ABE 580

Process Engineering of Renewable Resources

Course Objectives

1. Analyze bioprocesses using engineering design principles, bioreactor simulations, application of basic separations methods, and applying engineering economic analysis

2. Develop process models for batch and continuous fermentation, cell culture, and enzymatic bioreactors

3. Analyze the impact of fundamental advances in bio-sciences on bioprocess engineering and the environment, and the potential of these advances to solve societal problems.

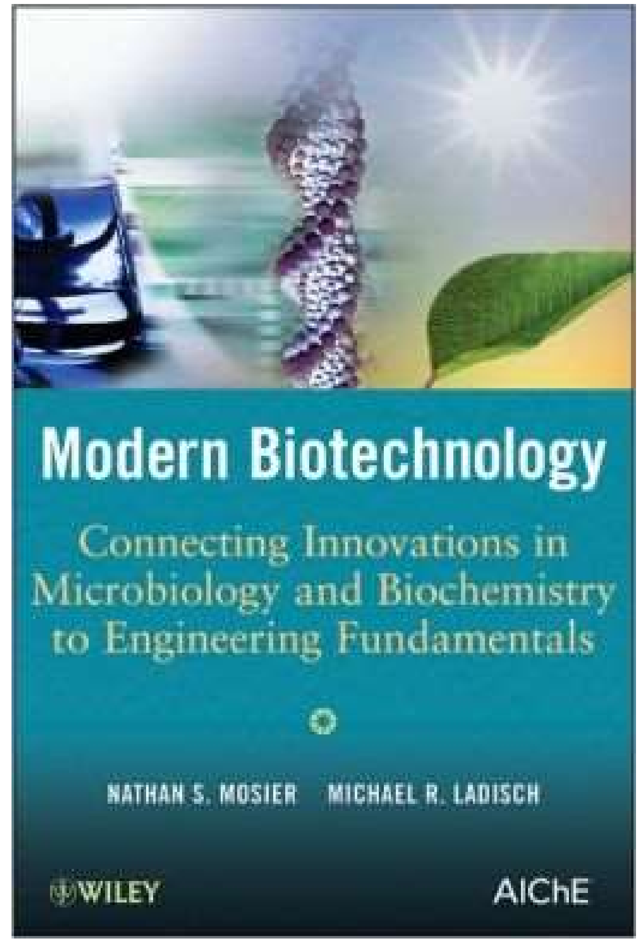
4. Understand the impact of biosafety and regulatory considerations on process design

Blackboard

- Syllabus
- Grades
- Files
  - VisualBasic Module (within Excel)
  - Literature needed for homework, etc.

Textbook

- **Modern Biotechnology: Connecting Innovations in Microbiology and Biochemistry to Engineering Fundamentals**, Nathan S. Mosier and Michael R. Ladisch, John Wiley and Sons, NY, 2009.



Grades

A > 89.9%

B 80.0 - 89.9%

C 70.0 - 79.9%

D 60.0 - 69.9%

F < 60.0%

3 Midterm Exams (200 pts each)

~8 Homework Assignments

Week	Lecture Topic
1	Chapter 4: Microbial Fermentations - classification of fermentation type, basic metabolism unstructured modeling of fermentation
2	Chapter 5: Modeling and Simulation – Unstructured Modeling of cell growth and bioproduct formation in anaerobic bioreactors
3	Chapter 5 continued – Type II fermentation models, batch versus chemostat bioreactors
4	Chapter 6: Aerobic Bioreactors
5	Chapter 6 continued: Butanediol case study **Exam 1**
6	Chapter 7 Enzymes: properties, classification system, assays, Michaelis-Menten kinetics, thermal stability
7	Chapter 8 Enzyme Kinetics: Rapid equilibrium vs pseudo steady-state kinetics. King Altman method; integrated vs initial rate equations
8	Chapter 8 Continued: Enzymes for industrial bioreactors
9	Chapters 9-11: Metabolism and Microbial Energetics **Exam 2**
	Spring Break – No Class

Week	Lecture Topic
10	Chapters 9-11 continued: Auxotrophs and industrial bioproduct production (amino acids case study)
11	Chapter 12-14: Genes and Genetic Control – tools for gene manipulation, application of molecular biology for industrial bioproduct production
12	Chapter 12-14 continued: Cellular engineering, metabolic engineering
13	Bioseparations: Recovery of Soluble Products
14	Bioseparations continued **Exam 3**
15	Emerging Topics in Biotechnology

Introduction

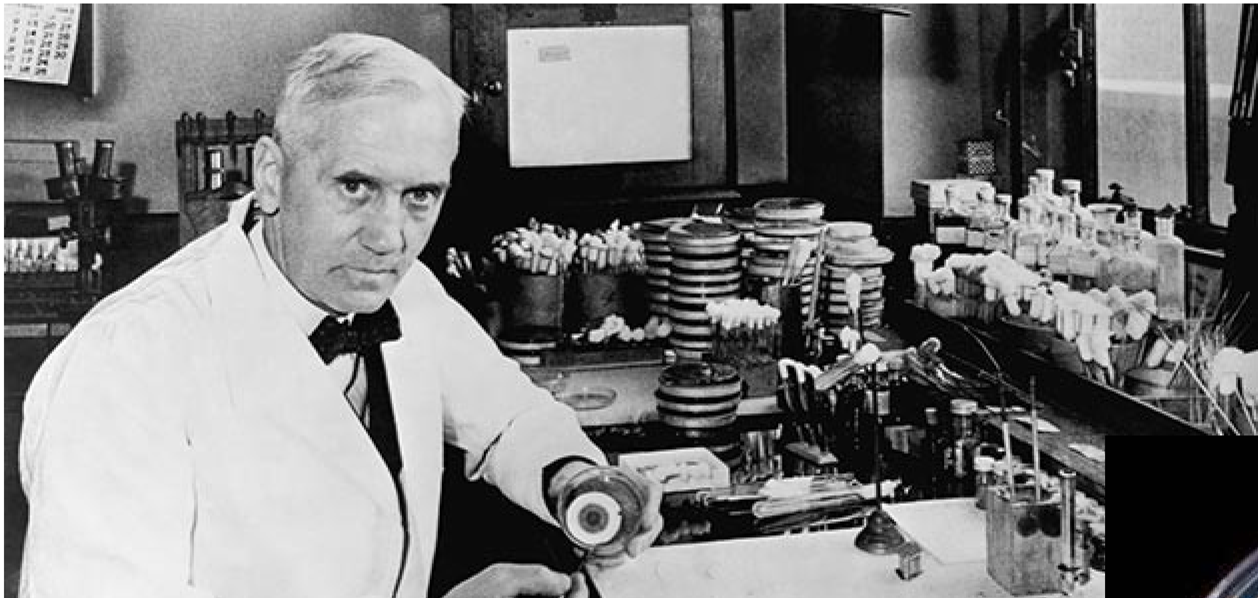
Biotechnology

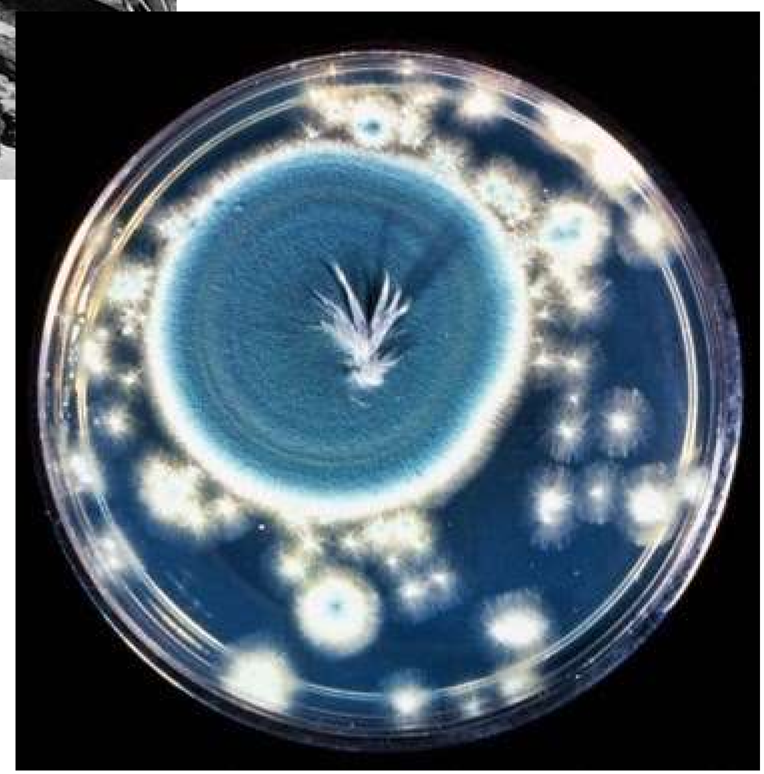
- "Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use."

