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Nanocellulose: Technology Applications, and Markets

Presented by:
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TAPPI

Thank you

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  - Wadood Hamad, Principal Scientist, FPInnovations; Adjunct Professor, Depts. Of Chemistry and Chemical BioEngineering, University of British Columbia
  - Robert J Moon, U.S. Forest Service
  - Jeff Youngblood, Associate Professor, School of Materials Engineering, Purdue University

Thank you

- Richard Berry, Chief Technology Officer, V.P., CelluForce Inc.
- Mike Bilodeau, University of Maine
- Jean Bouchard, Principal Scientist, FPInnovations
- Malcolm Brown, University of Texas, Professor
- Ron Crotogino, President and CEO, ArboraNano
- Gilles Dorris, Research Director, FPInnovations
- John Dorgan, Professor of Chemical and Biochemical Engineering, Colorado School of Mines; Co-founder, Polynew Inc.
- Luiz Fernando X Farah, Founder, Cellaxis Biotech
- Robert Evans, Managing Director, Engineered Fibers Technology
- Leonard Fifield, Senior Research Scientist, Pacific Northwest National Laboratory
- Ulla Forsström, Principal Scientist, Energy and Pulp & Paper, VTT Technical Research Centre of Finland
- Anne Savage Franey, President, Bio Vision Technology Enterprises
- Wadood Hamad, Principal Scientist, FPInnovations; Adjunct Professor, University of British Columbia
- Sean Ireland, Manager of New Technologies, Verso Paper Corp.
- Tom Lindström, Senior Research Manager, Innventia
- Terry Knee, Communications Director, FPInnovations
- Greg Maloney, Principal Partner, BioApplied – Innovation Pathways
- Robert Moon, USDA Forest Service, Forest Products Laboratory
- Jean Moreau, CEO, CelluForce Inc.
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- David Paterson, CEO, Verso Paper Corp.
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- Kirsi Seppalainen, Communications and Sustainability, Stora Enso Biomaterials,
- Kristin Syverud, Sr. Research Scientist, PFI Norway
- Hiroyuki Yano, Professor, Research Institute for Sustainable Humanosphere (RISH), Kyoto University
- Jeff Youngblood, Associate Professor, School of Materials Engineering, Purdue University

