Fraunhofer | **UNIVERSITY OF DELAWARE.**

Inaugural Fraunhofer – Delaware Technology Summit

Inaugural Fraunhofer – Delaware Technology Summit

Energy and Life Sciences – Solutions for Sustainability

University of Delaware
Clayton Hall
March 5/6, 2013

Fraunhofer | **UNIVERSITY OF DELAWARE.**

Inaugural Fraunhofer – Delaware Technology Summit

LIFE SCIENCES SOLUTIONS

Keynote Presentation
"Life Sciences Addressing Global Challenges"

– Douglas Muzyka
Senior Vice President and
Chief Science & Technology Officer
DuPont

Life Sciences Addressing Global Challenges

Douglas Muzyka, PhD
Senior Vice President and Chief Science & Technology Officer, DuPont
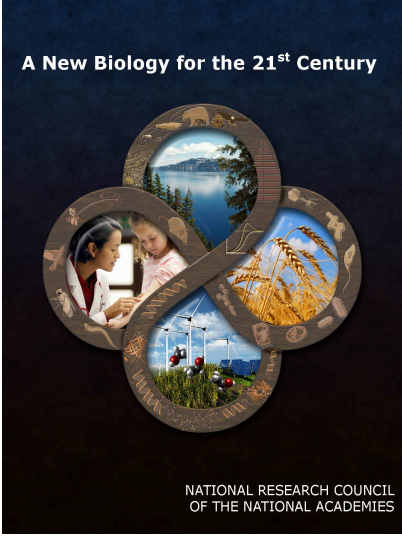

Key messages

- Science can address global challenges
- Integration of scientific disciplines is more powerful than any one alone
- Collaboration is key to delivering solutions

Agenda for Life Sciences: Global Challenges

A New Biology for the 21st Century

NATIONAL RESEARCH COUNCIL
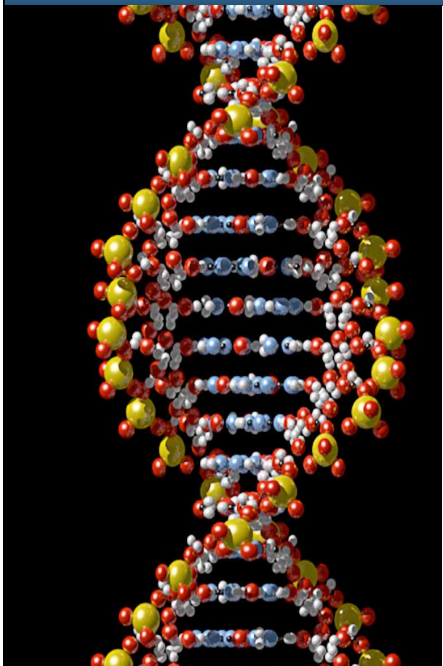OF THE NATIONAL ACADEMIES

National Academies propose "New Biology" initiative (2009)

- Biological Sciences at inflection point in their capacity to solve problems

- Opportunity to propel science to a new level

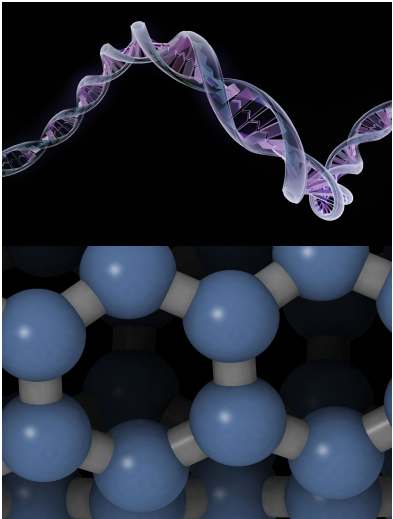- Goal is to address significant societal needs
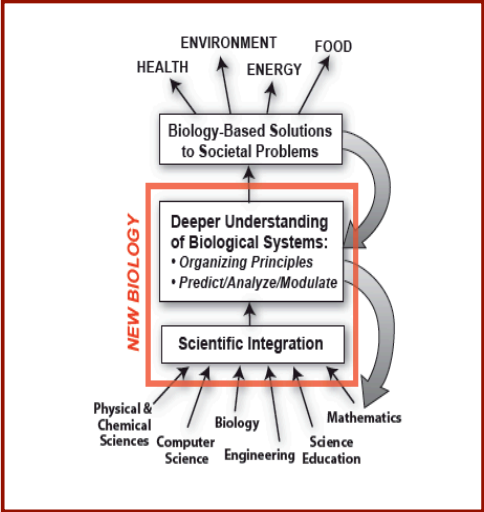
Biology at Inflection Point