History of Biotechnology

History of Biotechnology

Alexander Fleming

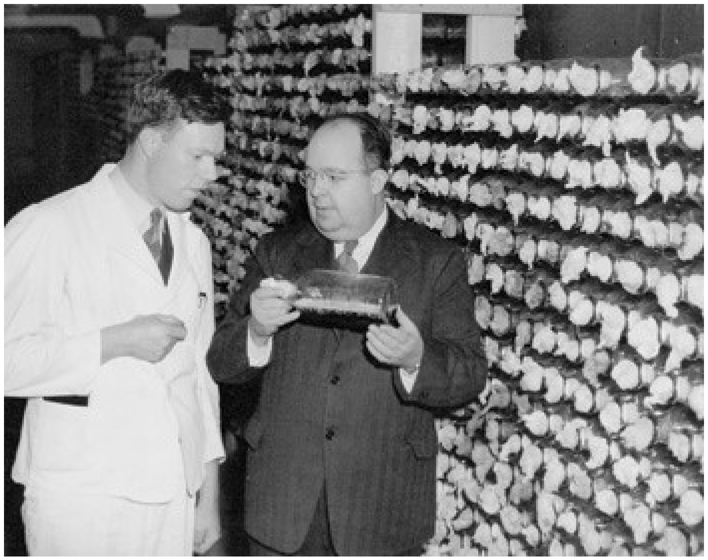




Ernst Boris Chain and Edward Abraham at Oxford University translated penicillin from laboratory curiosity to practical therapeutic by isolating the active ingredient and developing method to purify it in a stable form.

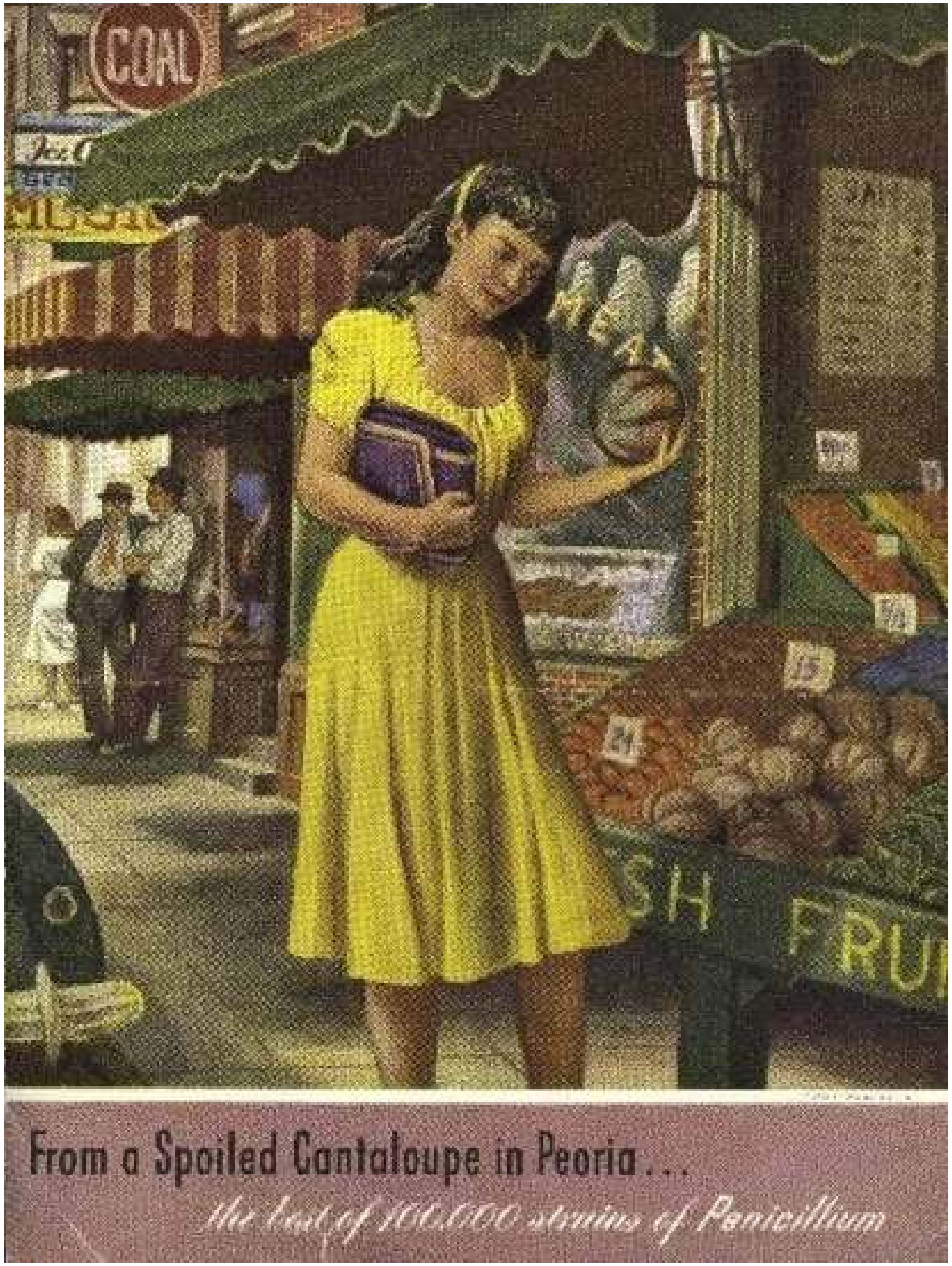
Discovery in 1928
First Patient Treated in 1942

Scale Up of Penicillin



March 14, 1942, First Patient Treated. This consumed ½ of global supply of product

June 1942, scaled-up production (shown here) produced enough penicillin to treat 10 patients



“Moldy” Mary Hunt

Bacteriologist at USDA Research Lab in Peoria, IL

"The mold is as temperamental as an opera singer, the yields are low, the isolation murder, the purification invites disaster. Think of the risks and then think of the expensive investment in big tanks – think of what it means if you lose a 2000-gallon tank against what you lose if a flask goes bad. Is it worth it?!"

- John Smith, Pfizer executive, 1942

Penicillin Production Poster

By June 1945, over 646 billion units were being produced per year

Margaret Hutchinson Rousseau

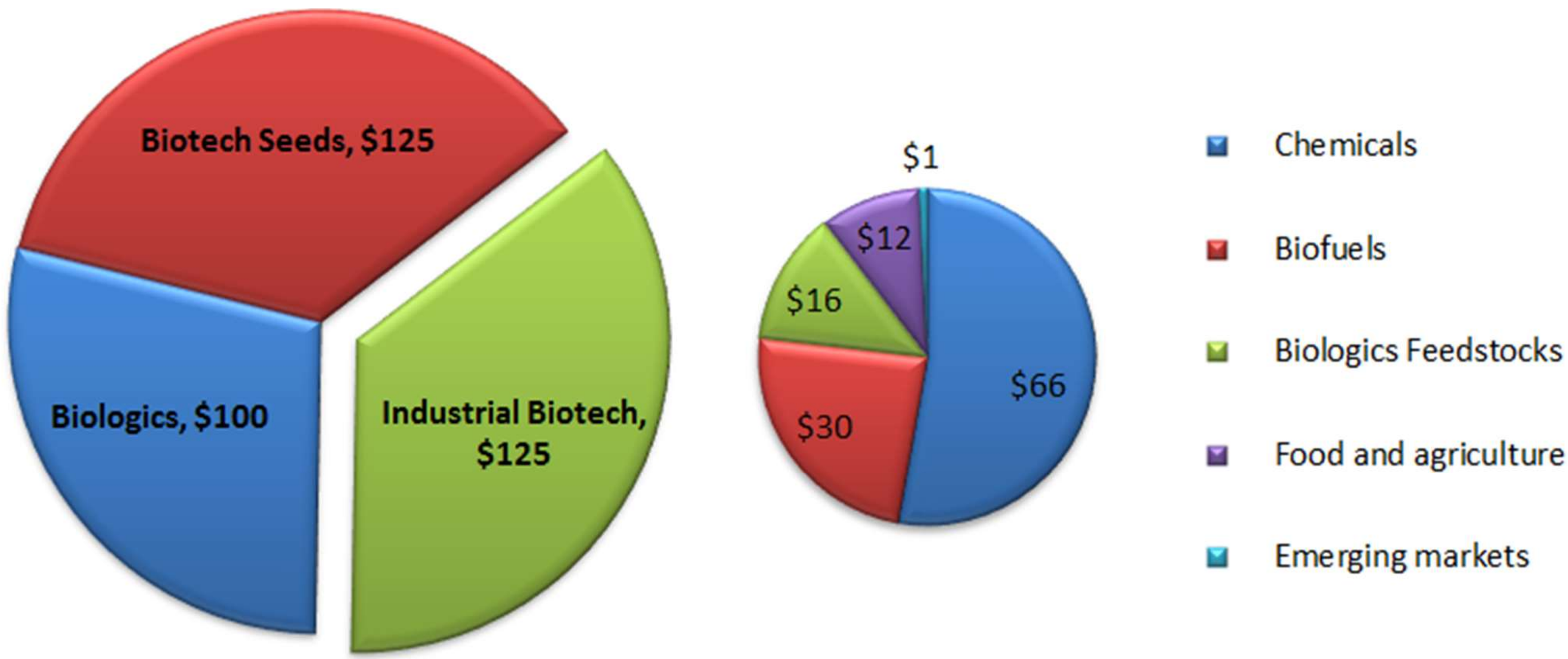
Designed first commercial penicillin production plant in 1943-1944.

