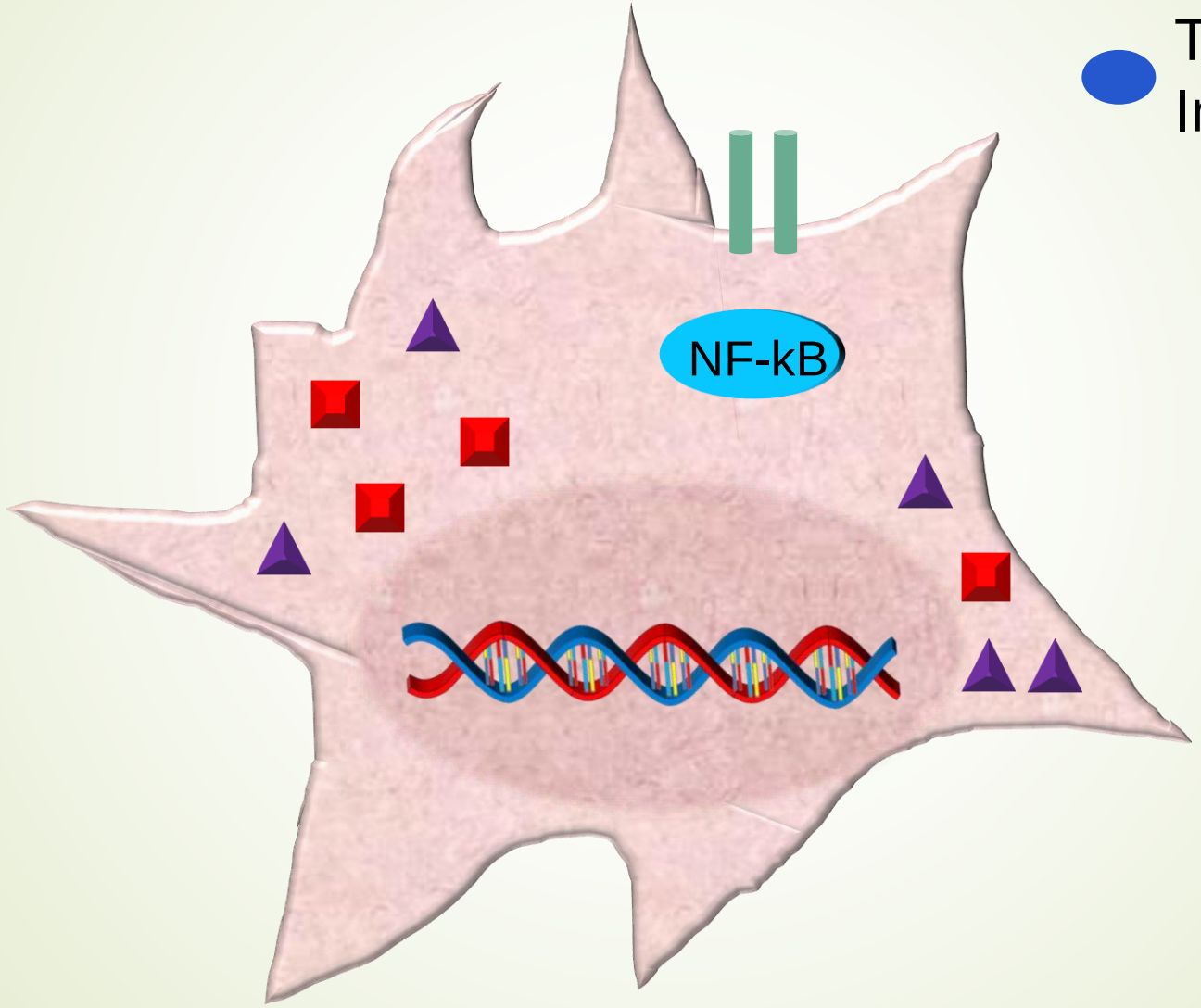
Whole grain

Bran

Extract



Mouse Macrophage Inflammation Model

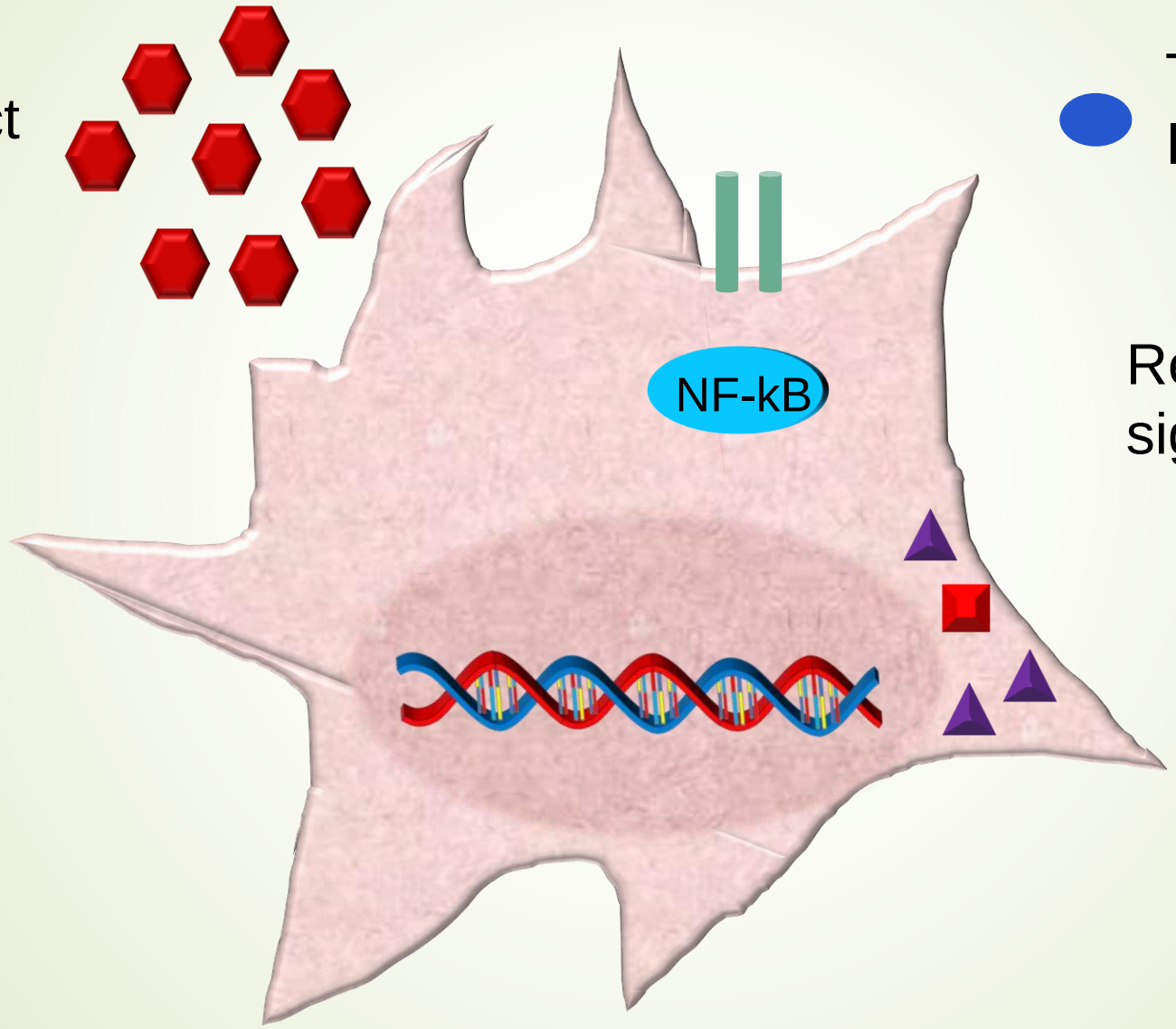