- Increasingly integrating the sub-disciplines of biology

- Integrating with other disciplines: physical, computational, earth scientists, engineers

- Technological advances enables unprecedented data collection: quantity and quality

- Past investments providing value beyond expected

Slide 1

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New Biology: Integration of Disciplines

Diagram: ENVIRONMENT, HEALTH, ENERGY, FOOD → Biology-Based Solutions to Societal Problems → **NEW BIOLOGY**: Deeper Understanding of Biological Systems: • Organizing Principles • Predict/Analyze/Modulate → Scientific Integration ← Physical & Chemical Sciences, Computer Science, Biology, Engineering, Mathematics, Science Education

Slide 2

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New Biology Initiative

SOCIETAL CONCERNS

GOVERNMENT POLICIES

TECHNOLOGY ADVANCES

MARKET DISCONTINUITIES

Recommendations

Launch New Biology Initiative to:
- Accelerate the emergence and growth of the New Biology
- Achieve solutions to societal challenges in food, energy, environment, and health

Initiative should be:
- Interagency
- Ten years minimum duration
- Funded in addition to base missions

Develop the information sciences and technologies that will be critical to the success of the New Biology

Develop interdisciplinary curricula, graduate training and educator training needed to create and support New Biologists

The National New Biology Initiative

Setting big goals: Address societal problems

- Food
- Environment
- Energy
- Health

DuPont applies science to develop solutions for these major challenges

FOOD

ENERGY

PROTECTION

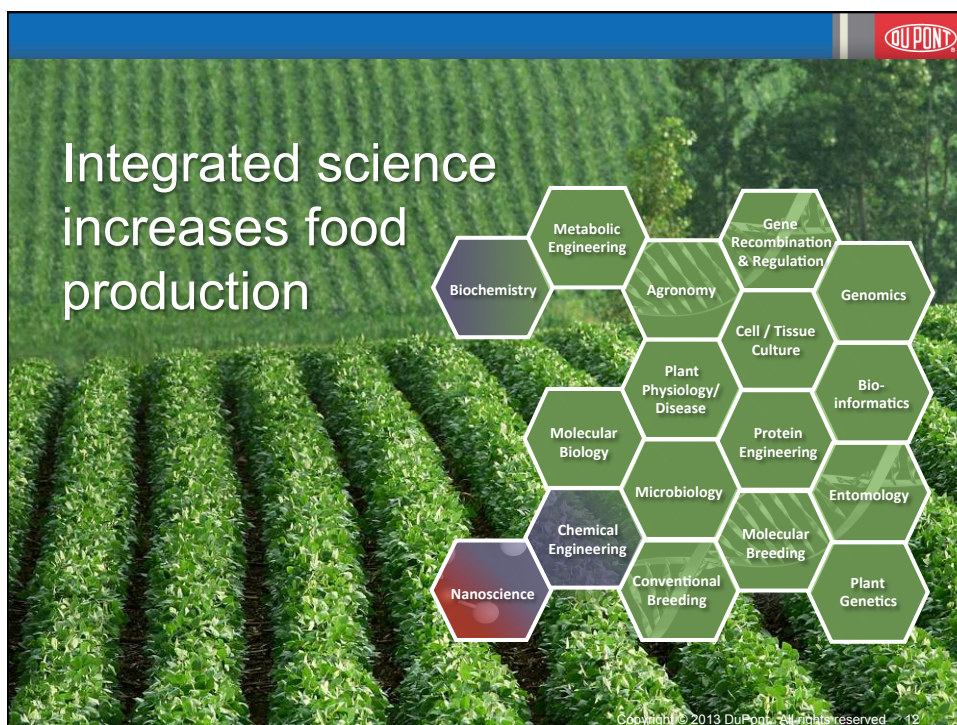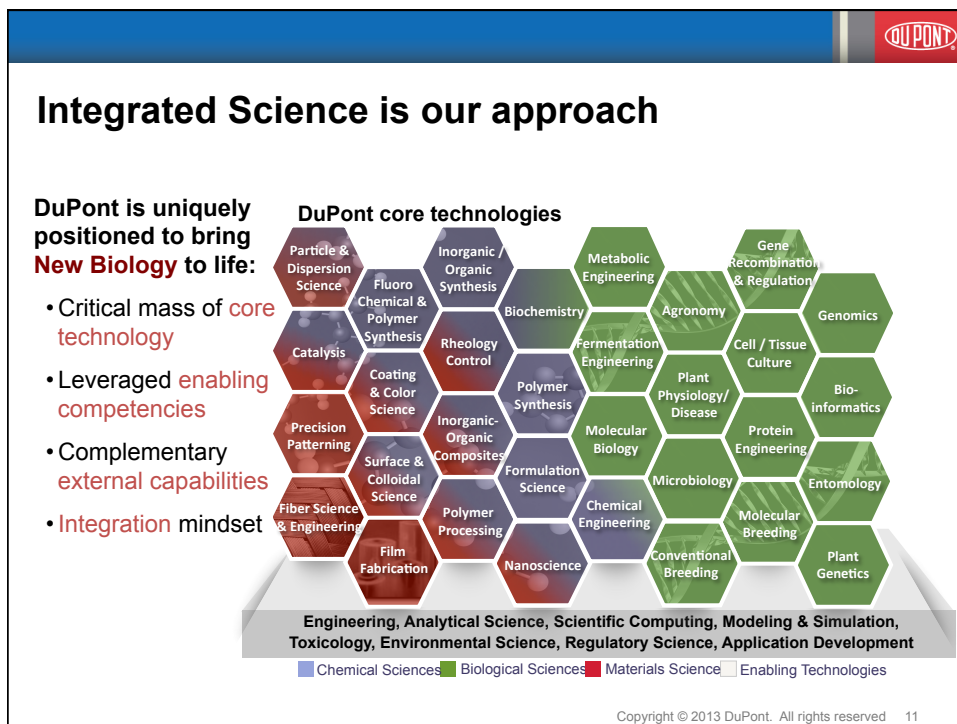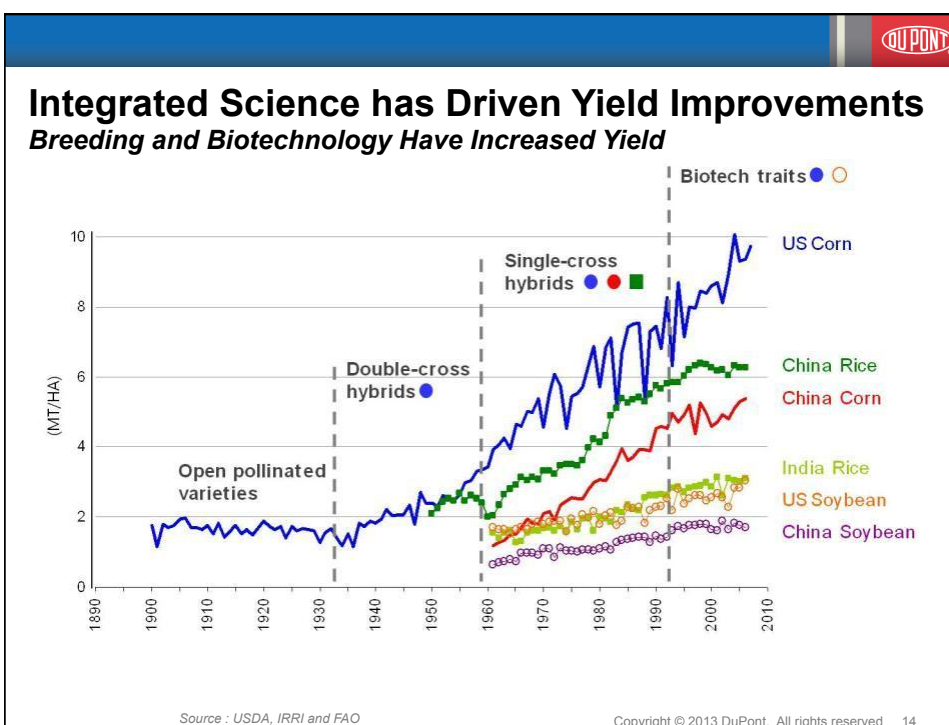FEEDING
THE WORLD

