

# What is Biotechnology?

Singularity University, July 2011

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At its simplest, biotechnology is technology based on biology.

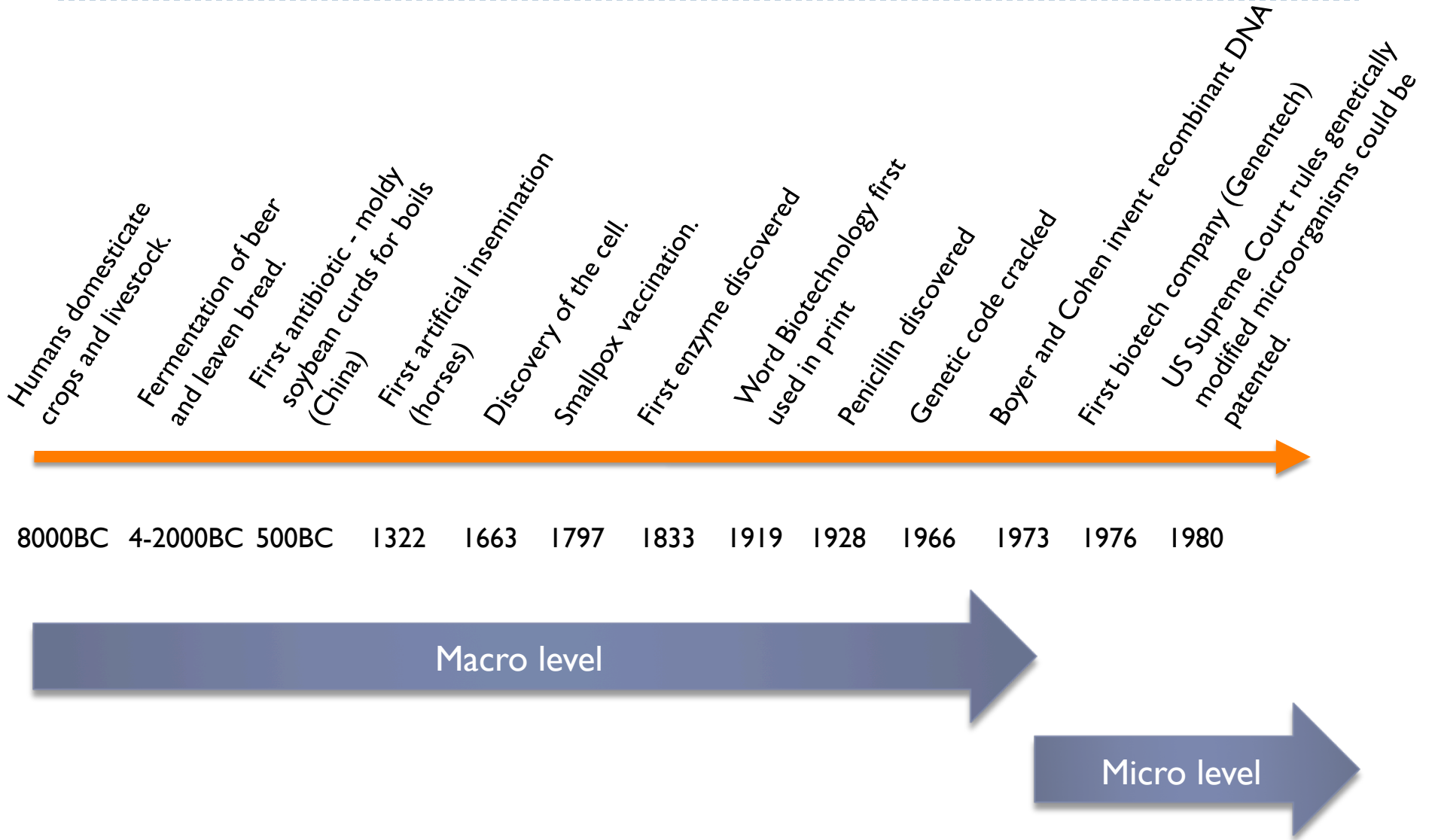
# Overview

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- ▶ A very brief history
- ▶ Health
- ▶ Food
- ▶ Fuel and industrial applications



# History





Health



# Medicine

- ▶ Diagnostics (Genomics)

- ▶ Therapeutics

- ▶ Natural products (Taxol)
- ▶ Recombinant protein therapeutics (insulin)
- ▶ Monoclonal antibodies (Avastin)
- ▶ Gene therapy (cure for HIV)
- ▶ Xenotransplants