First female member of AIChE

Biotechnology

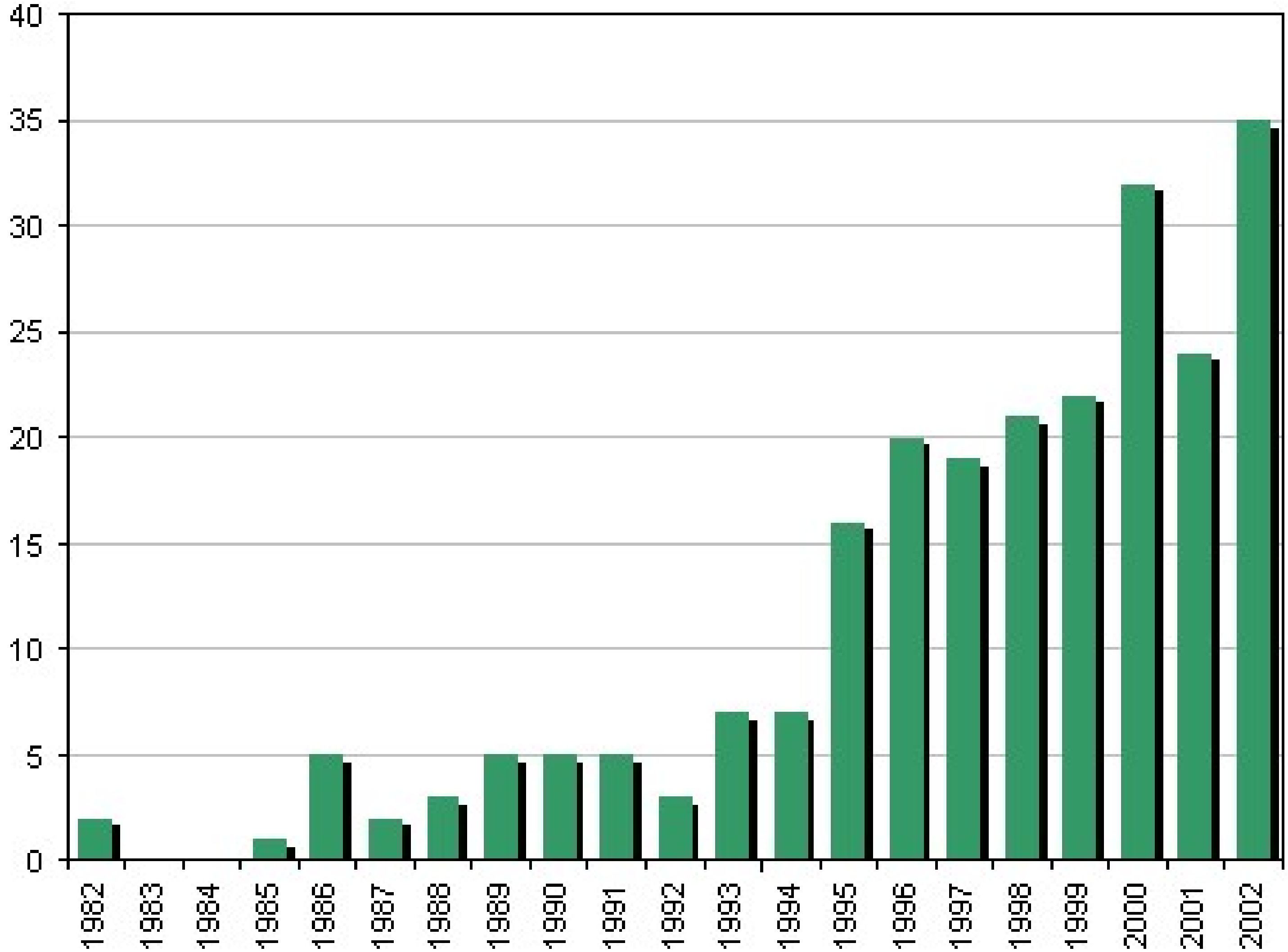
- Red Biotechnology
  - Medical biotechnology
- Green Biotechnology
  - Plant biotechnology for agriculture
- <u>White Biotechnology</u>
  - Industrial biotechnology
  - Biofuels, biopolymers, biochemicals
  - Biorefinery Concept

$369 Billion/year
5 million US jobs

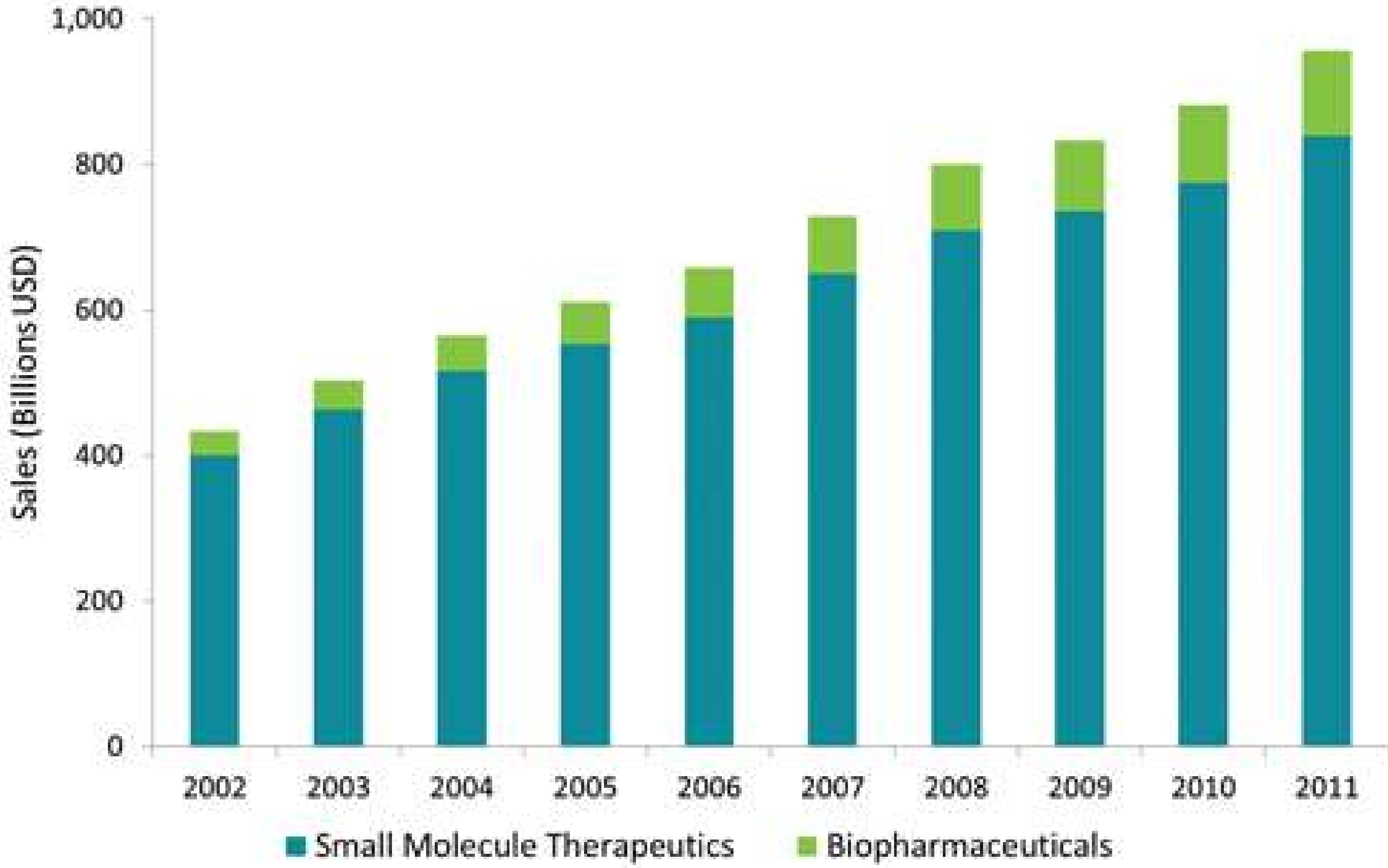


Source: Rob Carlson, industrial biotech breakdown provided by Darlene Solomon of Agilent Technologies.

