Grains and nutrition: *a cereal scientist's perspective:* cereal starches, fibers, and gluten

Dr Andrew Ross

OSU Oregon State University

OSU Oregon State University

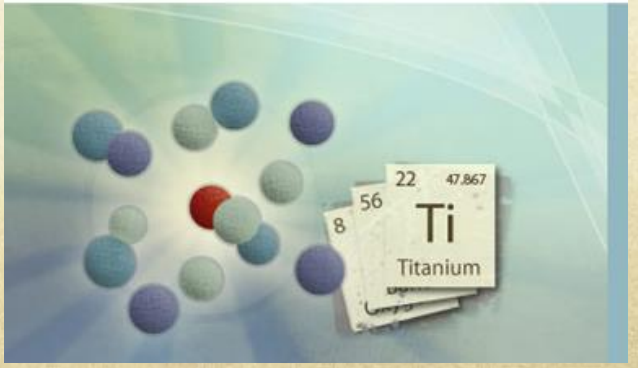
Crop & Soil Science

College of Agricultural Sciences

Food Science & Technology

Materials Science

AT OREGON STATE UNIVERSITY



Outline

- Full disclosure
- Some basic assertions
- Interactions between cereal and nutrition sciences
- Raw material development
- Primary Processing
- Secondary Processing
- Gluten

Funding


OWC
OWC
OREGON WHEAT COMMISSION


AGRICULTURAL
RESEARCH FOUNDATION
promoting agricultural research since 1934


IDAHO Barley Commission


USDA
United States Department of Agriculture
National Institute of Food and Agriculture

Affiliations

AACC INTERNATIONAL

the Bread Bakers Guild of America

Western Wheat Quality Laboratory
Pullman, Washington - U.S.A.
USDA ARS

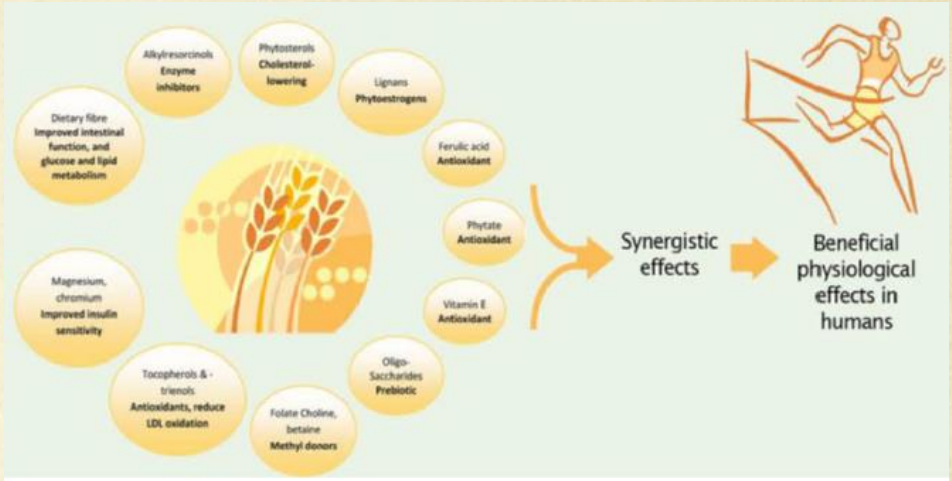
Washington State University
Mount Vernon Research Center
College of Agricultural, Human, & Natural Resources
The Bread Lab

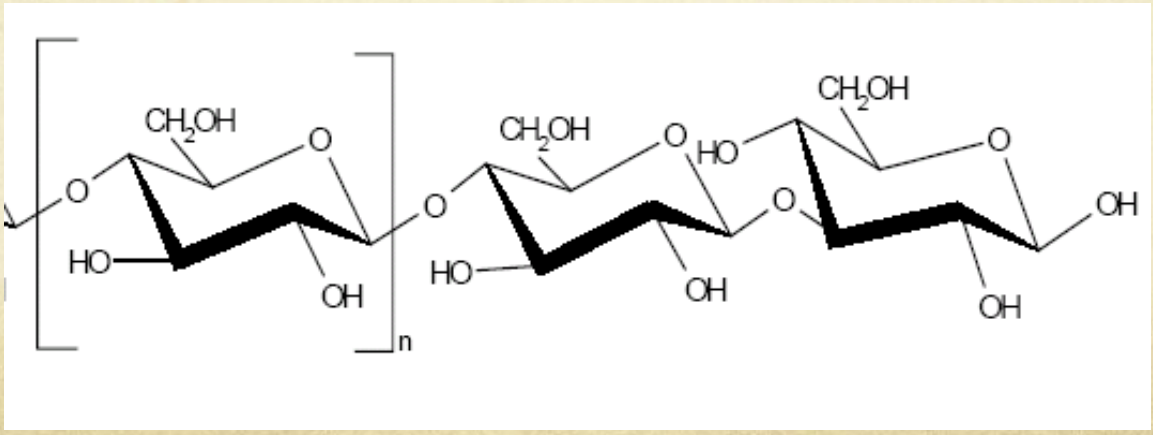
WHEAT MARKETING CENTER

Pacific Northwest Wheat Quality Council
Serving the Needs of the Wheat Industry

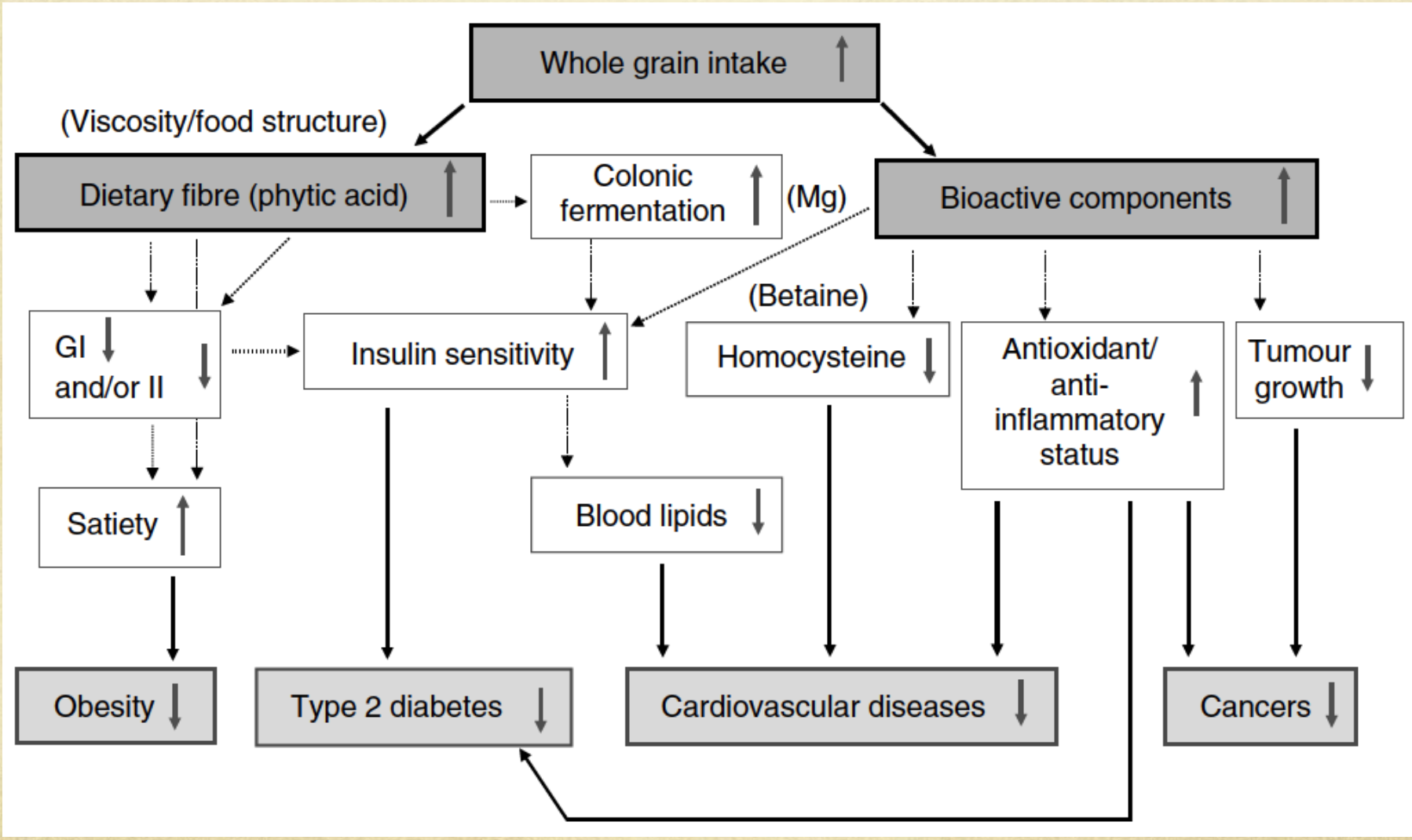
College of Public Health and Human Sciences
Moore Family Center

Some basic assertions...





1: Wholegrain consumption leads to health benefits in humans



Fardet, A. "New hypotheses for the health-protective mechanisms of whole-grain cereals: what is beyond fibre?." Nutrition Research Reviews 23.01 (2010): 65-134.