- ▶ Personalized Medicine

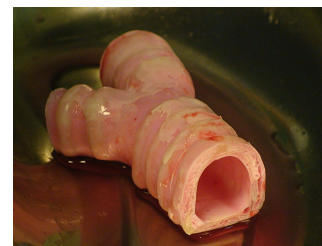
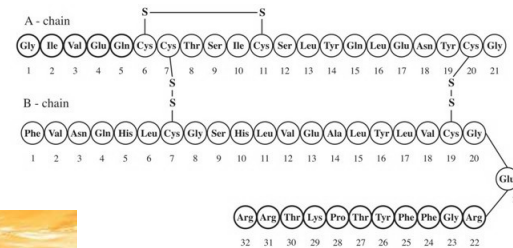
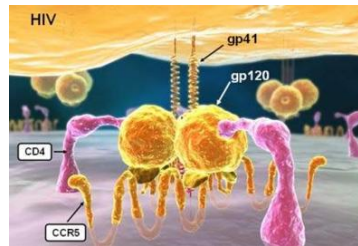
- ▶ Cancer (Herceptin and Her2)
- ▶ Race and gender-based medicine (2005 FDA approval of BiDil for heart failure in “self – identified black patients”)

- ▶ Regenerative Medicine

- ▶ Tissue engineering (trachea transplant)

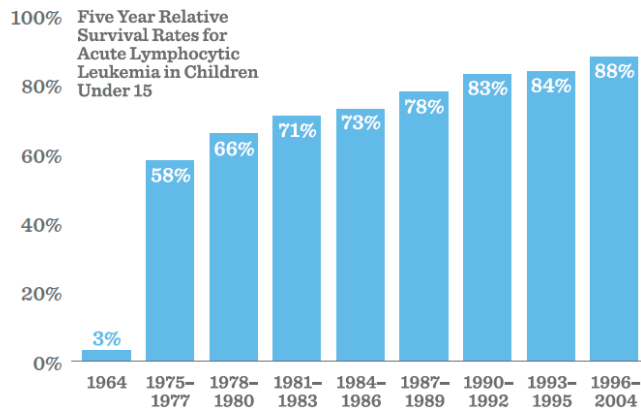
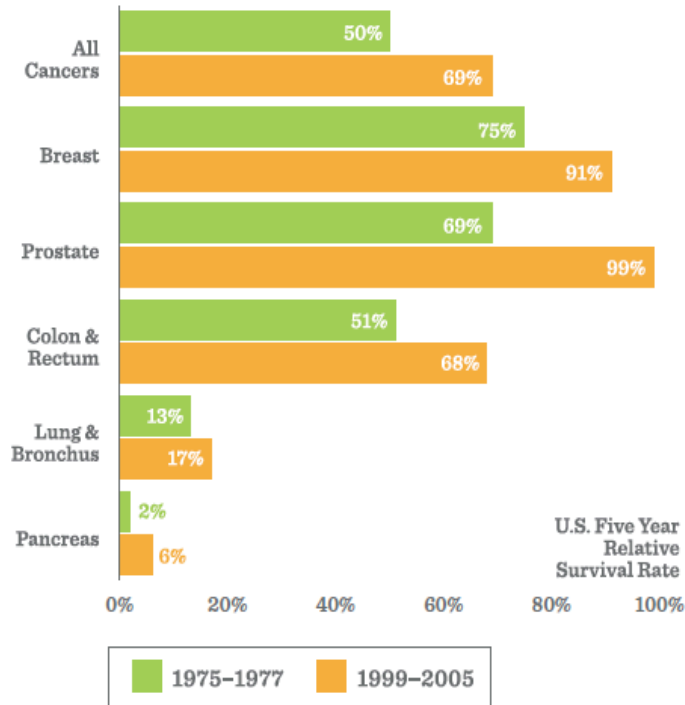
- ▶ Vaccines

- ▶ Production (recombinant expression)
- ▶ Delivery (incorporation of proteins into food)



