Applying Engineering & Technology For The Extreme Poor

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CSUCI
&
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Don Quique's family and electricity generator. Passajquim, Sololá, Guatemala

Outline

1. **Engineering for the Poor**
2. **Pearl Millet (MIT & Africa)**
   - **The Metaphysics of Innovation**
3. **Corn Threshing (Caltech & Guatemala)**
4. **Fluorescence Microscopy (Etaluma Inc., California)**
5. **The Meta-Problem**

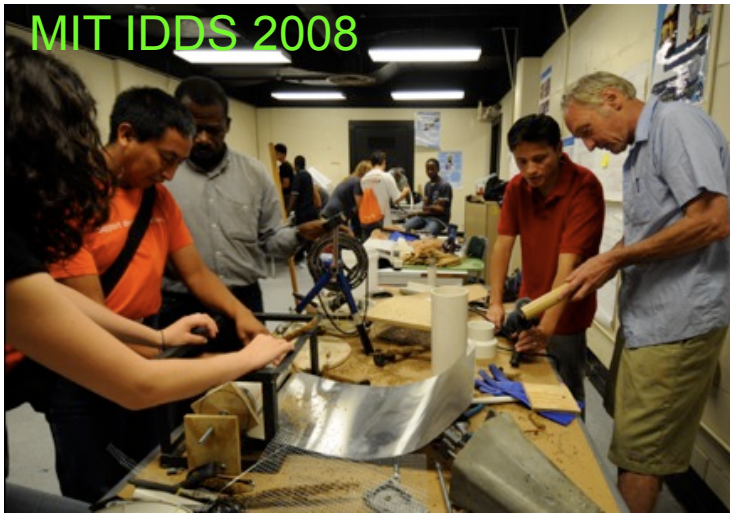
BoP

- The distribution of wealth is roughly pyramidal
- The base of the economic pyramid (“BoP”) consists of ~3 billion people earning <$2.5/day*
- The BoP is the largest emerging market
- Growing numbers of students are eager to learn about and work in this sector

The process:

Educating for Development

- The “Professional pyramid” is inverted:
  - >90% of professionals work for the top <10% of the economic pyramid (“ToP”)
- Education focuses on the ToP
  - The BoP has many different problems, resources, constraints, methods, challenges, and contexts
- A few university engineering programs focus on the BoP



International Development Design Summit

MIT

18 July - 9 Aug 2008

The pearl millet challenge

- Pearl Millet is a staple grain for millions of African and Indian families
- 75% of the pearl millet grown in Namibia is threshed manually by mortar and pestle or beating
- A faster, affordable threshing device could improve the health and economics of millions of poor families relying on millet for food or sale.

The process:

Defining and selecting projects

- Choosing what to work on is tricky
  - Follow smart people
- A key problem is often defining “what is the problem?”
  - Language and framing can strongly constrain the solution path
  - Different stakeholders frame the problem differently
  - Limited intuition about different cultures, economies, geographies, etc.
- If framed too abstractly, it’s hard to find solutions. If framed to concretely, potential solutions maybe excluded.

- Paul Polak’s “Out of Poverty” gives additional guidelines

The “Mahangurinas”

Michelle Marincel (USA), George Yaw Obeng (Ghana), Thalia Konaris (Cyprus), Francisco Rodriguez (Mexico), Brian Rasnow (USA), and mentor Donna Cohn (USA, not shown) www.milllet.wikifoundry.com

DiveRSITY

- I attribute our success to embracing our diversity
  - 3 grad students, 3 faculty
  - 3 guys, 3 gals
  - 3 engineers, architect, physicist, …
  - 3 North Americans, 3 foreigners
- Diversity is *inefficient* – it impedes communication and productivity
  - Its always easier to communicate with others like yourself
- Diversity creates opportunities for ideas
  - We have to work hard to understand other ideas, encourage them to grow, and spawn new ones
- Invention is a very *inefficient* process
  - Few companies support it for long

Our Problem Statement

- What are the constraints?
  - Economic, materials, technological, social
- What scale of solution should we consider?
  - ~$1000 “community” thresher
  - ~$20 “personal” thresher
- What existing or competing solutions are there?
- Who will be affected by our solution, and how?
- How reliable is our information?
  - What happens if it is wrong?

How to design a $20, 10kg/hr pearl millet thresher suitable for manufacture and sale in Africa and India?

Structure of millet

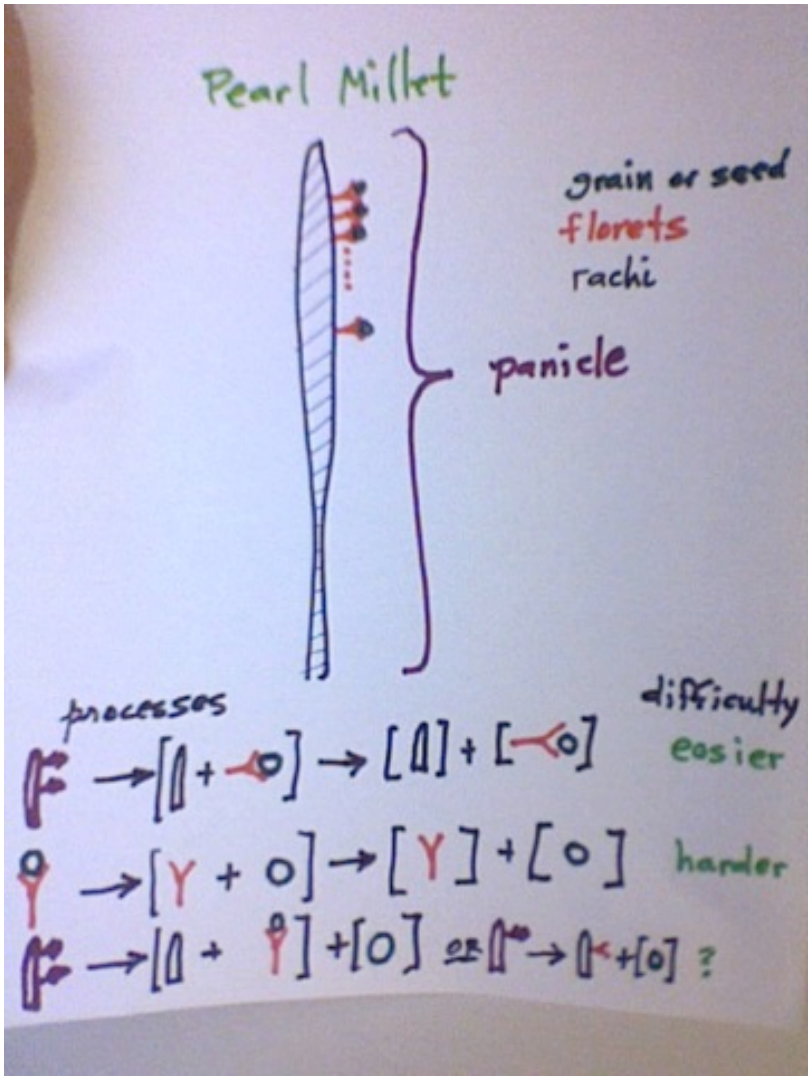
- Millet grows on a **panicle** consisting of:
  a **stalk**, **florets**, and **grain**