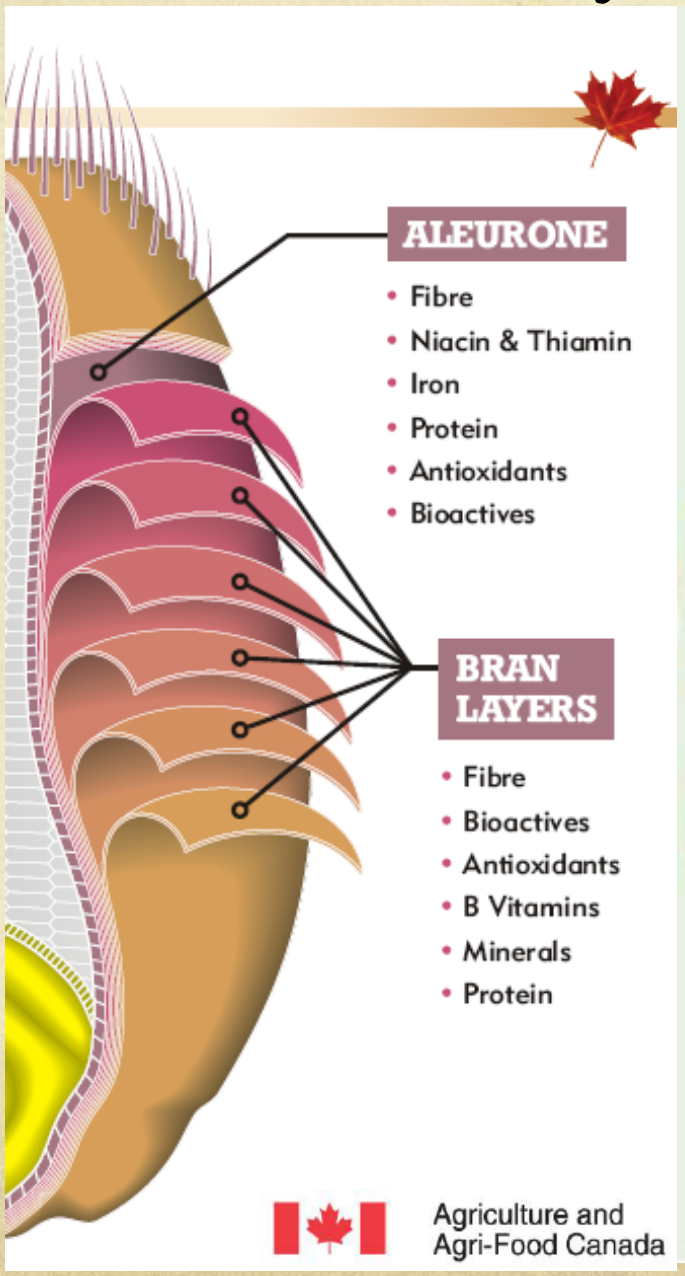
2: Dietary fiber can be defined

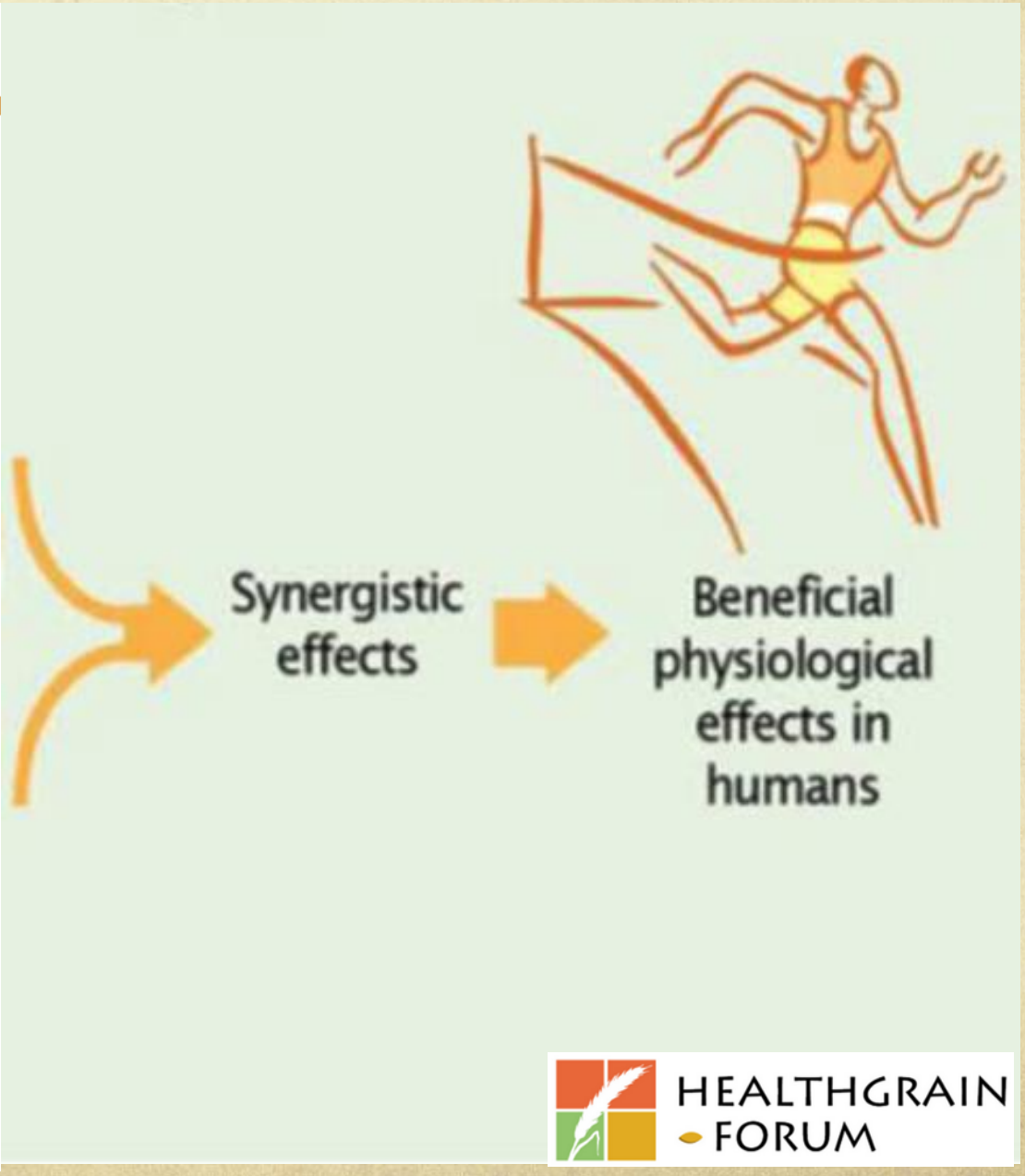
For example: this broadly inclusive definition.

"*dietary fiber consists of all carbohydrate components that are non-digestible to mammalian enzymes*"

MCBURNEY, M. I. 2010. Dietary fibres insights and opportunities. Pp 153-166 in Dietary fibre: new frontiers for food and health. J.W. Van Der Kamp, J.M. Jones, B.V. McCleary, & D.L. Topping eds. Wageningen Academic Publishers,.

3: More than just fiber





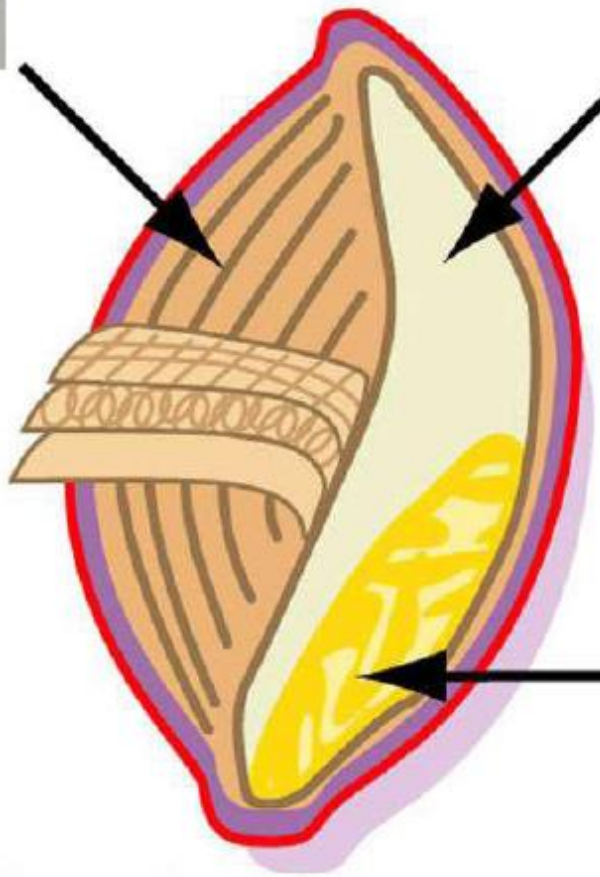
4: Whole grain does not = fiber

Bran

- Dietary fiber
- Phenolic acids
- Vitamins and minerals

Endosperm

- Starch
- Protein
- Some vitamins and minerals



Germ

- Unsaturated fats
- Phytosterols
- Tocotrienols
- Sphingolipids
- Protein
- Vitamins and minerals

Photo: Rob's Red Mill.

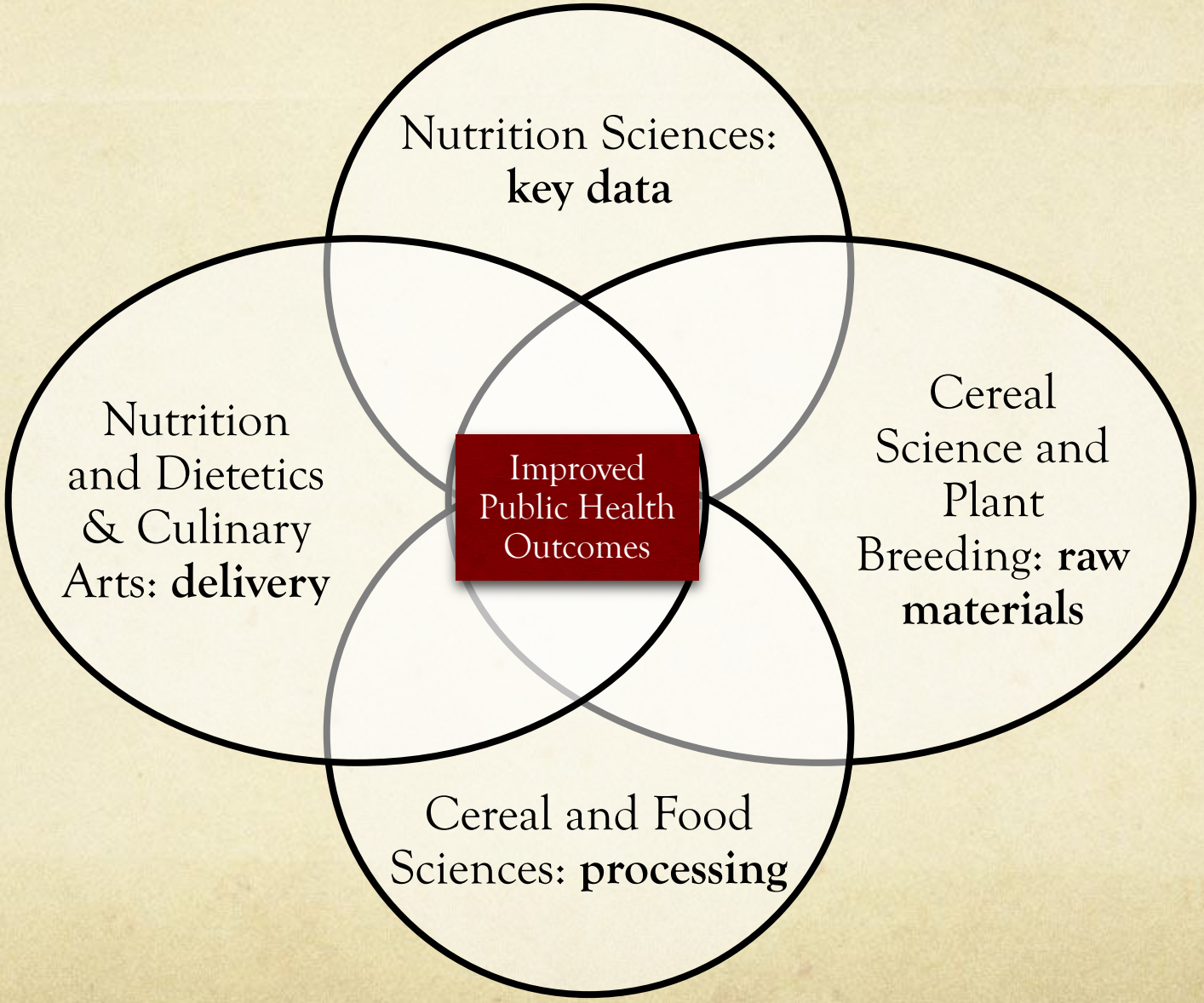
Slavin (2003) Proc. Nutr. Soc. 62:129-134.

Whole grain definition

Whole grains shall consist of the intact, ground, cracked or flaked kernel after the removal of inedible parts such as the hull and husk. The principal anatomical components - the starchy endosperm, germ and bran - are present in the same relative proportions as they exist in the intact kernel.

Small losses of components - i.e. less than 2% of the grain/10% of the bran - that occur through processing methods consistent with safety and quality are allowed.

Interdisciplinary interactions:



Raw materials

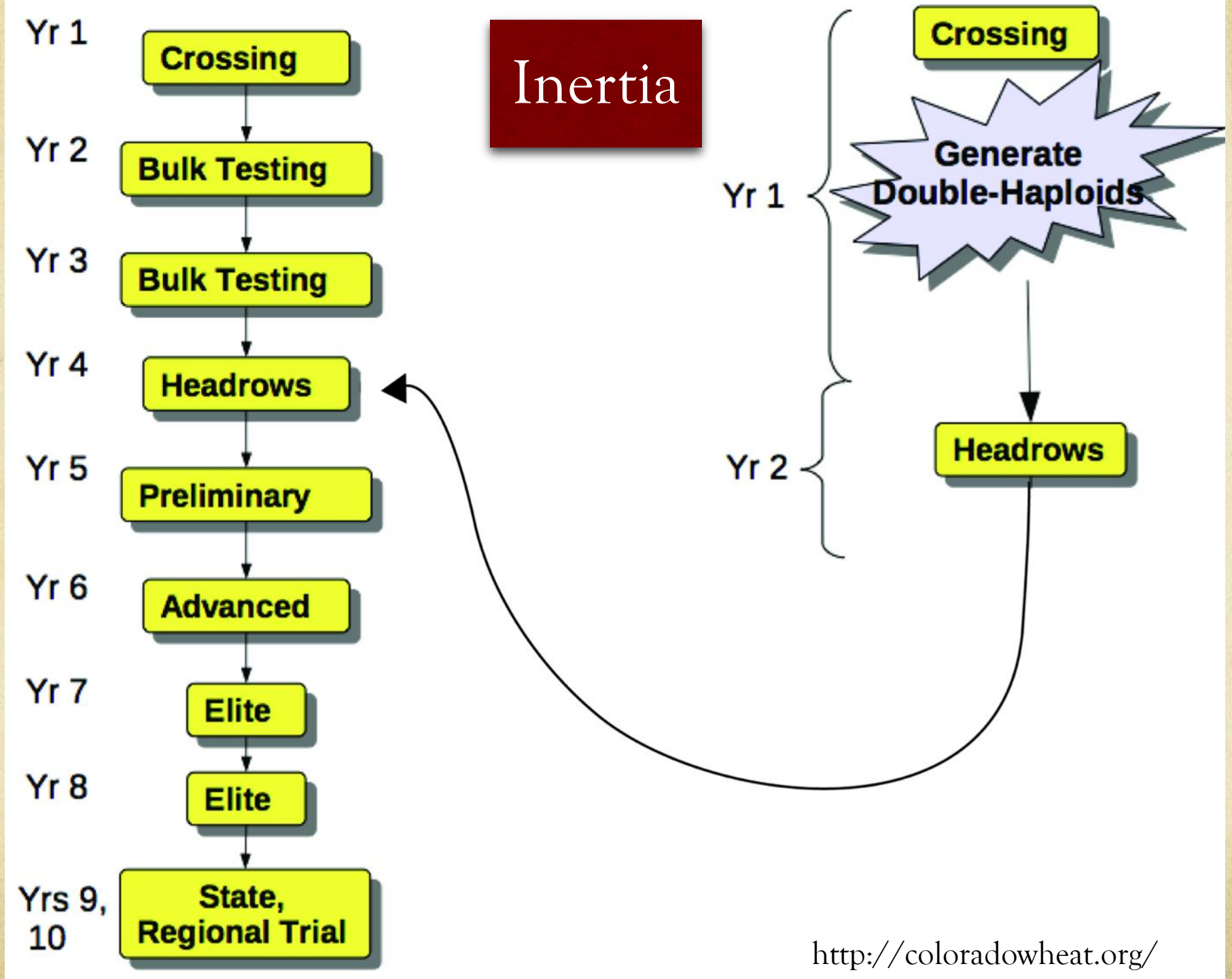
- **Wheat**
  - Multiple species and mulitple varieties within species
    - Einkorn (diploid)
    - Emmer, Durum, Kamut (tetraploid)
    - Spelt, Aestivum (hexaploid)
- **Barley**
  - Multiple varieties
- **Rye**, oats, sorghum, millets, teff, rice, pseudo-cereals…
- Growth environment


Einkorn

Raw materials: considerations in plant breeding

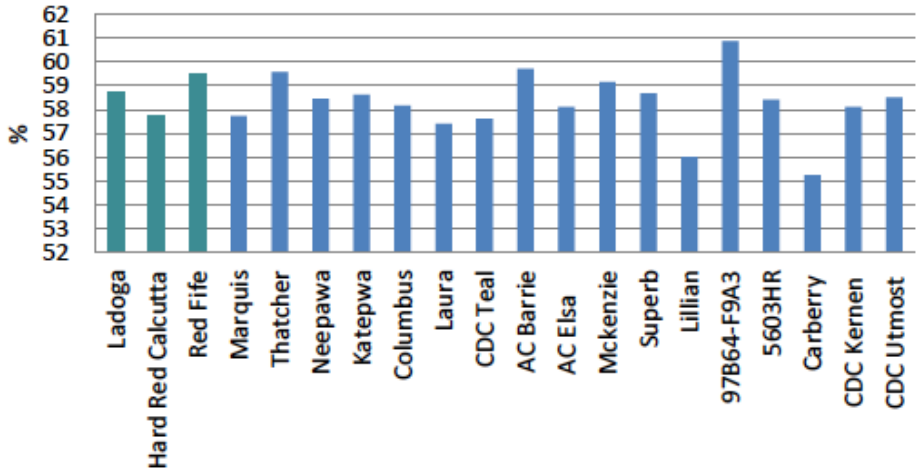
- Types of fiber: AX vs BG; both; partitioning between soluble and insoluble
- Other nutrients and anti-nutritional factors
- Anatomical locations
- Molecular weight and viscosity building potential of fiber [physiological effects and food texture/mouthfeel]
- Types and accessibility of starches
- Type, digestibility, and quality of proteins

Inertia



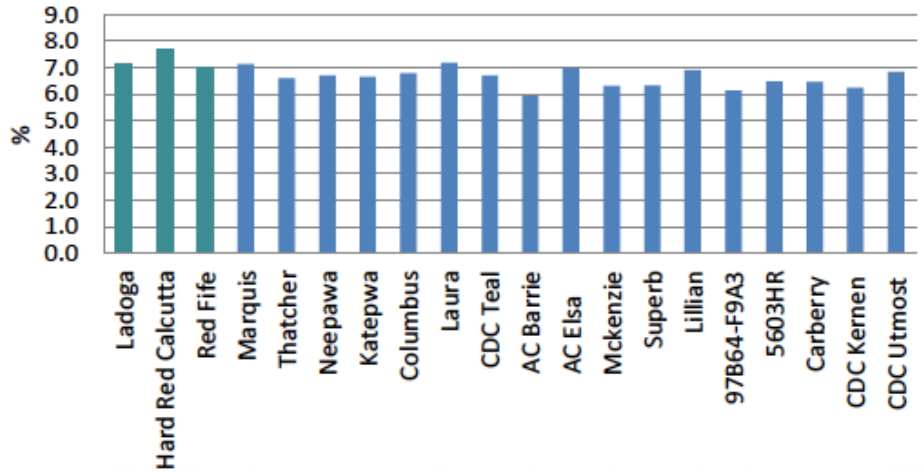
http://coloradowheat.org/

Starch

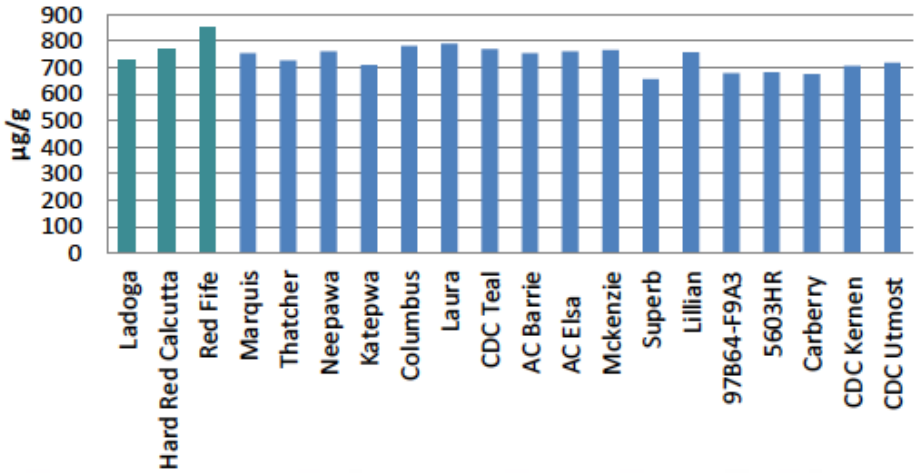


- **Some reductions in total starch content**
- **Analysis in progress:**
  - Dietary Fibre
  - Trehalose, Betaine, Cysteine
  - Minerals

Arabinoxylan – Soluble Fibre



Ferulic Acid



Ideal Grain Ingredients: Breeding Wheat for Health

Dr. Nancy Ames
Agriculture and Agri-Food Canada
Richardson Centre for Functional Foods and Nutraceuticals
September 2013

Raw materials: The OSU food barley experience

- **Hulled versus hull-less**
  - Interacts with whole-grain definition[s]
- **Beta-glucan**
  - Variable levels: GxE interactions
- **Starches**
  - Waxy
  - Normal
  - High amylose [RS]

Raw materials: OSU Food Barley

- **Fiber**
  - Primarily beta-glucan [BG]
  - Increase arabinoxylan [AX] in endosperm
  - Change AX in hulls [see processing]
- **Functionality**
  - E.g. hard versus soft
    - Water absorption in flour applications
  - Texture in whole-kernel applications

Standard Food Barley Reference Panel

Varieties	Row type	Hull type	Growth habit	Protein (%)	Grain beta-glucan (%)	Starch type

The Journal of Nutrition
Nutrient Physiology, Metabolism, and Nutrient-Nutrient Interactions

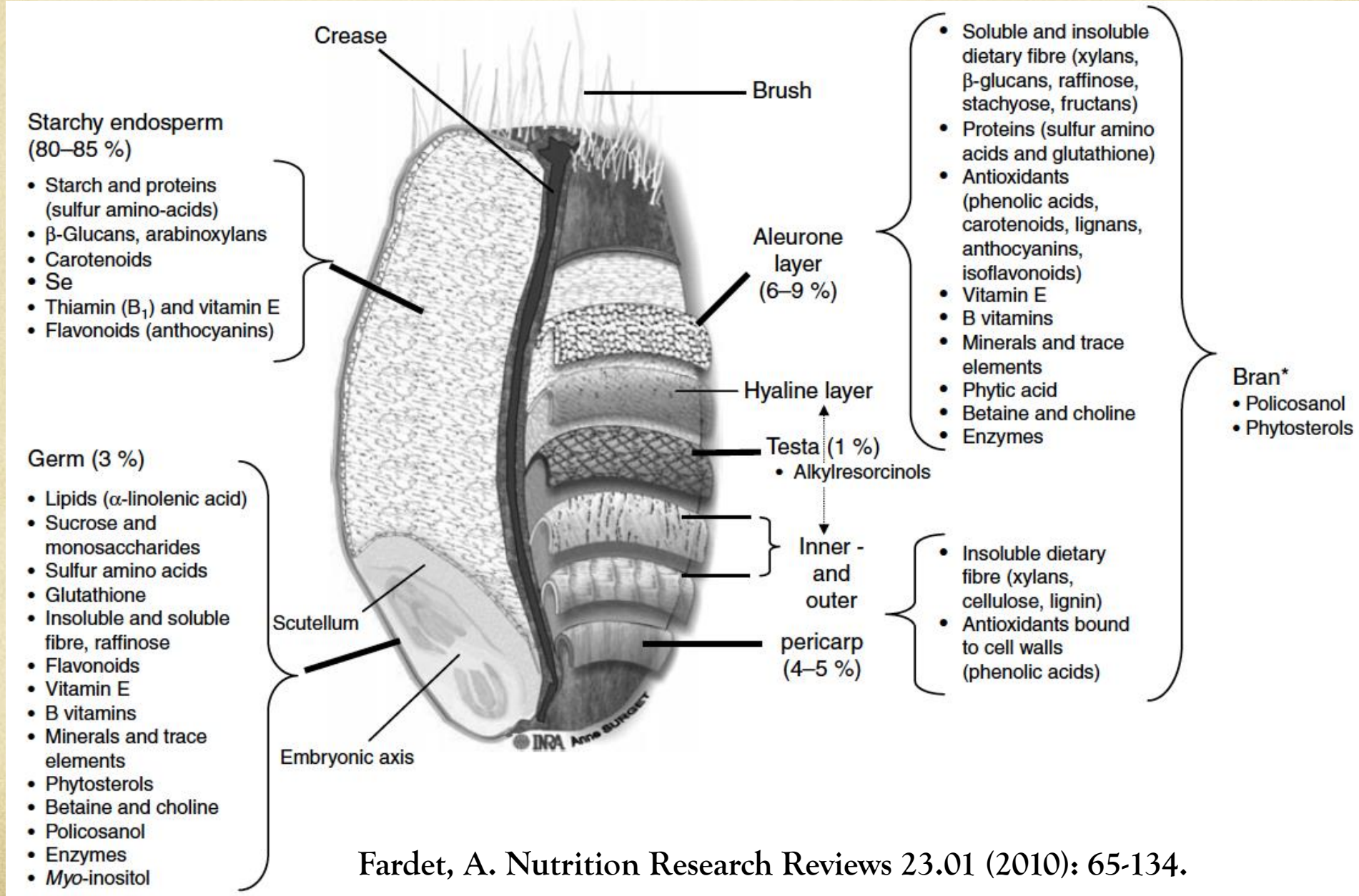
Barley Cultivar, Kernel Composition, and Processing Affect the Glycemic Index[1–3]

Ahmed Aldughpassi,[4] El-Sayed M. Abdel-Aal,[5] and Thomas M. S. Wolever[4]*

GI was correlated with total fiber ($r = -0.75$, $P = 0.002$) but not with measures of starch characteristics…

GI of barley is influenced by cultivar, processing, and food form but is not predicted by its content of amylose or other starch characteristics

