Novel solutions to complex diseases for subsistence agriculture

David Hughes
Center for Infectious Disease Dynamics
College of Ag Science & Eberly College of Science
"Civilization and anarchy are only seven meals apart"  Spanish Proverb

“What has been will be again, what has been done will be done again; there is nothing new under the sun”  Ecclesiastes 1:9
Novel solutions to complex diseases for subsistence agriculture

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College of Ag Science & Eberly College of Science
Parasite, from the word *Parasitos* which the ancient Greeks called a person who would “eat from another’s table”
40% of the global crop lost to parasites
When you were born, you were the:

3,973,326,076th

[Graph showing population growth from 1500 to 2050, with a note that the population is estimated at 500 million in 1500 and reached 7 billion in 2011.]

http://www.bbc.co.uk/news/world-15391515
“The battle to feed all of humanity is over. In the 1970s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now. At this late date nothing can prevent a substantial increase in the world death rate.” Paul Ehrlich 1968
An Ohioan farmer boy who saved 2 billion people

He left the farm to go to college following his Grandfather’s advice who said:

"You're wiser to fill your head now if you want to fill your belly later on"
The Green Revolution (1940s-1970s): Successes

- More rice
- More and better corn
- More wheat
- Farmed fish grow 60 percent faster
- Better varieties

Source: FAO

Embracing technology
CHART 1: AVERAGE YIELD OF CEREAL BY COUNTRY

SOURCE: Bill and Melinda Gates Foundation, Aug 2011 Agricultural Development strategy overview
See handout
Industrial farming is not feasible in Sub-Saharan African

Proportion of Farmers in Rich Countries Declining

By comparison, the proportion of farmers in most developing countries is still high.

Sources: USDA National Agriculture Statistical Service (1850-1990) and the International Labour Organization (2000-2008)

One Billion people hungry each day
There is no **single** solution to increasing food supply in Africa?

- Recognizing the complexity at hand
  - Biology
  - Climate
  - Soil
  - Social
  - Politics
  - Trade
Alliance for Green Revolution in Africa (AGRA)

- ¾ of world's poor farm an area the size of a football field or smaller
- 80% of work by women but only 5% of extension
THE COMING FAMINE
THE GLOBAL FOOD CRISIS
AND WHAT WE CAN DO TO AVOID IT

JULIAN CRIBB
My Talk

• Past, Present and Future: stories of plant disease
• Movement of agriculture:
  1) Enemy release...but then Catch-up
  2) Adoption
• The role of institutes like Penn State
I work with diseases of ant societies
Understanding where disease is located
Zombie ants: a fungal disease that controls ant behavior causing them to die on leaves

http://www.youtube.com/watch?v=2irXpAMBHkE
Observing disease at the global level

- Atlantic Rainforests, Brazil
- Temperate wood PA & SC
- Boreal Forests Finland
- Vineyards in Tuscany
- Tropical forests China
- Tropical forests Thailand
- Tropical forests Australia
- Eucalyptus woods Australia
- MesoAmerica Mexico & Costa
- Amazon
- Ghana
- Tropical forests Australia
Choose your travel companions carefully... because of the danger of learning too much

102 days doing field work together in the last two years

Dr Harry Evans
Senior Scientist at CABI UK
Excellent Plant pathologist
Recognizing changed landscapes: Coffee in Brazil
Recognizing changed landscapes: Coffee in Brazil

Atlantic Rainforest: 92% destroyed
Highly important with 40% of plants endemic (meaning only found there)
Recognizing changed landscapes: Agrotourism (Brazil)
Recognizing changed landscapes: Cattle (Brazil)
Observing subtle differences

Chromolaena odorata poisoning soils of food crops
101 uses including embalming bodies
Crop domestication has been well-studied by Archaeologists and Archaeobotanists

H. Balter, Science 2007, 316:1833
Small Grain Cereals Were Domesticated in the Fertile Crescent and Became Globally Distributed Relatively Recently