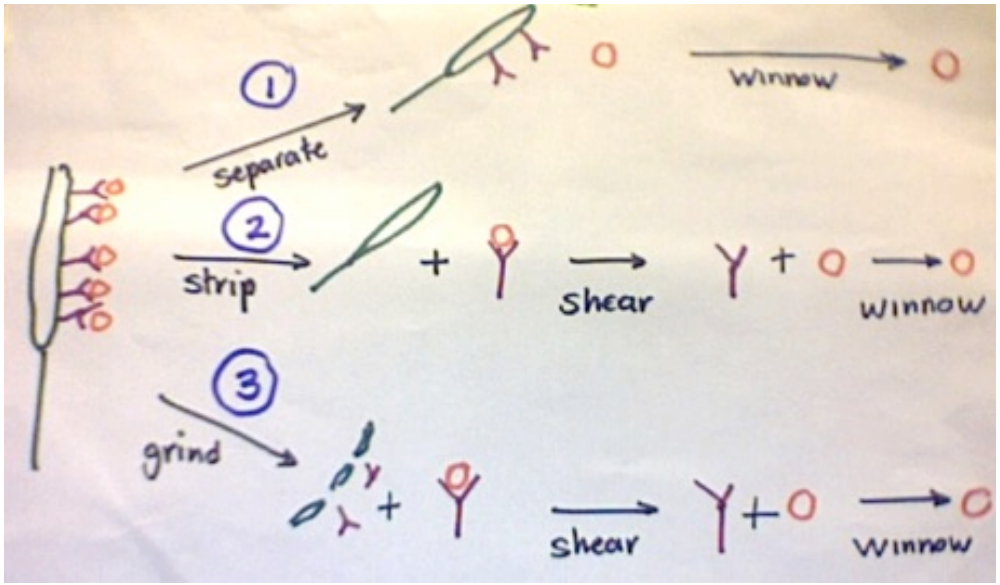
- The panicle has complex physical properties, e.g.,
  - Panicles vary in size over a factor of 2
  - Grinding damages the grain
  - Twisting breaks the stalk
  - Rubbing removes florets from stalk
  - Etc.

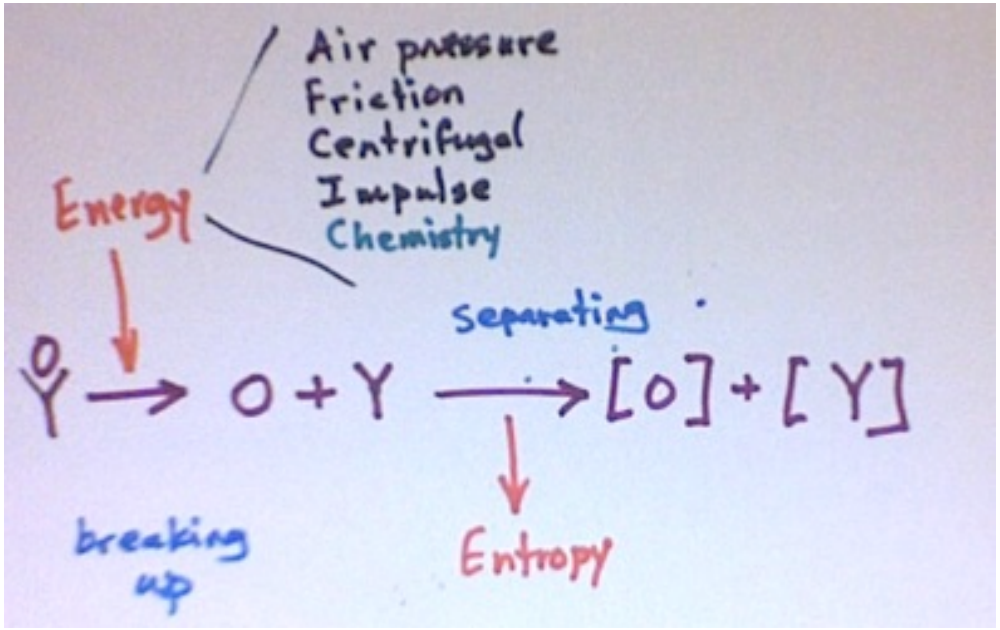
panicle

Representation and reduction

Millet mathematics







The process:

Metaphysics of Innovation

- What cognitive processes foster learning and discovering new ideas?
  - Aristotle established “classical” processes like reductionism and the scientific method as powerful tools for *validating* theories
  - However, many scientists describe their discovery/invention of theories in very romantic, holistic, intuitive terms
- Broad literature exists about managing innovation
  - Many successful companies that develop economies of scale for production lose their abilities to innovate
  - Processes for improving existing products are very different than processes for discovering new products

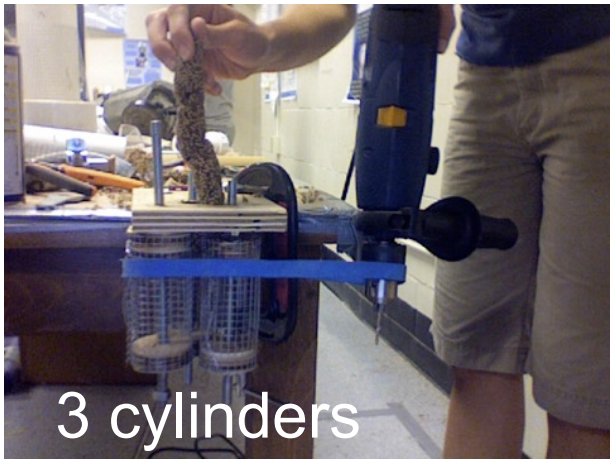
The process:

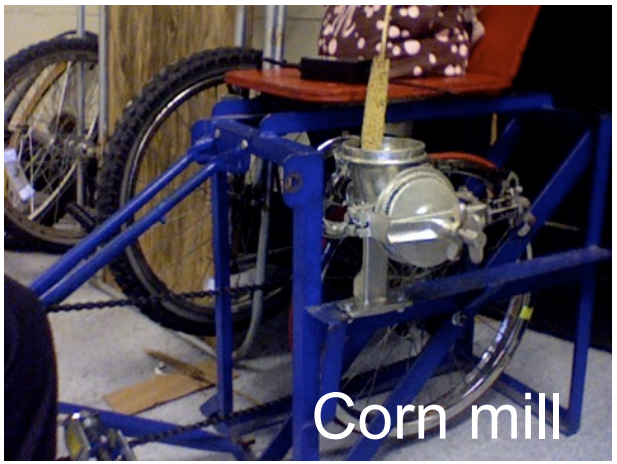
Dichotomy of processes

- Discovering solutions and comparing solutions are very different cognitive processes
  - You discover solutions by
    - Exploring different (*distant*) domains
    - Using different recognition criteria
    - (You won't find anything new by looking in the same way at the same place)
  - You compare solutions by
    - Placing them *close* to each other
    - Using the same criteria to measure their Quality
- Successful problem solvers act romantically *and* classically
  - Need a creative, open mind to find diverse solutions, and an analytical mind to sort the bad ones from the best ones
  - Fundamentally different cognitive processes dominate each of these activities

What didn't work

"Fail quickly, fail often"
Knowing what doesn't work can be as valuable as knowing what does.





The Breakthrough

We discovered that

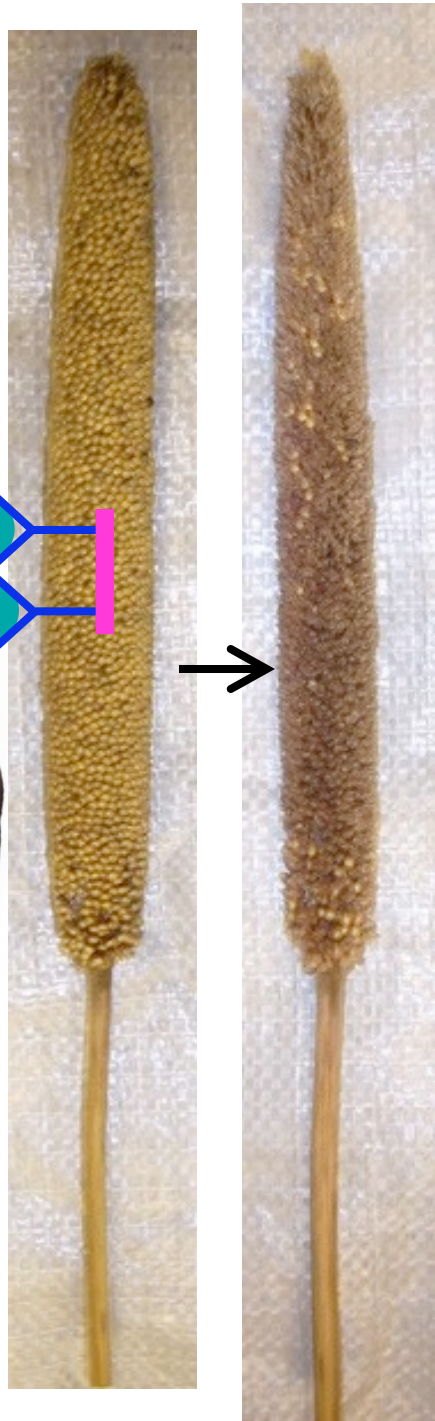
~1-10 m/s impact on the grains,

directed toward the panicle tip,

knock off grains,

and leave the florets on the stalk.