Raw materials: other components



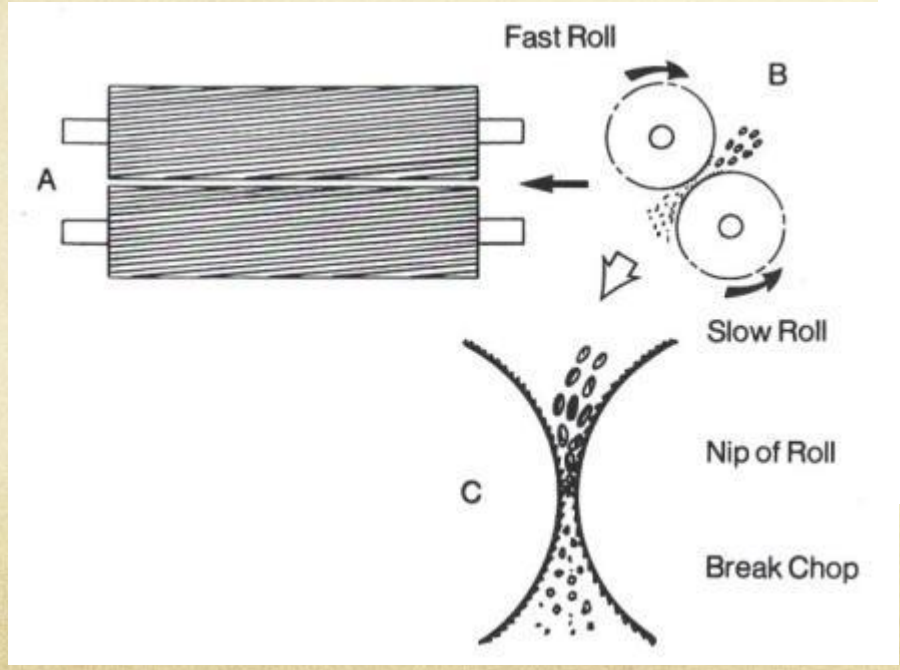
Fardet, A. Nutrition Research Reviews 23.01 (2010): 65-134.

OCOLOR
Systematic introgression of Himalayan food barley traits

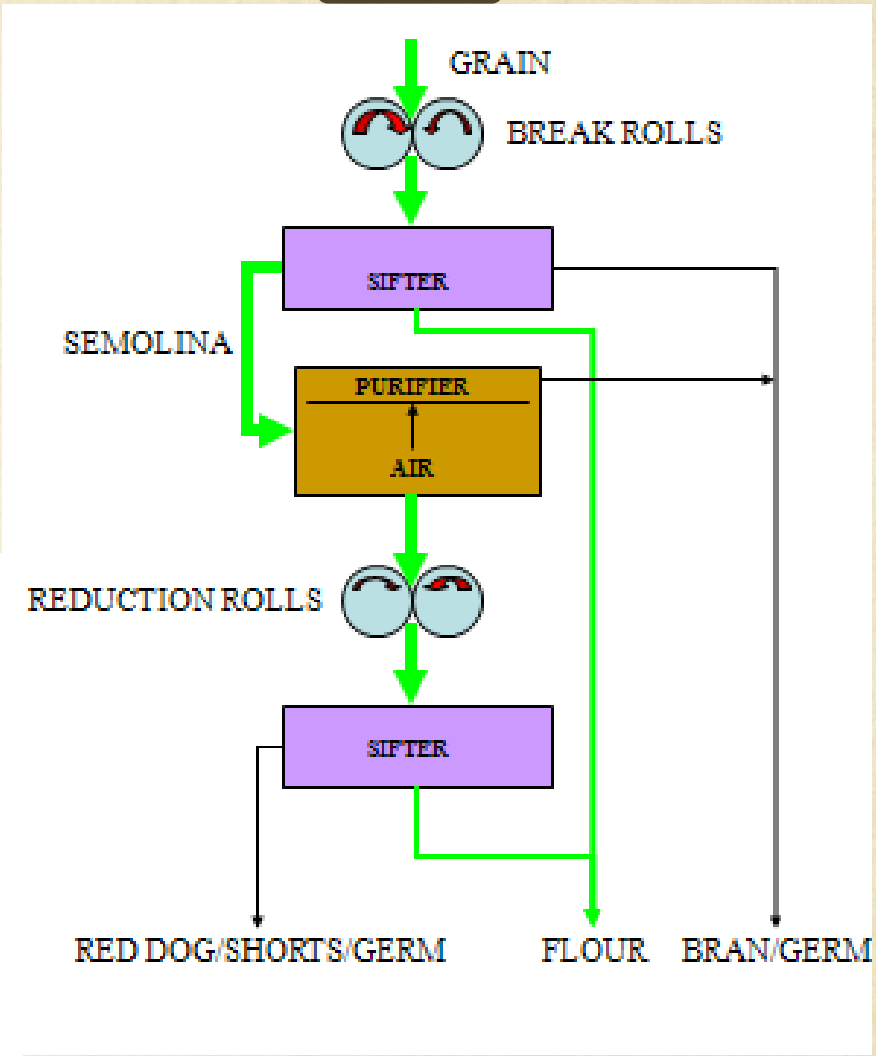
- **Primary processing**
  - Effects of milling or other primary processes on composition of the process intermediate [e.g. flour refinement, “pearls”]
  - Interactions between raw materials and primary process
    - E.g. hardness and milling & hardness and flaking [e.g. Streaker flakes]
  - Effects of milling on particle size distributions of derived flours and downstream processing effects
  - Potential partitioning of fiber rich or depleted fractions
    - E.g. conventional milling and separation of endosperm and bran
    - E.g. separation of beta-glucan rich barley endosperm fractions


OREGON GROWN
GROWN BY
HUNTON'S FARM
STREAKER BA
FLAKES
1.5lb./680g
Streaker
NAKED
Barley
Directions: Use a ratio of 2:1 water to rolled barley, cook for 8 to 10 minutes
Streaker is a naked (hull-less) winter barley, the first of its type adapted to the Pacific Northwest. Developed by the Oregon State University Barley Project, Streaker is a blend that will be continually improved by a participatory plant breeding process involving Hunton's Farm and other local farmers. Enjoy!

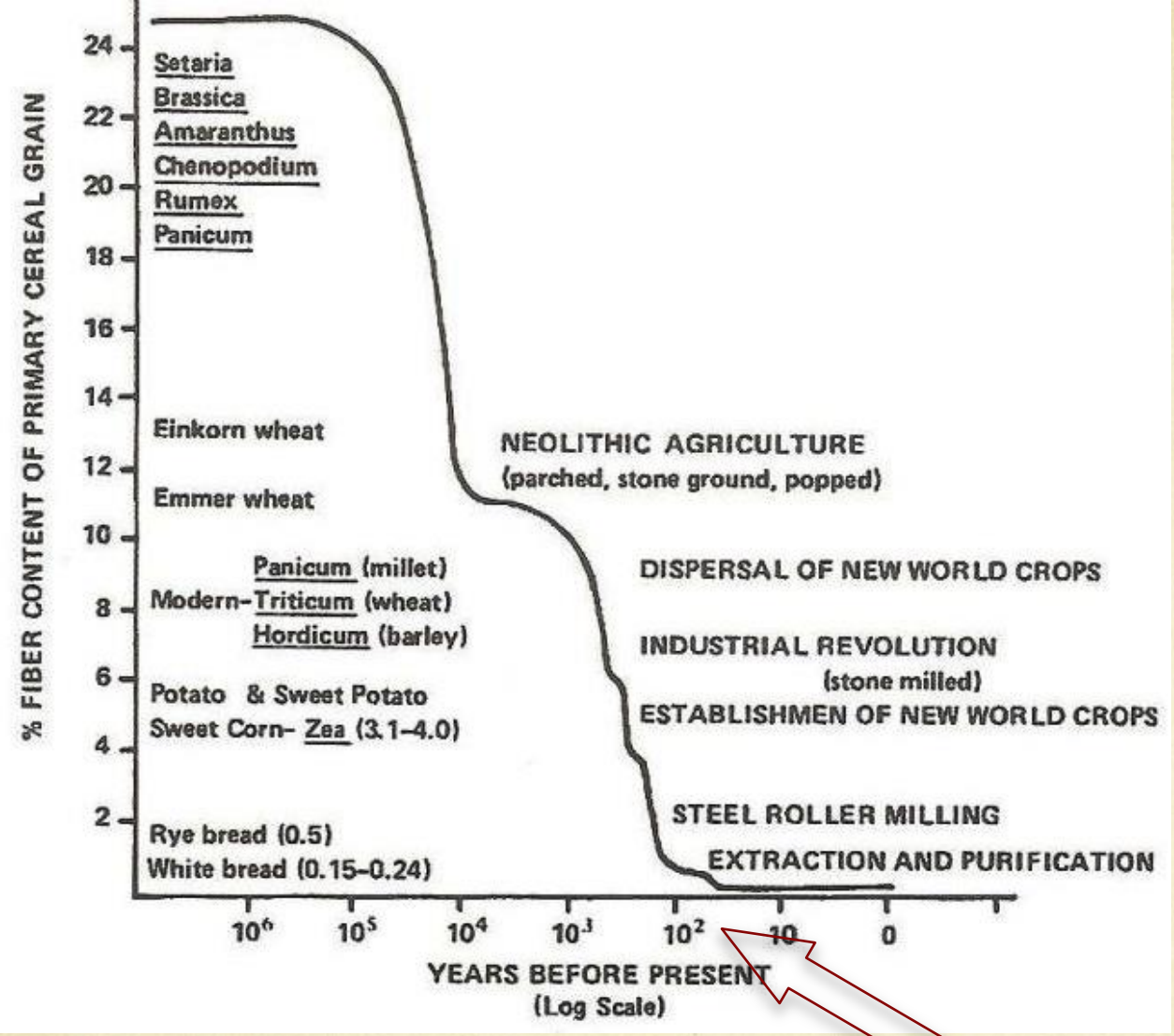

FOOD
For Lane County



Tempering



Atwell 2001



Whole Grains, Whole Wheat, and White Flours in History G. A. Spiller

Edited by Len Marquart, Joanne L. Slavin, and R. Gary Fulcher

Refined flour becomes universally available

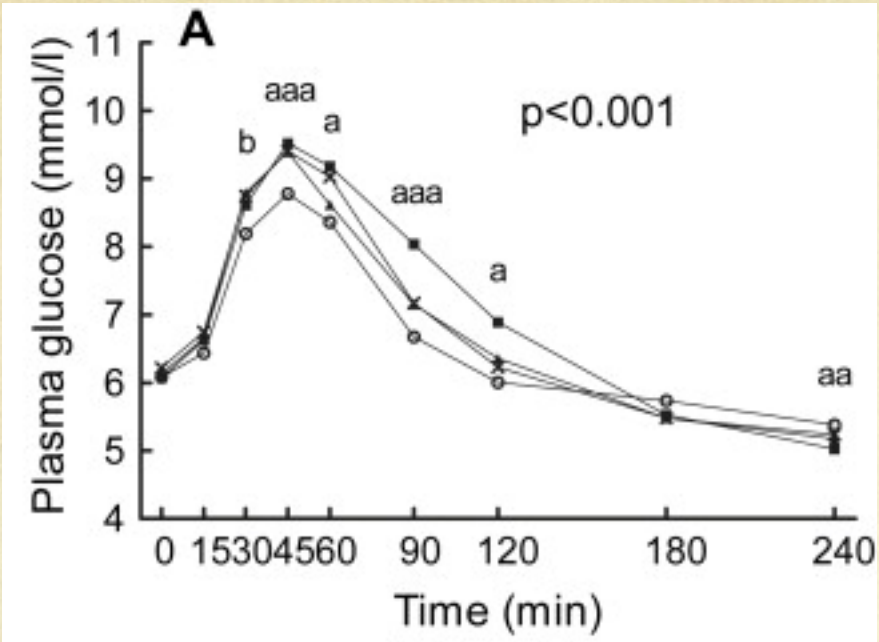
Experimental Grinding and Ancient Egyptian Flour Production*