Wheat and barley domestication 10,000 years BP

Neolithic migrations, retreating glaciers, northern Europe 5000 BP

Neolithic migrations, China 4500 BP

Neolithic migrations, India 5000 BP

European colonization 200 BP

European colonization South Africa 350 BP

European colonization 500 BP

Neolithic migrations, China 4500 BP

Neolithic migrations, India 5000 BP

European colonization 200 BP

European colonization South Africa 350 BP

Europe—an example of crop domestication.
My Talk

• Past, Present and Future: stories of plant disease

• Movement of agriculture:
  1) *Enemy release*...*but then Catch-up*
  2) *Adoption*

• The role of institutes like Penn State
Stories of crop disease: Past, present & future

How plant disease...
- Changed how we viewed crop destruction
- Forced the English to drink Tea!
- Elect a President

How plant diseases are...
- Threatening staples like Cassava (mealybug)
- And Wheat (Ug99)

How plant diseases could...
- Change the world economy
- Rubber
- Cocoa
- Coffee
- Wheat

Time
Story One

Irish Potato Famine of 1845-1847: The birth of plant pathology
Domesticated 7,000 years BP (before present) in Peru (USDA work, David Spooner)

Between two to four times the food quantity of grain crops. Up to seven times more water efficient

Increasing from less than 30 million metric tons in the early 1960s to more than 165 in 2007

Source: FAO (Food and Agricultural Organization of UN)
Principal food in Ireland before 1845

When I was 16 I spent a year working at a Quaker built monastery (from 1840’s)

...and taking tourists out on Connemara Ponies
Late Blight - *Phytophthora infestans*

**Figure 1. Population of Ireland and England, 1700–1970**

- 9 million
- 1 million died
- 2 million emigrated
5 million between 1845-1915
US Census of 2000 listed 41 Million Irish Americans
The science of the potato famine

“A fatal malady has broken out amongst the potato crop. On all sides we hear of the destruction. In Belgium the fields are said to have been completely desolated. There is hardly a sound sample in Covent Garden Market “

‘The first obvious sign is the appearance on the edge of the leaf of a black spot which gradually spreads; the gangrene then attacks the haulms (stems), and in a few days the latter are decayed, emitting a peculiar and rather offensive odor. When the attack is severe the tubers also decay” Dr John Lindley, Editorial of The Gardeners Chronicle and Agricultural Gazette, on August 23rd, 1845.
The Gardeners' Chronicle.

SATURDAY, SEPTEMBER 13, 1845.

MEETINGS FOR THE TWO FOLLOWING WEEKS.

WEDNESDAY, Sept. 17—South London Floricultural 1 P.M.

COUNTRY SHOWS.

WEDNESDAY, Sept. 17—H’ham Floral and Horticultural.
FRIDAY, Sept. 19—Devon and Exeter Botanical and Hort.
THURSDAY, Sept. 25—Surrey Horticultural and Floral.

We stop the Press, with very great regret, to announce that the Potato Murrain has unequivocally declared itself in Ireland. The crops about Dublin are suddenly perishing. The conversion of Potatoes into flour, by the processes described by Mr. Babington and others in to-day's Paper, becomes then a process of the first national importance; for where will Ireland be, in the event of a universal Potato rot?
Ferrante Imperato's Dell'Historia Naturale (Naples 1599), the earliest illustration of a natural history cabinet
The history of the natural sciences

Musei Wormiani Historia 1655 (after Ole Worm died)
The history of the natural sciences

Wondertooneel der Nature (Wonder Theater of Nature)
Levinus Vincent, opened museum 1705
1845

Antony van Leeuwenhoek around 1668
developed lenses

Robert Hooke,
*Micrographia* 1665

*The Book of Nature, or The History of Insects* (1758) de Jan Swammerdam
The history of the natural sciences
Germ Theory (The science of disease) did not exist

- Fungus on potatoes was assumed to be the consequence of potato murrain (i.e. die off) and **not the cause**
- Reverend Berkley “a gentleman eminent above all other naturalists of the United Kingdom in his knowledge of the habits of fungi”. Dr Lindley
- Based on his observations of fungi in onion, French potatoes (from Dr Montagne) and infected silkworms from Italy (Father Agostino Bassi) in 1835 Berkley proposed a novel hypothesis: the fungus caused the disease (this is the Germ Theory)
- Radical departure and anticipating Pasteur almost 25 years.
The science of the potato famine