REDUCING OUR DEPENDENCE
ON FOSSIL FUELS

KEEPING PEOPLE AND
THE ENVIRONMENT SAFE

Integrated Science is our approach

DuPont is uniquely positioned to bring New Biology to life:

- Critical mass of core technology
- Leveraged enabling competencies
- Complementary external capabilities
- Integration mindset

DuPont core technologies

Particle & Dispersion Science · Fluoro Chemical & Polymer Synthesis · Inorganic / Organic Synthesis · Metabolic Engineering · Gene Recombination & Regulation · Catalysis · Biochemistry · Agronomy · Genomics · Coating & Color Science · Rheology Control · Fermentation Engineering · Cell / Tissue Culture · Precision Patterning · Polymer Synthesis · Plant Physiology/ Disease · Bio-informatics · Inorganic-Organic Composites · Molecular Biology · Protein Engineering · Fiber Science & Engineering · Surface & Colloidal Science · Formulation Science · Microbiology · Entomology · Polymer Processing · Chemical Engineering · Molecular Breeding · Film Fabrication · Nanoscience · Conventional Breeding · Plant Genetics

Engineering, Analytical Science, Scientific Computing, Modeling & Simulation, Toxicology, Environmental Science, Regulatory Science, Application Development

Chemical Sciences   Biological Sciences   Materials Science   Enabling Technologies

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Integrated science increases food production

Metabolic Engineering · Gene Recombination & Regulation · Biochemistry · Agronomy · Genomics · Cell / Tissue Culture · Plant Physiology/ Disease · Bio-informatics · Molecular Biology · Protein Engineering · Microbiology · Entomology · Chemical Engineering · Molecular Breeding · Nanoscience · Conventional Breeding · Plant Genetics

Science is at the core of increased productivity
Increased productivity created the equivalent of 275 million "virtual acres" in last 30 years

World* Corn Production: 1980-2015

27% increase in global area

97% increase in production

■ Production Attributed to Area
■ Genetics, Technology & Management

*Selected World Source: USDA, FAO, Global Insight; Resulting analysis: Pioneer Marketing Department

Integrated Science has Driven Yield Improvements
Breeding and Biotechnology Have Increased Yield

Drought-Tolerant Corn:
Integrated Science to Protect Yields

Conventional

Optimum® AQUAmax™ *Drought-tolerant*

Normal Water   Drought   Normal Water   Drought

Without transgene   With transgene

Drought

Nitrogen Use Efficiency (NUE)
Integrated Science to Improve the Sustainability of Agriculture

Normal Nitrogen

Increase in kernels per ear under nitrogen stress

Without Transgene   With Transgene

Nitrogen Stress

With Transgene

Without Transgene

Slide 1

Plenish™ High Oleic Soybeans

- Biotech soybean with **consumer** benefits
- Enhanced functionality for food preparation
- Industrial application benefits
- High-yielding Pioneer® brand Y series varieties

plenish   Hydrogenated Soy Oils

PLENISH™ HIGH OLEIC

Oleic

COMMODITY

Oleic

● Linoleic   ● Linolenic   ● Sats   ● Oleic

Slide 2

Integrated science unlocks the potential of advanced biofuels

- Particle & Dispersion Science
- Metabolic Engineering
- Gene Recombination & Regulation
- Biochemistry
- Agronomy
- Genomics
- Fermentation Engineering
- Formulation Science
- Bio-informatics
- Molecular Biology
- Protein Engineering
- Microbiology
- Chemical Engineering
- Conventional Breeding

Low Carbon, Scalable, Sustainable

Cellulosic Ethanol: Non-food Feedstocks

Advantages:

>60% greenhouse gas reduction

Non-food sources and marginal land

Multiple feedstock available

Excellent income for farmers

Biobutanol: Better Fuel

Advantages:

Drop-in fuel

High blends without infrastructure changes

Refinery can use more fractions of oil

Higher energy content

DuPont Cellulosic Ethanol Conversion Process

Feedstock	Milling & Pretreatment	Saccharification	Fermentation	Separation
• Large-scale test harvest • Commercial equipment • Agronomic understanding • Multi-year grower involvement	• Minimal capital • Facilitate enzymes • Minimize inhibitors • Mild process	• High solids • High sugar yield • High sugar titers • Low enzyme loading • Minimize inhibitors	• C5/C6 utilization • High ethanol yield • High ethanol titer	• Recover product • Recover lignin • Recycle water

Integrated Science and Collaboration are Key to Delivering Solutions

Integrated Science Creates Solutions
Cellulosic Ethanol: Saccharification Challenge

Biomass polysaccharides

Cellulose

Not shown: Lignin

Arabinoxylan

Enzyme Discovery
Protein Engineering

- Complex structure
- Requires at least 6-8 enzyme activities, each optimized for for activity and stability

- Protein production
- Specific activity
- Specific performance
- Inhibition
- Stability

- Steady improvement in enzyme performance
- Lower enzyme use ==> economic viability

Relative Enzyme Use (%): rutc30, spezyme cp, A1500, DUET, TRIO

Integrated Science Creates Solutions
Cellulosic Ethanol: Fermentation Challenge

D-Xylose   L-Arabinose

KEY
Endogenous Activity
Increased Activity
Added Activity

Xylose Isomerase
L-arabinose Isomerase
L-Ribulose
L-ribulokinase
D-Xylulose
Xylulokinase
ATP
ADP
L-Ribulose-5-P
L-ribulose-P 4-epimerase
D-Xylulose-5-P   D-Ribulose-5-P   Ribose-5-P

Transketolase
Sedoheptulose-7-P   Glyceraldehyde-3-P
Transaldolase
Erythrose-4-P   Fructose-6-P
Transketolase

ATP
ADP
Glucose-6-P
Gluconolactone-6-P
6-P-Gluconate
2-Keto-3-deoxy-6-P-Gluconate
Glyceraldehyde-3-P
1,3-P-Glycerate
ADP
ATP
3-P-Glycerate
2-P-Glycerate
Phosphoenolpy

Added Pathways for C-5

- Utilization of both 5 and 6 carbon sugars is essential
- Multiple pathways added in *Z. mobilis* to effect the C-5 conversion

C5-6 Fermentation to Ethanol

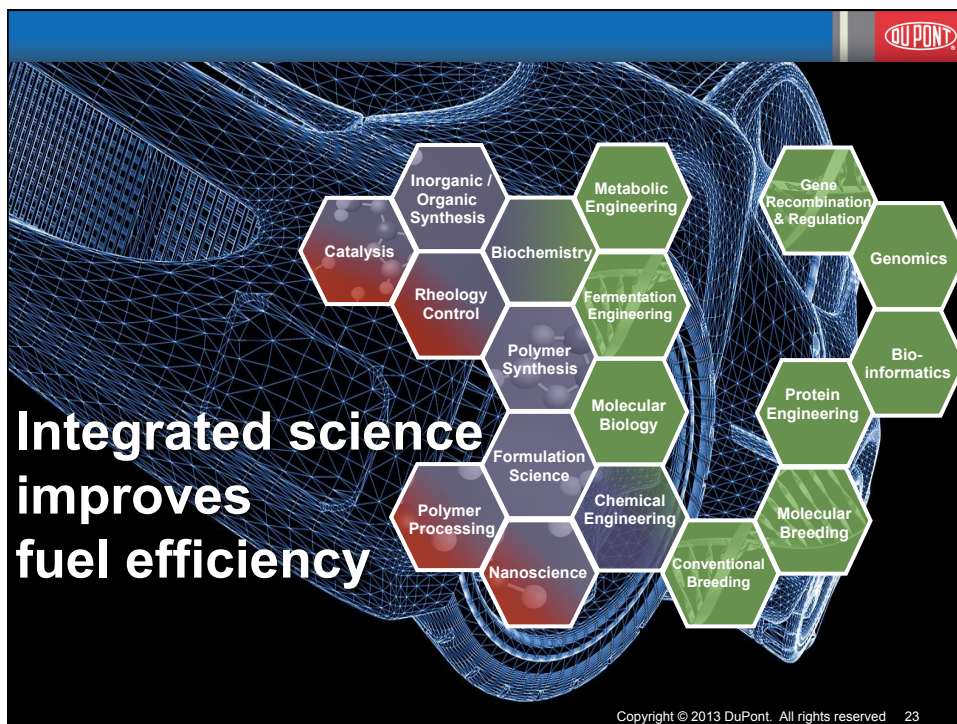Glucose / Xylose / EtOH (g/L) vs Time; Arabinose (g/L)