# Impact – Increased Survival

## Cancer

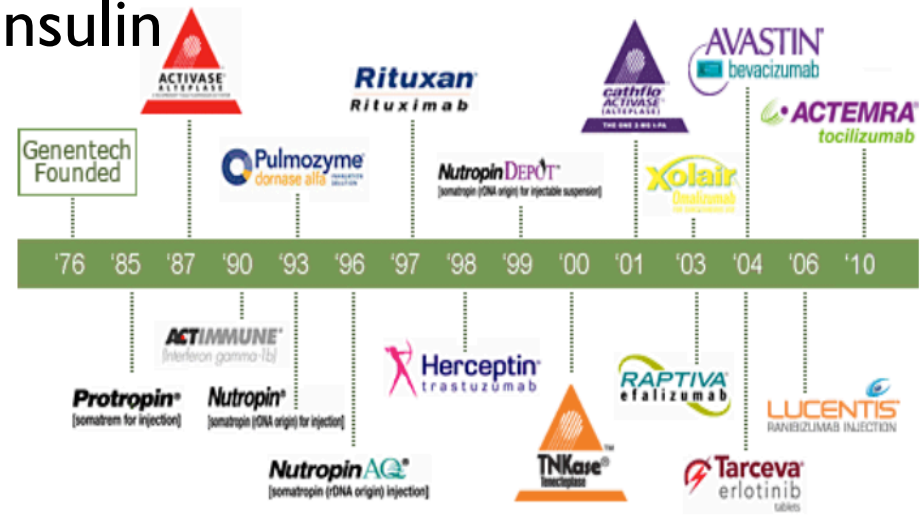


## Infectious Disease

	AVG. ANNUAL U.S. CASES, BEFORE VACCINE	PEAK ANNUAL U.S. DEATHS, BEFORE VACCINE	DECLINE IN U.S. CASES	DECLINE IN U.S. DEATHS
Diphtheria	21,053	3,065	100%	100%
Measles	530,217	552	99%	100%
Mumps	162,344	50	96%	100%
Polio	16,316	5,865	100%	100%
Rubella	47,745	2,184	99%	100%
Tetanus	580	511	93%	99%
Whooping cough	200,752	7,518	92%	99%
Chickenpox	4,085,120	138	85%	82%
Hepatitis A	117,333	298	87%	87%
Acute hepatitis B	66,232	267	80%	80%
Invasive pneumococcal disease	63,067	7,300	34%	25%

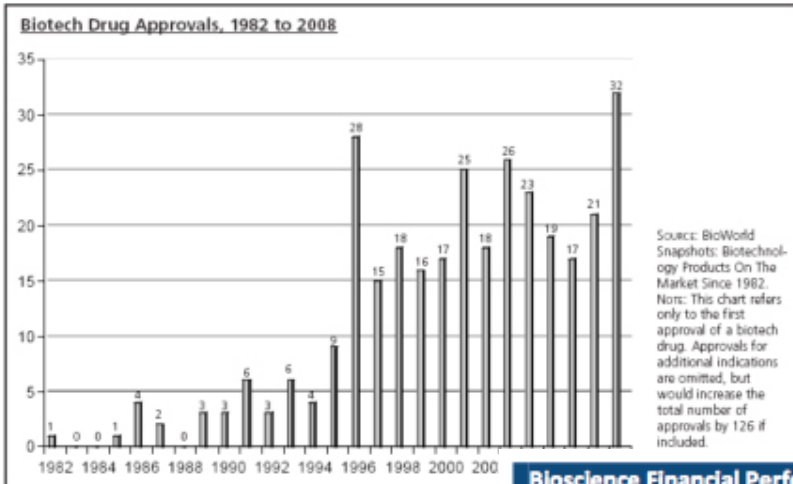
# Genentech

- ▶ Founded in 1976 by Bob Swanson and Herb Boyer
- ▶ 1980 – IPO raised \$35M. Shares increased from \$35 to \$85 in opening hour.
- ▶ 1982 – human recombinant insulin marketed
- ▶ 1999 - \$1B in sales.
- ▶ 2008 - \$10.5B in sales.
- ▶ 2009 – Merged with Roche.