- Anton de Bary continued this work and worked out the lifecycle of *Phytophthora infestans*
- Considered the father of plant pathology
- (He coined the term symbiosis that Marilyn Roossinck discussed last week)
Phytophthora — “plant destroyer”
Story 2: Why the English drink Tea

Boston Tea Party of 1773
A short history of coffee: the wine of the Arabs

- The plant *Coffea arabica* evolved in Ethiopia and used by Arabs in 1100AD to make a thick black drink called *qahwah* (the word coffee comes from the Turkish form *kahveh*).
- Coffee became a major drink in England in the 1600’s since drinking water was so hazardous.
- Now second largest commodity after oil ($70 Billion annually)
- In 1825, the British began development of their property in Ceylon (now Sri Lanka), and every suitable piece of land was planted to coffee plantations. By 1870, Ceylon was the world's greatest producer of coffee. *Java* remains a slang term for coffee, reflecting the time when coffee production centered in that part of the world.
- When the coffee rust fungus, *Hemileia vastatrix*, reached Ceylon in 1875, nearly 400,000 acres (160,000 hectares) were covered with coffee trees.
- In 1870, Ceylon was exporting 100 million pounds (45 million kilograms) of coffee a year. By 1889, production was down to 5 million pounds (2.3 million kilograms).
- The whole production switched to tea (*Camellia* spp).
- It would be another 100 years before the disease reached Latin America making America a coffee nation and England a tea nation.

The Vertue of the COFFEE Drink.
First publish'd and sold in England, by Pasqua Rosci.

The Grain or Berry called Coffee, grown upon little Trees, only in the Deserts of Arabia.
It is brought from thence, and drunk generally throughout all the Grand Seignors Dominions.

It is a simple innocent thing, composed into a Drink, by being dried in an Oven, and ground to Powder, and boiled up with Spring water, and about half a pint of it to be drunk, fasting an hour before, and not eating an hour after, and to be taken as hot as possibly can be endured, the which will never fetch the skin off the mouth, or raise any blisters, by reason of that Heat.
The Turks drink it at meals, and other times, is usually Water, and their Dyre consists much of Fruit, the Crudities whereof are very much corrected by this Drink.

The quality of this Drink is cold and Dry, and though it be a Dryer, yet it neither heats, nor inflames more then hot Coffee.

It doth refresh the Office of the Stomack, and fortifies the heat with its very good to help digestion, and therefore of great use to be hour; or a Clock after noon, as well as in the morning, which quickens the Spirits, and makes the Heart Lightsome.

It is good against sore Eys, and the better if you hold your Head over it, and take in the Steam that way.

It suppresteth Fumes exceedingly, and therefore good against the Head-ache, and will very much stop any Disfluxion of Remark, that distith from the Head upon the Stomack.

It is excellent to prevent and cure the Dropsey, Gout, and Swelling.

It is known by experience to be better then any other Drying Drink for People in years, or Children that have any running Humors upon them, as the Kings Evil.

It is very good to prevent Mif-carriages in Child-bearing Women.

It is a most excellent Remedy against the Spleen, Hypochondriaick Winds, or the like.

It will prevent Drawstings, and make one fit for business, if one have occasion to Watch, and therefore you are not to Drink of it after Supper, unless you intend to be watchful, for it will hinder sleep for 3 or 4 hours.

It is observed that in Turkey, where this is generally drunk, that they are not troubled with the Stone, Gout, Dropsey, or Swelling, and that their Skins are exceeding clear and white.

It is neither Laxative nor Restraining.

Made and Sold in St. Michaels Alley in Cornhill, by Pasqua Rosci,
At the Signe of his own Head.

1652 Advertisement for coffee
Coffee Rust *Hemileia vastatrix*,

(A) Defoliation in a coffee plantation, Coimbra, Minas Gerais, Brazil; (B) Leaf symptoms on abaxial surface (bar = 0.5 cm); (C) Detail of suprastomatal uredinial pustules coalescing over lower leaf surface (bar = 0.5 cm); (D) Uredinum showing arrangement of spores (bar = 20 μm); (E) Urediniospores - showing the thickened, heavily-ornamented or verrucose upper wall – containing carotenoid lipid guttules imparting the yellow-orange colour (bar = 10 μm). From Carvalho, Harry Evans et al 2011, PloS One
Story 3: How chocolate elected a President
The Spread of Cacao

