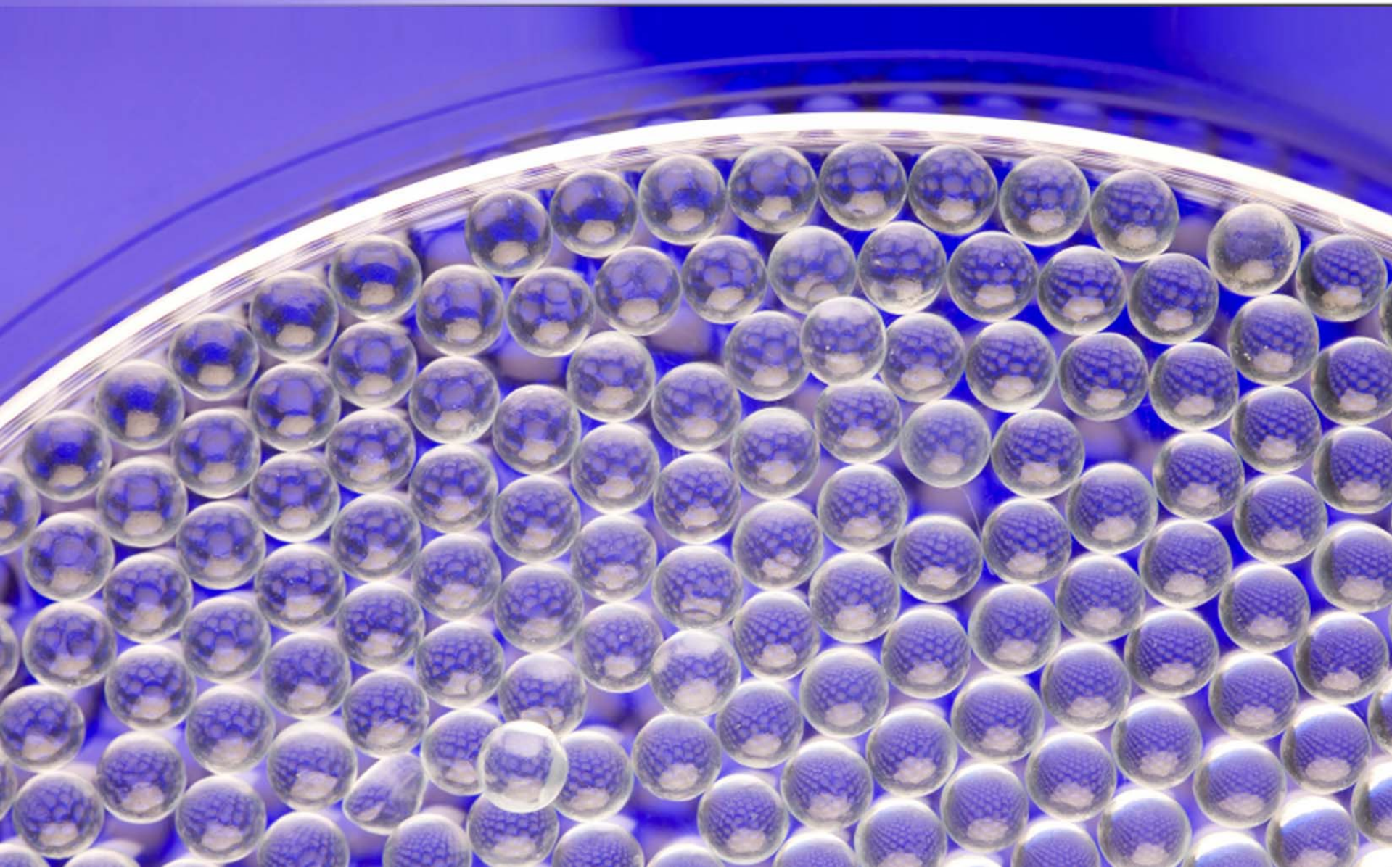
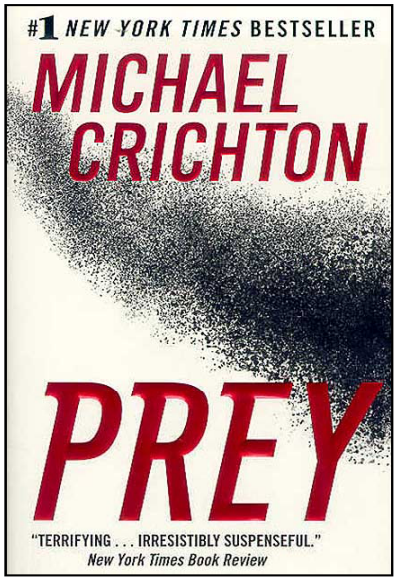
Nanotechnology