# Insulin Was Just the Start



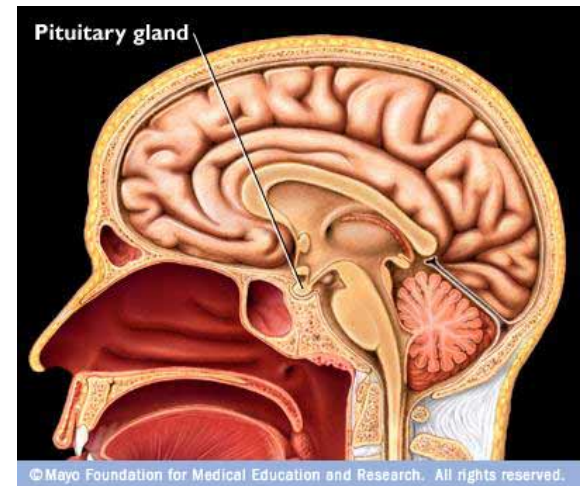
Bioscience Financial Performance by Subsector and Net Income, FY 2009						
Bioscience Subsector	Net Income	Number of Public Firms in Dataset	FY 2009 Revenue		FY 2009 Net Income	
			\$ Millions	% of Industry	\$ Millions	% of Industry
Agricultural Feedstock & Chemicals	Positive	20	\$116,711		\$8,379	
	Negative	14	\$3,531		\$(645)	
<b>Subsector Total</b>		<b>34</b>	<b>\$120,242</b>	<b>21%</b>	<b>\$7,734</b>	<b>10%</b>
Drugs & Pharmaceuticals	Positive	98	\$322,088		\$66,343	
	Negative	285	\$7,574		\$(8,334)	
<b>Subsector Total</b>		<b>383</b>	<b>\$329,661</b>	<b>57%</b>	<b>\$58,009</b>	<b>78%</b>
Medical Devices & Equipment	Positive	84	\$89,913		\$11,897	
	Negative	98	\$16,103		\$(4,776)	
<b>Subsector Total</b>		<b>182</b>	<b>\$106,016</b>	<b>18%</b>	<b>\$7,121</b>	<b>10%</b>
Research, Testing, & Medical Laboratories	Positive	22	\$20,152		\$1,910	
	Negative	28	\$1,278		\$(231)	
<b>Subsector Total</b>		<b>50</b>	<b>\$21,430</b>	<b>4%</b>	<b>\$1,680</b>	<b>2%</b>
<b>Total Biosciences</b>	Positive	<b>224</b>	<b>\$548,863</b>		<b>\$88,529</b>	
	Negative	<b>425</b>	<b>\$28,485</b>		<b>\$(13,985)</b>	
<b>Industry Total</b>		<b>649</b>	<b>\$577,349</b>	<b>100%</b>	<b>\$74,544</b>	<b>100%</b>

2009 Biotechnology revenue of \$577 Billion

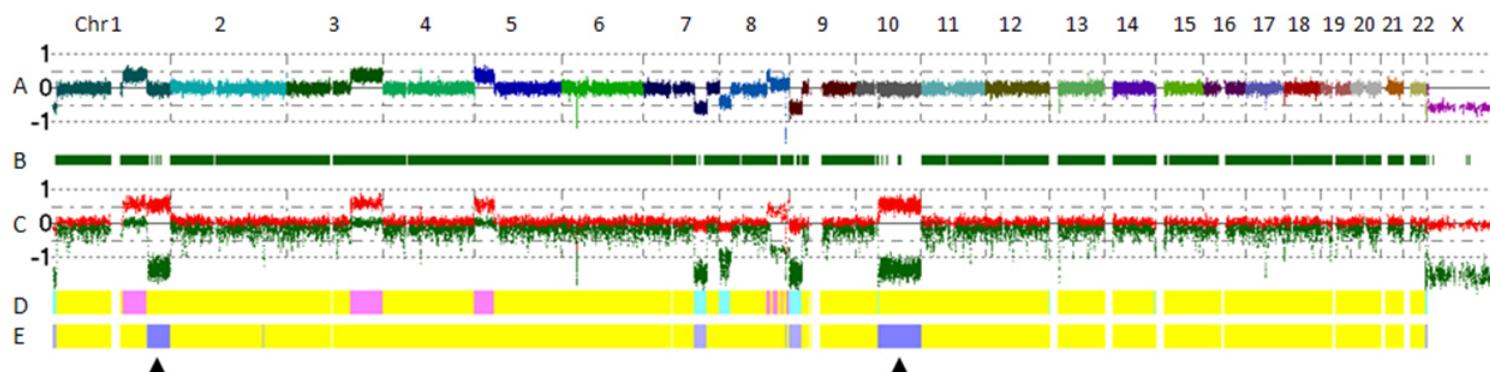
# Improvements Made by Biotechnology

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- ▶ **Growth hormone – cloned at Genentech in 1981**
  - ▶ Used to treat growth hormone deficiency and short stature.
  - ▶ Prior to cloning, the only way to get this drug was from the pituitary of human cadavers!
- ▶ **Cost**
  - ▶ A recent drug I worked on could be produced so cheap to produce that it cost less than the glass vial it was packaged in!



This CLL sample did not show any copy number abnormalities using the standard CLL FISH panel, while the SNP array karyotype captures the genomic complexity of this case, including acquired uniparental disomy (UPD) of 1q and 10q.