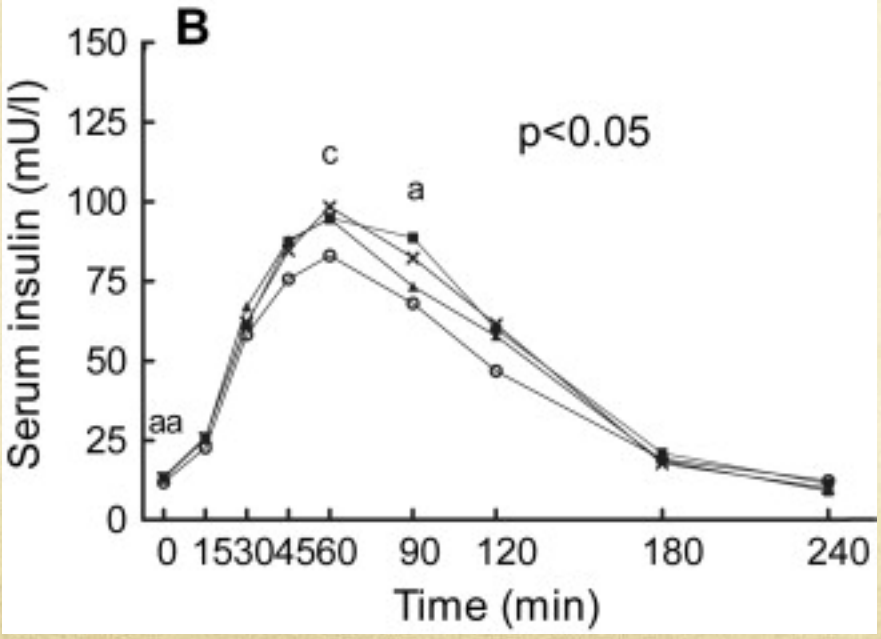
Delwen Samuel
King's College London, Nutritional Sciences Division

- Multistage milling for fine flours
- Sieving
- Tempering
  - [emmer can be hard like durum]

Samuel, D. 2010. Experimental grinding and Ancient Egyptian flour production. Pp. 456-477 in S. Ikram & A. Dodson (eds), Beyond the Horizon: Studies in Egyptian Art, Archaeology and History in Honour of Barry J. Kemp. Cairo: American University in Cairo Press.

- **Secondary processing/cooking**
  - Palatability, visual appeal, culinary qualities…
  - Fate of **fiber** components
    - E.g. Changes in extractability [± molecular weight; ± viscosity]
  - Changes in digestibility and accessibility of **starches**
    - Production of RS3 *in situ*
      - *e.g. sourdough and reduced post-prandial insulin response*
    - Exploitation of RS1





Journal of Cereal Science 51 (2010) 152–158

Contents lists available at ScienceDirect

Journal of Cereal Science

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

Sourdough fermentation of wholemeal wheat bread increases solubility of arabinoxylan and protein and decreases postprandial glucose and insulin responses

Jenni Lappi [a,*], Emilia Selinheimo [b], Ursula Schwab [a,c], Kati Katina [b], Pekka Lehtinen [b], Hannu Mykkänen [a], Marjukka Kolehmainen [a], Kaisa Poutanen [a,b]

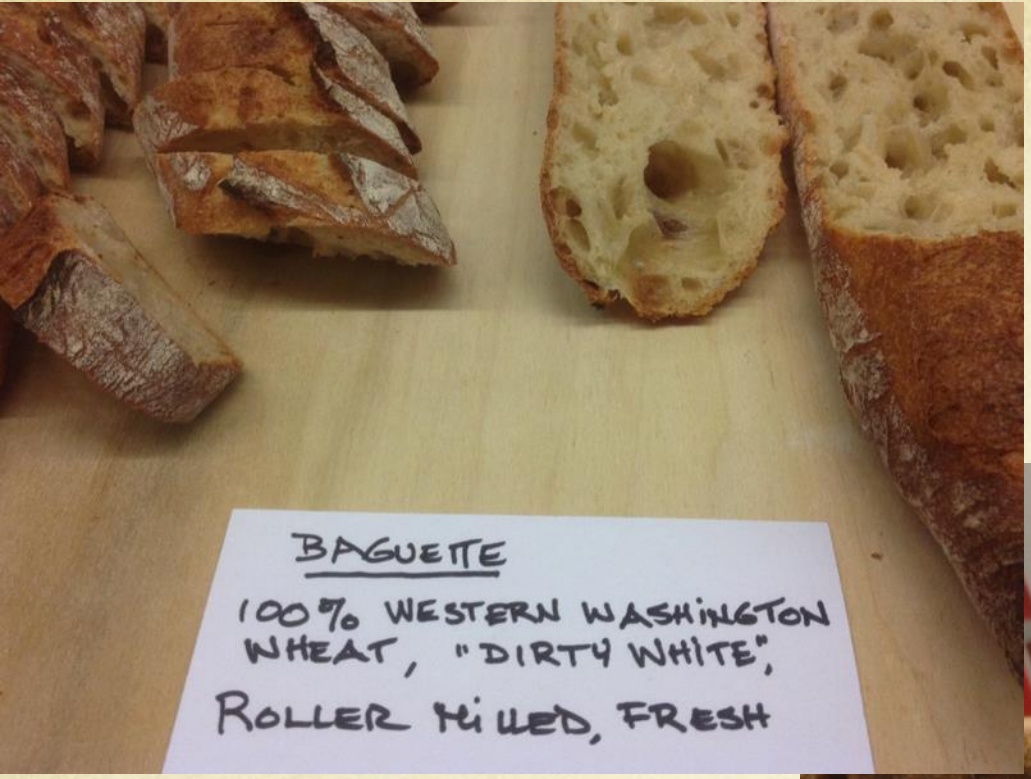
- **Secondary processing/cooking**
  - Changes in **protein** digestibility
    - E.g. mixed lactic acid bacteria (LAB) and "wild" yeast fermentations, versus single culture LAB or *Saccharomyces* fermentations
  - Changes in **mineral** availability
    - E.g. phytic acid degradation in cereal soaking or mixed LAB/wild yeast fermentations

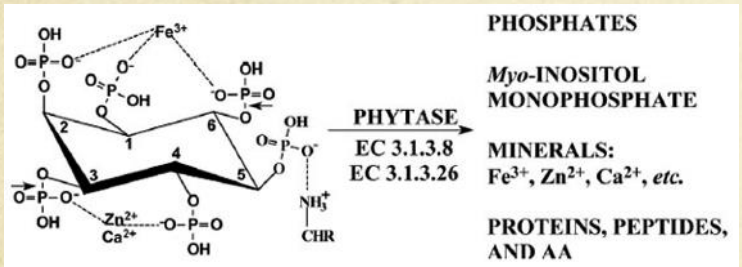
Washington State University

Mount Vernon Research Center

College of Agricultural, Human, & Natural Resources

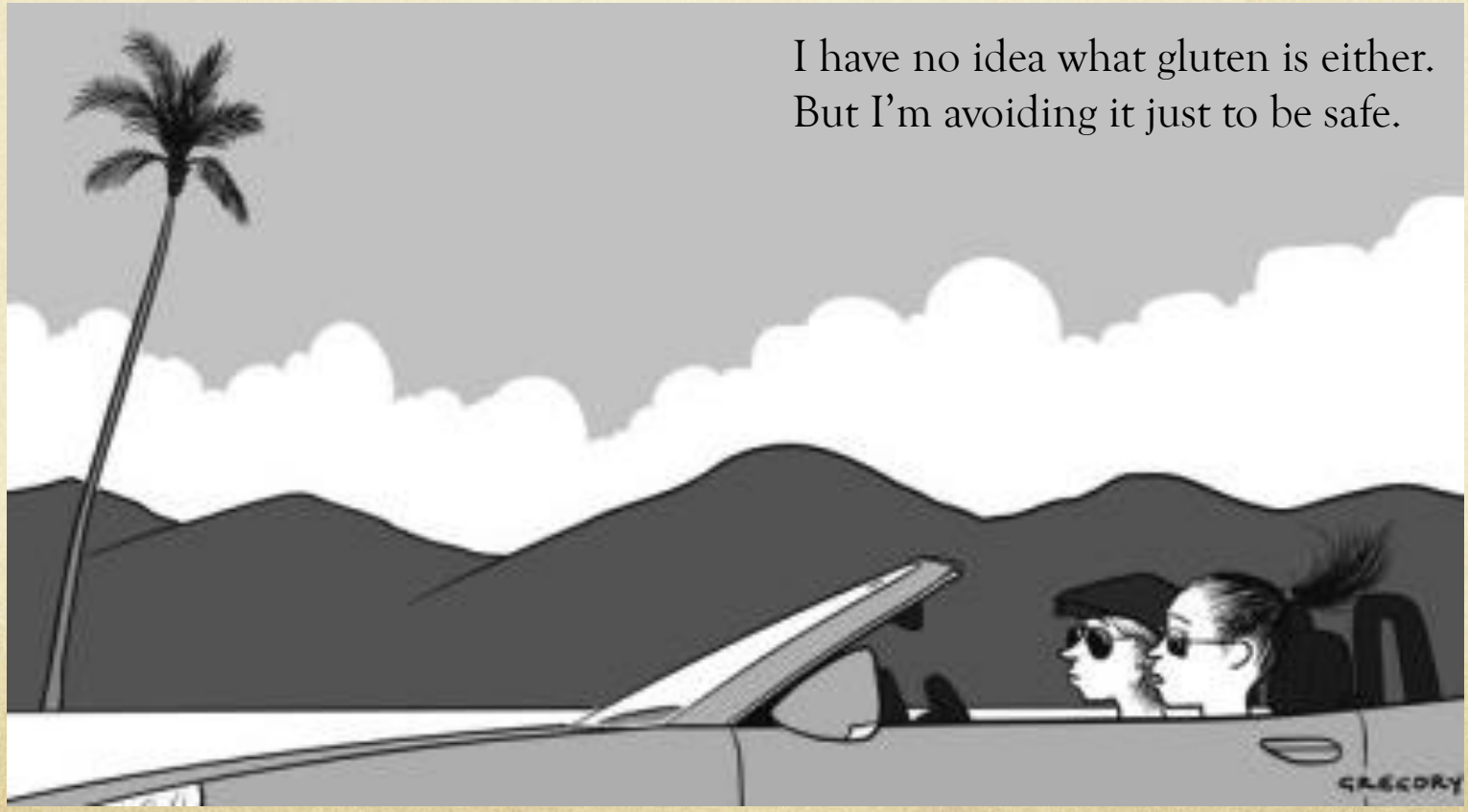
The Bread Lab



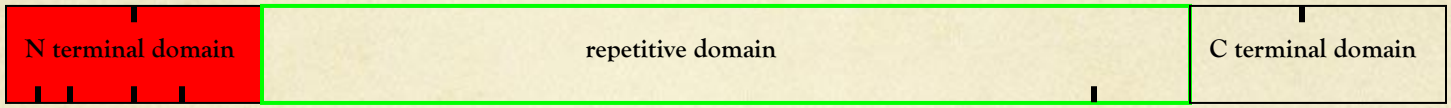


Gluten

- The emergent property of 2 protein classes…
  - Glutenins (**glutelins**) also part of "**elastomer**" superfamily
  - Gliadins (**prolamins**)