Nanotechnology

It's a Small World After All

- Split human hair 80,000 times to reach a width of 1 nm
- Red blood corpuscle is 7,000 nm
- Viruses = 20 nm to 300 nm
- 10 hydrogen molecules fit into one nanometer
- Over one million particles 1 nm in size would fit into the dot of this "i"



Nanotechnology

The Next Industrial Revolution

- Reduction of existing materials
  - Properties of materials change when brought to nanoscale
    - Color
    - Conductivity
    - Reactivity
    - Electrical
    - Magnetic
    - Toxicity
- Creation of new materials

Nanotechnology

Product Development vs. Toxicity / Environmental Safety

Governmental Spending

2011

- $2.18 billion for product development by U.S. government
- Corporations and V.C. invested billions more
- Less than 5% for health and safety
- 2011 – China – $2.25 billion in nano funding – first time China outspends U.S.
- Globally: >$17.8 billion (2010) product development vs. $??? on health and safety

2000 – 2012

- U.S. government: over $16 billion
- Globally: $67.5 billion

2013

- U.S. government: increasing nano spending by 4.1% to $1.8B

Nanotechnology

The Next Industrial Revolution

Since 2001

- Nanotechnology industry has grown 16%–33% annually

By 2015

- 15% of all goods manufactured will involve nanotechnology
- Market for nanomaterials could be over $1 trillion annually
- Products containing nanomaterials could reach $2.5 trillion
- Over 2 million people directly employed by nano industries within 15 years
- Secondary industries will employ many millions more

Nanotechnology

U.S. Companies Importing Nanomaterials

Developing Nano Products

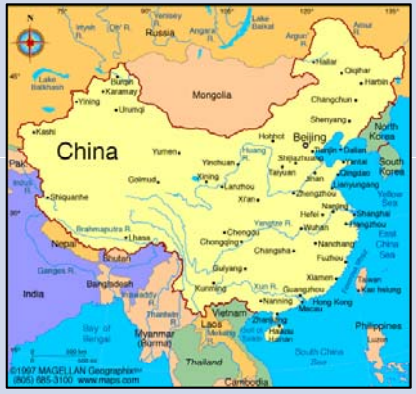
- Over 5,400 firms
- Over 50 countries with nano programs