Number of New Biotech Vaccines or Drugs Approved

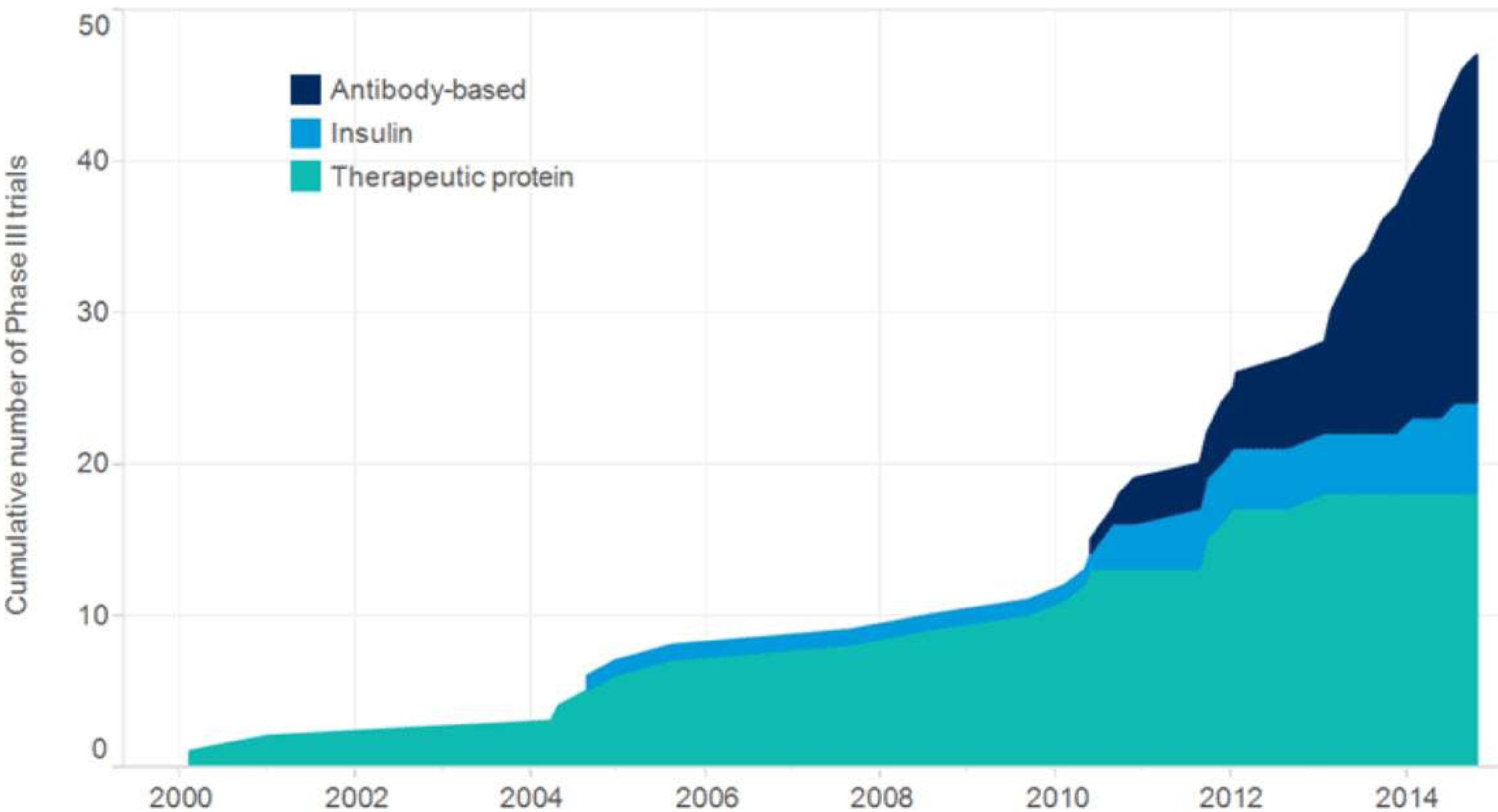


US Pharm Sales



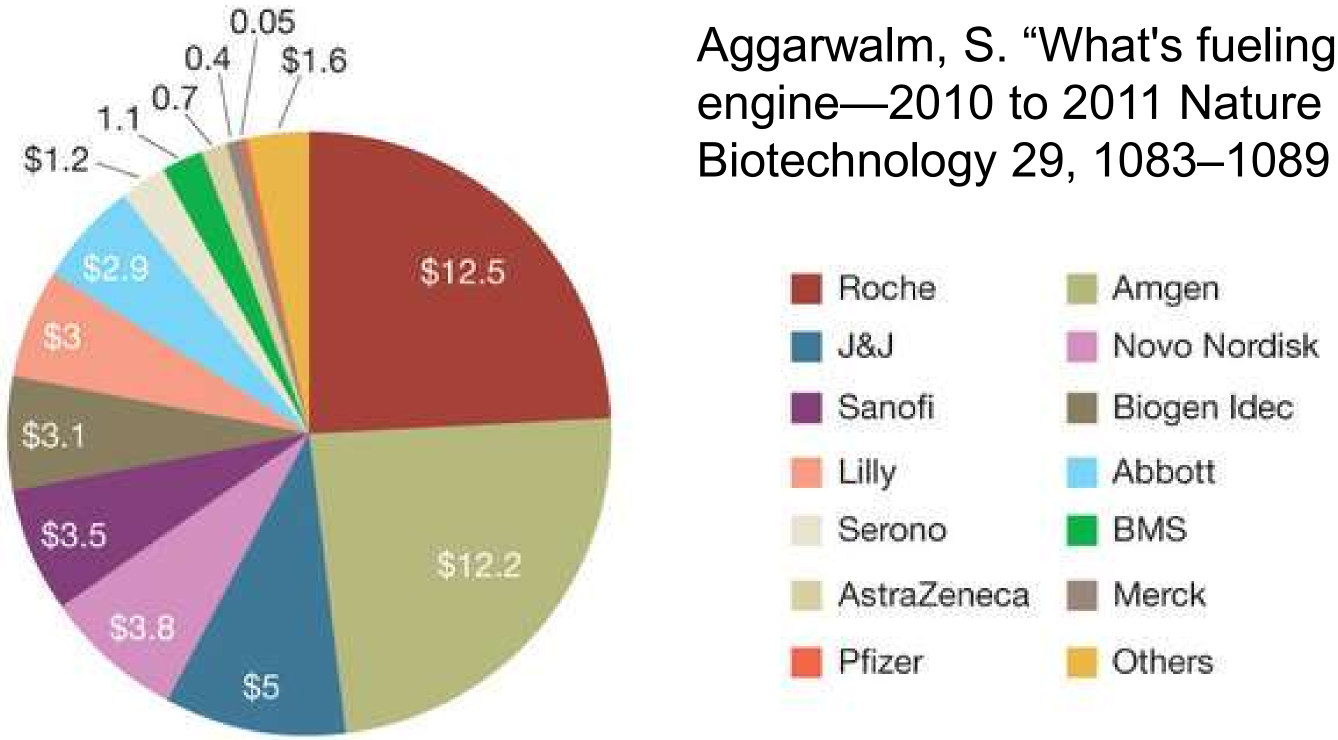
BIO

Phase III Clinical Trials



Datamonitor Healthcare 2015

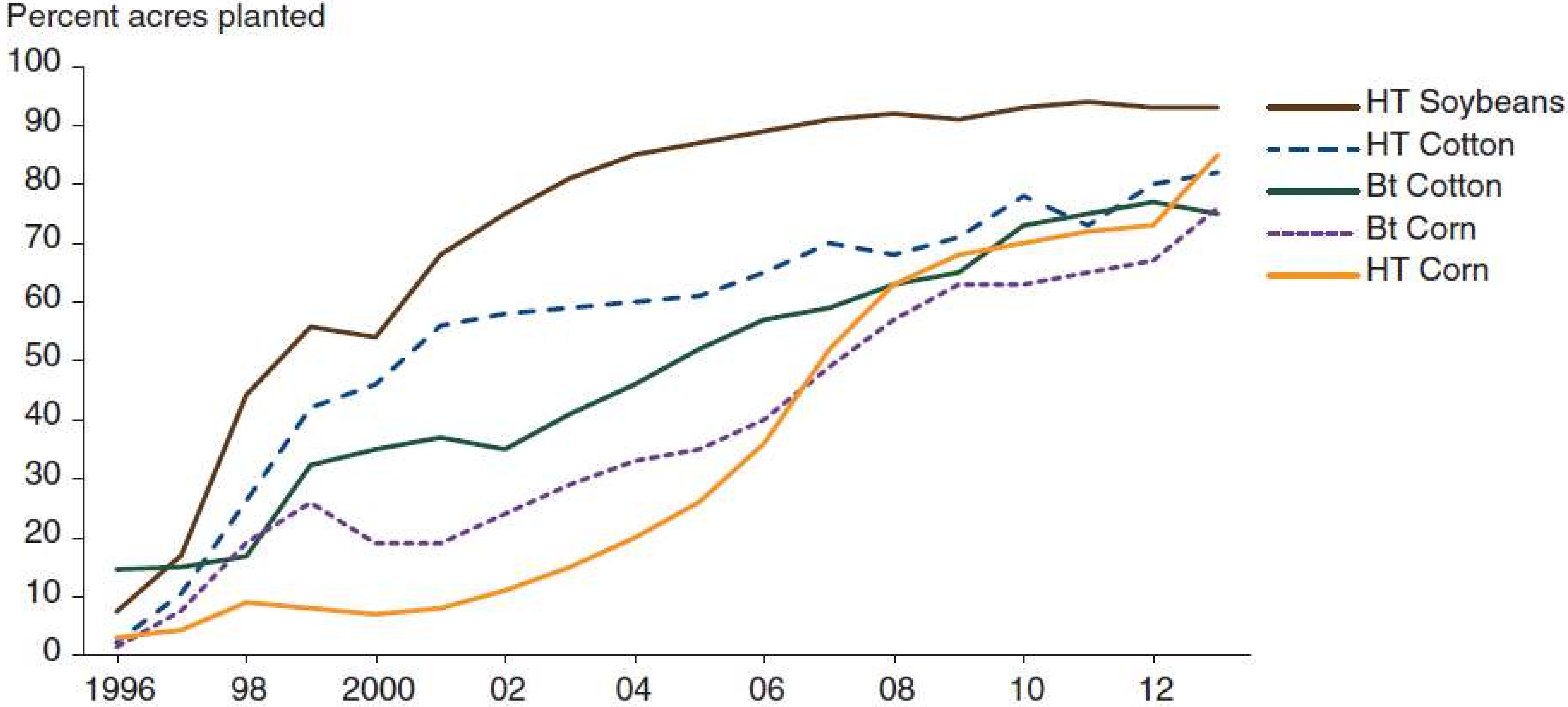
Aggarwalm, S. “What's fueling the biotech engine—2010 to 2011 Nature Biotechnology 29, 1083–1089 (2011)



	2009 ($ billions)	2010 ($ billions)	2009 growth rate	2010 growth rate
Roche	11.8	12.5	12.7%	6.2%
Amgen	12.0	12.2	–7.6%	1.7%
J&J	4.9	5.0	–0.7%	1.8%
Novo Nordisk	3.3	3.8	17.4%	16.0%
Sanofi	3.2	3.5	11.7%	10.4%
Biogen Idec	2.9	3.1	6.4%	7.3%
Lilly	2.8	3.0	8.0%	7.0%
Abbott	2.5	2.9	15.3%	15.0%
Serono	1.2	1.2	13.7%	4.8%
Others	1.1	1.6	–9.0%	52.2%

1st GMO Crop:
FlavrSavr Tomato, 1994
Bt corn & cotton and Round-Up Ready Soybeans, 1995