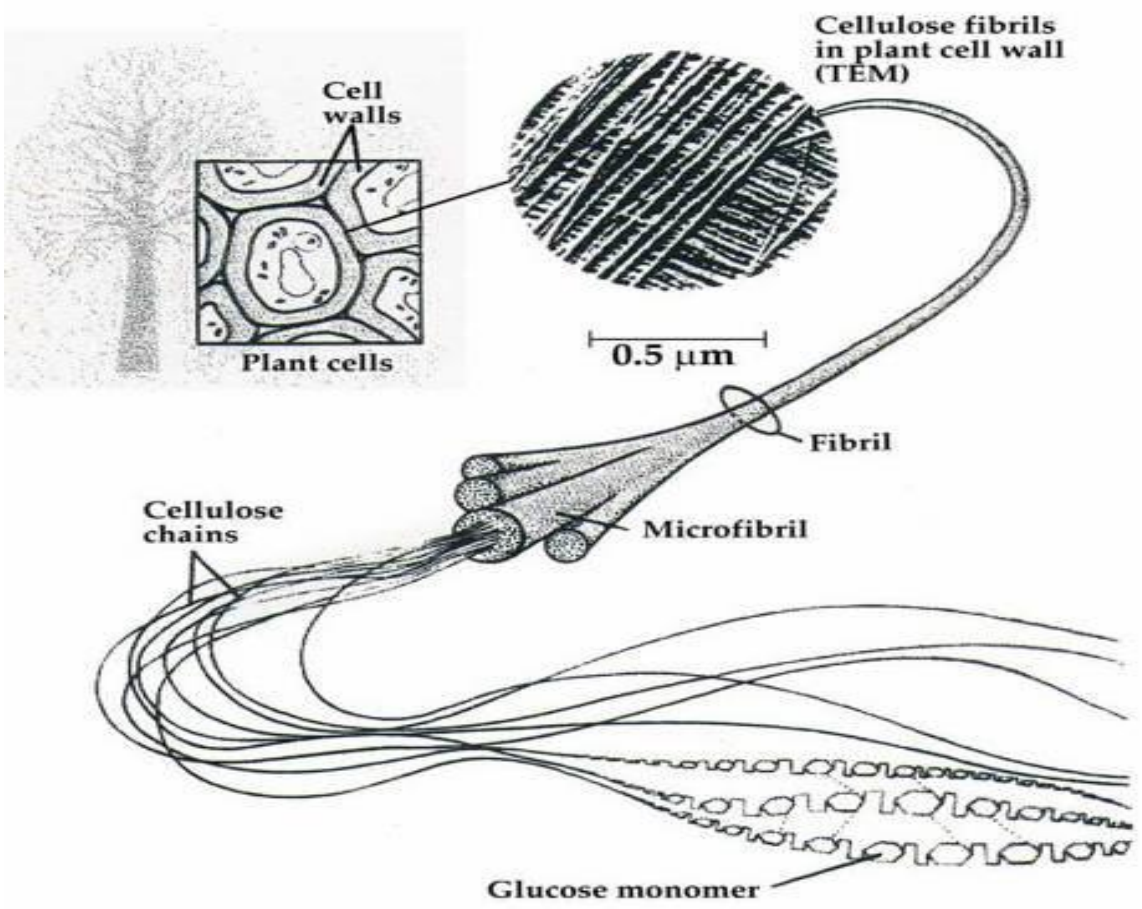
Nano

- Very, very small:
  - 10^{-9} meters
  - Virus: 50 nm
  - Wavelength of light: 400 nm to 700 nm
  - Bacteria: 5,000 nm
  - Human hair: 100,000 nm

Why nano?

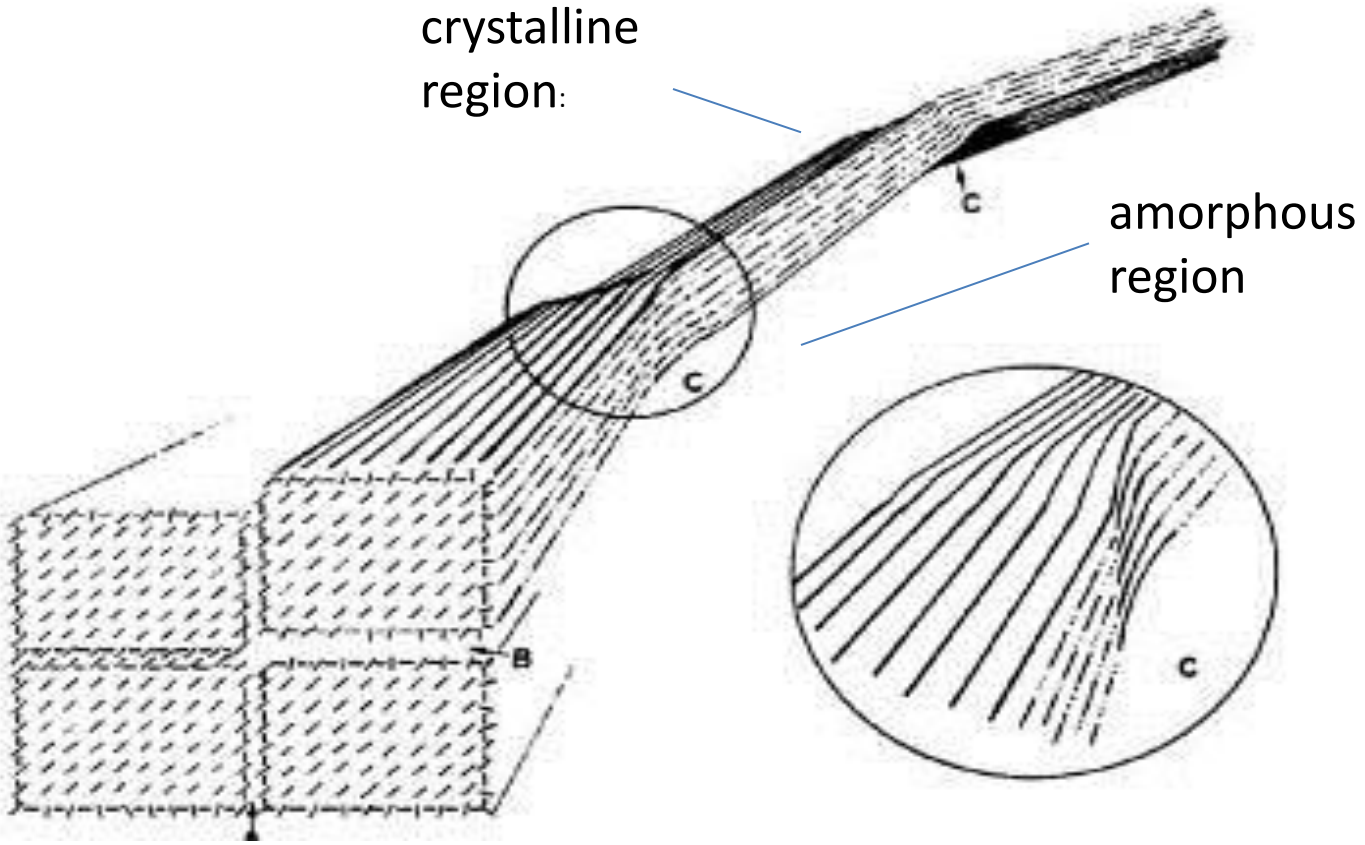
- Very strong
- Large surface area
- Highly reactive
- Defect free
- Unique optical, electrical, magnetic properties