Largest Exporters

Western Europe

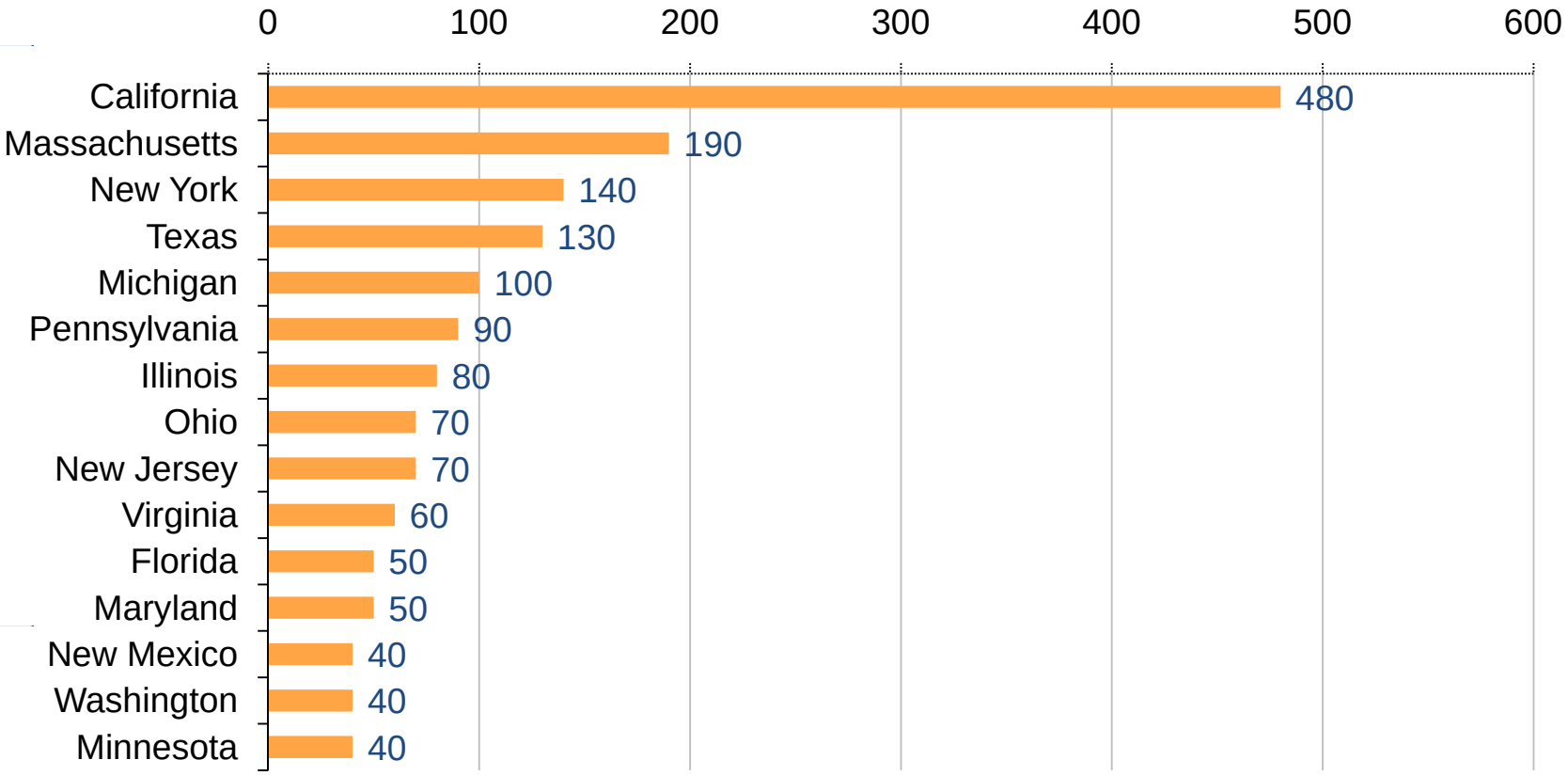
Japan

China



Nanotechnology

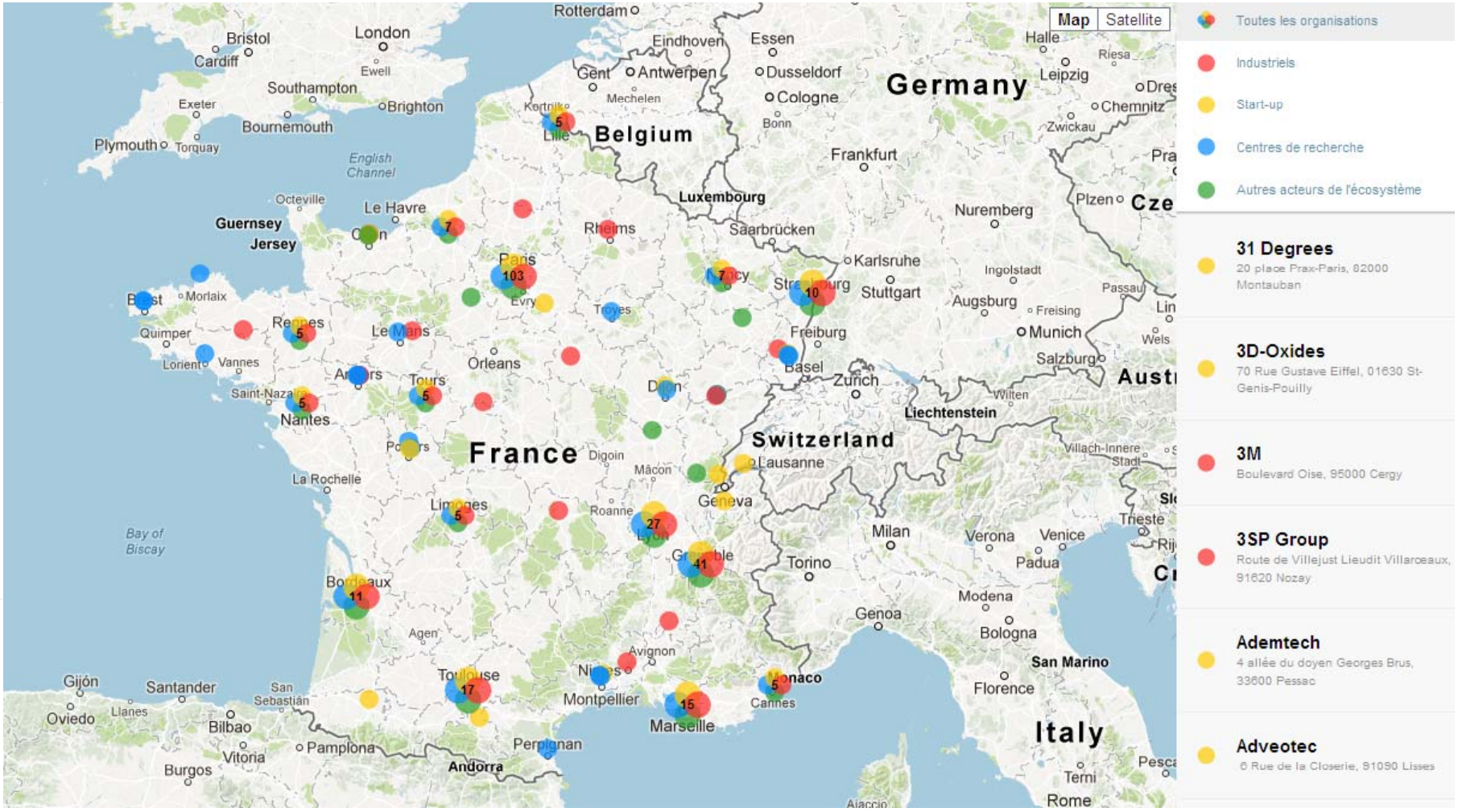
Number of Nano Companies



Source: nsti.org/directory/states/AL

Nanotechnology

Nanotechnology Companies and Research Centers in France



Source: NanoThinking – http://www.nanowerk.com/news2/newsid=28808.php

Nanotechnology

What We Don't Know

Regulations

- Can nanomaterials fit into existing regulatory schemes?
  - EPA
  - FDA
  - NIOSH
- Currently, no requirements for:
  - Labeling
  - Special toxicity assessments

Nanotechnology

2011 Survey of "Experts From Academia, Industry and Government in the Field of Nanotechnology"

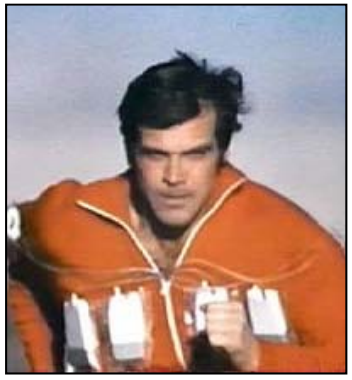
- "The < 100 nm definition is unhelpful regarding the size at which specific properties of MNS [manufactured nanomaterials] arise. "For the interaction with cells, particles > 100 nm (i.e., 200–300 nm) behave like nanoparticles."
- Current testing programmes use a single batch of each different MNM, but this is scientifically misguided in terms of assessing overall safety of nanomaterials, as the data might be representative only of that specific batch."
- "Properties of these particles can change in contact with other materials, so in theory it would be necessary to study every MNM in contact with every material that in real life it could be in contact with."