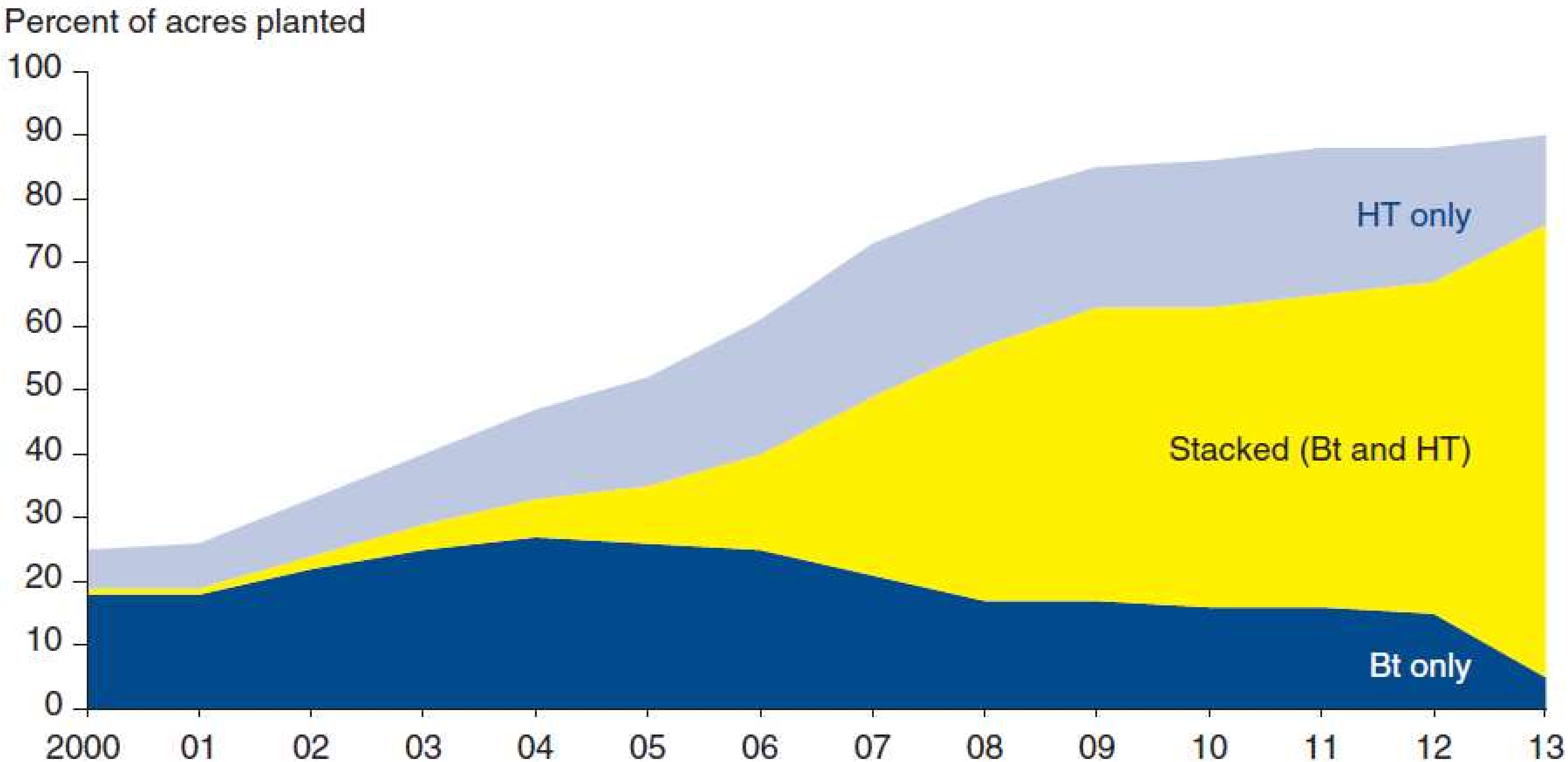
Figure 5
Adoption of genetically engineered crops in the United States



Bt crops have insect resistant traits; HT crops have herbicide tolerance traits.
Data for each crop category include varieties with both Bt and HT (stacked) traits.

Source: U.S. Department of Agriculture (USDA), Economic Research Service (ERS). 2013. *Adoption of Genetically Engineered Crops in the U.S.* data product.

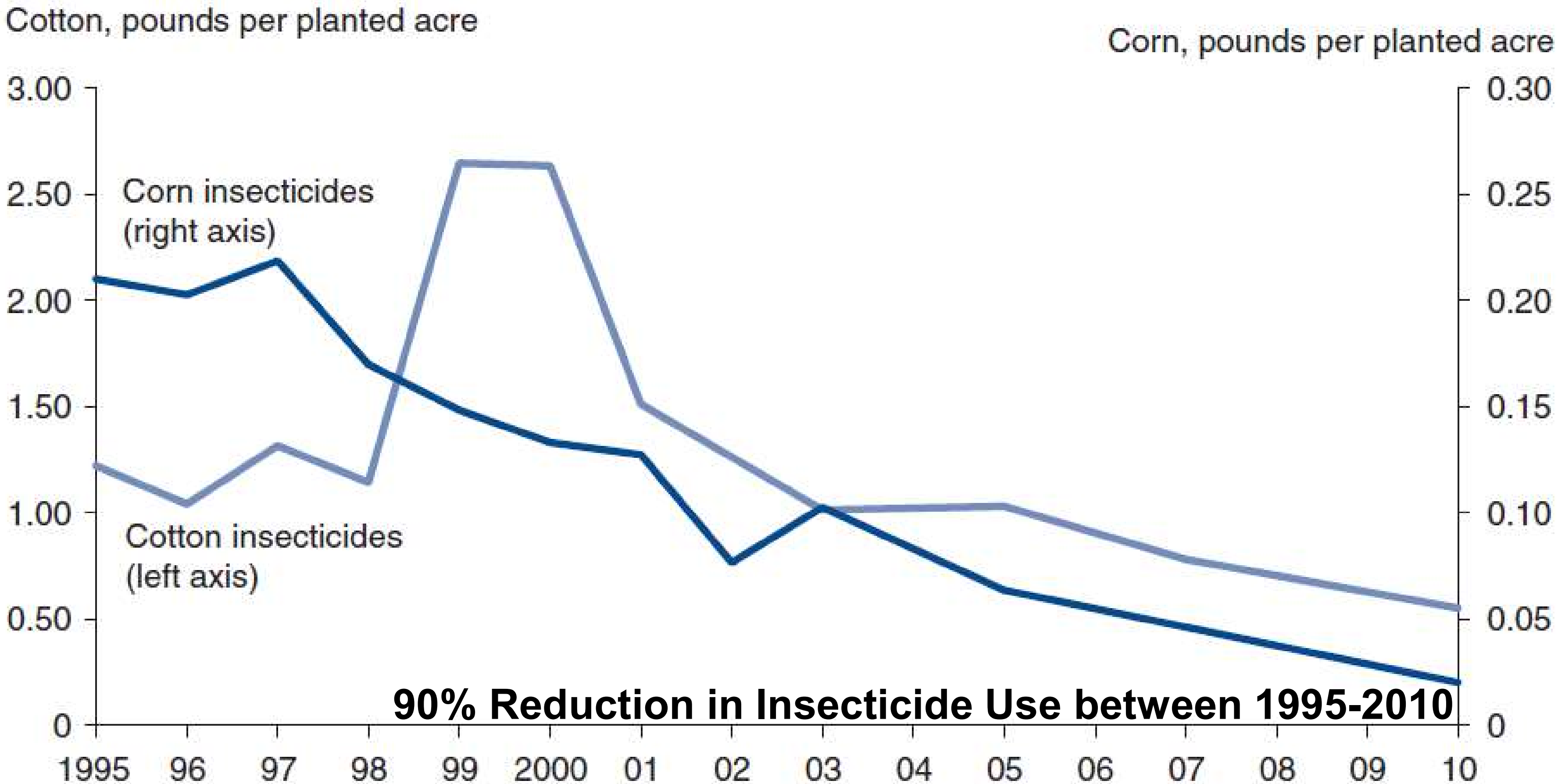
Figure 9
Adoption of genetically engineered corn: growth of stacked traits, 2000-2013



Bt crops have insect-resistant traits; HT crops have herbicide tolerance traits.

Source: U.S. Department of Agriculture (USDA), Economic Research Service (ERS). 2013. *Adoption of Genetically Engineered Crops in the United States,* data product.