- CLL patient
- Conventional Dx was not informative (FISH panel normal, no cytogenetics data due to no growth in culture)
- Virtual Karyotype showed increased genomic complexity – a poor prognostic indicator
- Patient passed away from CLL in less than one year
  - Most FISH normal CLL patients will live 10-20 years
  - In these cases, oncologists typically take 'watch and wait' approach.
  - With Karyotype data, oncologist would have been more aggressive (e.g. bone marrow transplant)



Food



# Agricultural Applications

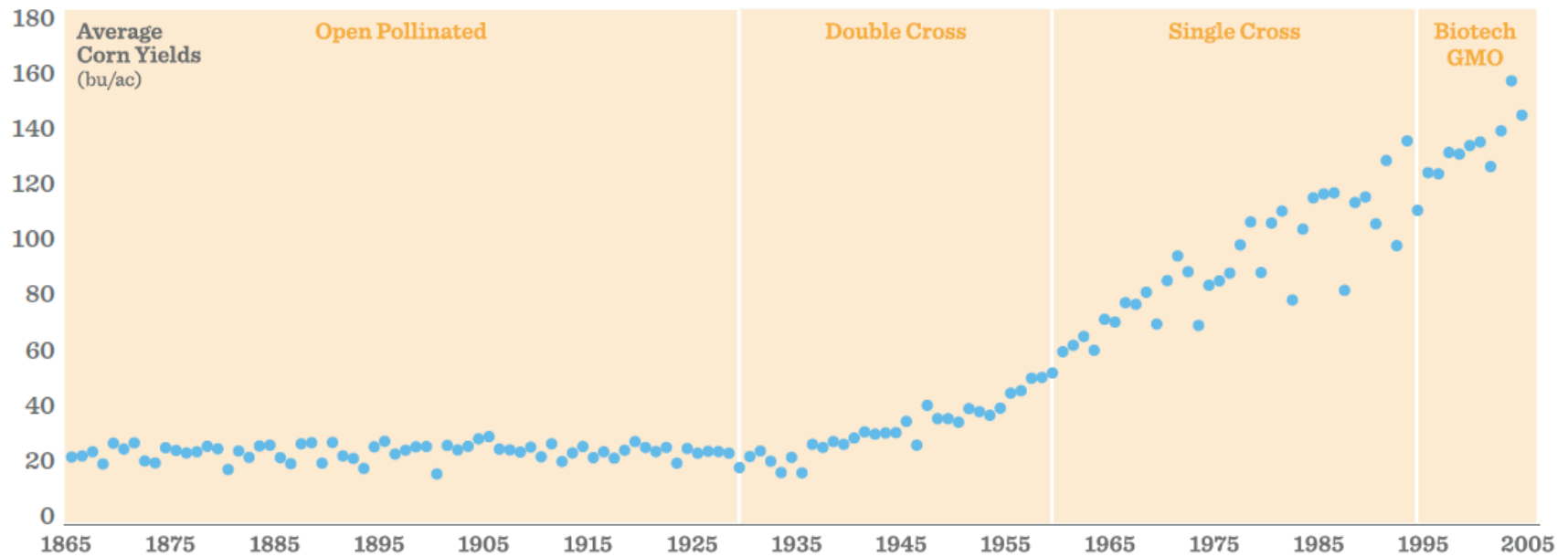
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- ▶ **Crop Biotechnology – Improving crop yields**
  - ▶ Natural protection for plants
  - ▶ Herbicide tolerance
  - ▶ Resistance to environmental stresses
  - ▶ Increased yields
- ▶ **Animal Biotechnology**
  - ▶ Animal genomics
  - ▶ Animal cloning
  - ▶ Genetically engineered animals
- ▶ **“Pharm” animals**
  - ▶ Production of pharmaceuticals in animals – typically in milk