- "Comparison of data from different laboratories, materials, techniques, etc. is difficult or impossible at present due to the number of variables and lack of detailed characterization in many cases."

Source: Geoffrey Hunt and Michael Riediker, Nanotechnology Perceptions Vol. 7 (2011)

Nanotechnology

The Possibilities

- Drug delivery
- Improved diagnostics
- Tumor killers / cancer cell hunters
- Much smaller, more powerful batteries
- Materials >100x stronger plus 8x lighter than steel
- Superconducting materials
- Smaller, faster computers with more storage
- Minute solar cells
- Super-efficient, hydrogen-based fuel cells
- Augmentation of living organisms



Nanotechnology

Exposures Already Here

Nanotechnology

Exposures Already Here

The Next Industrial Revolution

- Over 2,900 types of nanomaterials
- Thousands of tons produced annually
- Manufactured by 1,000 U.S. firms and Universities
- Many are small firms with 25 employees or less
- Incorporated into thousands of consumer products on the market
- NIOSH spokesperson: 180,000 nanotechnology workers in 2009
- Millions of other workers in secondary industries exposed on a regular basis

Source: International Council on Nanotechnology, October 2006

Nanotechnology

Exposures Already Here

2006 Survey of Nano Manufacturers

- 66% of firms and universities not conducting toxicity tests
- 61% not monitoring air to determine occupational exposure
- Many use “conventional,” protective equipment