HMW glutenins



An x-type high molecular weight glutenin

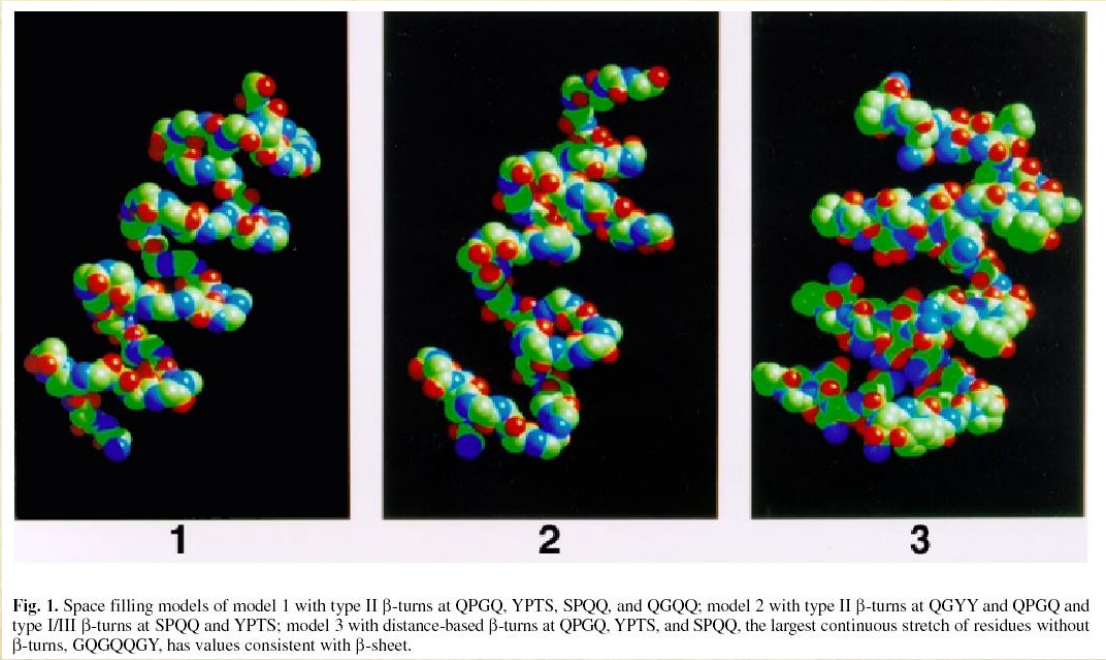
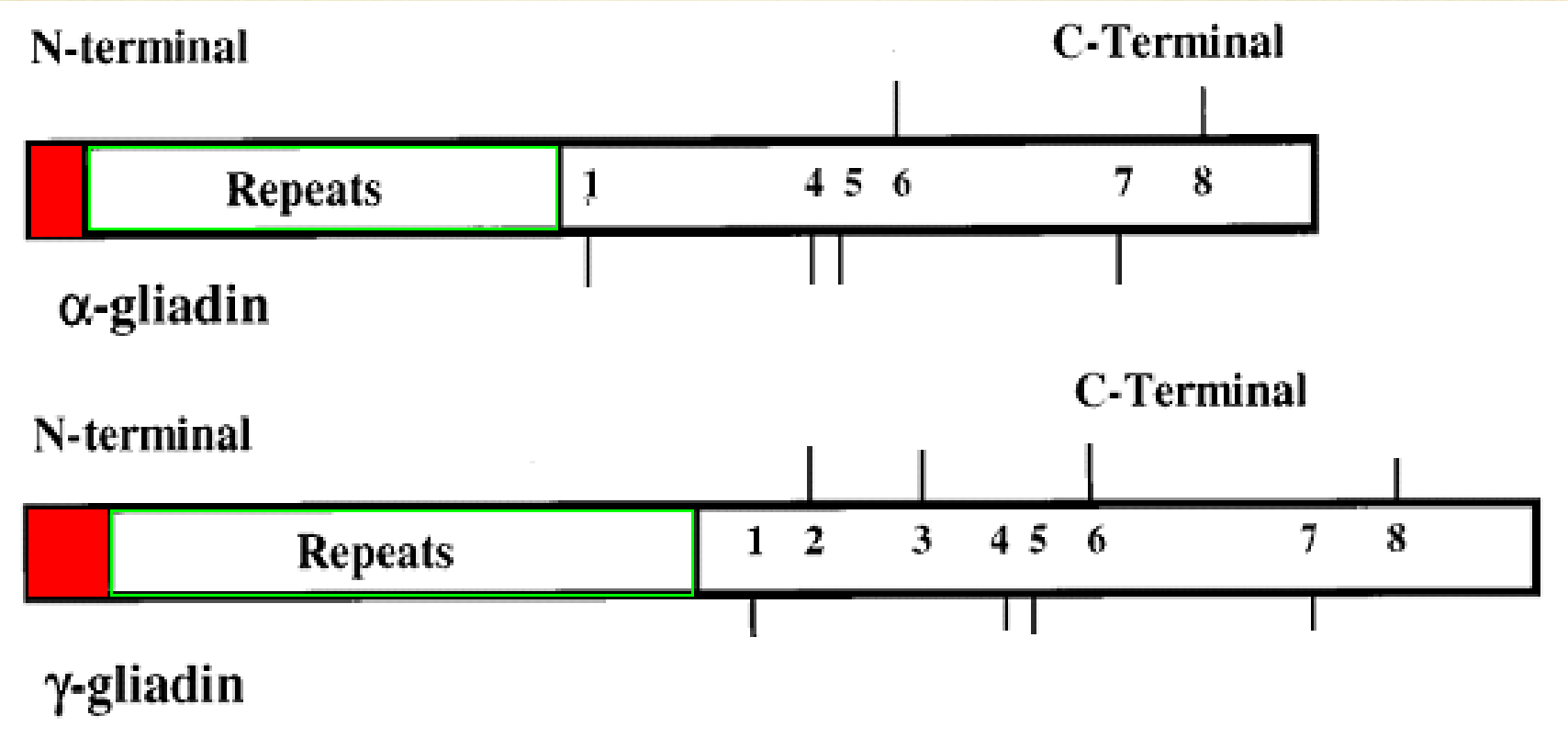


Fig. 1. Space filling models of model 1 with type II β-turns at QPGQ, YPTS, SPQQ, and QGQQ; model 2 with type II β-turns at QGYY and QPGQ and type I/III β-turns at SPQQ and YPTS; model 3 with distance-based β-turns at QPGQ, YPTS, and SPQQ, the largest continuous stretch of residues without β-turns, GQGQQGY, has values consistent with β-sheet.

Molecular Modeling of Unusual Spiral Structure in Elastomeric Wheat Seed protein. 2001. O. Parchment, P. R. Shewry, A. S. Tatham, and D. J. Osguthorpe. Cereal Chem. 78(6):658–662

Gliadins

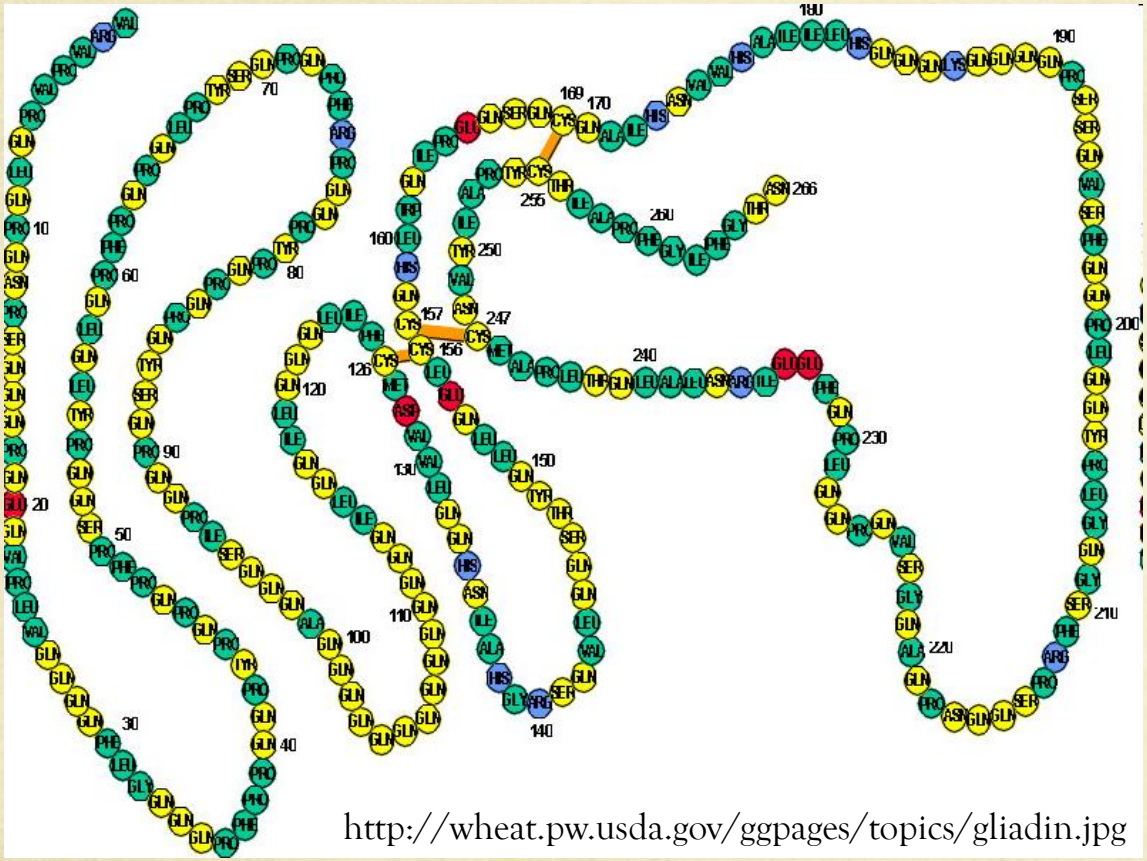

N-terminal
C-Terminal
Repeats
1
4 5 6
7 8
α-gliadin
C-Terminal
N-terminal
Repeats
1 2 3 4 5 6 7 8
γ-gliadin

Notably, almost all of the immunogenic sequences of α-gliadins map the N-terminal 57-89 region corresponding to the 33-mer peptide

Endocrine, Metabolic & Immune Disorders - Drug Targets, 2012, *12*, 207-219 207

Repertoire of Gluten Peptides Active in Celiac Disease Patients: Perspectives For Translational Therapeutic Applications

Alessandra Camarca[1,2] Andrea Del Mastro[2] and Carmen Gianfrani[1,2,*]



http://wheat.pw.usda.gov/ggpages/topics/gliadin.jpg

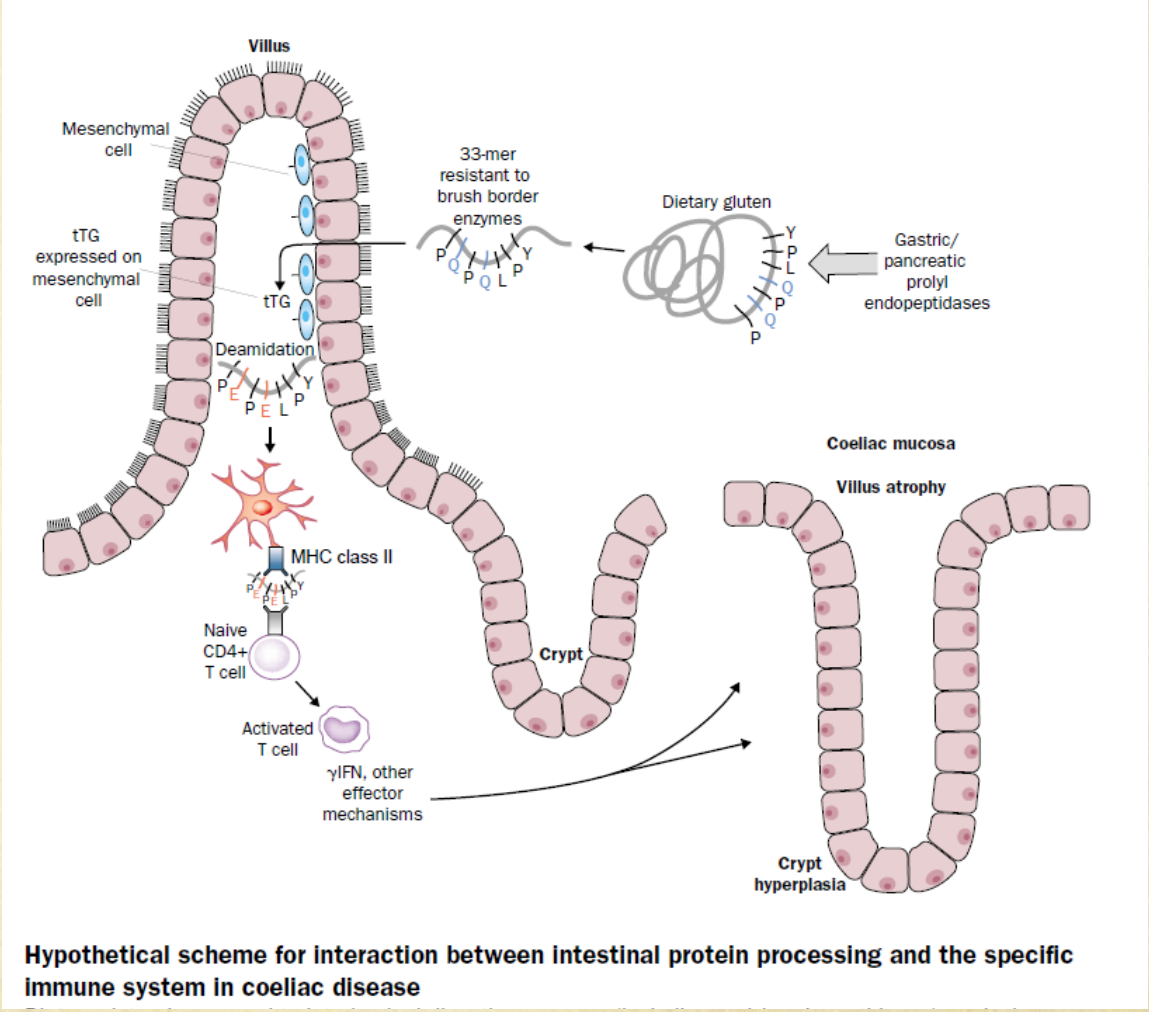
Deduced Amino Acid Sequence of an Alpha-Gliadin Gene from Spelt Wheat (Spelta) Includes Sequences Active in Celiac Disease

Authors: Kasarda DD. DOvidio R.