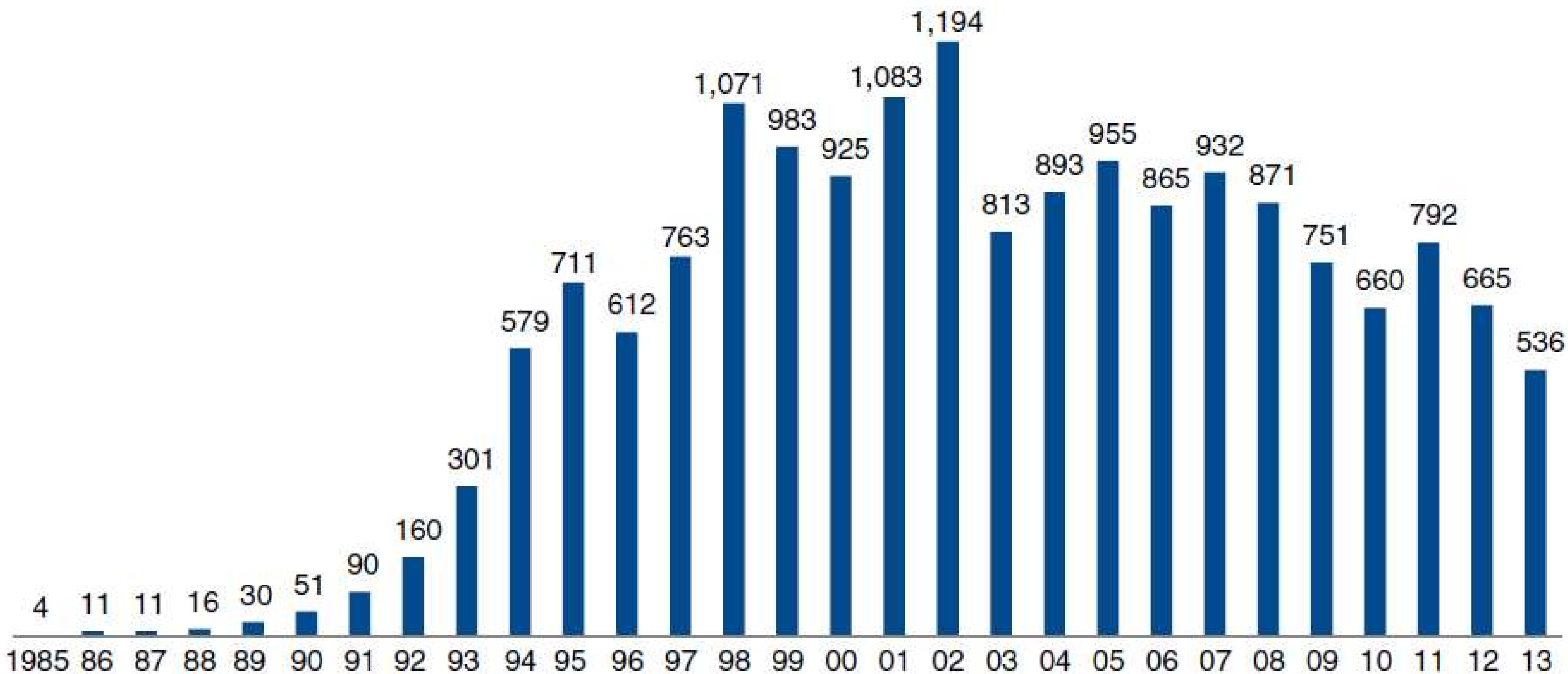
Figure 12
Insecticide use in corn and cotton production, 1995-2010



Source: USDA Economic Research Service using data from USDA National Agricultural Statistics Service Agricultural Chemical Usage reports.

Figure 1

Number of releases of genetically engineered (GE) organisms varieties approved by APHIS, 1985-2013* (Includes permits and notifications)

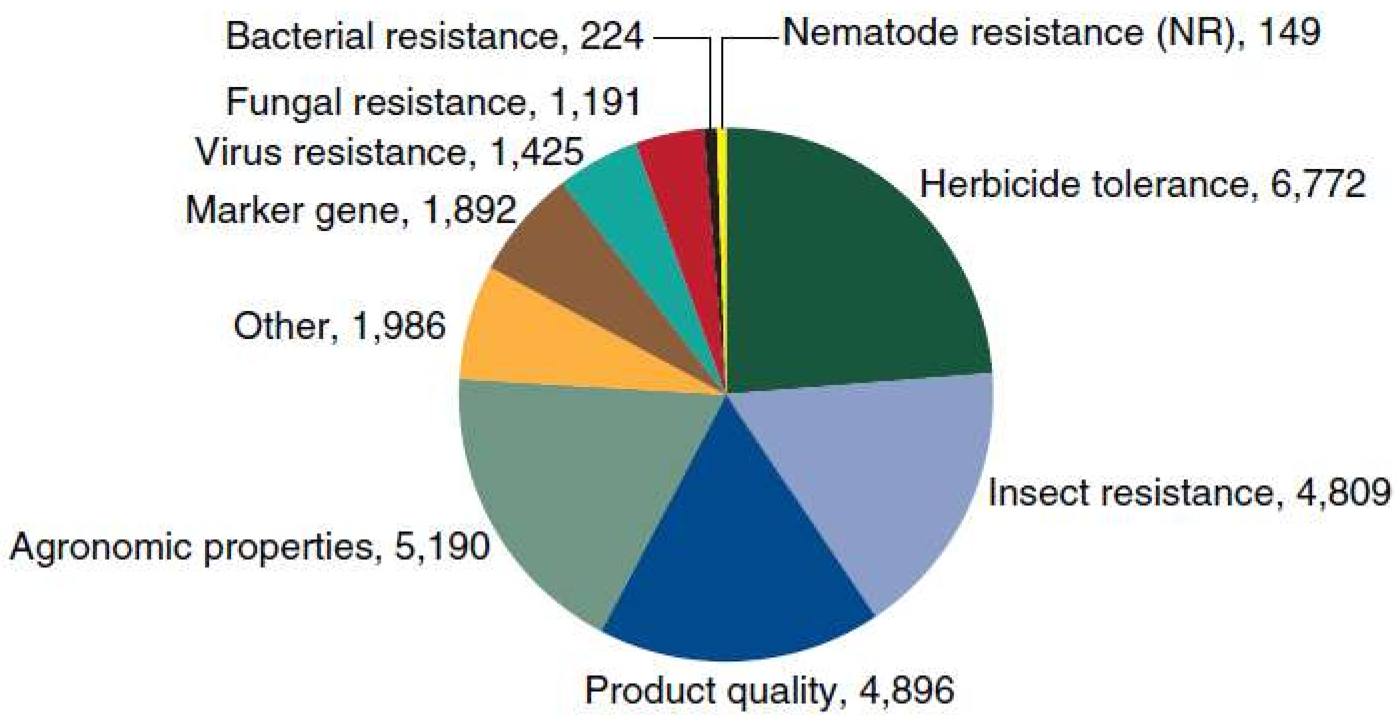


*As of September 24, 2013.

Authorizations for field releases of GE organisms (mostly plant varieties) are issued by USDA's Animal and Plant Health Inspection Service (APHIS) to allow technology providers to pursue field testing.

Source: Information Systems for Biotechnology (ISB, 2013).

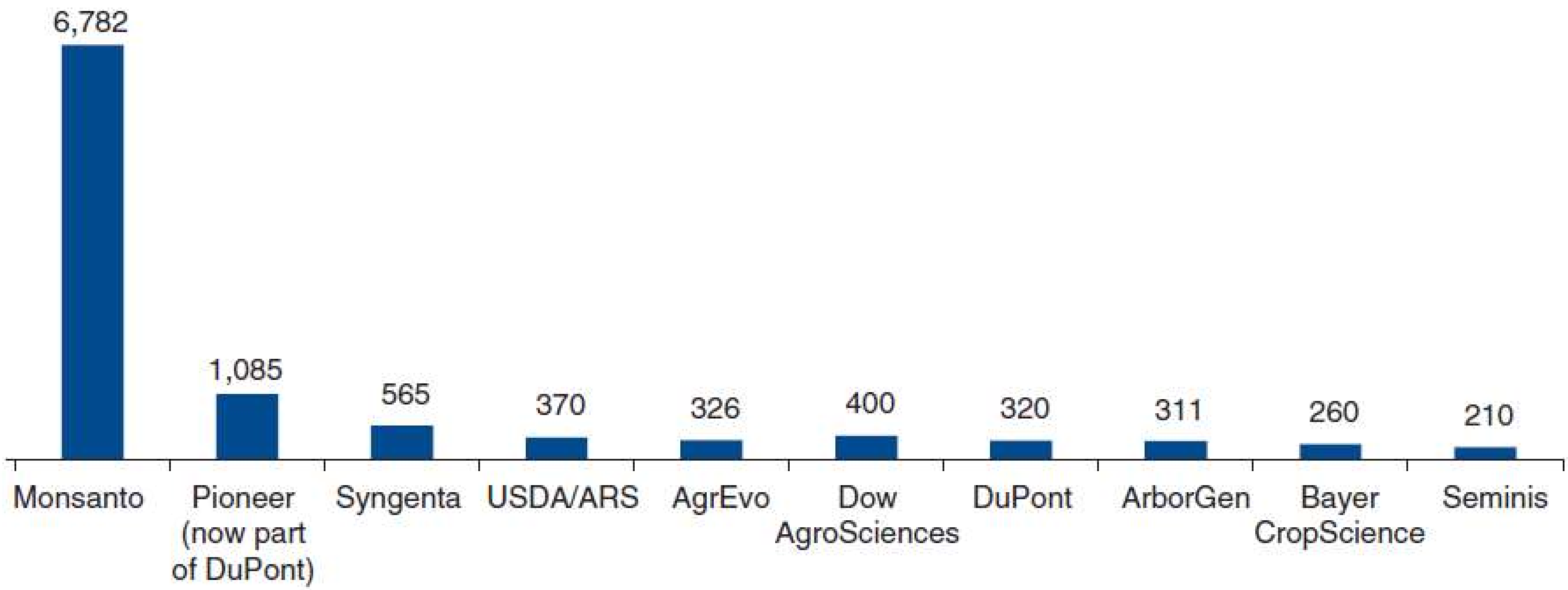
Figure 3
Number of releases approved by APHIS by GE trait (includes permits and notifications)*



*As of September 24, 2013.
Authorizations for field releases of GE plant varieties are issued by USDA's Animal and Plant Health Inspection Service (APHIS) to allow technology providers to pursue field testing. Counts refers to the actual number of approved release locations per phenotype category. http://www.aphis.usda.gov/biotechnology/status.shtml

Source: Information Systems for Biotechnology (ISB, 2013).