Nanotechnology

Exposures Already Here

NIOSH — July 2010 Study of Occupational Exposures in Labs Handling Nanomaterials

- Studied airborne releases of nanomaterials in labs during routine handling and processing
- Airborne nano particle concentrations increased when materials were weighed, transferred to beakers and sonicated
- Findings contradict belief that exposures are minimized when working with nanomaterials in liquid suspensions

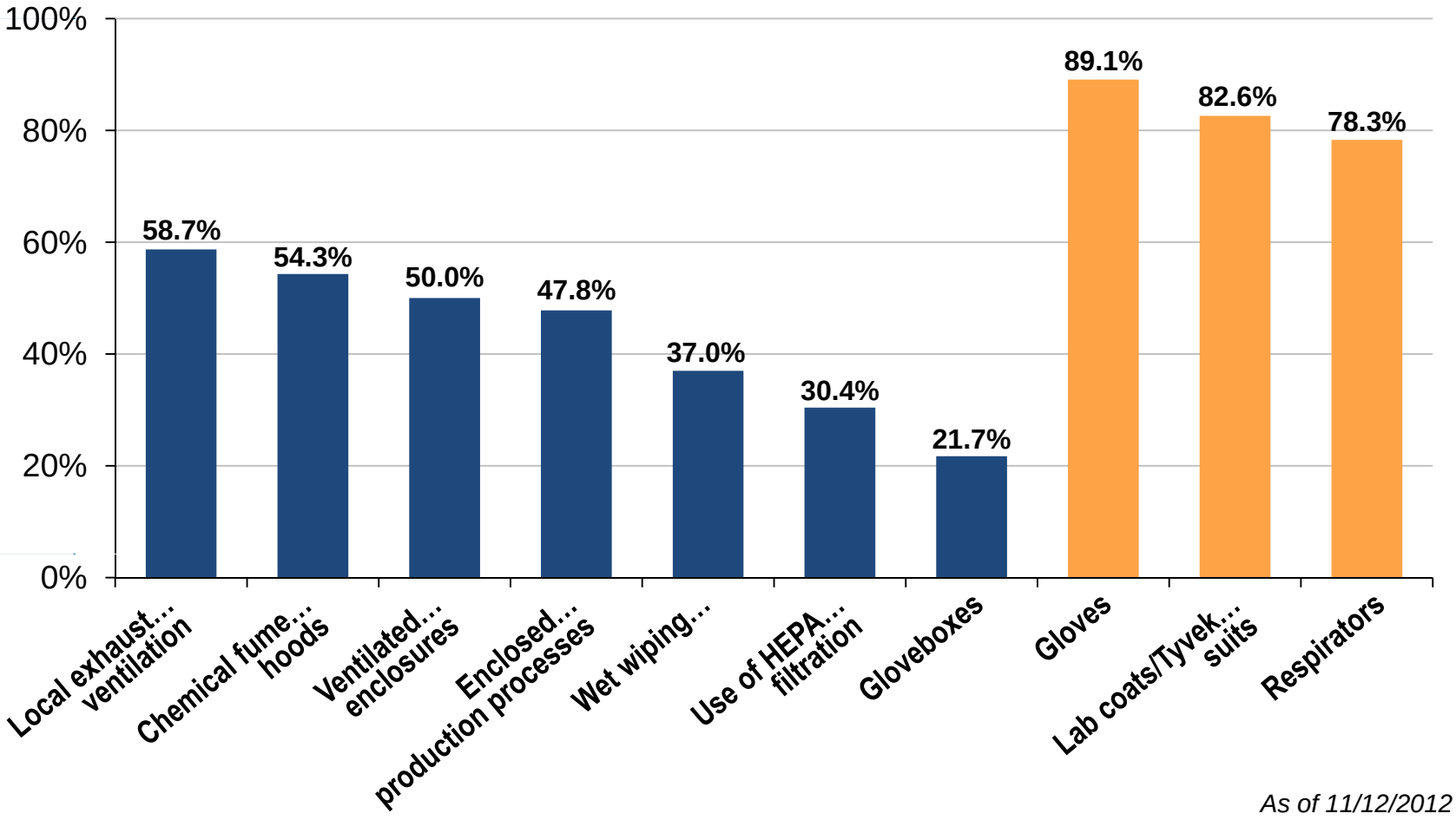
Nanotechnology

Exposures Already Here

- New Survey by University of California — Santa Barbara to be released end of 2012
  - 74 nanotechnology firms
  - 45 in U.S.
  - 65% had less than 50 employees
  - Used/manufactured 15 different NMs
- Only 46% had nano-specific EHS programs
- 13% had no EHS program
- 62% did not monitor occupational exposures
- Less than 50% required workers to wear PPE
- 30% use vacuuming and sweeping to clean NMs (against recommendation by NIOSH)
- 63% had no specific NM waste program