1585 Mexico to Spain
17th century: Bahia to Guinea
1879 to Ghana
1670 Philippines
Late 1800s Samoa and New Guinea
1901 East Africa
Bahia 1970’s by Harry Evans

Before

After

Witches Broom
Moniliophthora perniciosa
Deliberate introduction of disease crippled Cocoa barons

Bioterrorism

Socialist opposition supporters (Petistas) introduced the disease to destabilize the power of the pro-government, right-wing cocoa barons leading eventually to Da Sliva become president of Brazil (see Evans in Handout)
Stories of crop disease: Past, present & future

How plant disease affected...
- how we viewed crop destruction
- forced the English to Drink Tea!
- Elect a President

How plant diseases are...
- Threatening staples like Cassava (mealybug)
- And Wheat (Ug99)

How plant diseases could...
Change the world economy
- Wheat
- Rubber
- Cocoa
- Coffee

Time: Now
Cassava

Daily food of 250 people in Africa and 800 Million Africans eat it. Introduced to Africa 300 years ago from South America without any pests.
1973 Disaster: Accidental introduction of Cassava Mealybug and Green Mite from Sth America

Both mealybug and mite travelled across 27 countries reducing crops by 80-100%
Major international operation

- International Institute of Tropical Agriculture working with Centro Internacional de Agricultura Tropical (CIAT) in Colombia and the Commonwealth Institute of Biological Control (CIBC) in Trinidad began a massive bio control program
- Found a wasp in South America and quarantined it in CABI, UK
- Mealybug levels down to 10% of peak
- Every donor $ lead to $200-500 return in annual cassava production
- And of course the enormous societal cost as millions saved from startving

The hero: *Apoanagyrus lopezi*
Ug99- a potential famine maker
Cereal Rusts: a Problem in Agroecosystems for 1000s of Years

Biblical references to rusts, rust spores found in grain storage pits from 3000 years ago, Roman sacrifices to Robigus and Robigo (Robigalia) for 1700 years

Complicated life cycles with up to 5 spore types on two different hosts

Produce spores that are red, orange, yellow, or white

Exist as physiological races that can attack only certain plant species or even only certain genotypes within a species or population

Move mostly by wind-blown spores and over long distances

Three major cereal rusts:

Stem rust: *Puccinia graminis*
Leaf rust: *Puccinia recondita*
Yellow rust: *Puccinia striiformis*
Wheat Stem Rust Disease Cycle: Basidiomycete (*Puccinia graminis tritici*)

**Macrocyclic**: basidiospores + teliospores + urediospores + aeciospores

**Heteroecious**: alternate host barberry (*Berberis vulgaris*) needed to complete life cycle

### Spore types:
- **Macrocyclic** vs **Microcyclic**

### Hosts:
- **Heteroecious** vs **Autoecious**

Uredospores survive on wheat in warmer climates
Ug99 Race of the rust *Puccinia graminis*
Occurrence and Movement of Ug 99-TTKS

- Ug99 detected: 1999 in Uganda “Ug99”
- In Yemen and Sudan (’06 samples) declared in 2007,
- In Iran (07 Samples) declared in 2008
Ug99 Pathway: Current and Predicted Spread

Ug99 Spread 1999-2007

Expected New Spread Of Ug99??