Figure 4
Institutions having the most authorized permits and notifications (number held)

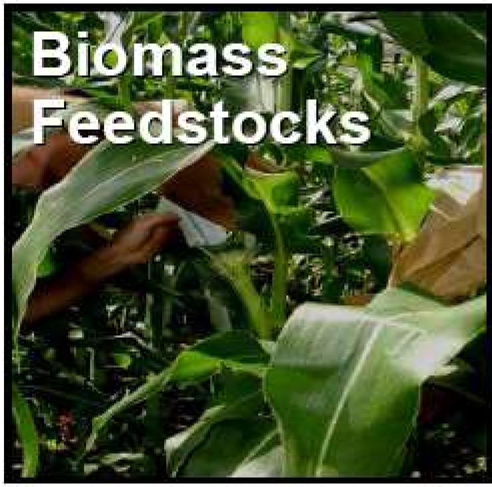


*As of September 24, 2013.

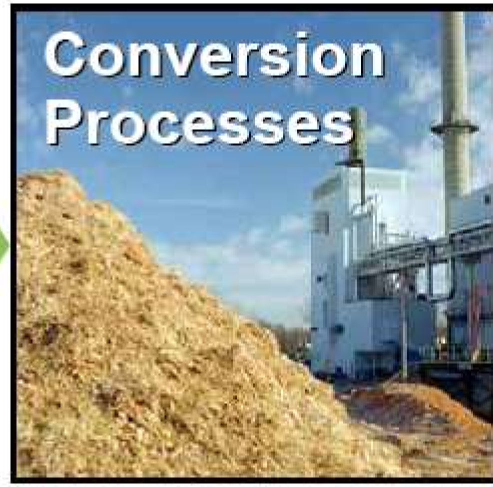
Authorizations for field releases of GE plant varieties are issued by USDA's Animal and Plant Health Inspection Service (APHIS) to allow technology providers to pursue field testing.

Source: Information Systems for Biotechnology (ISB, 2013).

White Biotechnology: Biorefinery Concept



- Trees
- Grasses
- Agricultural crops
- Residues
- Animal wastes
- Municipal solid waste
- Cereal grains
- Sugars



- Enzymatic fermentation
- Gas/liquid fermentation
- Acid hydrolysis/ fermentation
- Gasification
- Combustion
- Co-firing
- Pyrolysis

Uses

Fuels
- Ethanol
- Renewable diesel
- Renewable gasoline

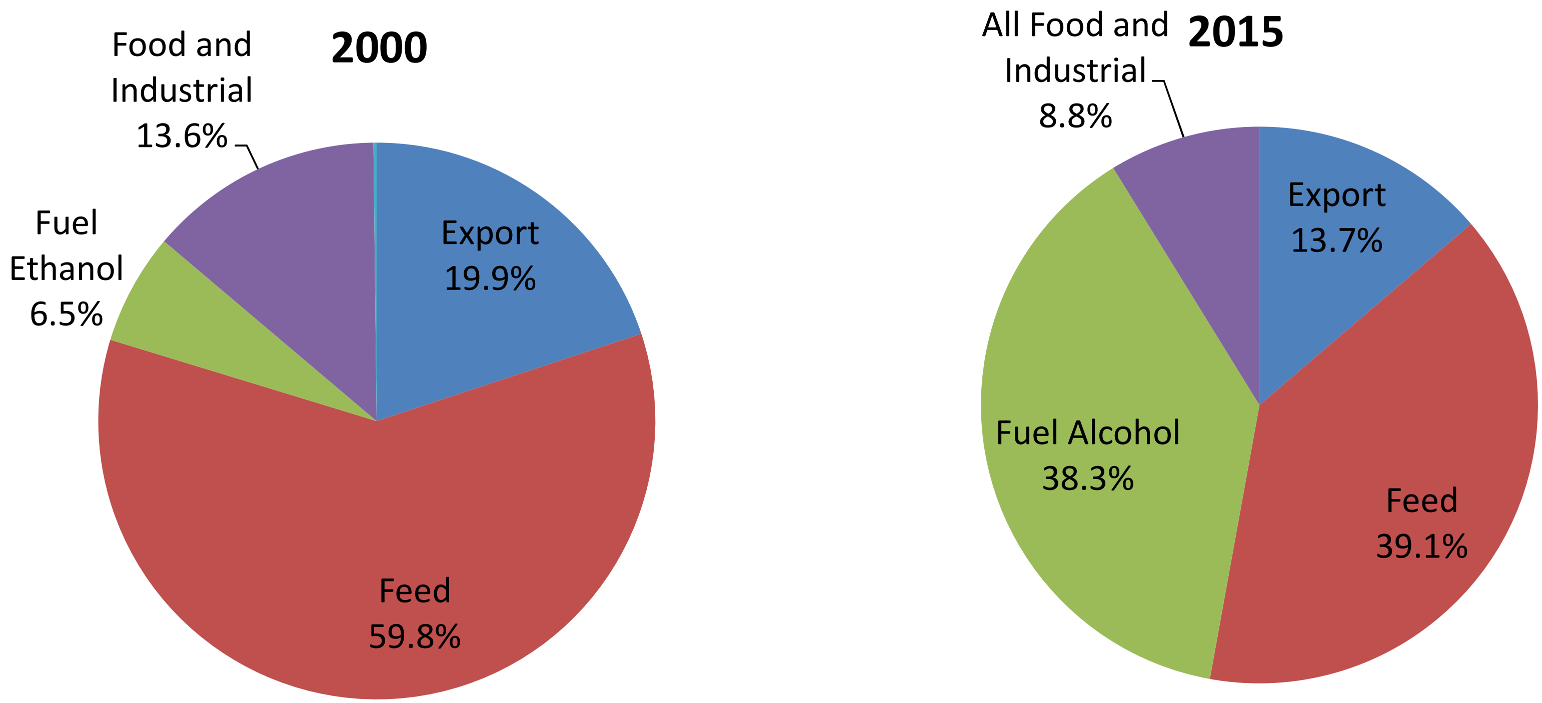
Power
- Electricity
- Heat

Chemicals
- Plastics
- Solvents
- Chemical intermediates
- Phenolics
- Adhesives
- Furfural
- Fatty acids
- Acetic acid
- Carbon black
- Paints
- Dyes, pigments, and ink
- Detergents

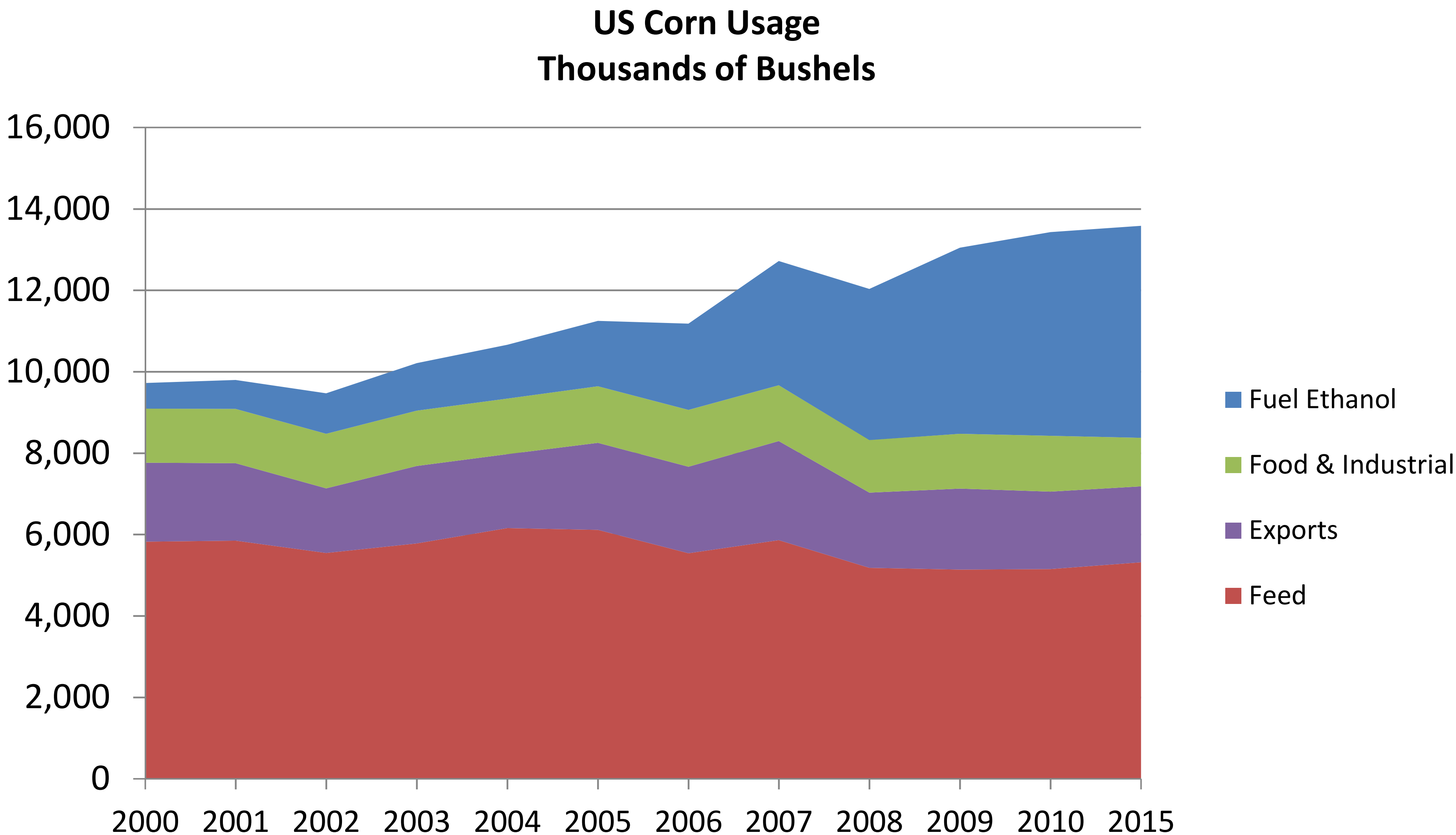
Food and Feed

Bain R.L. "Emerging Bioenergy Technologies For Transportation Fuels", NREL presentation;