Cellulose



Source: CelluForce

Nanocellulose



Source: CelluForce

Types of nanocellulose

- Cellulose nanofibrils: CNF

  Turbak 1973

- Cellulose nanocrystals: CNC

  Rånby 1951

- Bacterial nanocellulose: BNC

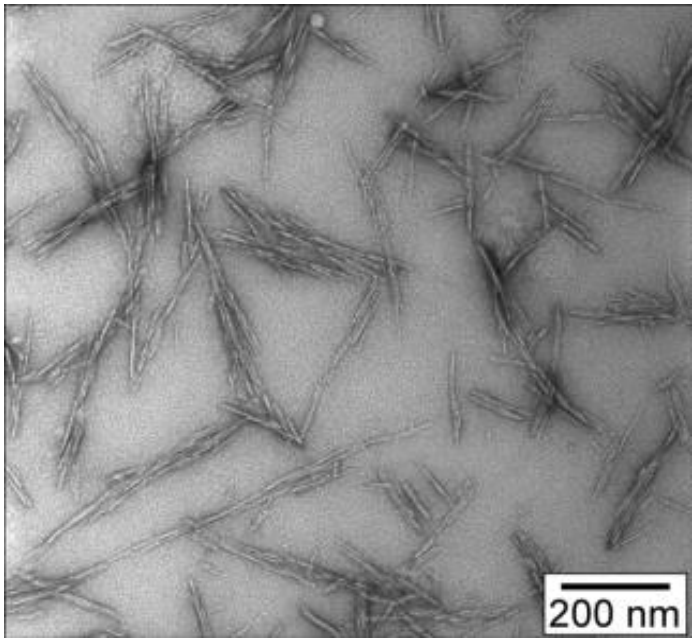
  Brown 1886

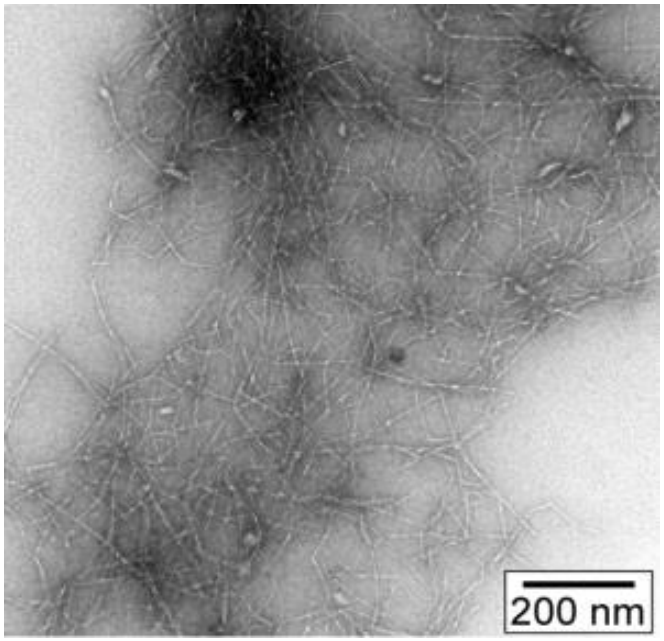
Typical Nanocellulose Characteristics

	Diameter	Length	Crystallinity
Cellulose nanofibril (CNF)	20 - 300 nm	> 2,000 nm	< 70%
Cellulose nanocrystal (CNC)	3 - 5 nm	50 - 500 nm	up to > 90%
Bacterial cellulose	10 - 100 nm	100 to >1000 nm	~70%

Source: Fukuzumi et al, Moon et al, Lee et al, Miao and Hamad

Cellulose Nanocrystals and Cellulose Nanofibrils





Source: U.S. Forest Products Lab; Purdue University School of Materials Engineering

Why nanocellulose?