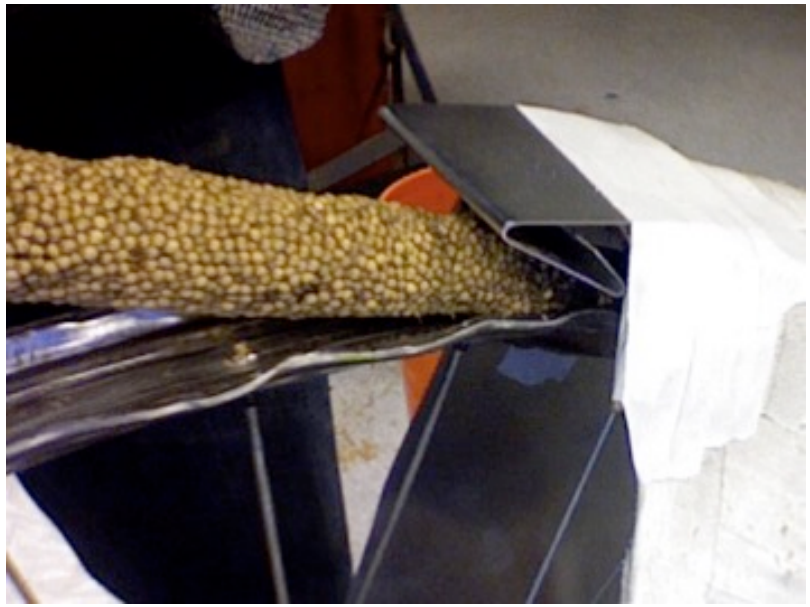
(Impacts from other directions break the florets or the stalk)



Same panicle, before and after ~5 seconds of threshing

The MIT Thresher

- Spoke nuts protruding through the rotating rim on an inverted bike efficiently thresh millet
- A metal plate bent as a spring presses the millet against the rim
- A grain sack collects the grain



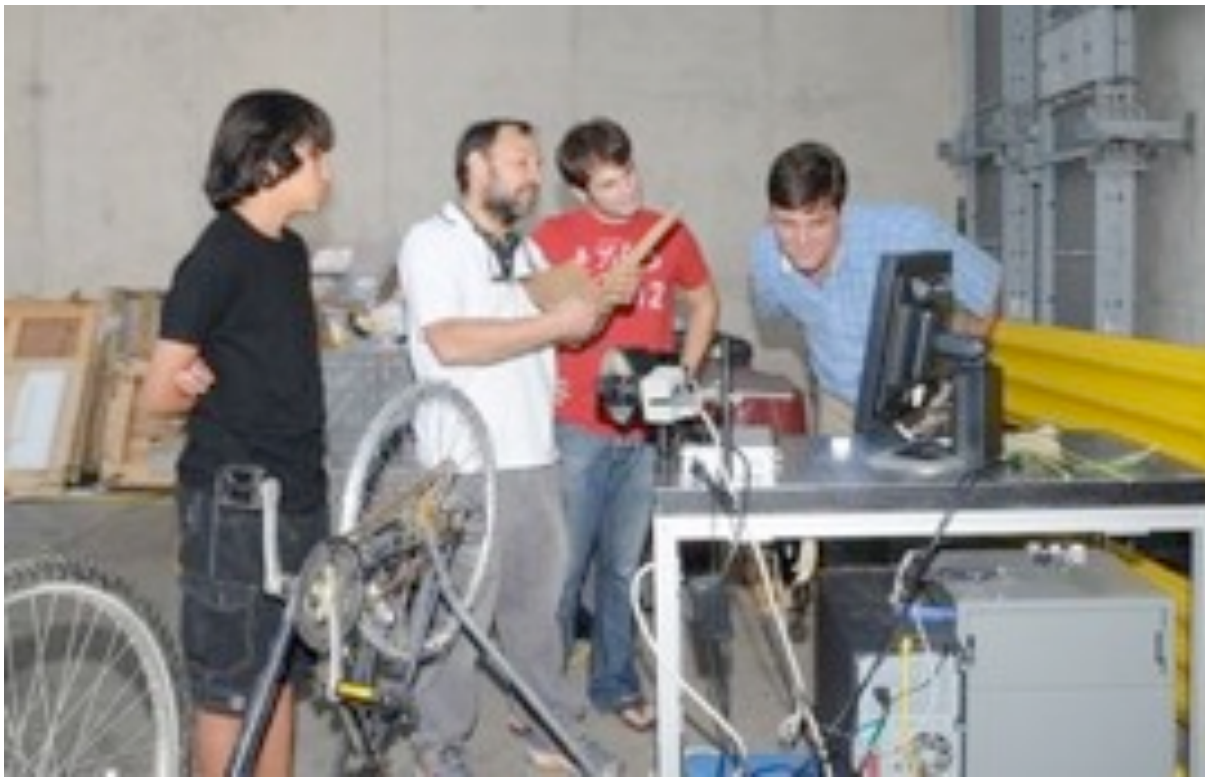
The process:

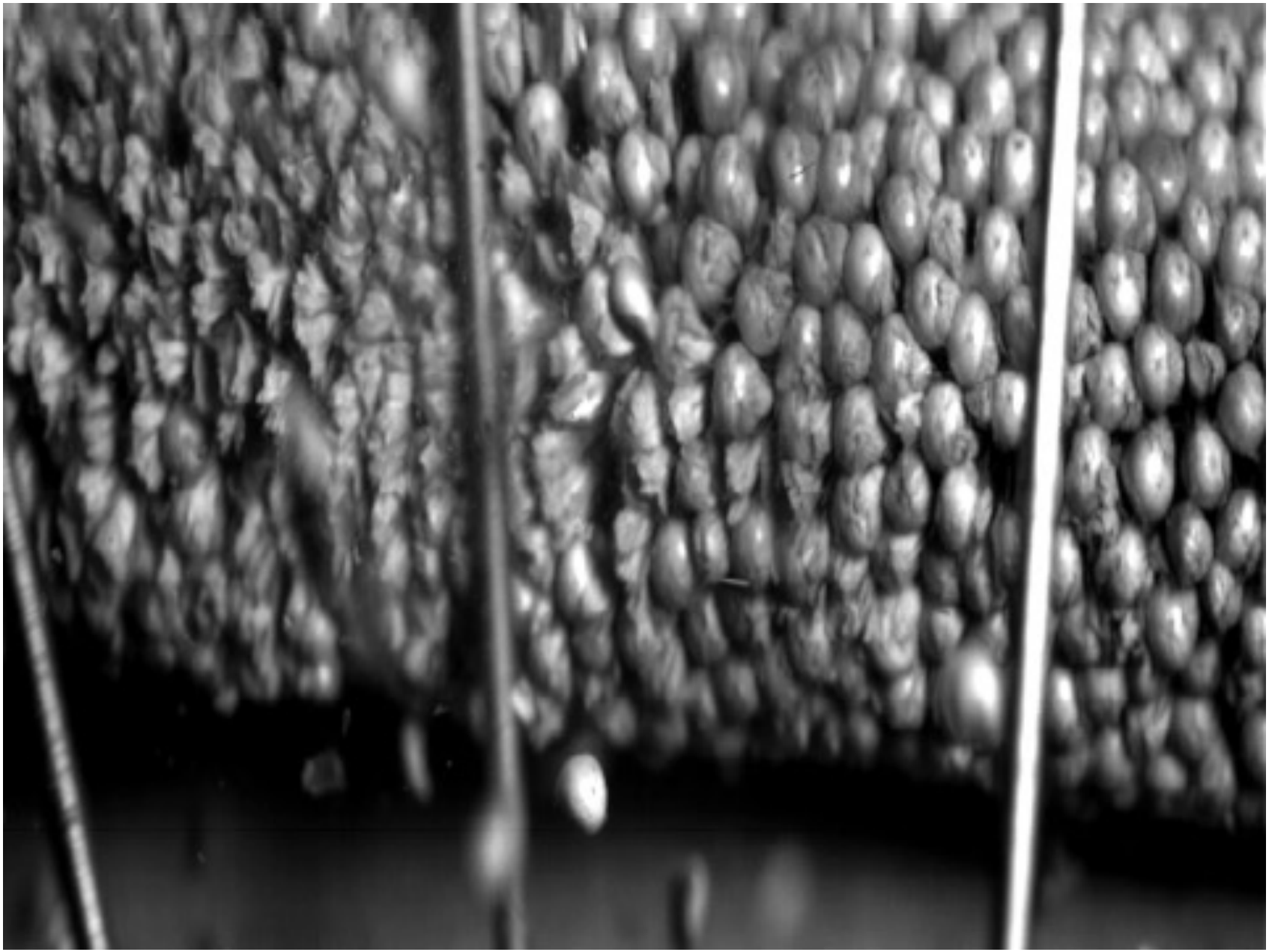
General lessons

- Do lots of experiments
  - Try to frame the problem in multiple ways
  - Reduce key ambiguity and uncertainty
- Don't plan far ahead
  - Use today's results to drive tomorrow's exploration
- Seek simple, cheap, quick paths to your goal
  - E.g., discovering the anisotropy of millet was key, but we did it without directly measuring tensile strength, density, etc.
- Unconventional approaches to old problems are more likely to succeed than conventional ones
  - If a problem has been around a long time then the obvious approaches have likely been tried (and don't work)

Visualizing threshing dynamics

- Amgen's high speed video system captured 2000 frames/sec
- Threshing was done on the spokes, and imaged through the wheel (so every other spoke is out of plane of the millet)

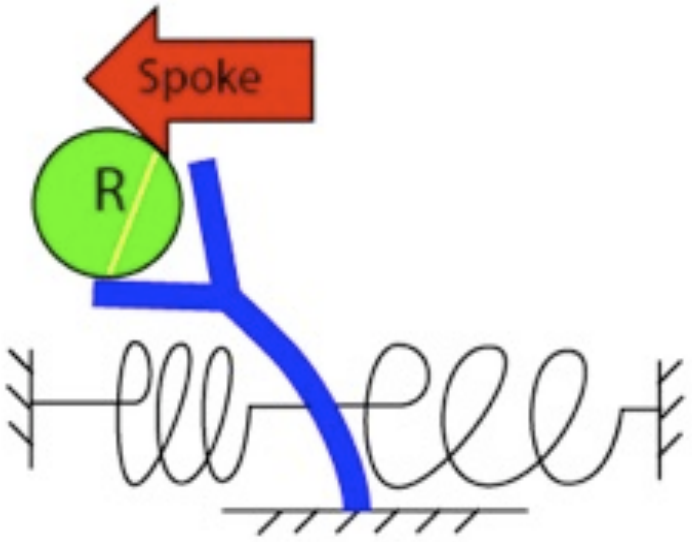




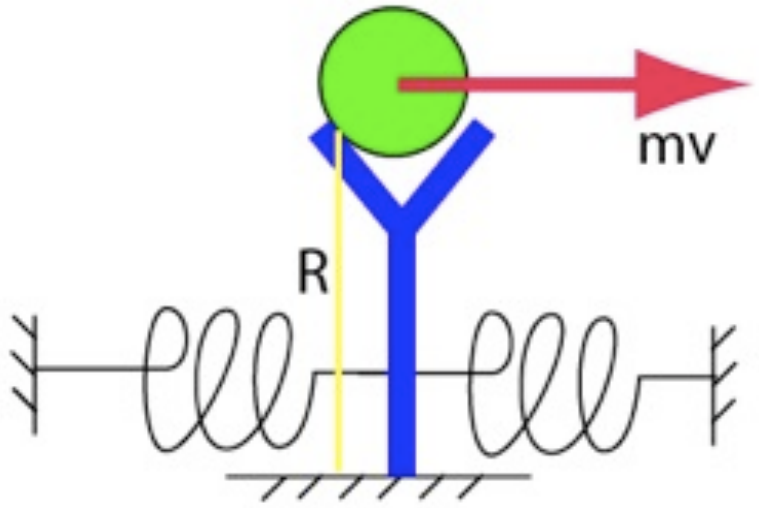
1/8000 sec shutter, 2000 frames/sec, shown 1/133 real time

What the video suggests

- The millet's motion is highly damped
  - It stops moving before the next spoke hits (~10 msec later)
  - Energy doesn't accumulate, there is no resonance
  - This contributes to the robustness of the method
- Grain often flies off on the *rebound* from spoke impact
  - Impact weakens attachment to floret; rebound of floret catapults grain



Impact



Rebound

Hampshire College

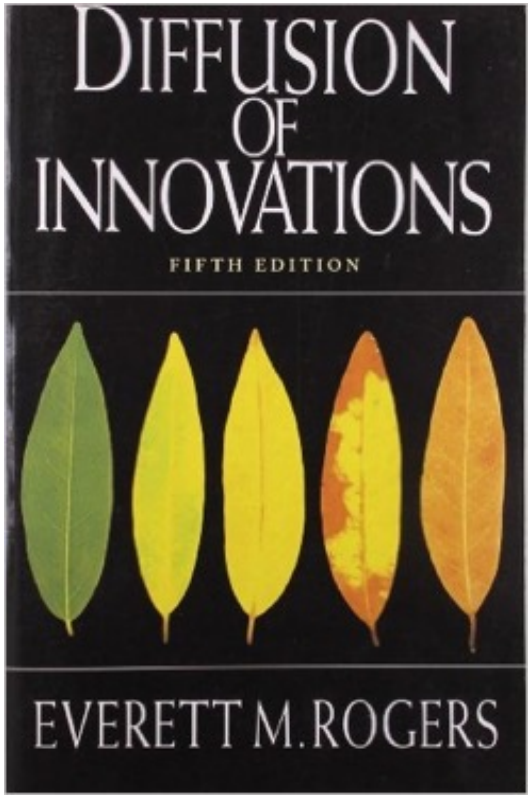
Gates Foundation

$95k grant

Trials in Mali & Ghana

Future Challenges

- Diffusion of innovations is often a slow and tricky process
- Millet threshing has a big social component for many people
  - Our bike thresher won't save money, but could free 1 month per year for some women
- A major challenge is adding diverse social science skills to the team
  - Technical diversity was a big contributor to our technical success
  - Social engineering diversity will likely be key for dissemination



I went to MIT to study engineering …

… and built this bike

Note: it was exhibited at the Smithsonian Institute

A great product but failed business

- **We developed an innovative corn husker in Guatemala using PVC pipe and screws**

  - **Market tested it**
  - **Set up a cooperative to produce and sell them**
  - **And it failed**

Lake Atitlán, Guatemala; Tzútujil people

LU1516

DSC_8099

Market Testing

No sales until price dropped to $0.80

- A year later the project had stalled
- Why couldn't a $1 device that saved blisters and increased speed ~5x succeed??
  - It was hard to make for <$0.80
  - The widows running the coop couldn't overcome the business challenges
- *Product success requires much more than technical success*