Toxin to Induce Inflammation

Inflammatory signaling proteins

Effects of Sorghum Flavonoids on Inflammation

Flavonoid Extract



Toxin to Induce Inflammation

Reduced Pro-inflammatory signaling proteins

Rhodes et al, 2016 *Journal of Chemistry*

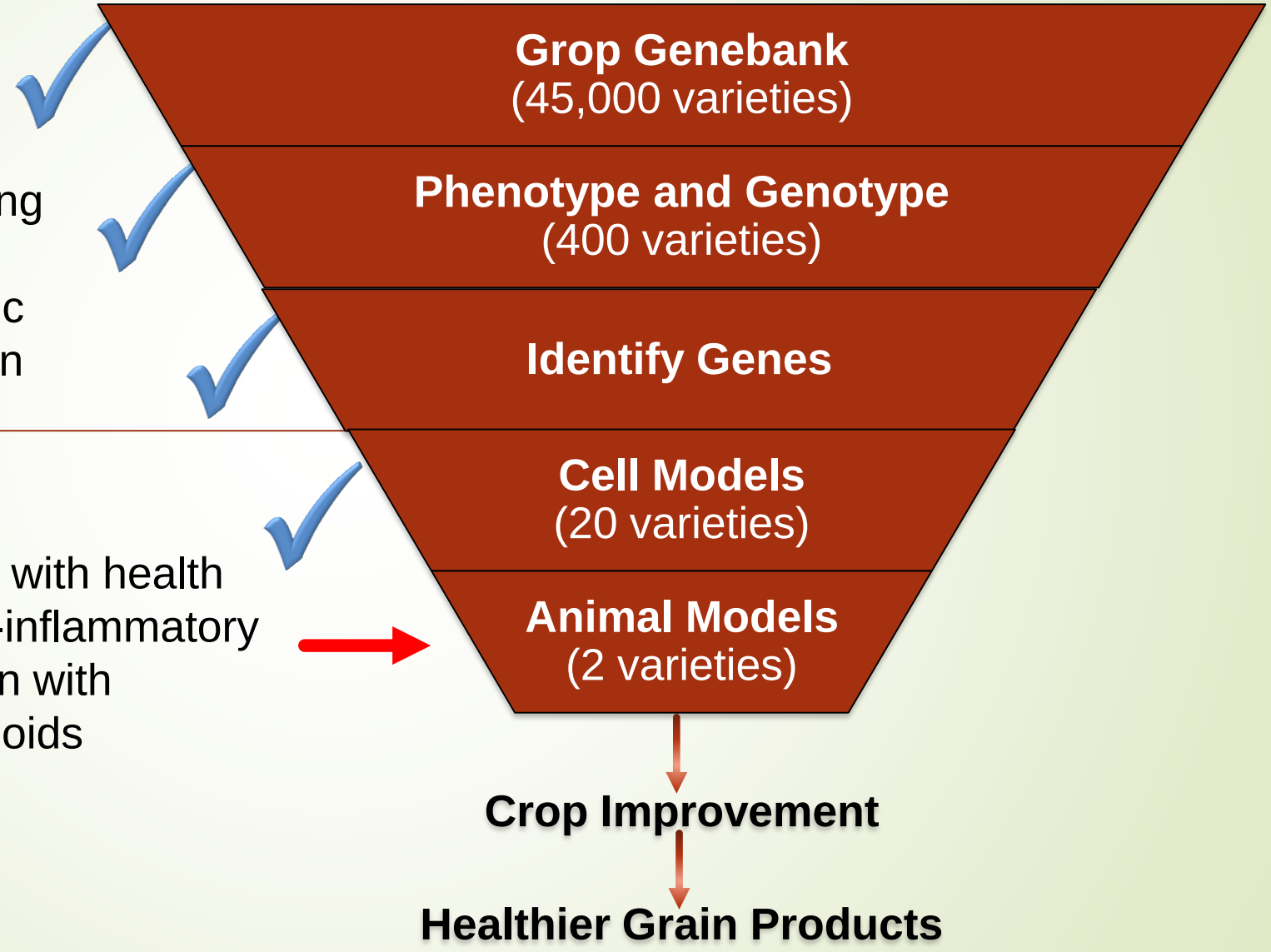
Developing Resources to Increase Sorghum Flavonoids