Nanotechnology

NIOSH: Use of Engineering Control and Personal Protective Equipment in 46 Nanomaterial Facilities



As of 11/12/2012

Nanotechnology

Exposures Already Here

- Market value of nano-enabled products
  - $336 billion globally in 2011
- Hundreds of Consumer products
  - $134 billion in U.S. in 2011
- Products including:
  - Skin Creams and Cosmetics
  - Sun Block and Suntan Lotions
  - Personal Care Products
  - Joint and Muscle Pain Relief Creams
  - Paint and Coatings
  - Plastic Wrap / Food Containers
  - Lubricants
  - Automobiles and Aircraft Parts
  - Fabrics
  - Computer Chips
  - Electronics
  - Bedding

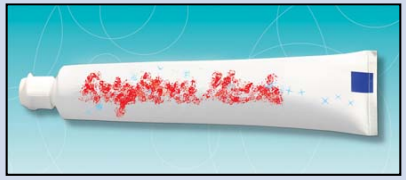
Nanotechnology

Exposures Already Here

Other Products Containing Nanomaterials

- Medicine Capsules
- Sports Equipment
- Wound Dressings
- Deodorants
- Toothpastes
- Shampoos
- Air Sanitizers / Purifiers
- Joint and Muscle Pain Relief Creams
- Wet Wipes
- Cleansers
- Imported Animal Feed
- Imported Veterinary Medicine





Nanotechnology

Exposures Already Here

Building Materials

- Concrete
- Insulation
- Glass coatings
- Flame retardants
- Countertop coatings

Nanotechnology

Exposures Already Here

Food

- Cooking Oils
- Confectionary Products
- Vitamin and Mineral Dietary Supplements
- Diet Shakes and Other Diet Beverages
- Chewing Gum
- Canola Oil
- Tea
- Ice Cream
- Cheeses
- Salad Dressing
- Sauces
- Cake, Muffin and Pancake Mixes
- Icing / Frosting
- Food Additives
- Powdered Donuts
- Pudding
- Candy
- Koolaid
- Marshmellows
- Coffee Creamers
- Poptarts

Nanotechnology

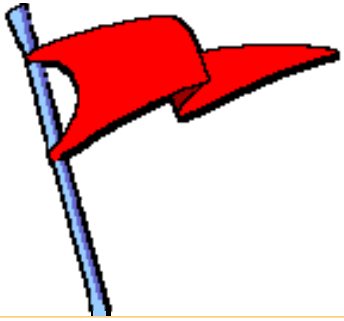
Exposures Already Here

- Spraying fruit and vegetables from Central and South America with a thin wax-like edible nanomaterial to extend shelf-life and protect the color and flavor longer
- Using nanomaterials as non-stick coatings to make it easier to get the last drops of ketchup out of the bottle

Nanotechnology

First Studies

- Progressive dysfunction and cell death of human brain cells
- Gathered and remained in the liver and spleen
- Nano titanium dioxide damaged neurons
- Four different nanomaterials caused proteins to misfold
- Damage DNA and may increase risk of cancer
- Some pass through the skin / distributed throughout the body
- Decreased function in cells exposed to nanosilver
- Promote blood-clotting
- Penetrate deep into lungs — causing death
- Inhaled can pass into brain through blood / brain barrier
- Caused death by suffocation
- Increase in brain damage
- Increase in genetic and cellular damage
- Kill human liver and skin cells
- By-products harmed aquatic life



Nanotechnology

In Vitro Study
(Petri Dish)
Suggests

2/08 First EPA Study of a Nanomaterial

- Nano-sized titanium dioxide widely used in sun blocks suggests damage to brain cells
- Found cellular apoptosis after 6 hours of exposure

Nanotechnology

Post-2008 Studies of Carbon Nanotubes

2008

February
Japan's National Institute of Health Sciences
- Can mimic asbestos

May
University of Edinburgh (UK) and U.S. Project on Emerging Nanotechnologies
- Exposure caused development of lesions and precancerous masses similar to those that precede mesothelioma