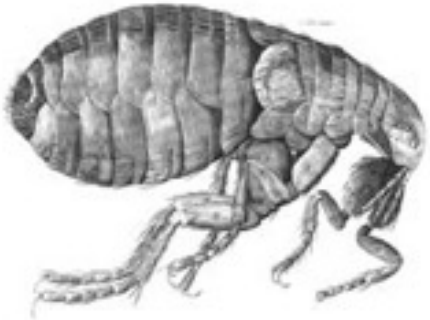
Microscopes are …

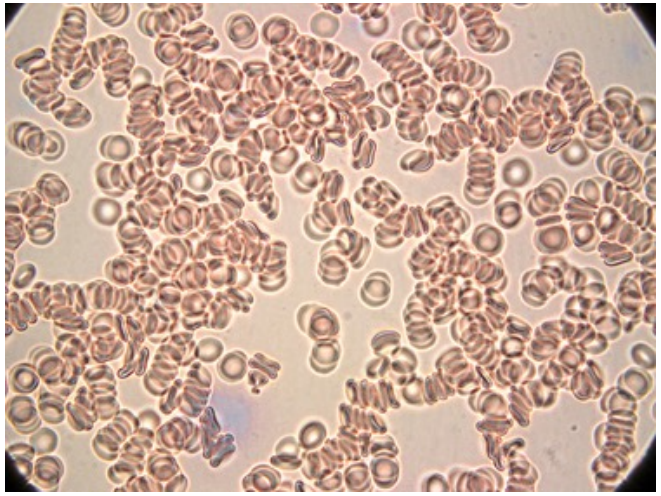
Big machines to see small things

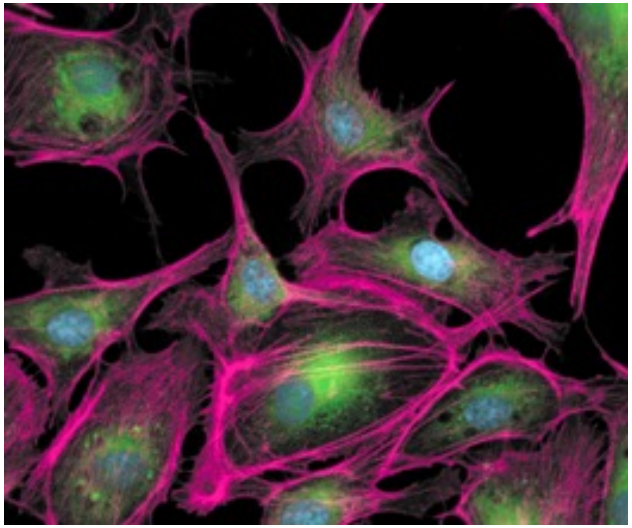
~1660

~1940

~1990







Microscope evolution

- In 350 years the underlying design hasn't changed
- Technology has added flexibility and capability
- And complexity, fragility, …
- And the cost remains high
  - $25k->250k for fluorescence microscopes

Problem statement

- Microscopy has become an indispensable tool for medical diagnosis
- The prices (and capabilities) of modern microscopes are out of reach
  - And they are complicated to use and repair

⇒ *How can we make a radically cheap, simple microscope suitable for the developing world?*

Prior attempts

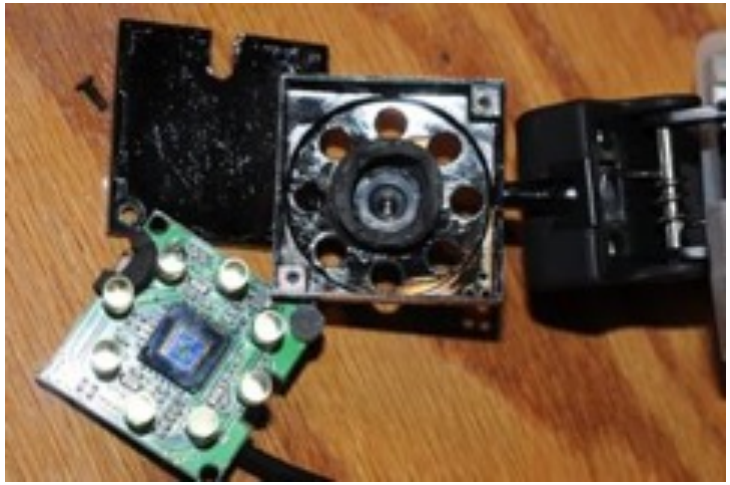
- Bamboo microscope
  - Created by Jodo Gyan, a small nonprofit in New Delhi.
  - 2500 sold @150 rupees (~$4)
  - Educational tool

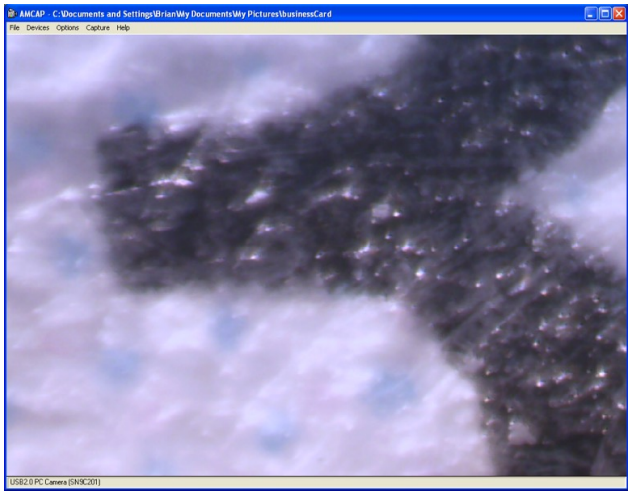
Webcam microscope

- Webcams are simple, cheap, and contain most <u>essential</u> components of a microscope
  - Lens
  - Light
  - Detector

- By abandoning a visual interface to our eyes, can we save orders-of-magnitude of cost, complexity, fragility, …?