- Objective 1

  Develop marker assisted breeding resources by quantifying grain flavonoids and identifying genetic markers controlling their variation

- Objective 2

  Identify specific genotypes with health benefits by identifying anti-inflammatory properties of sorghum grain with contrasting levels of flavonoids



Characterization of Effects of High Flavonoid Sorghum Grain on Obesity, Insulin Resistance, and Inflammation

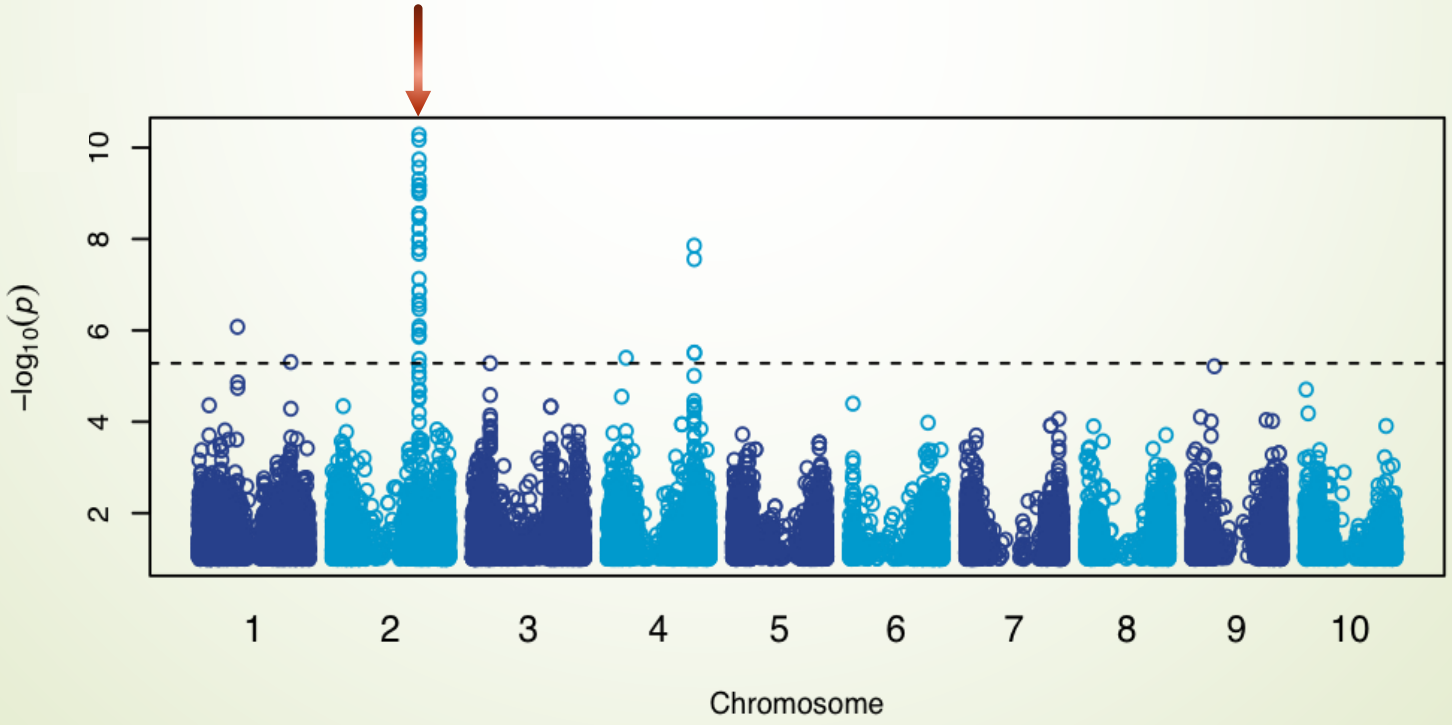
- Objectives:
  - characterize the anti-inflammatory effects of high flavonoid sorghum grain using mouse models of disease
  - measure the bioavailability of high flavonoid sorghum grain using cell and animal models