- Strong
- Lightweight
- Electrically charged
- Chemically reactive
- Renewable
- Non-toxic
- Biodegradable
- Relatively inexpensive

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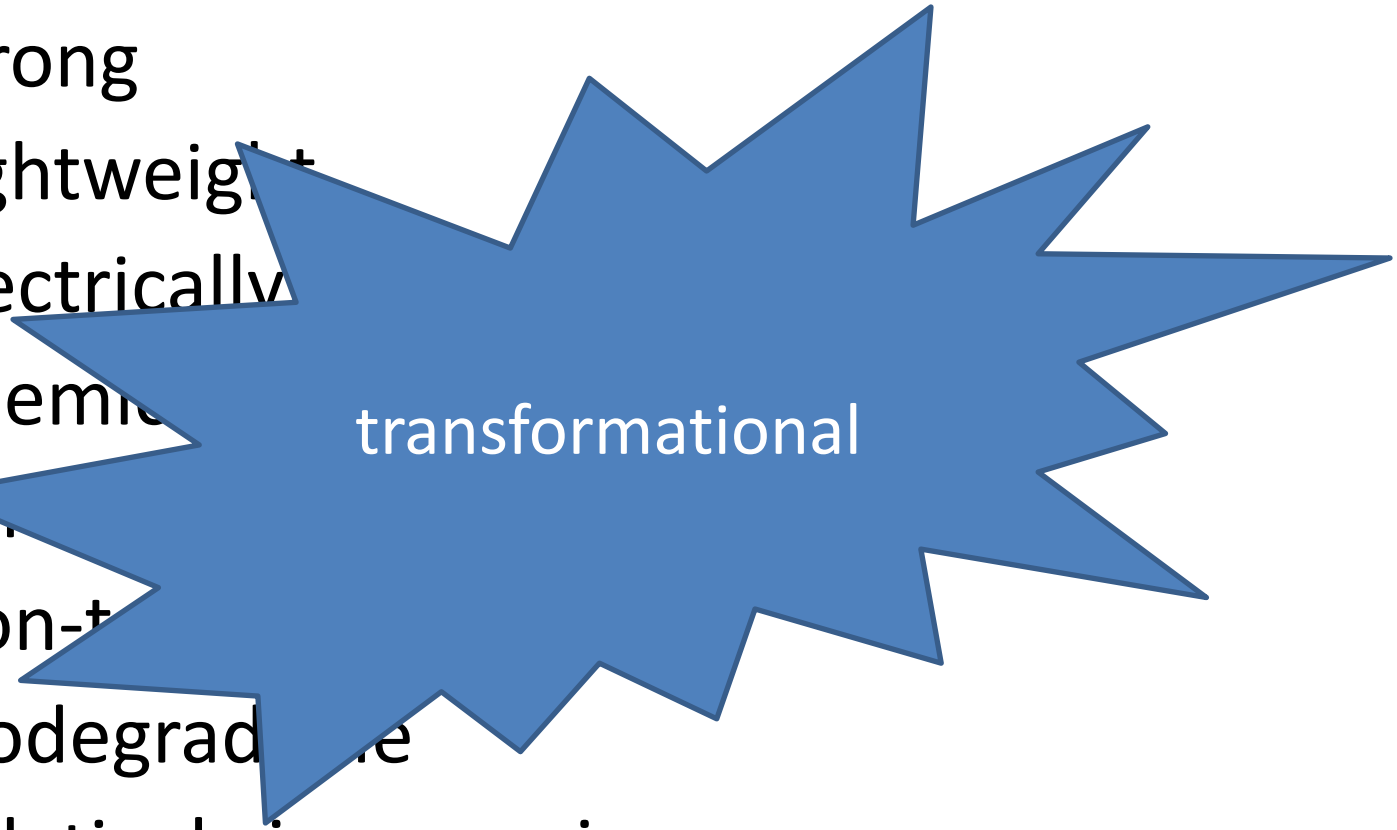
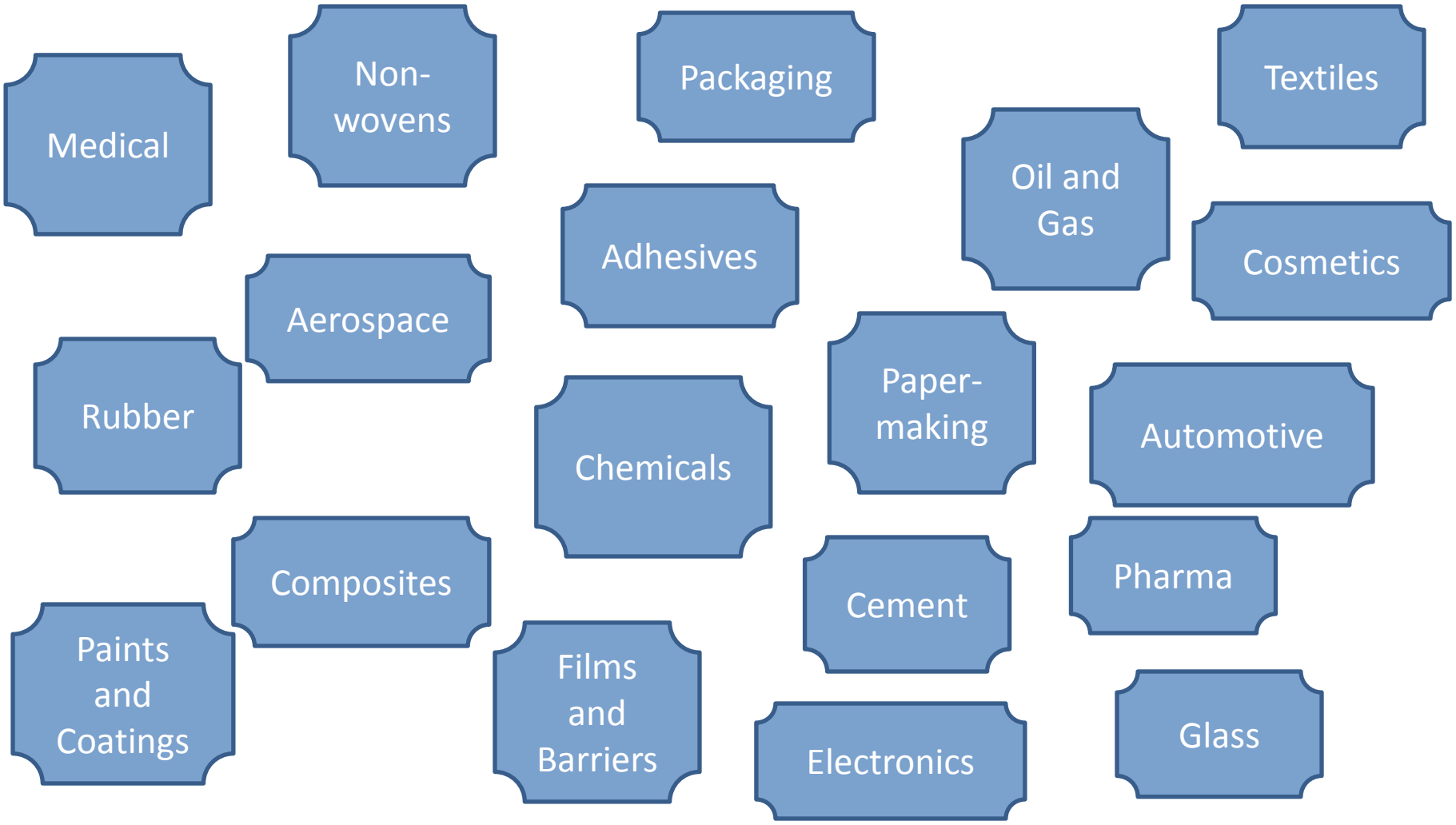