Turning a $10 webcam into a microscope

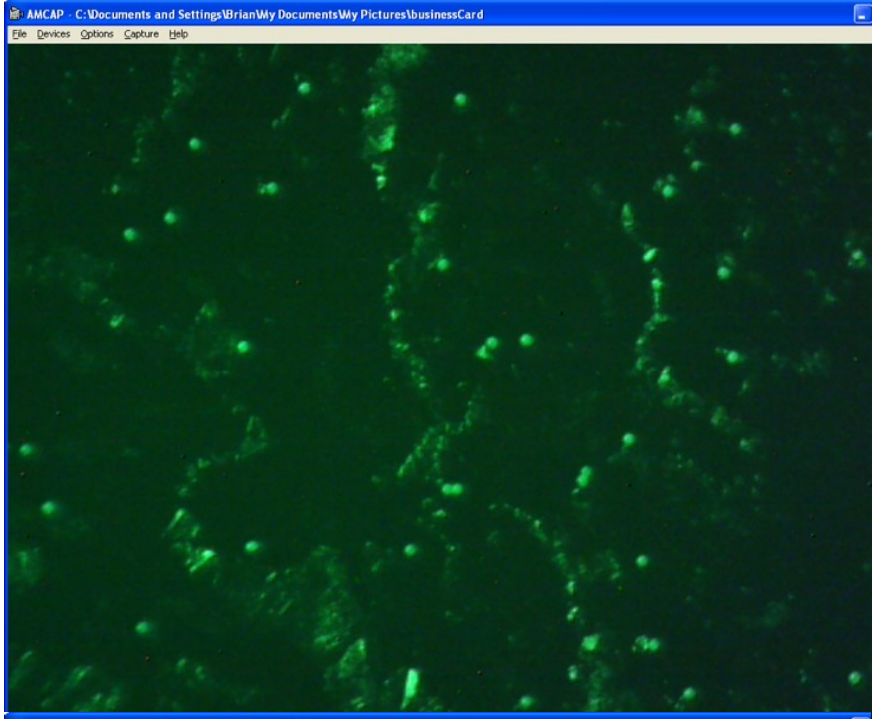




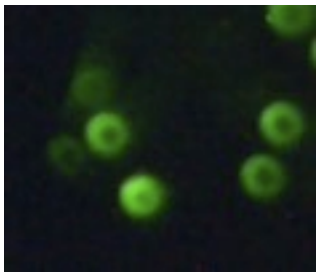
"3" at 1.3 μm per pixel

Epifluorescence Microscope

10 μm FITC beads in dried saline. Same FOV with and w/o broadband illumination



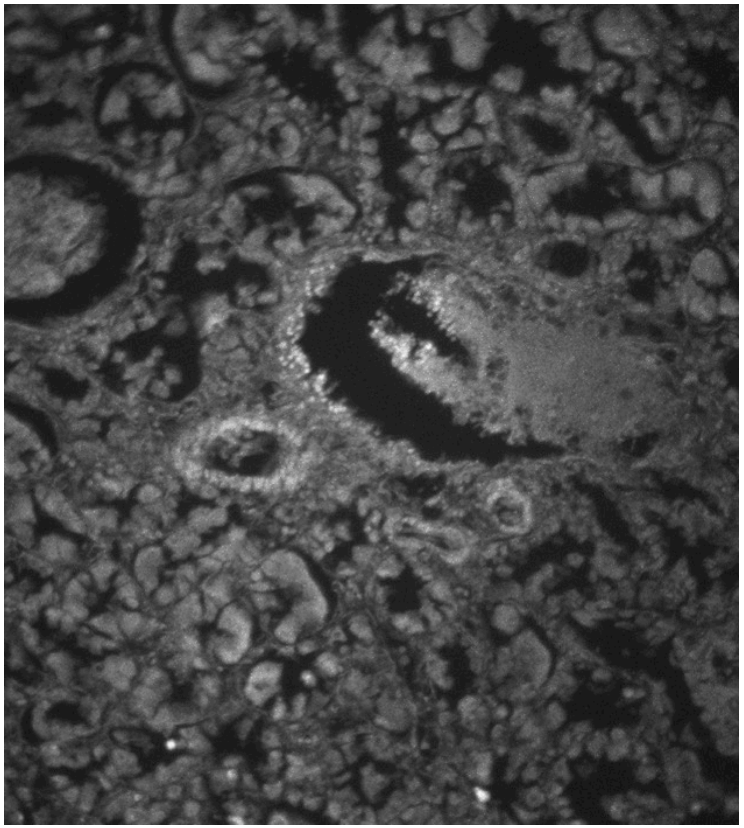
Zoom shows light is from bead's spherical surface

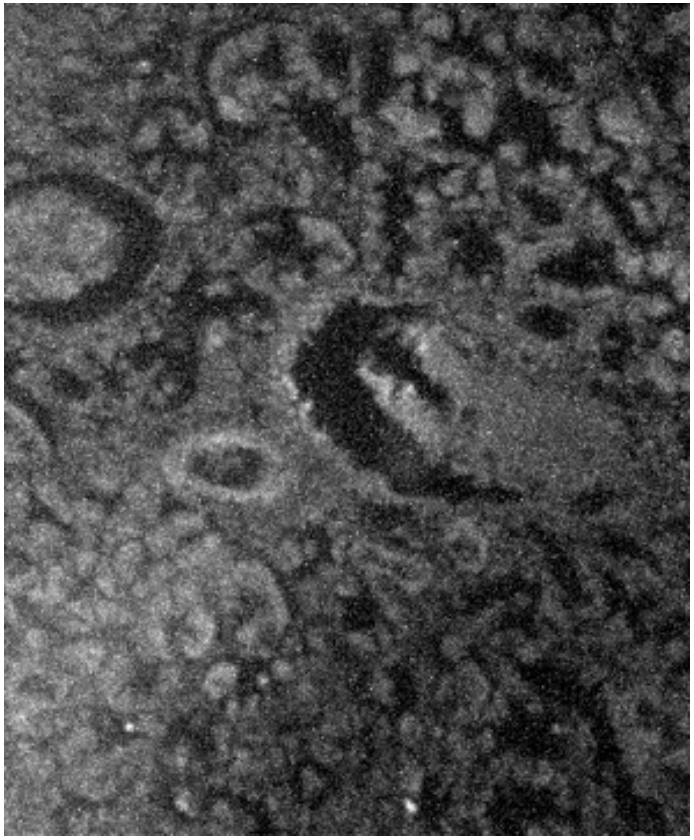


Fluorescent Tissue Slice

etaluma

A slightly more complex prototype is nearly as good as $40k instrument

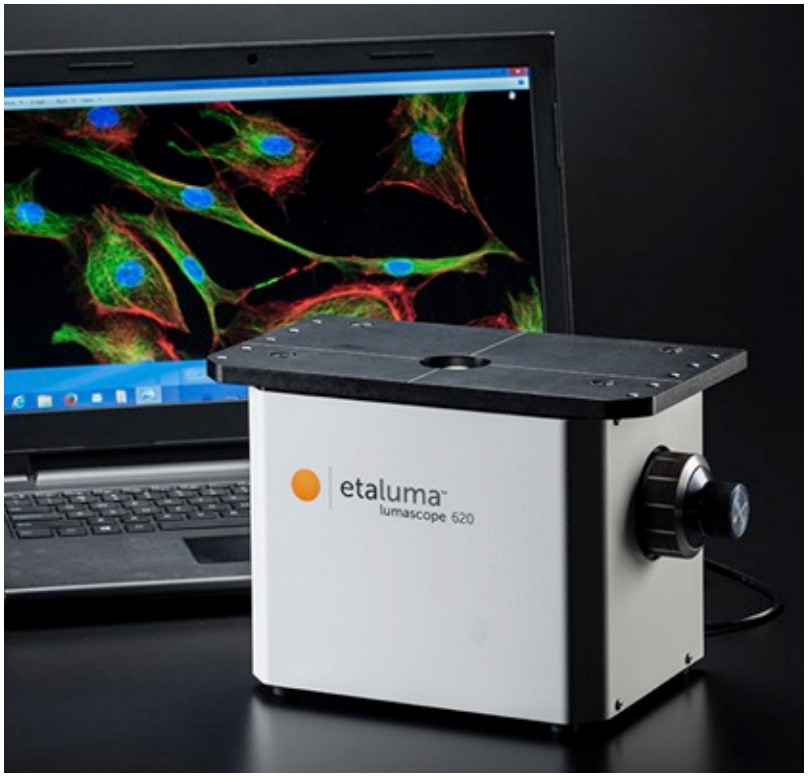




Should we make it cheaper? Or should we make it better?