Development of Molecular Breeding Resources for Increased Grain Carotenoids in Sorghum

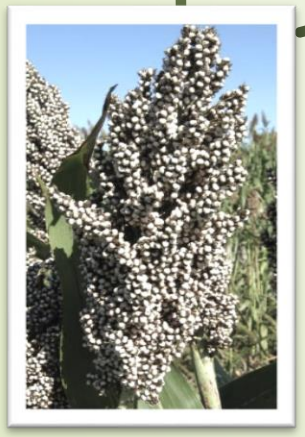
- Objectives:
  - Find sorghum varieties with high concentrations of carotenoids
  - Develop a fast and economical method to measure carotenoid concentrations
  - Identify genes controlling carotenoid concentrations

Genetic Improvement of Sorghum Grain Protein

- Objectives:
  - characterize the protein composition and bioavailability in improved varieties
  - Identify genes controlling protein composition for breeders to use to develop high protein varieties



Biofortification Using Cereal Diversity Improves Health



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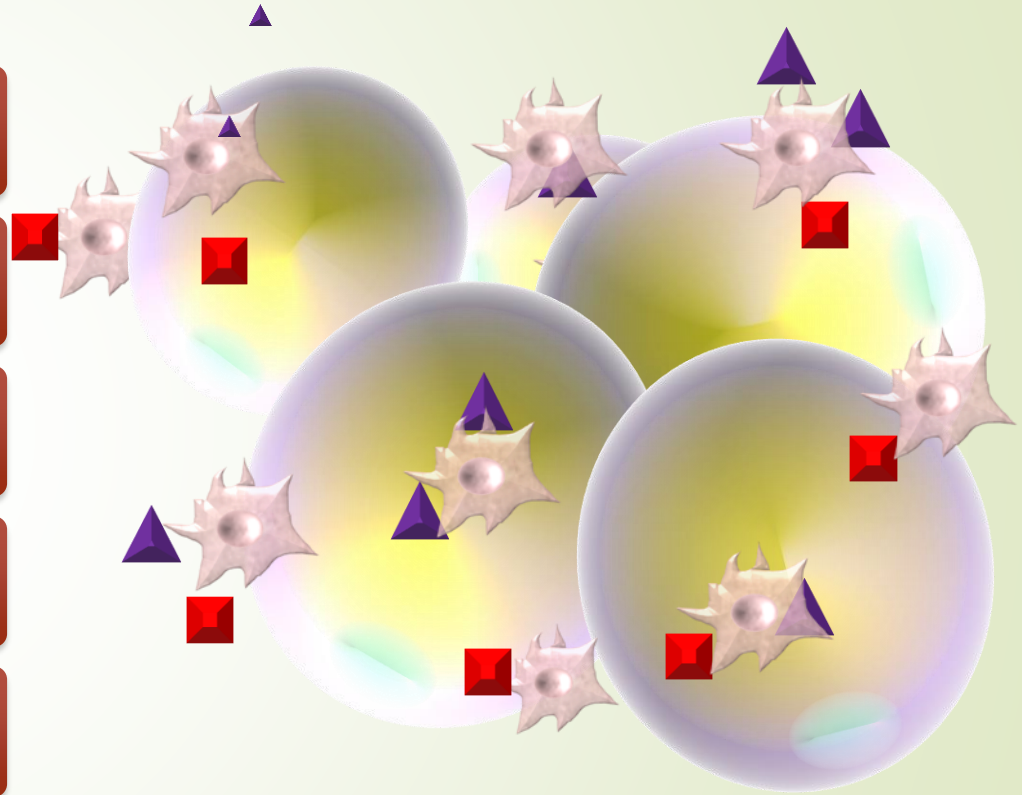
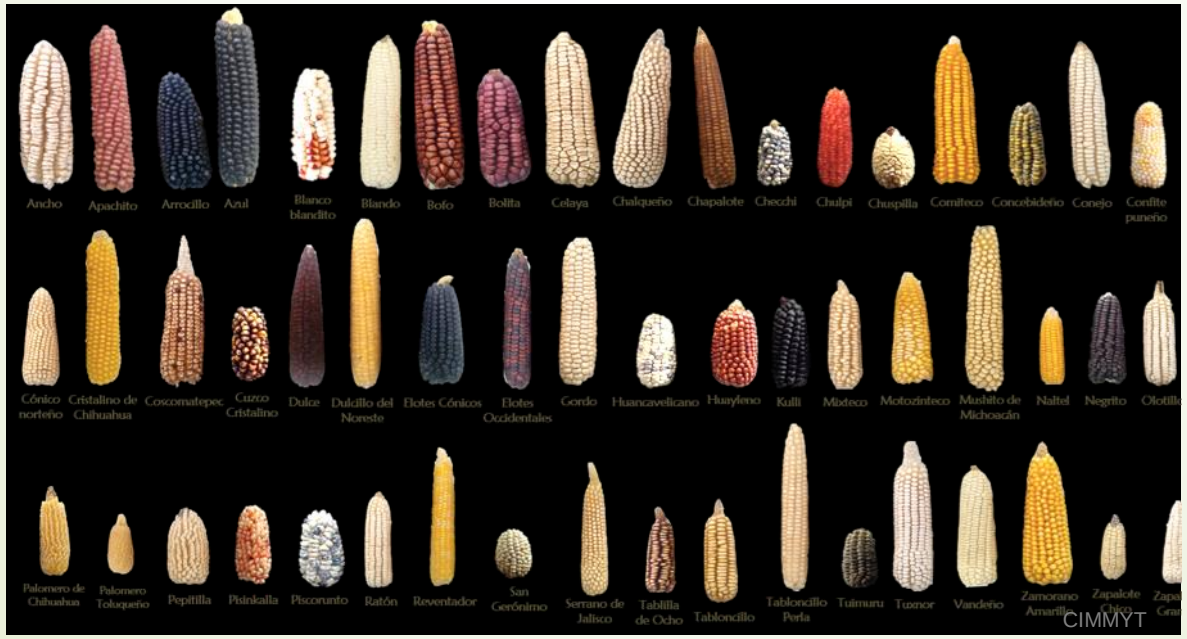