Use for US Corn Production



Corn Use (US) from USDA Economics Research Service



Corn Use (US) from USDA Economics Research Service

BioProducts Today

Polyols

PHA

Polylactic Acid

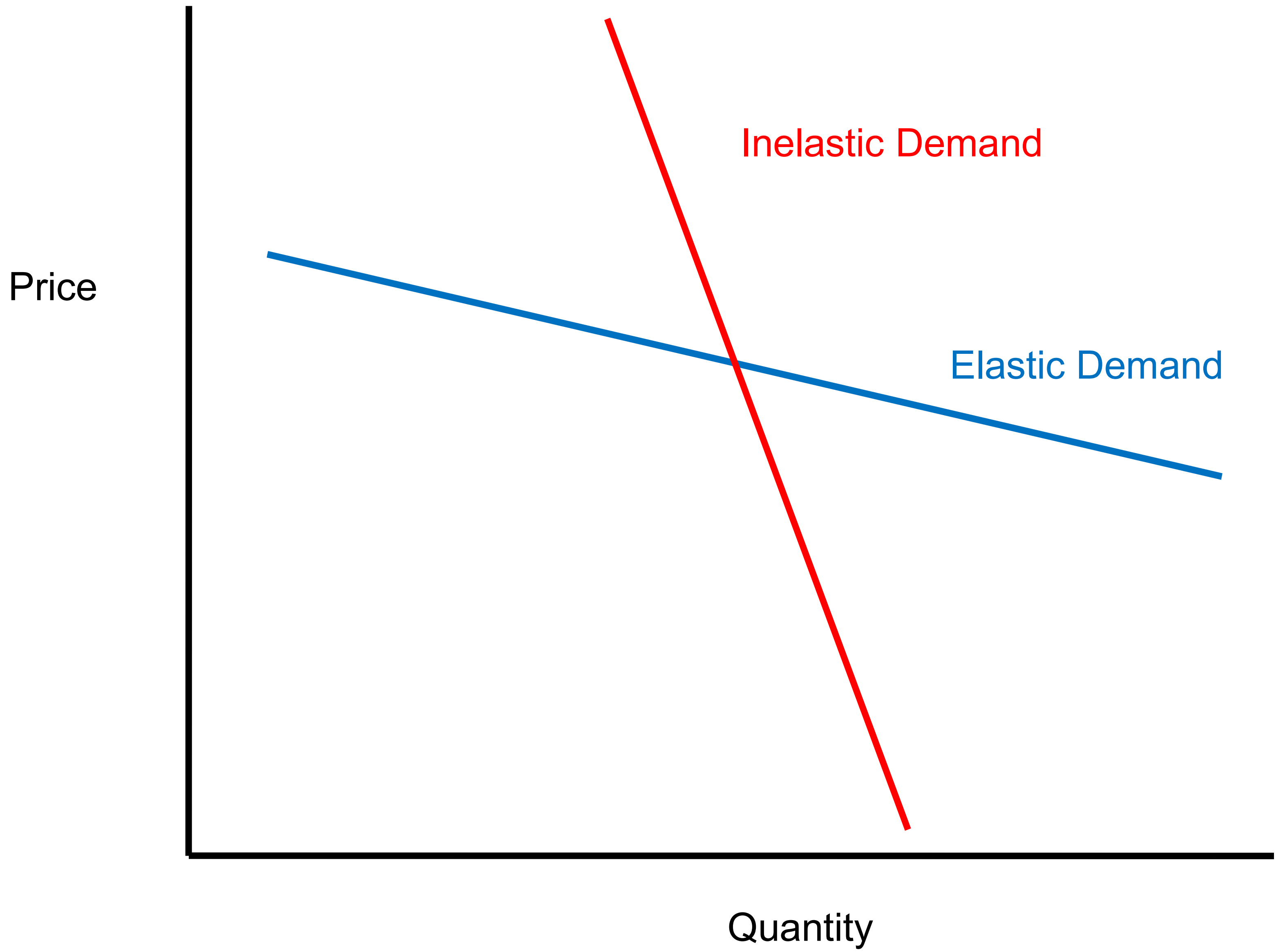
Enzymes and Biobased Solvents for Cleaners

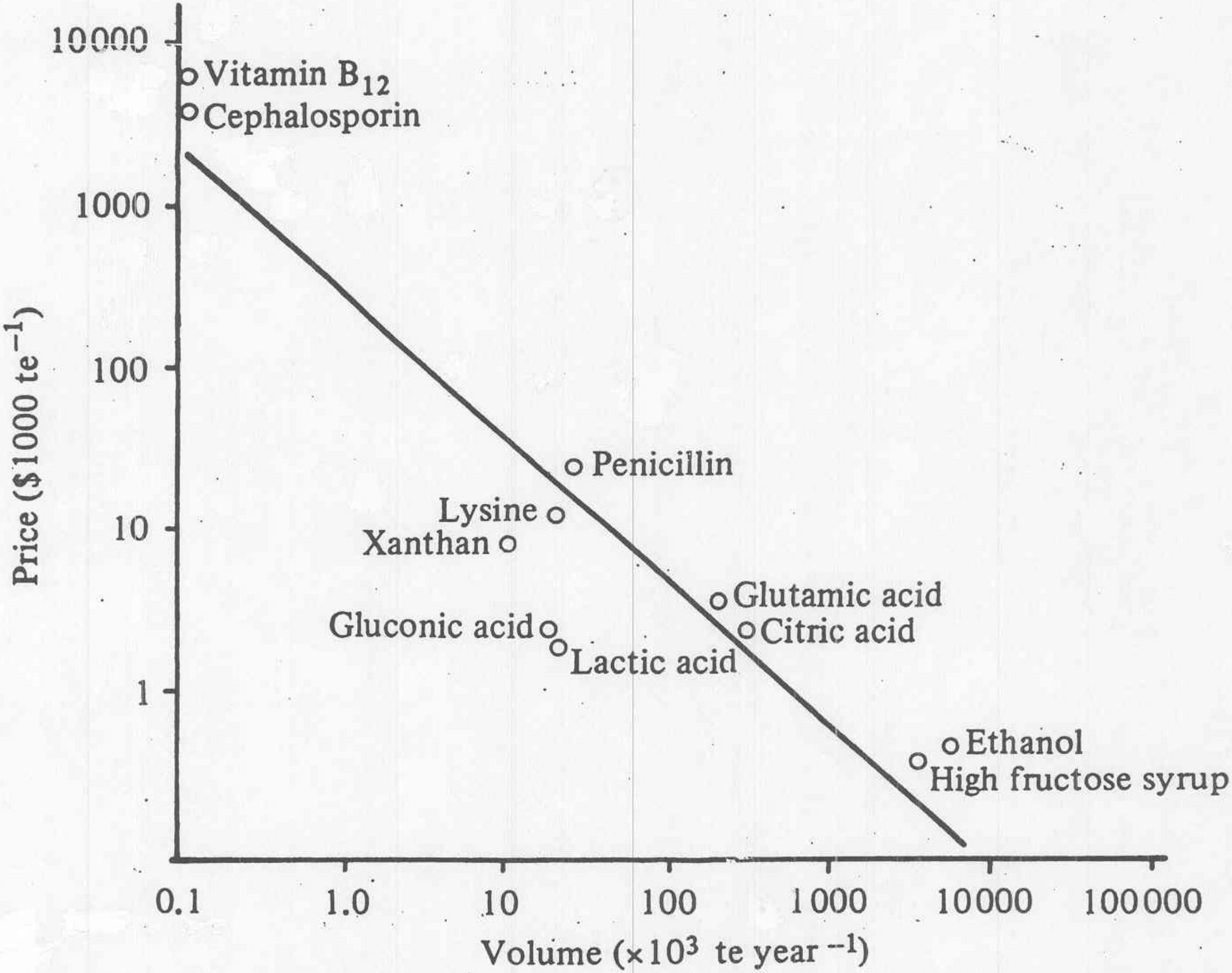
SmartStrand®

with DuPont™ Sorona® renewably sourced polymer*

Bioproducts via Biotechnology

Products	**Value**	**Price Elasticity**
Industrial Chemicals	Low	Elastic
Single Cell Proteins		
Foods and Beverages		
Polysaccharides		
Amino Acids		
Pesticides		
Vitamins		
Carotenoids		
Pharmaceuticals	High	Inelastic


Inelastic Demand
Price
Elastic Demand
Quantity



Price ($1000 te^{-1})
10000
1000
100
10
1
Vitamin B_{12}
Cephalosporin
Penicillin
Lysine
Xanthan
Glutamic acid
Citric acid
Gluconic acid
Lactic acid
Ethanol
High fructose syrup
0.1
1.0
10
100
1000
10000
100000
Volume ($\times 10^3$ te year^{-1})