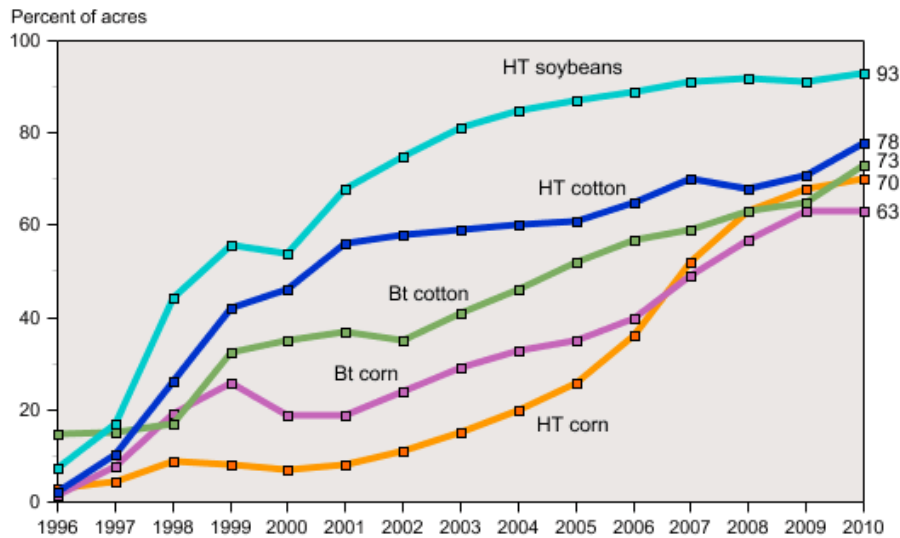
# Impact – Improved Corn Yields

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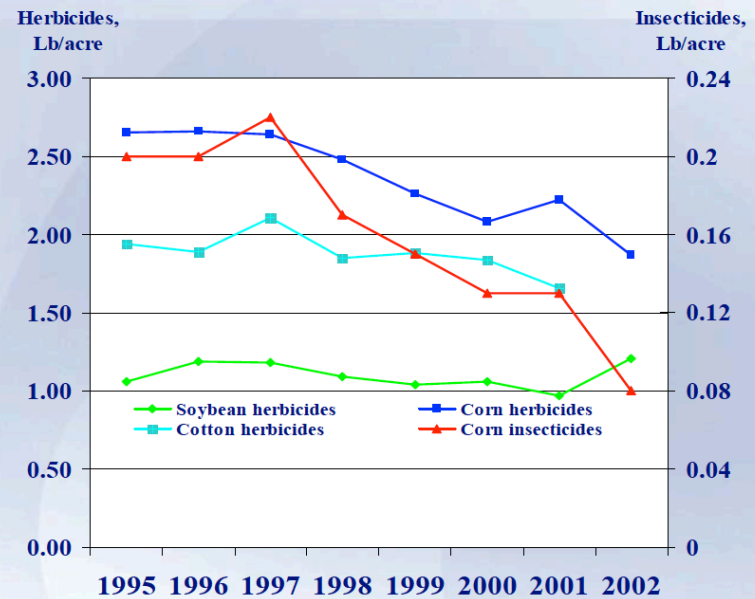
# GMO Crops and Pesticide Use

## Rapid growth in adoption of genetically engineered crops continues in the U.S.



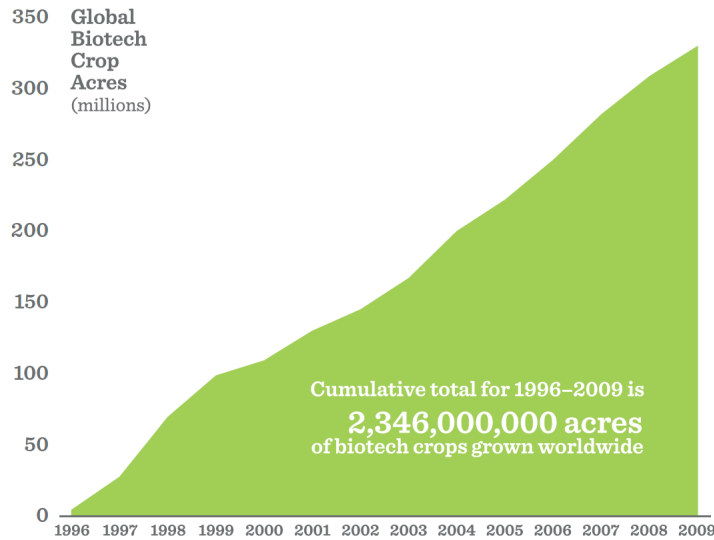
Data for each crop category include varieties with both HT and Bt (stacked) traits.  
 Sources: 1996-1999 data are from Fernandez-Cornejo and McBride (2002). Data for 2000-10 are available in the ERS data product, Adoption of Genetically Engineered Crops in the U.S., tables 1-3.

## Pesticide use per planted acre in major field crops

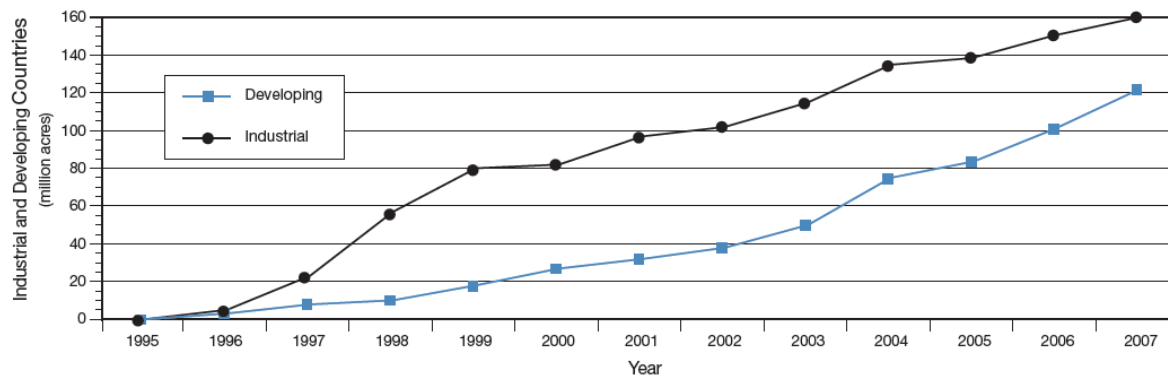


Source: USDA/NASS surveys

# Global Impact – GMO Crops



Global Area of Transgenic Crops, 1995 to 2007:  
Industrial and Developing Countries (million acres)