Source Cereal Chemistry. 76(4):548-551, 1999 Jul-Aug

Celiac disease

CELIAC DISEASE (CD) is an immune-mediated enteropathy triggered in genetically susceptible individuals by the ingestion of gluten-containing grains (wheat, barley, and rye). The disease is associated with human leukocyte antigen (HLA) DQ2 and DQ8 haplotypes. In the continued presence of gluten, CD is self-perpetuating.[1] Given the undisputed role of gluten in causing inflammation and autoimmunity, CD represents a unique example of an immune-mediated disease for which early serologic diagnosis and dietary treatment can prevent severe, sometimes life-threatening complications.



Hypothetical scheme for interaction between intestinal protein processing and the specific immune system in coeliac disease

ORIGINAL INVESTIGATION

Prevalence of Celiac Disease in At-Risk and Not-At-Risk Groups in the United States

A Large Multicenter Study

Alessio Fasano, MD; Irene Berti, MD; Tania Gerarduzzi, MD; Tarcisio Not, MD; Richard B. Colletti, MD; Sandro Drago, MS; Yoram Elitsur, MD; Peter H. R. Green, MD; Stefano Guandalini, MD; Ivor D. Hill, MD; Michelle Pietzak, MD; Alessandro Ventura, MD; Mary Thorpe, MS; Debbie Kryszak, BS; Fabiola Fornaroli, MD; Steven S. Wasserman, PhD; Joseph A. Murray, MD; Karoly Horvath, MD, PhD

CME

Gluten Causes Gastrointestinal Symptoms in Subjects Without Celiac Disease: A Double-Blind Randomized Placebo-Controlled Trial

Jessica R. Biesiekierski, B Appl Sci[1], Evan D. Newnham, MD, FRACP[1], Peter M. Irving, MD, MRCP[1], Jacqueline S. Barrett, PhD, BSc, MND[1], Melissa Haines, MD[1], James D. Doecke, BSc, PhD[2], Susan J. Shepherd, B Appl Sci, PhD[1], Jane G. Muir, PhD, PGrad Dip(Dietetics)[1] and Peter R. Gibson, MD, FRACP[1]

Non-Celiac Wheat Sensitivity Diagnosed by Double-Blind Placebo-Controlled Challenge: Exploring a New Clinical Entity

Antonio Carroccio, Pasquale Mansueto, Giuseppe Iacono, Maurizio Soresi, Alberto D'Alcamo, Francesca Cavataio, Ignazio Brusca, Ada M Florena, Giuseppe Ambrosiano, Aurelio Seidita, Giuseppe Pirrone and Giovanni Battista Rini

CONCLUSIONS:

Our data confirm the existence of non-celiac WS as a distinct clinical condition. We also suggest the existence of two distinct populations of subjects with WS: one with characteristics more similar to CD and the other with characteristics pointing to food allergy.

Colon/Small Bowel

The American Journal of Gastroenterology **107**, 1898-1906 (December 2012) | doi:10.1038/ajg.2012.236

Non-celiac gluten-intolerance

Has gluten fundamentally changed in the modern era?

Sapone *et al. BMC Medicine* 2012, **10**:13
http://www.biomedcentral.com/1741-7015/10/13

BMC Medicine

OPINION Open Access

Spectrum of gluten-related disorders: consensus on new nomenclature and classification

Anna Sapone[1,2], Julio C Bai[3], Carolina Ciacci[4], Jernej Dolinsek[5], Peter HR Green[6], Marios Hadjivassiliou[7], Katri Kaukinen[8], Kamran Rostami[9], David S Sanders[10], Michael Schumann[11], Reiner Ullrich[11], Danilo Villalta[12], Umberto Volta[13], Carlo Catassi[1,14] and Alessio Fasano[1*]

Conclusions

...One possible explanation is that **the selection of wheat varieties with higher gluten content** has been a continuous process during the last 10,000 years, with changes dictated more by technological rather than nutritional reasons.

Has gluten content increased?

Table 1. Average Percentages of Protein in Spring Wheat Marketed through Minneapolis, MN, by Crop Years (Data Excerpted from Table 42 of Reference 12)

crop year	no. of samples	av protein (%)	standard deviation (σ)	av moisture content (%)
1925	33246	12.49	1.34	
1926	26145	13.28	1.55	13.7
1927	63944	11.96	0.78	13.2
1928	49964	12.42	0.77	13.4
1929	37202	13.70	1.41	13.4
1930	52041	14.85	1.47	13.1
1931	17182	15.00	1.22	
1932	45027	14.21	0.99	11.7
1933	28829	15.03	0.89	11.5
1934	12900	14.80	1.04	11.4
1935	28544	15.30	1.71	11.8
1936	16698	15.92	1.64	
1937	12185	14.83	1.28	11.6
1938	13169	18.78	1.04	11.5

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Perspective

pubs.acs.org/JAFC

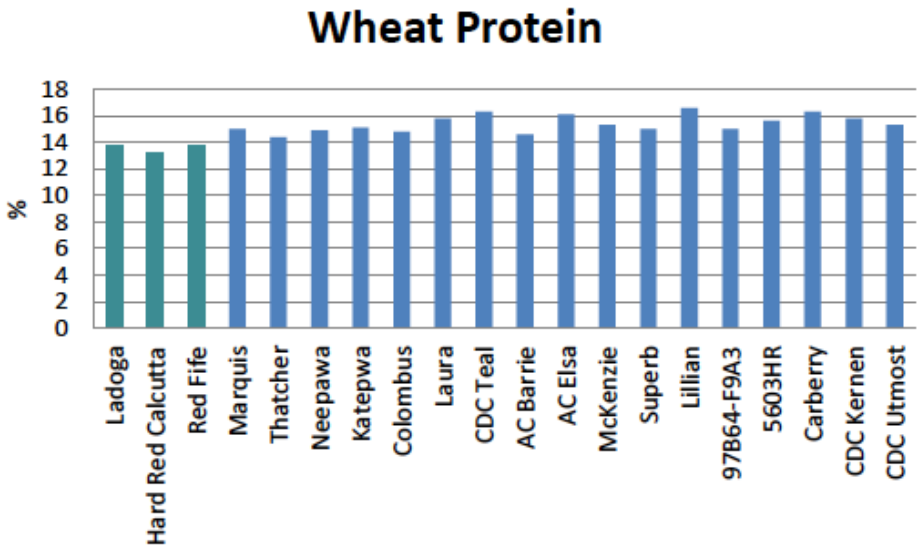
Can an Increase in Celiac Disease Be Attributed to an Increase in the Gluten Content of Wheat as a Consequence of Wheat Breeding?

Donald D. Kasarda

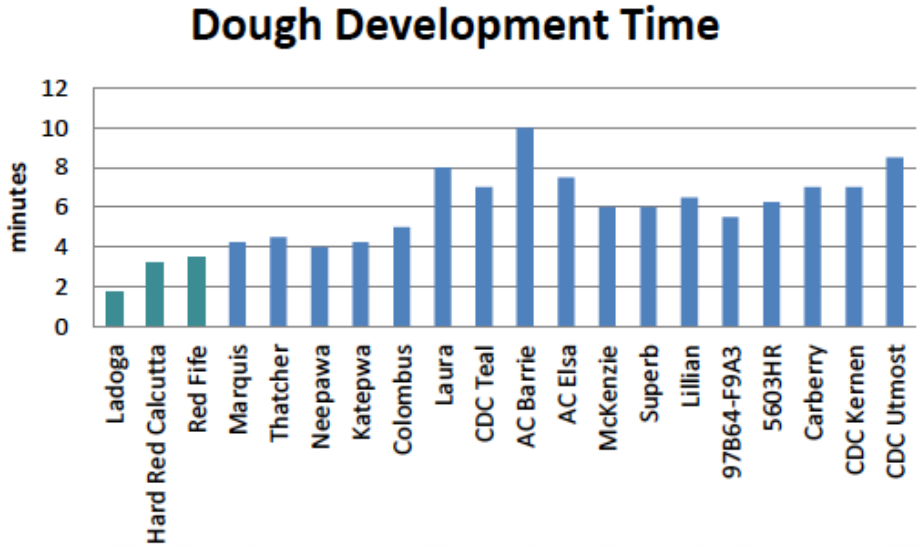
Table I: Nutritional composition (%) of hulled wheats: einkorn, emmer and spelt compared to common wheat

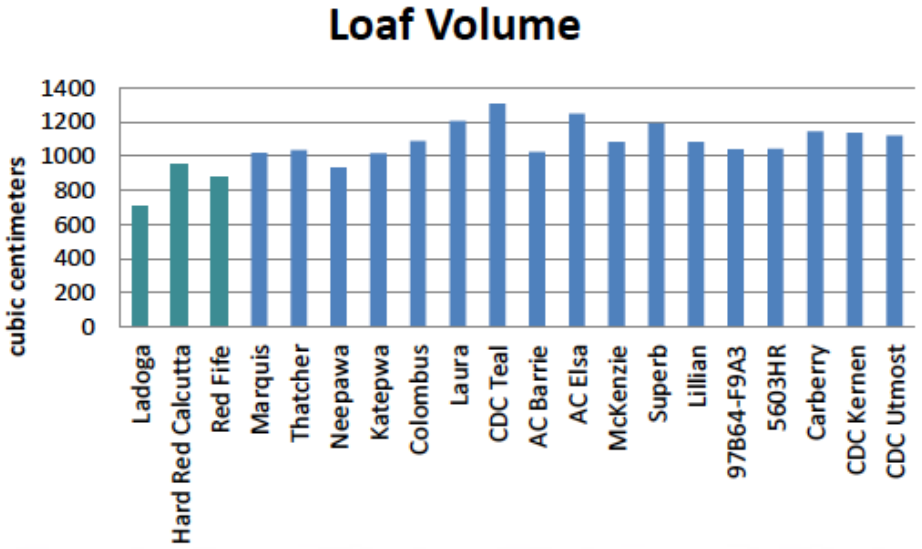
	Protein (%)
Spelt[a]	16.3 - 17.5
Emmer[b]	13.5 - 19.05
Einkorn[a,d]	18.2±1.48
Common wheat[c,a]	13.85±0,16

Hammed, A. M., & Simsek, S. (2014). Hulled Wheats: A Review of Nutritional Properties and Processing Methods. Cereal Chemistry, .



- ~ 1% increase in protein over Red Fife
- Improvement in strength
- Water absorption
- Loaf volume





Ideal Grain Ingredients: Breeding Wheat for Health

Dr. Nancy Ames
Agriculture and Agri-Food Canada
Richardson Centre for Functional Foods and Nutraceuticals
September 2013

Questions of quality? Is functionality a bad thing?

"In 1793, nothing marked the limits of the Revolution… more powerfully than the fact that for some time [people] have been eating grayish bread of poor quality that smells dusty and gives most people a stomach ache.

Concern with quality was a matter of ordinary dignity, not a question of luxury or displaced envy."

"GOOD BREAD IS BACK: A contemporary history of French bread, the way it is made, and the people who make it."

Steven L. Kaplan
Cornell

Has gluten changed qualitatively,
and therefore,

have wheat breeders been engaged
in an epic conspiracy of
monumental proportions?