December
University of Dayton (U.S.)
- Accumulate in cells resulting in cell death
- Increased cell mutations by two times

2009

January
Institute of Occupational Medicine, Edinburgh
- Carbon nanotubes and nanowires have same characteristics as asbestos; likely to have similar pathalogy

March
University of Dayton
- Surpresses immune response of human lung cells

July
University of Dayton
- Surpresses immune response in lungs

2010

April
NIOSH
- Inhalation causes inflammation of the brain

2011

January
Sweden Lulea University of Technology
- Increased risk of lung cancer

July
U.S. FDA
- Casused clots in the blood that obstruct flow

June
University of Edinburg, UK
- Same effects as asbestos

August
Indiana University – Purdue University
- Exposure to even low levels penetrated kidney cells

2012

March
Ingested
- Alters normal blood vessel function

2013

March
Potent cancer promoter

Nanotechnology

Additional Studies

- Quantum dots toxic to cells under certain conditions
- Nanorods and nanowires may also cause asbestos-like effects
- Accumulate and damage kidney cells
- Dissolve in cell membrane, pass into cells, reform and damage cells
- Four Nanoparticles when inhaled cause cancer
- Inhaled Nanoparticles can cause chronic or acute illness
- Injected quantum dots damaged kidneys
- Airborne nanoparticles can be more hazardous than their larger scale counterparts
- Buckyballs have high potential of accumulating in tissue
- Diesel nanoparticles get trapped in lungs — inhibit fluid that facilitates breathing

Nanotechnology

Additional Studies

- Inhaled nanoparticles of titanium dioxide may pass through the blood-brain barrier and damage neurons
- Gold nanparticles increases nitric oxide production which can result in cell death
- Nano zinc oxide — direct contact with colon cells caused death of cells
- Quantum dots made from cadmium and selenium released toxins into soil
- Nickel nanoparticles contribute to lung cancer
- Zinc oxide nanoparticles damaged DNA; may cause cancer
- Magnetic core nanomaterials caused DNA damage and accumulated in the liver
- Inhaled cerium oxide nanoparticles used as a diesel fuel additive travel from lungs to liver and damage liver
- Nanoplatelets stay airborne — penetrate deeply into lungs
- Silver and titanium dioxide nanoparticles damaged testicular cells and DNA

Nanotechnology

Nano Titanium Dioxide

Additional Studies

- Nano titanium dioxide when ingested damaged or destroyed DNA and chromosomes
- Nano titanium dioxide caused damage to the heart muscle
- Nano titanium dioxide caused eczema
- 2009 – WHO – International Agency for Cancer Research declares nano-titanium dioxide a “possible carcinogen”
- 2011 – NIOSH: Data supports finding nanoscale titanium dioxide as an “occupational carcinogen”
- 2011 – Exposure caused holes to form in parts of the brain and killed nerve cells in the brain
- Ingested Nanospheres alters normal blood vessel function

Nanotechnology

Additional Studies

- Children's lungs more susceptible to nano materials
- Graphene nanodiscs can accumulate in lungs and cause damage
- Plastic nanoparticles are transported through the aquatic food chain —effects fish metabolism and behavior
- Poorly soluble nano-sized nickel particles cause lung cancer in humans
- Cerium oxide and zinc oxide nanoparticles—take up and distributed throughout edible plant tissue. Plant growth and yield diminished.

Nanotechnology

Additional Reasons for Concern

- Coatings?
- Ability to stay airborne for longer periods
- Some are coated with solvents
- 12/08 study by EU researchers found coating tungsten nanoparticles with cobalt caused “markedly” increased cytotoxic effects
- Aging nanoparticles

Nanotechnology

Exposure to Synergistic Effects

November 2008 — Helsinki University of Technology, Finland

- Even if nanoparticle does not appear toxic, interactions with other common compounds in the human body may cause serious problems to cell functions.
- Number of possible combinations to nanoparticles and various biomolecules is enormous—practically impossible to research them systematically.