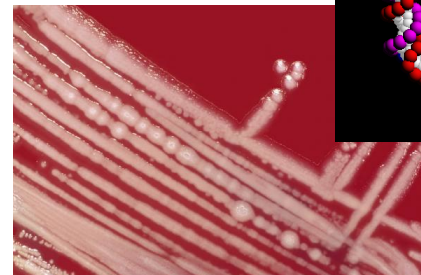
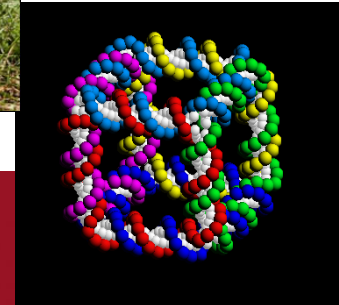
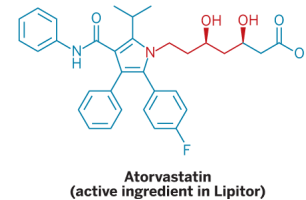
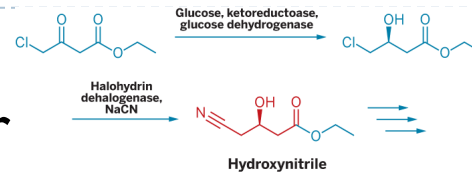




# Fuel and Industrial Biotechnology

# Fuel and Industrial Biotech

- ▶ Biocatalysts – using enzymes for improved catalysis.
- ▶ Biofuel – ethanol from cellulose using microorganisms and/or enzymes.
- ▶ Green plastics – using sugar converted to polylactic acid (PLA) for plastics instead of petroleum.
- ▶ Nanotechnology – using genetic codes to build nanostructures.
- ▶ Environmental biotechnology – using microorganisms to clean up hazardous waste or pollution.