Yemen Gate
Transboundary diseases

Ug99 Spread 1999-2007
# Current Importance of Wheat Rusts

<table>
<thead>
<tr>
<th>Region</th>
<th>Yellow Rust</th>
<th>Leaf Rust</th>
<th>Stem Rust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australasia</td>
<td>Major</td>
<td>Local</td>
<td>Minor</td>
</tr>
<tr>
<td>East Asia</td>
<td>Major</td>
<td>Local</td>
<td>Minor</td>
</tr>
<tr>
<td>South Asia</td>
<td>Major</td>
<td>Local</td>
<td>Minor</td>
</tr>
<tr>
<td>West Asia</td>
<td>Major</td>
<td>Local</td>
<td>Minor</td>
</tr>
<tr>
<td>Central Asia</td>
<td>Major</td>
<td>Major</td>
<td>Local</td>
</tr>
<tr>
<td>Russia/Ukraine</td>
<td>Local</td>
<td>Major</td>
<td>Minor</td>
</tr>
<tr>
<td>Middle East</td>
<td>Major</td>
<td>Local</td>
<td>Minor</td>
</tr>
<tr>
<td>North Africa</td>
<td>Major</td>
<td>Local</td>
<td>Minor</td>
</tr>
<tr>
<td>Eastern Africa</td>
<td>Major</td>
<td>Local</td>
<td>Major</td>
</tr>
<tr>
<td>Southern Africa</td>
<td>Major</td>
<td>Local</td>
<td>Local</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>Local</td>
<td>Local</td>
<td>Minor</td>
</tr>
<tr>
<td>Western Europe</td>
<td>Major</td>
<td>Local</td>
<td>Minor</td>
</tr>
<tr>
<td>North America</td>
<td>Major</td>
<td>Major</td>
<td>Minor</td>
</tr>
<tr>
<td>Central America</td>
<td>Major</td>
<td>Local</td>
<td>Minor</td>
</tr>
<tr>
<td>South America</td>
<td>Local</td>
<td>Major</td>
<td>Local</td>
</tr>
</tbody>
</table>
Yellow rust (Vir. Yr9) spread 1986-1998
Major yield losses across the region recorded

Stem rust Ug99 followed the expected migration but moved faster to Yemen
Trans-boundary wheat rust

Ug99 represents a much greater threat than yellow rust Vir Yr9.

Estimated 80% of current global wheat varieties are susceptible.
Stories of crop disease: Past, present & future

How plant disease affected...
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How plant diseases could... Change the world economy
- Wheat
- Rubber
- Cocoa
- Coffee

Time: Soon
The Threat of South American Leaf Blight (*Microcyclus ulei*)

Between 1920-1940, Henry Ford planted >20,000 acres with hundreds of thousands of trees: all failed.

*Hevea brasiliensis* accounts for 40% of world’s rubber...and all the best stuff.

Source: UNCTAD secretariat (Data: FAOSTAT database)
My Talk

• Past, Present and Future: stories of plant disease

• Movement of agriculture:
  1) Enemy release...but then Catch-up
  2) Adoption

• The role of institutes like Penn State
Movement: Center of Origin to Introduced area

- **Potato:** Peru to Europe
- **Coffee:** Ethiopia to Sri Lanka and Americas
- **Cocoa:** Ecuadorian Amazon to Central and South America, West Africa and SE Asia
- **Cassava:** Sth America to Africa
- **Rubber:** Brazil to SE Asia
Ecology: Enemy Release

Figure 1. World map showing the native range of the green crab and regions where it has been introduced (numbers are in chronological order). 1 – East Coast, USA (early 1800s), 2 – Australia (early 1900s), 3 – South Africa (1983), 4 – West Coast, USA (1989), and 5 – Tasmania (1992). * Indicates invasion of the very similar Mediterranean species (C. aestuarii) to Japan (1984).

Table 3. Prevalence (%) or presence (+) of parasites infecting green crabs in native and introduced regions.

<table>
<thead>
<tr>
<th>Native region</th>
<th>Native crab</th>
<th>Introduced region</th>
<th>EUSA</th>
<th>WUSA</th>
<th>JAPAN*</th>
<th>VICT</th>
<th>TASM</th>
<th>SAFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>EURO</td>
<td>N((N^a))</td>
<td>372 (284)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(N^a N^b)</td>
<td>2221* (550*)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trematodes</td>
<td>81 (80)</td>
<td>40 (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cestodes</td>
<td>10 (14)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nematodes</td>
<td>0 (0)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acanthocephalans</td>
<td>8 (8)</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhizocephalans</td>
<td>19 (20)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Entomisch isopods</td>
<td>1 (0)</td>
<td>0</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Nemerteans</td>
<td>13 (17)</td>
<td>0</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

* Indicates prevalences for the closely related Mediterranean green crab, C. aestuarii (not used in our comparative analyses).