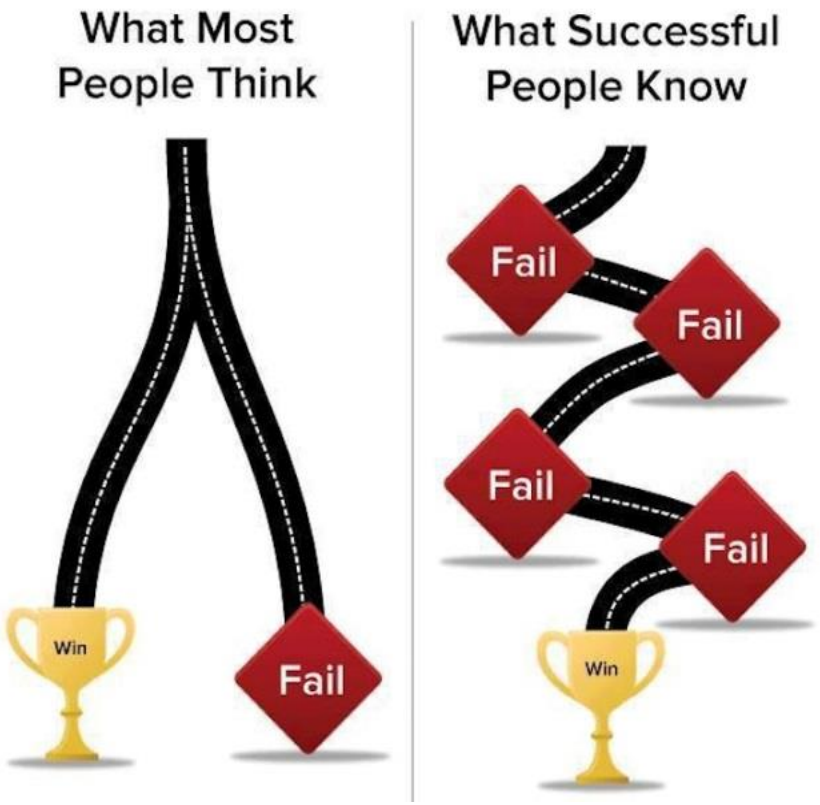
Transform your business



Why now?

- Explosion of research driven by interest in nanotechnology and declining paper markets
- Growing demand for renewable, recyclable, and biodegradable materials
- Nanocellulose makes the leap from lab to market.

We must be patient and resilient



Source: http://e27.co/wp-content/uploads/2013/08/Success.jpg

23 million tonne potential

(000 tonnes)

	Market Size	Potential Loading	Nano Cellulose Potential	Potential @ 5% Market Penetration	CNF Potential	CNC Potential	CNF	CNC
Paper and Paperboard	400,000	5.0%	20,000	1,000	95%	5%	950	10*
Paints and Coatings	40,000	2.0%	800	40	5%	95%	2	38
Composites	9,000	2.0%	180	9	5%	95%	0	9
Films and Barriers	9,670	2.0%	193	10		100%	0	10
Excipients	4,600	2.0%	92	5	10%	90%	0	4
Natural Textiles	34,500	2.0%	690	35		100%	0	35
Manufactured Textiles	56,300	2.0%	1,126	56		100%	0	56
Cement	15,000	0.5%	75	4	5%	95%	0	4
Oil and Gas	17,500	1.0%	175	9	10%	90%	1	8
Nonwovens	7,000	2.0%	140	7		100%	0	7
Adhesives	4,000	2.0%	80	4	5%	95%	0	4
TOTAL			**23,551**	**1,178**			954	184