# consumer goods

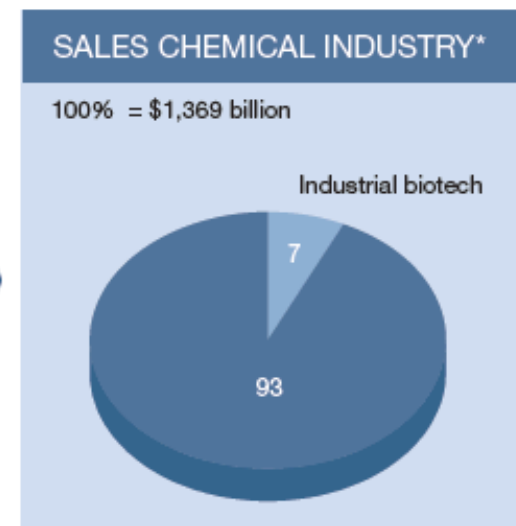
## Made With Industrial Biotech

CONSUMER PRODUCT	OLD PROCESS	NEW INDUSTRIAL BIOTECH PROCESS	BIOTECH ENABLING TECHNOLOGY	CONSUMER BENEFIT
Detergent	Phosphates added as brightening and cleaning agents	Addition of biotechnology enzymes as brightening and cleaning agents: <ul style="list-style-type: none"> <li>● Proteases remove protein stains</li> <li>● Lipases remove grease stains</li> <li>● Amylases remove starch stains</li> </ul>	Genetically enhanced microbes or fungi engineered to make enzymes	<ul style="list-style-type: none"> <li>● Elimination of water pollution from phosphates</li> <li>● Brighter, cleaner clothes with lower-temperature wash water</li> <li>● Energy savings</li> </ul>
Bread	Potassium bromate, a suspected cancer-causing agent at certain levels, added as a preservative and a dough strengthening agent	Addition of biotechnology enzymes to: <ul style="list-style-type: none"> <li>● enhance rising</li> <li>● strengthen dough</li> <li>● prolong freshness</li> </ul>	Microorganisms genetically enhanced to produce baking enzymes (directed evolution and recombinant DNA)	<ul style="list-style-type: none"> <li>● High-quality bread</li> <li>● Longer shelf life</li> <li>● No potassium bromate</li> </ul>
Polyester Bedding	Polyester produced chemically from petroleum feedstock	Biotech polyester (PLA) produced from corn sugar feedstock	Existing bacillus microbe used to ferment corn sugar to lactic acid; lactic acid converted to a biodegradable polymer by heating; polymer made into plastic products and polyester	<ul style="list-style-type: none"> <li>● PLA polyester does not harbor body odor like other fibers</li> <li>● Biodegradable</li> <li>● Not made from petroleum</li> <li>● Does not give off toxic smoke if burned</li> </ul>
Vitamin B2	Toxic chemicals, such as aniline, used in a nine-step chemical synthesis process	One-step fermentation process uses vegetable oil as a feedstock	Genetically enhanced microbe developed to produce vitamin B2 (directed evolution)	<ul style="list-style-type: none"> <li>● Biologically produced without chemicals</li> <li>● Greatly reduces hazardous waste generation and disposal</li> </ul>
Stonewashed Jeans	Open-pit mining of pumice; fabric washed with crushed pumice stone and/or acid	Fabric washed with biotechnology enzyme (cellulase) to fade and soften jeans or khakis	Textile enzymes produced by genetically enhanced microbe (extremophiles and recombinant DNA)	<ul style="list-style-type: none"> <li>● Less mining</li> <li>● Softer fabric</li> <li>● Reduces energy consumption</li> <li>● Lower cost</li> </ul>
Paper Bleaching	Wood chips boiled in a harsh chemical solution to yield pulp for paper making	Enzymes selectively degrade lignin and break down wood cell walls during pulping	Wood-bleaching enzymes produced by genetically enhanced microbes (recombinant DNA)	<ul style="list-style-type: none"> <li>● Reduces use of chlorine bleach and reduces toxic dioxin in the environment</li> <li>● Cost savings due to lower energy and chemical costs</li> </ul>
Ethanol Fuel	Food and feed grains fermented into ethanol (a technology that is thousands of years old)	Cellulase enzyme technology allows conversion of crop residues (stems, leaves, straw and hulls) to sugars that are then converted to ethanol	Genetically enhanced organism developed to produce enzymes that convert agricultural wastes into fermentable sugars (directed evolution, gene shuffling)	<ul style="list-style-type: none"> <li>● Renewable feedstock</li> <li>● Reduces greenhouse gas emissions</li> <li>● Increases domestic energy production</li> <li>● Is more energy efficient to produce than old process</li> </ul>
Antibiotics	Chlorinated solvents and hazardous chemicals used to produce antibiotics through chemical synthesis	One-step biological process uses direct fermentation to produce antibiotic intermediate	Genetically enhanced organism developed to produce the key intermediate of certain antibiotics (recombinant DNA)	<ul style="list-style-type: none"> <li>● 65% reduction in energy consumption</li> <li>● Overall cost savings</li> </ul>
Contact Lens Solution	Surfactants and/or saline solutions (do not remove protein deposits) used to clean lenses	Protease enzymes remove protein deposits from the contact lens	Genetically enhanced microbes engineered to make protease enzymes (directed evolution)	<ul style="list-style-type: none"> <li>● More effective contact lens cleaning</li> <li>● Less eye irritation</li> </ul>

## Industrial Biotech–Related Sales in Chemicals, 2005: \$95.5 Billion

Billions of dollars

SEGMENT	BIO-DEPENDENT SALES 2008	PRODUCT EXAMPLES/COMMENTS
Biofuels	26	Ethanol, Biodiesel
Plant extracts	24	Hydrocolloids (gums, industrial starches...), essential oils, botanicals
Pharmaceutical ingredients	12	Biocatalytically produced APIs, antibiotics, therapeutic proteins**
Bulk/polymers	12	Natural rubber, biopolymer PLA, biobased polyols
Food/feed ingredients	9	Citric acid, lysine, glutamic acid, Vitamin B12, polyunsaturated fatty acids
Oleochemicals	9	Fatty acids, fatty alcohols, surfactants, glycerol
Enzymes	2.5	Detergent enzymes, textile processing aids, grain processing enzymes
Others	1	Other specialties, R&D services
<b>Total BIO</b>	<b>95.5</b>	



\* Current chemical industry sales excluding B2C sales in pharma and personal care: \$1,369 billion

\*\* Top-down estimate based on industry interviews; assumes 25% share of total intermediate and active pharmaceutical ingredient sales.

Source:  
McKinsey & Co.



# Other Applications

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- ▶ **Pandemics and biodefense**
- ▶ **Forensics**
- ▶ **Paternity**
- ▶ **Anthropology**
- ▶ **Wildlife management**



Questions?

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