Economic constraints

- Without *significant, sustained,* funding, the *only* choice was better → aim for the wealthy market
  - Our economic system (once again) favors the wealthy
  - As much as we wanted to help the poor, and as big a market as they are, we couldn't afford to do so
  - Our microscopes cost $4k-40k



Engineering for the Poor

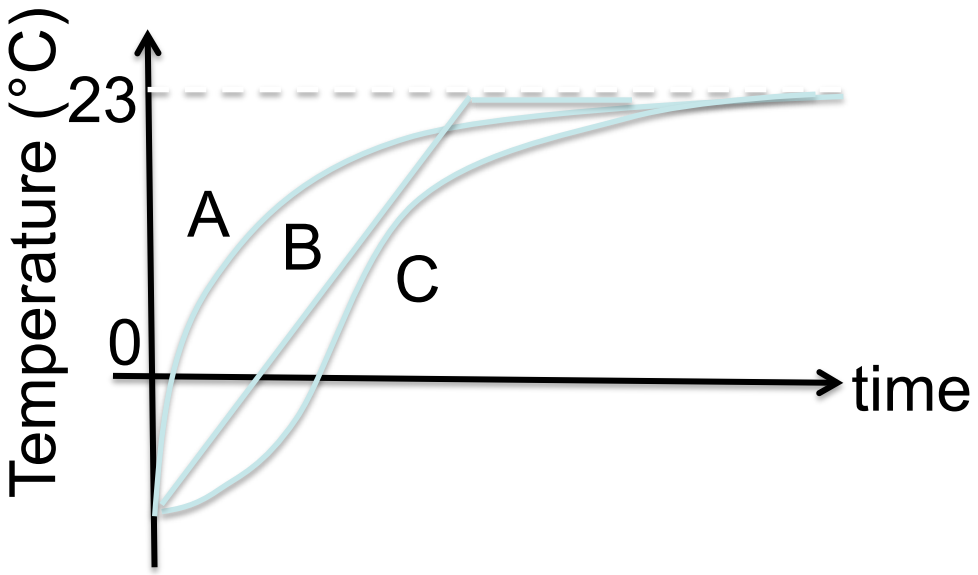
- Why is achieving social and economic justice so hard?
  - After many decades and many billions of dollars of foreign aid invested (supposedly) for these goals the *majority* of humankind live their lives in poverty
- Not only in the "developing world", but even in USA, we have persistent, widespread poverty, unemployment, inequality, racism, sexism, …
- And there's a bigger problem here ...

State of the World

- ½ the forests worldwide are gone, ½ the rainforests have been cut since 1950
- 1/3 of the world's arable land became unproductive in the last 50 years due to erosion
- 90% of all large fish (since 1950) are gone — not just in some areas, not just for some species, but all large fish species from the tropics to the poles
- 9 of the 10 warmest years on record are since 2000
- Miami's sea level has risen 1"/year for last 5 years
- Arctic sea ice is declining by 13%/year
- …
- *Where did all this (common) wealth go???*
- *Taken together (with other irrefutable evidence), these facts tell a rationally undeniable (albeit unpleasant) story*

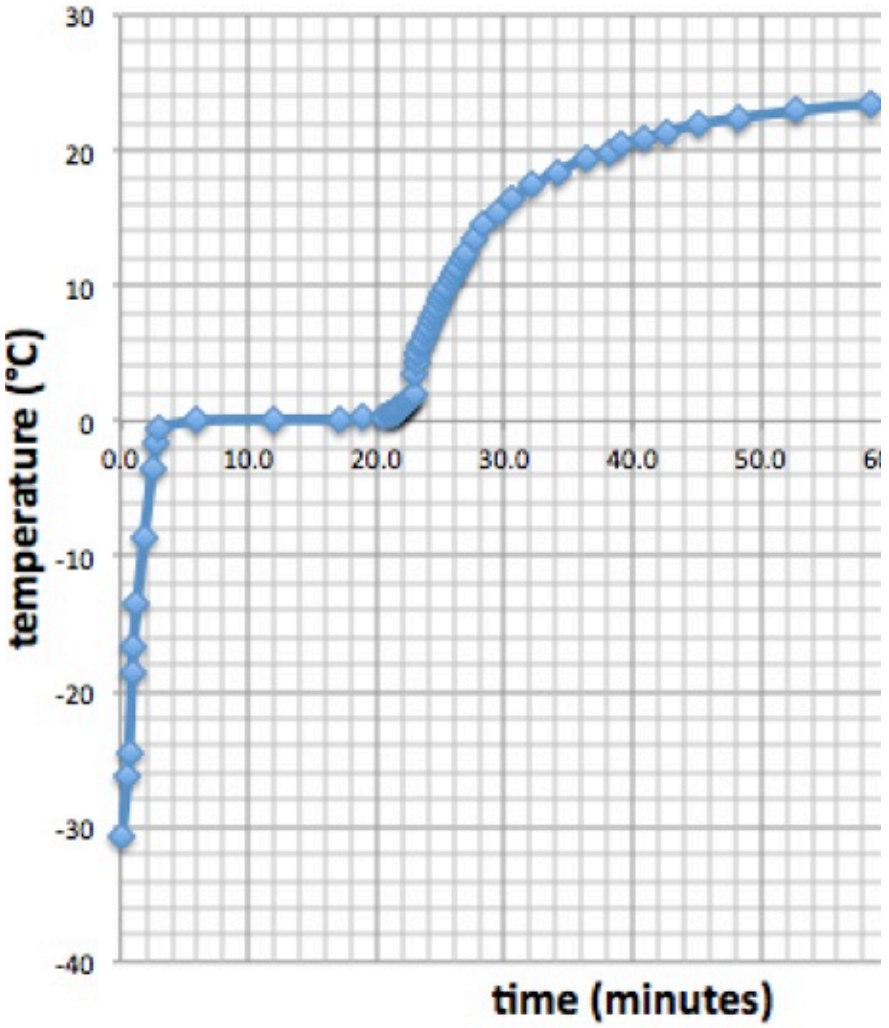
Melting Ice Experiment

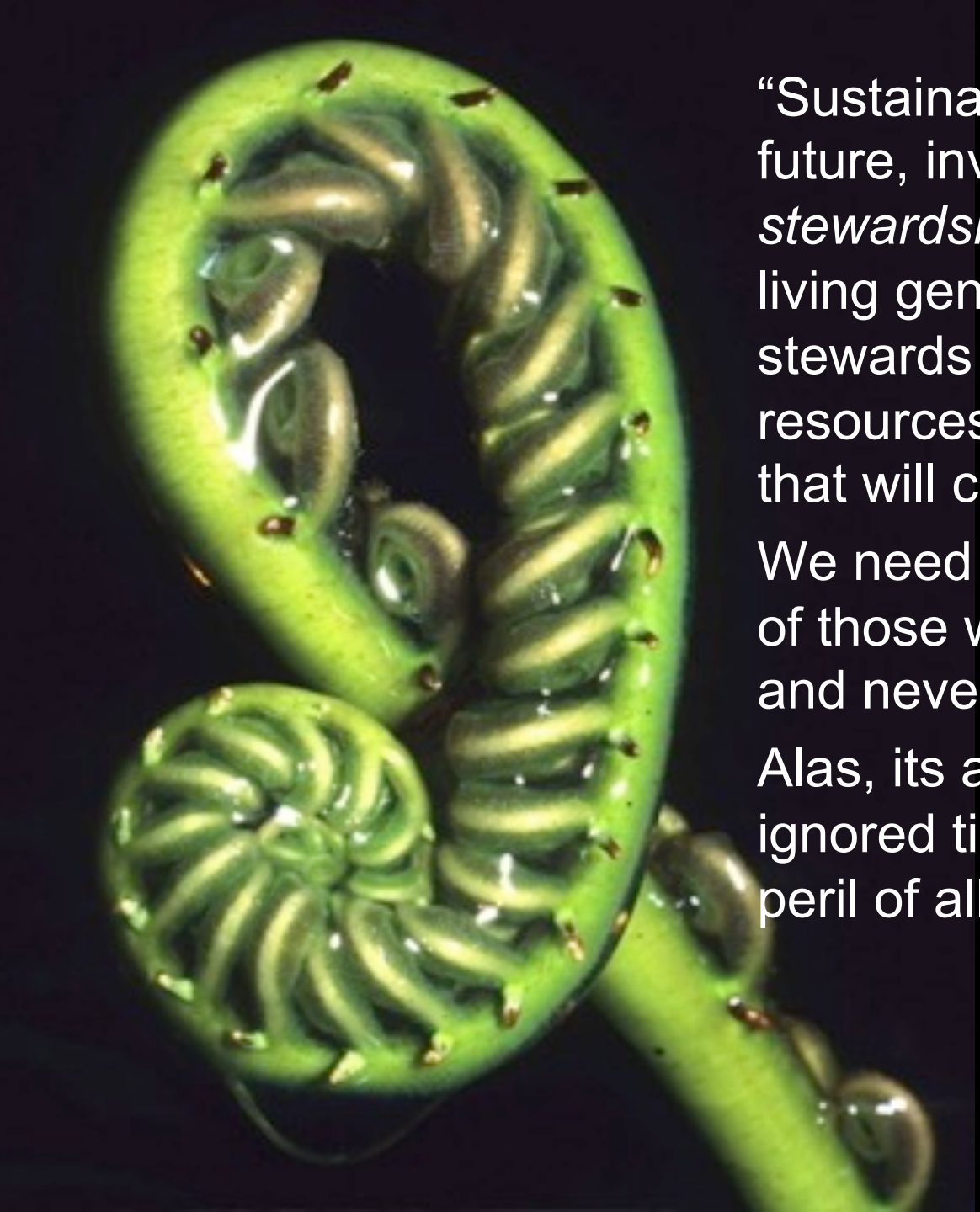
If we place a small piece of ice in the classroom and measure its temperature, what will the resulting graph look like?