Nanotechnology

New Regulations

- CA Department of Toxic Substances
- Data Call for Nanomaterials of Concern
  - CNTs
  - Nano Titanium Dioxide
  - Nano Silver
  - Nano Zero Valent Iron
  - Nano Zinc Oxide
  - Nano Cerium Oxide
  - Quantum Dots

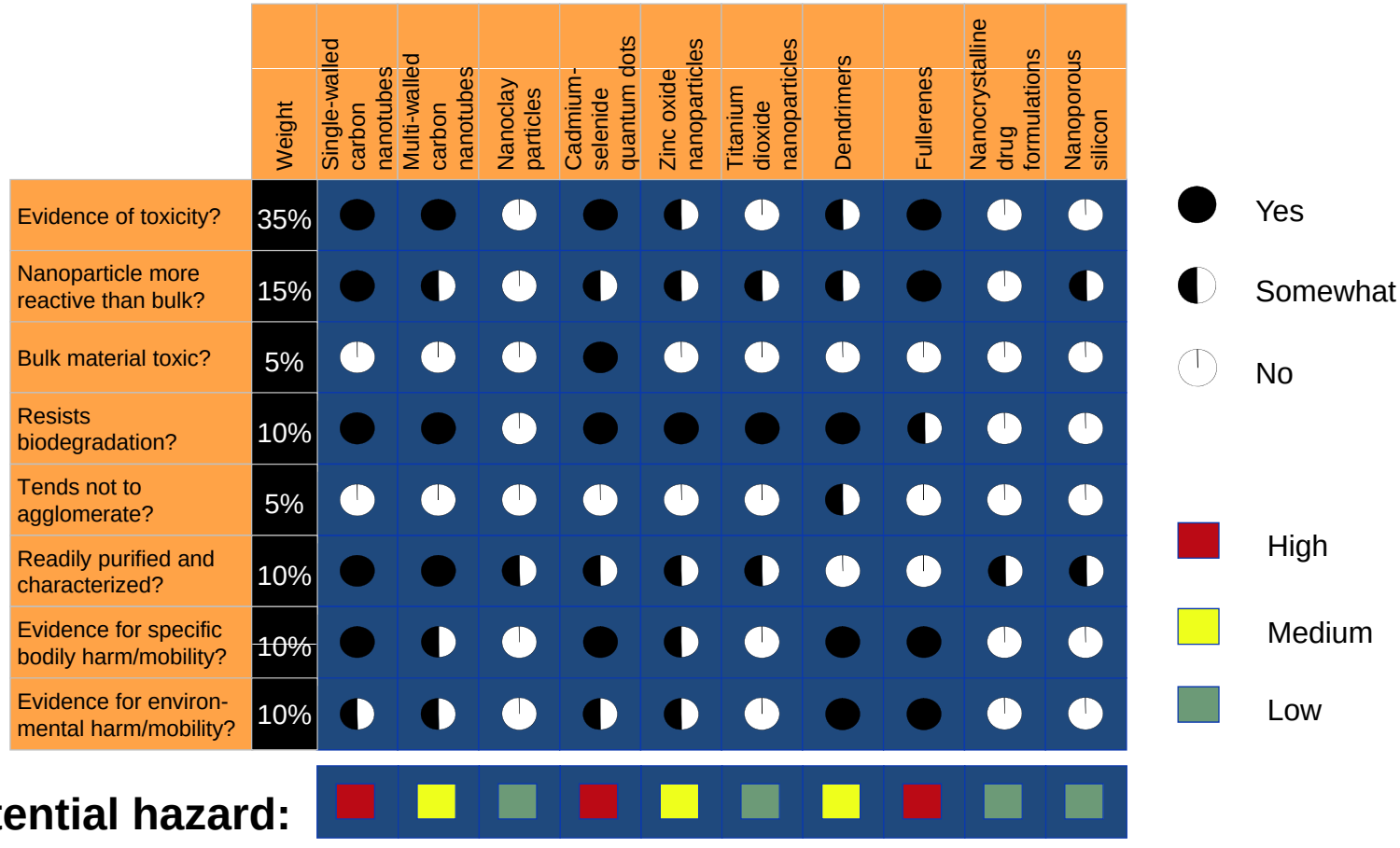
Nanotechnology

Hypothetical Sizing Exercise

- Currently over 2,900 Nanomaterials
  - If 99% are benign = 29 new toxic substances
  - If 97% are benign = 87 new toxic substances
- Potential impact on P/C insurance industry? Occupational and consumer exposure.

Nanotechnology

Risk Management Framework



Source: Lux Research Report "A Prudent Approach to Nanotechnology Environmental, Health, and Safety Risks"

Nanotechnology

Coverage Issues

- CGL and Commercial Umbrella
- No Specific Nano Exclusions or Terms
- Applicability of:
  - Absolute Pollution Exclusion
  - Total Pollution Exclusion
- Applicable Trigger

Nanotechnology

The Next Industrial Revolution