Source: RISI, *Nanocellulose: Technology Applications, and Markets*

3,625 lbs
25 million tons

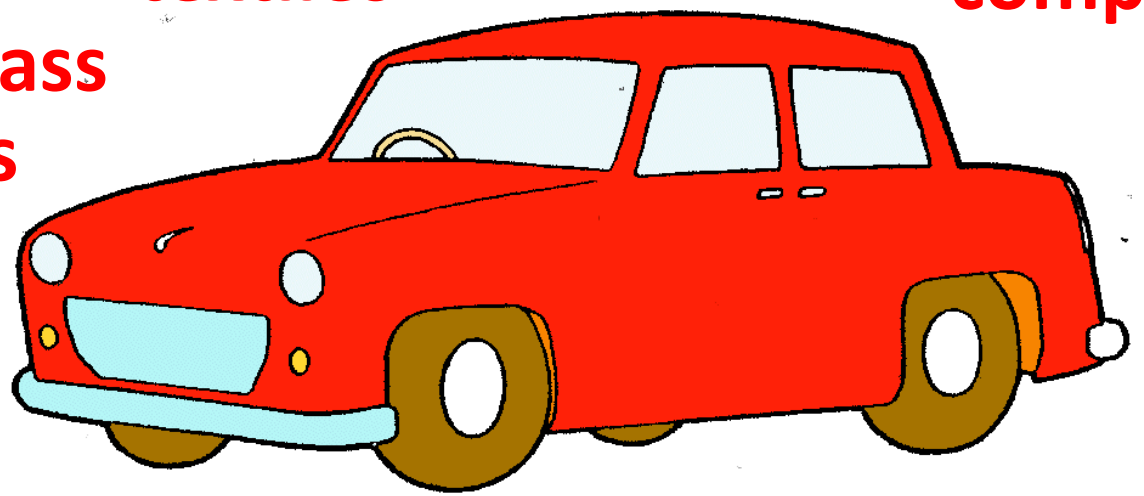
nonwovens

biopolymers

textiles

composites

glass



electronics

paint

metal

plastics

filters

rubber

Transformation takes time

Source: RISI, *Nanocellulose: Technology Applications, and Markets*

Timeline

- **PLA**

Carothers 1932

Patent 1954

NatureWorks formed 1997

Plant startup 2002

Second plant 2016

- **CNC**

Rånby 1951

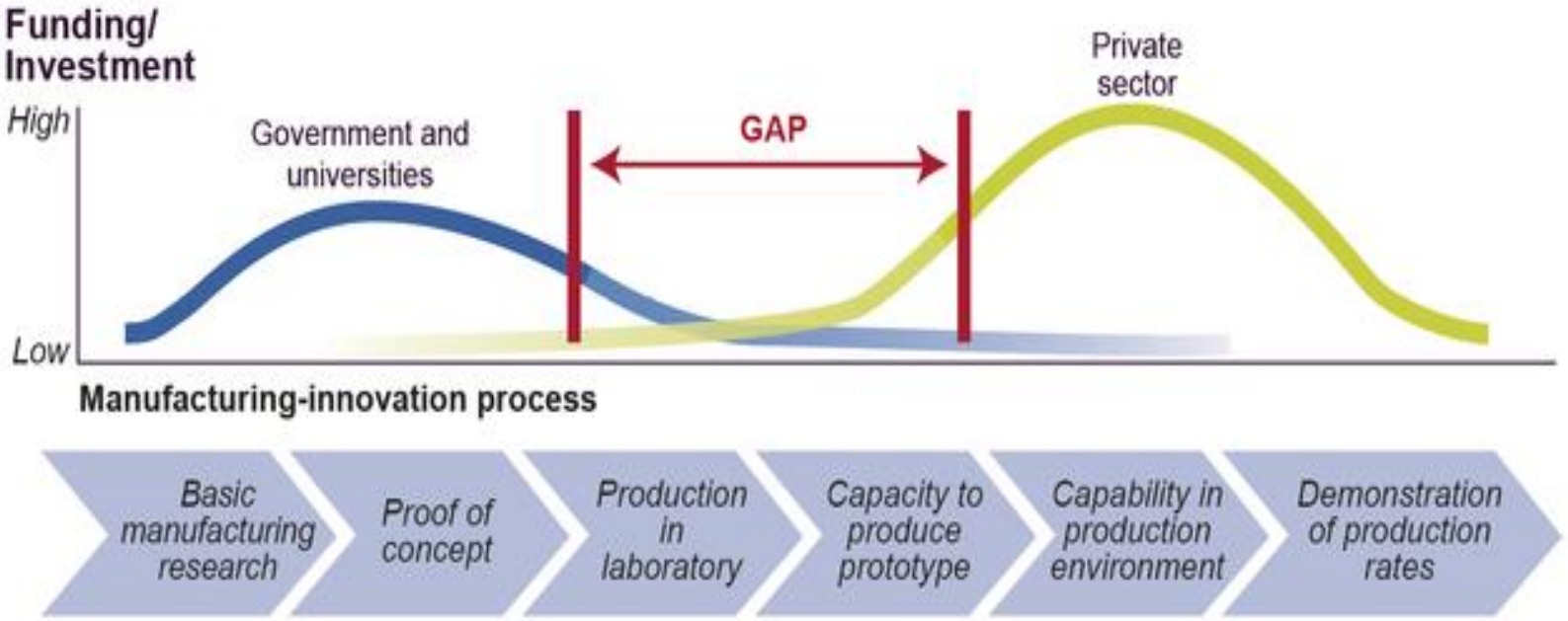
Patent 1997

CelluForce formed 2010

Plant startup 2012

Second plant ????

Investment Gap



Source: GAO

“We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten.”

--Bill Gates

Thank you

PRESENTED BY

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