I find this graph *frightening*!!

- Many people are surprised at their ignorance about water
- Thermodynamics gives a theoretical explanation
- Where is the Arctic on this graph?
- What can we *expect* will happen in the Arctic when its ice has all melted (within ~a decade)?
- Is this a valid climate model?





“Sustainability, or fairness to the future, involves the concept of *stewardship*, the idea that the living generation must be stewards of the earth’s resources for the generations that will come later.

We need to defend the interests of those whom we’ve never met and never will.

Alas, its a role that we’ve mostly ignored till now, to the increasing peril of all who will follow.”

-- Jeffrey Sachs

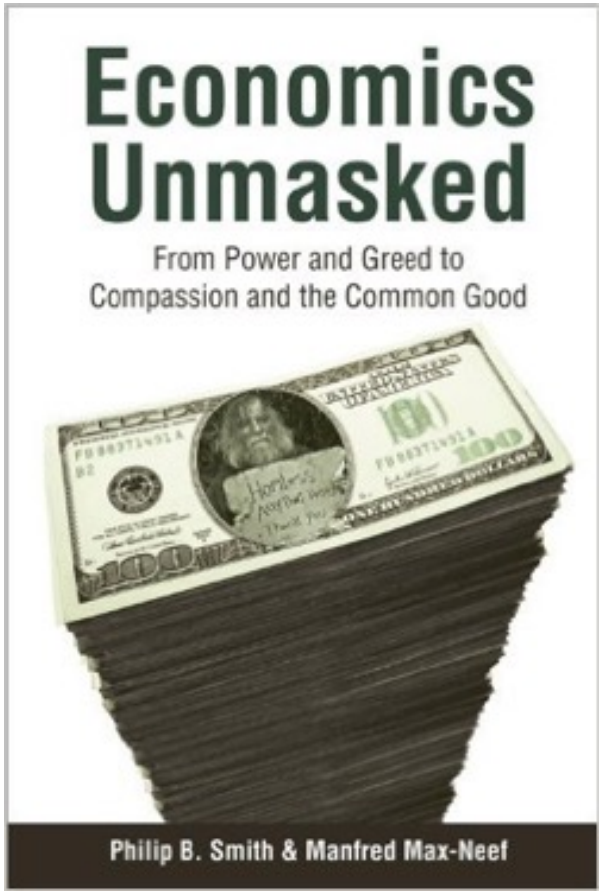
Knowledge vs. Understanding

- Engineers understand technology and love to tinker
  - This is only one component of solving problems for the poor
- We need to *understand* the problems of the poor, and the reasons for their poverty (past, present, and future)

- Global warming consequences will destroy people who have inadequate power (wealth) to protect themselves from the coming onslaught of change

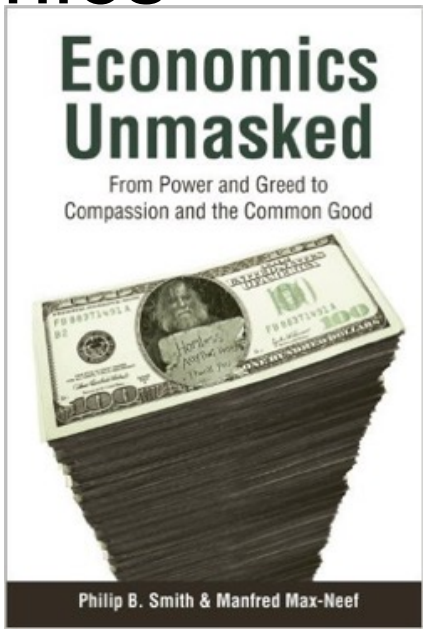
Economics Unmasked

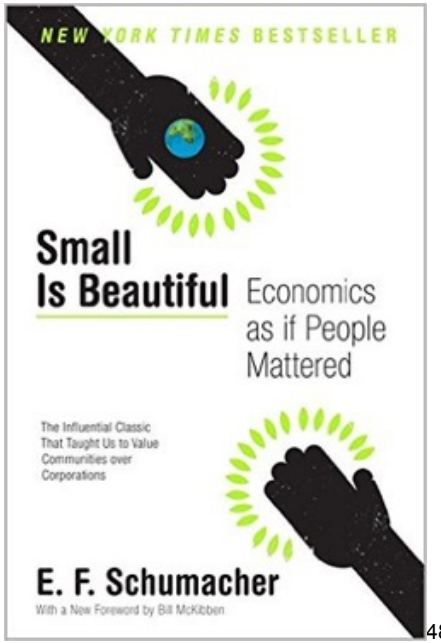
- "The distribution of economic and financial power determines how just a society is"
  - Unregulated "free" markets lead irrevocably to concentration of economic power, i.e., injustice
- "Political power is subservient to economic power"
  - The political regime is visible, the workings of the underlying economic system are largely invisible



Postulates for a new economics

1. The economy is to serve the people, not the people to serve the economy
2. Development is about people, not about objects
3. Growth is not the same as development, and development does not necessarily require growth
4. No economy is possible in the absence of ecosystem services
5. The economy is a sub-system of a larger and finite system, the biosphere; hence permanent growth is impossible
6. No economic interest, under any circumstances, can be above the reverence for life






CLIMATE
SUMMIT
WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?
• ENERGY INDEPENDENCE
• PRESERVE RAINFORESTS
• SUSTAINABILITY
• GREEN JOBS
• LIVABLE CITIES
• RENEWABLES
• CLEAN WATER, AIR
• HEALTHY CHILDREN
• ETC. ETC.
JOEL PETT

Summary (finally!)

- Science and technology can be applied to make simple and inexpensive products for the poor (and others)
  - Components from bikes to webcams can be hijacked to serve useful, unintended functions
  - Diversity fosters creativity and innovation, although it challenges communication and lowers productivity by conventional measures
  - Engineering is just one of many necessary skills to establish most innovations
- Global poverty won't be solved by any invention, because it results from a systemic economic system that concentrates and protects wealth and power
  - Why are the poor poor?

Summary

- Transitioning to any new economic system will be resisted by those who benefit from the present system
- Physical constrains like running out of cheap fossil energy or groundwater, climate change/sea level rising, etc., will force change if we don't change sooner
  - If you think everything is fine, then I encourage you to get outside more …
    - You don't need to travel very far – many parts of the USA have become like 3rd world countries, "sacrificial zones"
- Reducing wealth disparity will create more democracy and justice, and stop a few from extracting huge profits by damaging the environment and putting future generations at risk

Referenced Books

- Moritz Thomsen, “Living Poor”
- E.F. Schumacher, “Small is Beautiful: Economics as if People Mattered”
- Everett Rogers, “Diffusion of Innovations”
- Philip Smith & Manfred Max-Neef, “Economics Unmasked: From power and greed to compassion and the common good”
- Paul Polak, “Out of Poverty”
- Robert Pirsig, “Zen and the Art of Motorcycle Maintenance”
- Daniel Quinn, “Ishmael”

- www.idds.org

(Photo of my son became Guatemala's 2012 Earth Day Poster)