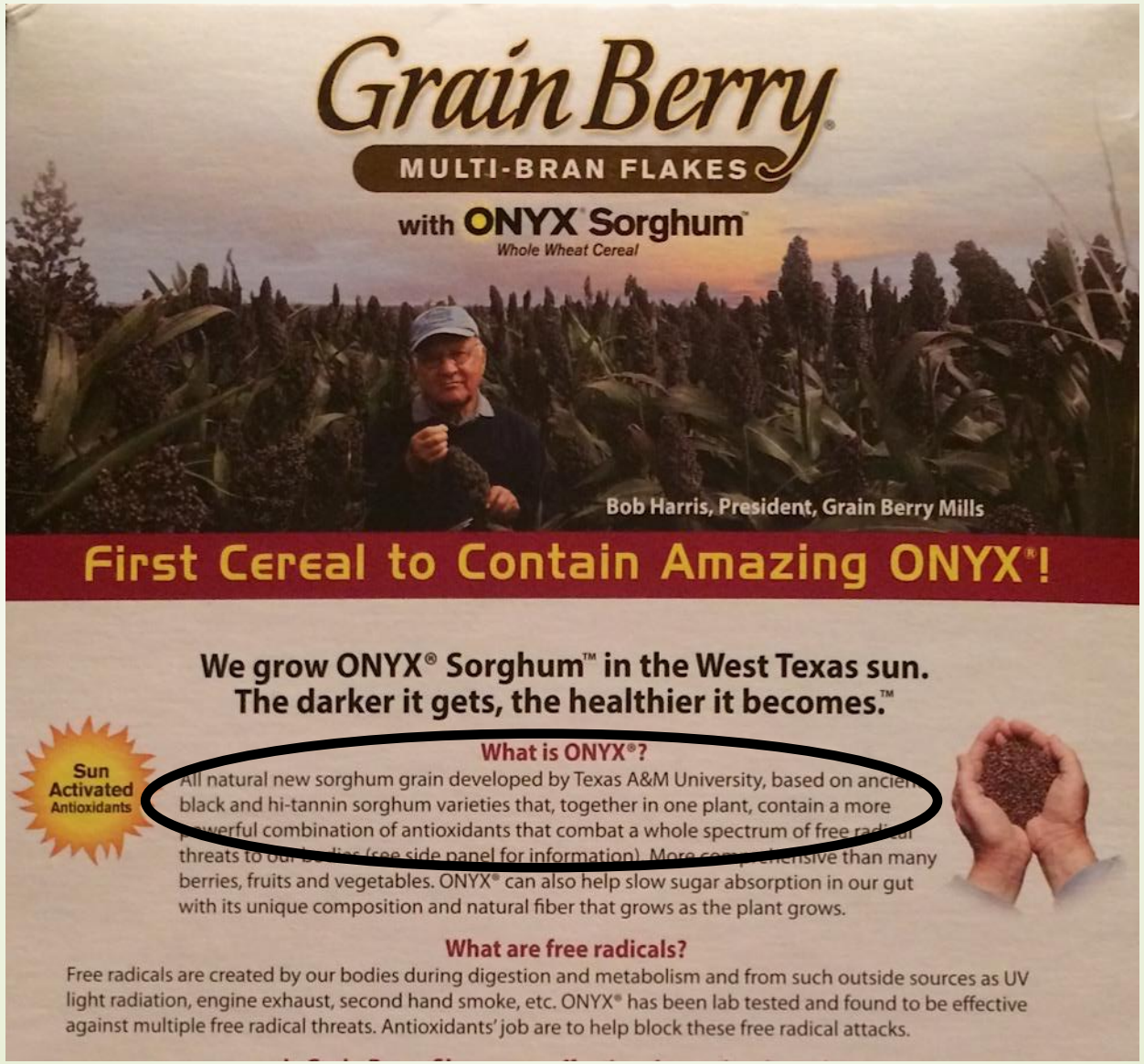
Next Steps

- Work with breeders to develop biofortified varieties
- Determine effects of food processing on biological activity
- Feedback from food companies on their priorities



Breeding for Health

Breeding for Health



Acknowledgements

Kresovich Lab-USC/Clemson
Stephen Kresovich, Rick Boyles, Zach Brenton

Rooney Lab-TAMU
Bill Rooney, Leo Hoffmann

Fantuzzi Lab-UIC
Giamila Fantuzzi, Maria Pini

USDA-ARS
Tom Herald, Scott Bean, Brian Ioerger, Sarah Cox, Neil Baker

Sorghum Breeding Programs-KSU
Tesfaye Tesso, Ramasamy Perumal, Daniel Hopper

Molecular Breeding Group-KSU
Ramasamy Perumal, Elfadil Bashir, Geoff Morris, Terry Felderhoff, Zhenbin Hu, Sandeep Marla

Funding
USDA NIFA AFRI
United Sorghum Checkoff Program

Questions?

Background: Path to Nutritional Genomics

- **M.S. Human Nutrition, University of Illinois at Chicago**
  - Genetics research
  - Clinical nutrition
- **Professional Experience**
  - Diabetes education, Endocrine Clinic, Mt. Sinai Hospital
  - Genetic research on inflammation and chronic disease
- **PhD Integrative Biology, University of South Carolina**
  - Diversity, genetics, and health benefits of sorghum grain
- **NIFA Postdoctoral Fellow, USDA-ARS**
  - Sorghum grain carotenoids
- **Assistant Professor, Kansas State University**
  - Nutritional Genomics