Glucose (g/L)   Xylose (g/L)
Ethanol (g/L)   Arabinose (g/L)

Demonstrating performance at 80,000L scale

Integrated science improves fuel efficiency

Catalysis · Inorganic / Organic Synthesis · Biochemistry · Metabolic Engineering · Gene Recombination & Regulation · Genomics · Rheology Control · Fermentation Engineering · Polymer Synthesis · Bio-informatics · Molecular Biology · Protein Engineering · Formulation Science · Polymer Processing · Chemical Engineering · Molecular Breeding · Nanoscience · Conventional Breeding

Bio-PDO™ – A New Building Block

DUPONT PIONEER. · DUPONT · DuPont Tate & Lyle BioProducts

Corn → Starch → Glucose → *Yeast* → Glycerol → *Bacterium* → PDO

Combined in a Single Biocatalyst

HO-CH$_2$-CH$_2$-CH$_2$-OH
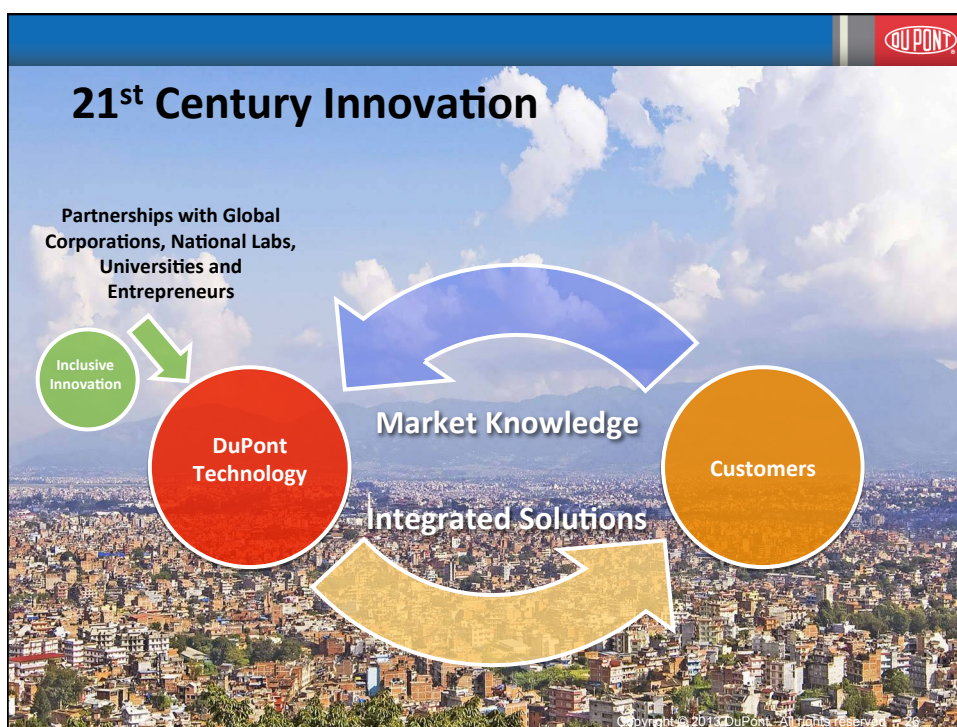
45k ton/yr, Loudon, TN

Sorona® Polymer – Sustainable, High Performance

- Unique product attributes driving adoptions
- Advantaged cost of manufacture & low capital intensity
- Life cycle benefit

Bio-PDO™ → Sorona® Polymer

21st Century Innovation

Partnerships with Global Corporations, National Labs, Universities and Entrepreneurs

Inclusive Innovation

DuPont Technology

Market Knowledge

Integrated Solutions

Customers

Conclusions

- Science addresses global challenges
- Integration of scientific disciplines is more powerful than any one discipline alone
- We must collaborate to deliver solutions

WELCOME TO THE GLOBAL COLLABORATORY

DUPONT
The miracles of science™