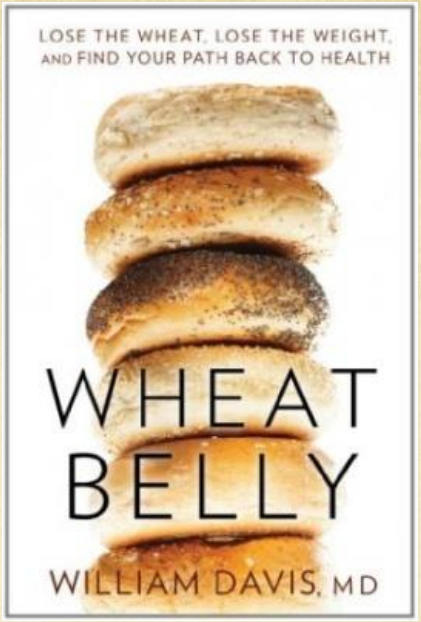
Theor Appl Genet (2010) 121:1527–1539
DOI 10.1007/s00122-010-1408-4

ORIGINAL PAPER

Presence of celiac disease epitopes in modern and old hexaploid wheat varieties: wheat breeding may have contributed to increased prevalence of celiac disease

Hetty C. van den Broeck · Hein C. de Jong · Elma M. J. Salentijn · Liesbeth Dekking · Dirk Bosch · Rob J. Hamer · Ludovicus J. W. J. Gilissen · Ingrid M. van der Meer · Marinus J. M. Smulders

"It's an 18-inch tall plant created by genetic research in the '60s and '70s, this thing has many new features nobody told you about, such as *there's a new protein in this thing called gliadin*. It's not gluten".



Are we eating more?

Looking back over the last five decades, several trends are apparent in wheat consumption: **an increase in wheat consumption per capita** (Rubio-Tapia et al. 2009) (http://www.ers.usda.gov/AmberWaves/september08/findings/wheatflour.htm)

Presence of celiac disease epitopes in modern and old hexaploid wheat varieties: wheat breeding may have contributed to increased prevalence of celiac disease

Hetty C. van den Broeck · Hein C. de Jong · Elma M. J. Salentijn · Liesbeth Dekking · Dirk Bosch · Rob J. Hamer · Ludovicus J. W. J. Gilissen · Ingrid M. van der Meer · Marinus J. M. Smulders

After 5 years of declining flour use in the U.S., ERS estimates an increase in per capita wheat flour use to 137.9 pounds in 2007, up 2.3 pounds from a year earlier. The 2007 total is still down 8.9 pounds from its high in 1997. ERS calculates per capita use by dividing the total annual availability by the U.S. population in the same year. These per capita availability estimates provide an indication of trends in Americans' consumption of various foods over time.

Between 1972 and 1997, U.S. wheat producers and millers could count on rising per capita food use of wheat flour to expand their domestic market. Contributing to this growth was the boom in away-from-home eating, the desire of consumers for greater variety and more convenient food products, promotion of wheat flour and pasta products by industry organizations, and wider recognition of health benefits stemming from eating high-fiber, grain-based foods.

The decades-long growth ended in 1997, as changing consumer preferences, led by the increased adoption of low-carbohydrate diets after 2000, reduced per capita wheat consumption. Per capita flour use dropped rapidly at first and then fell more slowly until reaching a low of 134.2 pounds in 2005. In response, the flour milling industry began to downsize, leading to the closure of some smaller, older, and less efficient mills. From 2000 to early 2006, 12 percent of the 223 mills listed in the industry publication *Grain and Milling Annual* closed, and milling capacity fell by 7 percent.

U.S. per capita wheat flour use

Source: USDA, Economic Research Service.

The baking industry responded by developing products to satisfy these new dietary preferences, particularly the increased demand for higher fiber and protein. According to Datamonitor, 558 wheat-flour products were introduced in 2007—more than a fourfold increase from the 97 new wheat-flour products that hit the shelves in 1997. Eighty-six whole-wheat flour products were introduced in 2007, up from 16 in 1997. These new product introductions appear to be succeeding because per capita use bottomed out and then rose sharply in 2007.

Despite the recent increase in per capita consumption and new recommendation in the 2005 *Dietary Guidelines for Americans* that whole grains should account for half of all grains consumed, Americans still favor refined-wheat flour products over whole-wheat flour products. According to *Milling & Baking News*, whole-wheat flour grew from 2.1 percent of total flour production in 2002-03 to 4.1 percent in 2006-07.

Gary Vocke, gvocke@ers.usda.gov
Jean C. Buzby, jbuzby@ers.usda.gov
Hodan Farah Wells, hfarah@ers.usda.gov

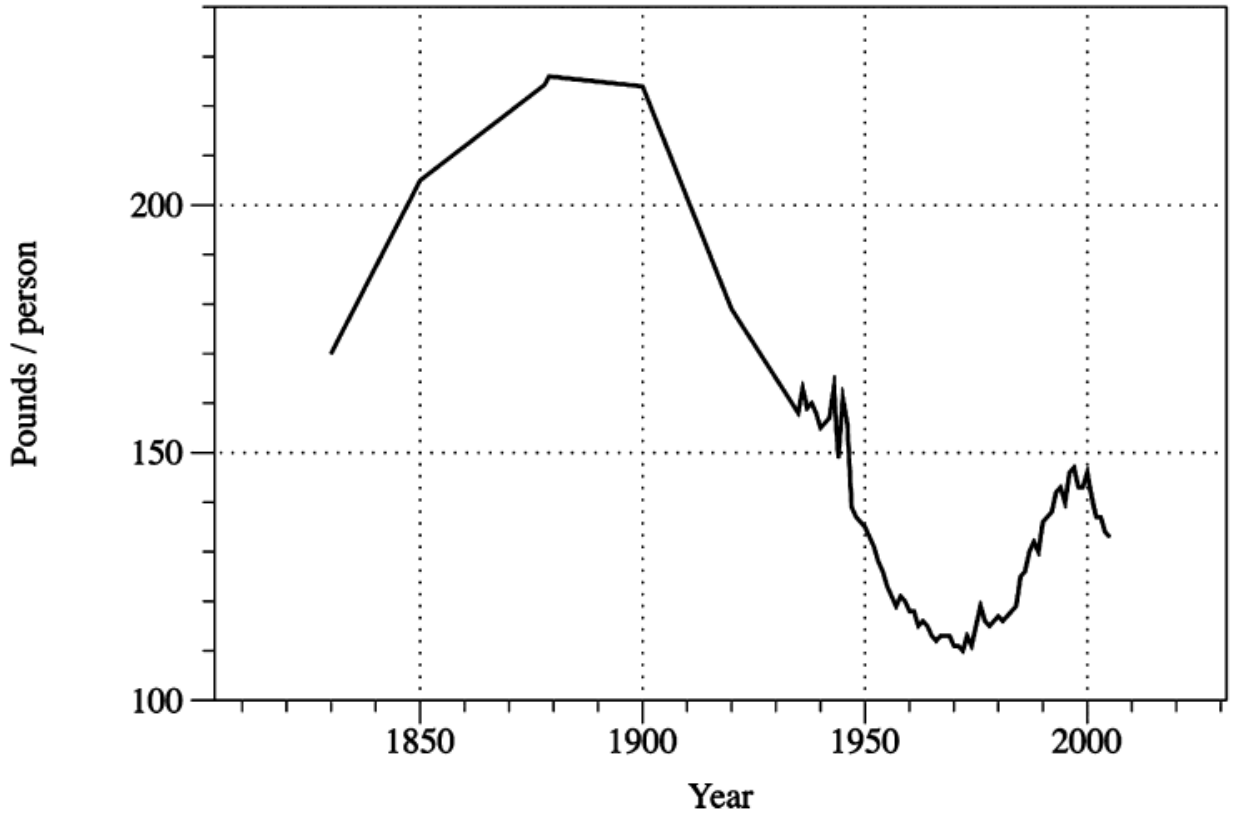
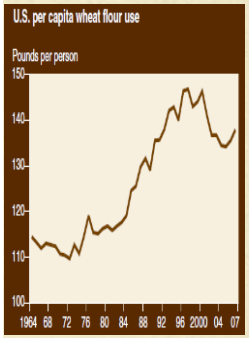


Figure 5. U.S. per capita wheat flour use (figure redrawn from ref 18 and data supplied by G. Vocke).



JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Perspective

pubs.acs.org/JAFC

Can an Increase in Celiac Disease Be Attributed to an Increase in the Gluten Content of Wheat as a Consequence of Wheat Breeding?

Donald D. Kasarda

What about lack of exercise?

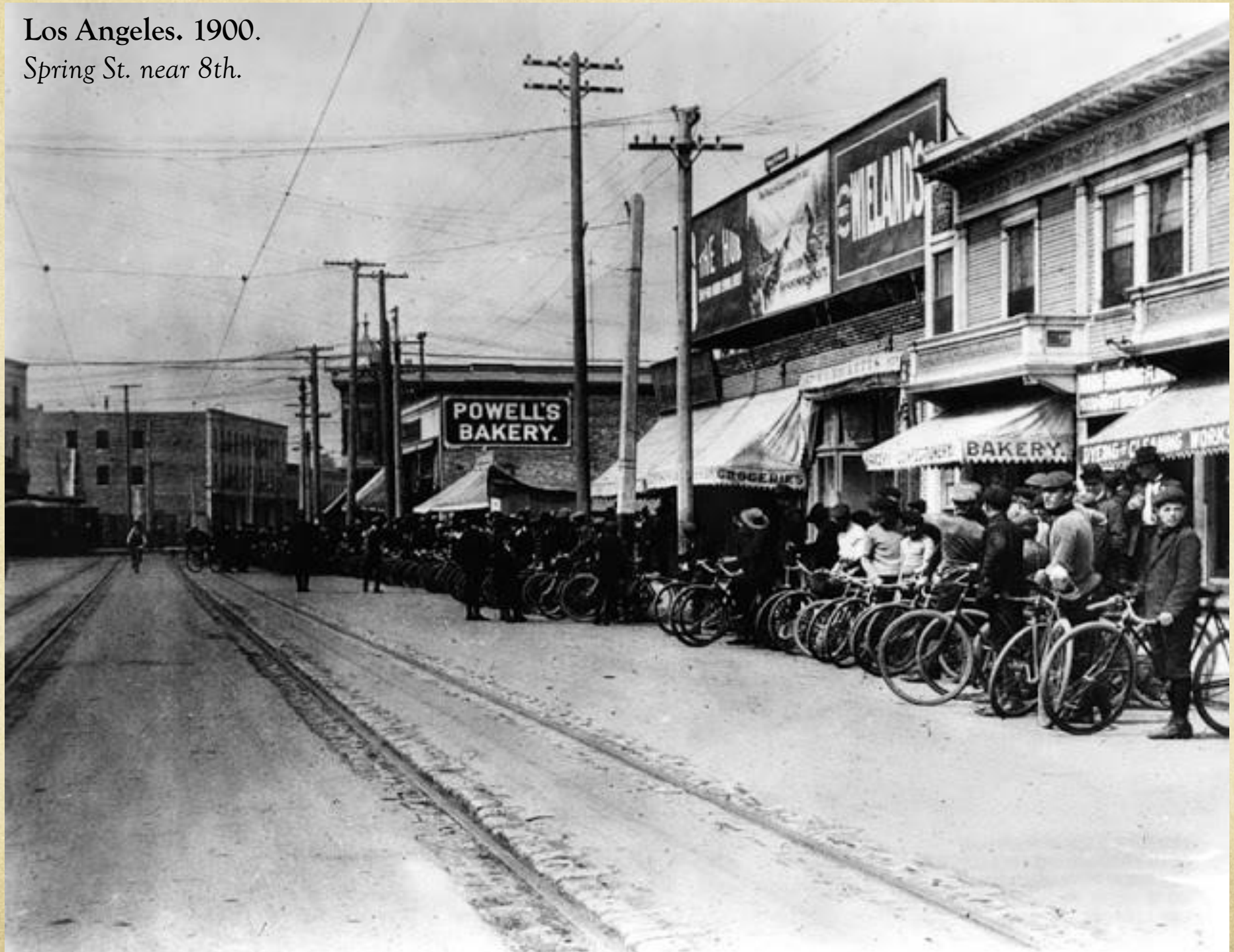
What about changes in infant feeding practices?

What about processing?

What about gut microbiota?

What about hygiene?

Other components: fructans, amylase-trypsin inhibitors?



Los Angeles. 1900.
Spring St. near 8th.