Notes: Prevalences (%) are for parasites collected from all habitats and by all collection methods. Prevalences in parentheses are for similar habitats (protected bays) and by the same technique (traps). + indicates parasites present in samples collected by other means. Parasitic castrators and egg predators in boldface. \(N\) is sample size, \(N^a\) is sample size for crabs trapped in bays or estuaries. \(N^b\) is sample size examined for rhizocephalans, and \(N^b\) is sample size examined for nemerteans.
Plants introduced to USA had less pathogens

**letters to nature**

*Figure 2* Composition of pathogen assemblages in the plant’s native and naturalized ranges in terms of pathogen type and origin.

Figure 3 More complete release from pathogens increases the degree of noxiousness and invasiveness in the naturalized range. More complete release was measured by the difference in number of associated pathogen species between native and naturalized ranges divided by number associated in the native range. a, Degree of noxiousness in the naturalized range, measured by the proportion of states in which the pathogen is governmentally declared noxious; b, degree of invasiveness in the naturalized range, measured by the proportion of groups listing the species as an invasive problem in natural areas. Each circle represents one plant species; slight random noise was added to species with identical values to render each one visible. A highly influential outlier, *S. halepense* (Johnsongrass), was excluded from statistical analyses and is shown as an open circle.
After invasion by Cryptostegia grandiflora

“The biggest single threat to natural ecosystems in tropical Australia”.
McFadyen, R.E. & Harvey, G.J. (1990)
Maravalia [Hemileia] cryptostegiae (Chaconiaceae: Pucciniales) on Cryptostegia grandiflora in Madagascar

AUS $250 million dollar saving
Crop Movement: Humans benefited from Enemy release of crop plants

- Potato: Peru to Europe
- Coffee: Ethiopia to Sri Lanka and Americas
- Cocoa: Ecuadorian Amazon to Central and South America, West Africa and SE Asia
- Cassava: Sth America to Africa
- Rubber: Brazil to SE Asia
Coffee exemplifies this small population effect

• Arabs employed terminator technology (cf GMO’s today) when they made the cultivation of coffee elsewhere impossible by rendering the beans infertile through parching or parboiling. They traded but no plants grew outside Arabia. (Ukers, 1948)

• The Dutch smuggled plants out and dominated the market with plantations in Java and Sri Lanka (remember tea)

• In 1714 the Mayor of Amsterdam gave King Louis XIV a single five foot as a diplomatic give

• The gift would topple the Dutch from the position as leaders
The romance of Captain Gabriel de Clieu *

By 1777 there were 18,791,680 coffee trees in Martinique.

He stole a seedling from the original tree of King Louis XIV (Jardin des Plantes) by bringing the Kings physician a “lady of quality to whom M de Chirac could give no refusal

• In 1723 he set sail to Martinique (Caribbean) with one plant
• “Water was lacking to such an extent,” says de Clieu, “that for more than a month I was obliged to share the scanty ration of it assigned to me with this my coffee plant upon which my happiest hopes were founded and which was the source of my delight.”
• Upon arrival it was guarded day and night by slaves and surrounded by thorn bushes

* http://ukersallaboutcoffee.wordpress.com/tag/the-romance-of-coffee/ not on handout
But of course enemies do catch up
My Talk

• Past, Present and Future: stories of plant disease

• Movement of agriculture:
  1) Enemy release...but then Catch-up
  2) Adoption

• The role of institutes like Penn State
Adoption is for life not just for tourists
My Talk

• Past, Present and Future: stories of plant disease
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• The role of institutes like Penn State
The declining prominence of Agricultural Science

Sources: USDA National Agriculture Statistical Service (1850-1990) and the International Labour Organization (2000-2008)
There has been a shift from public to private funding for Agricultural Science.

**Real agricultural R&D funding 1970-2008**

- **Total**
- **Private**
- **Public**

Note: Data for 2007-08 are preliminary. Source: USDA, ERS based on data from National Science Foundation, USDA’s Current Research Information Systems (CRIS), and various private sector data sources. Data are adjusted for inflation using an index for agricultural research spending developed by ERS. See the documentation for details.
Situation is now dire

• Total Aid spending on agriculture fell 58% in real terms between 1980 and 2006 (Royal Institute for International Affairs report)
• “we have only ourselves to blame....The world has a shortage of leaders who read history books and understand global trends” Tom Lumpkin director general of the International Maize and Wheat Improvement Center
Historic role of Philanthropy

• Green Revolution: a casual comment in 1941 between Henry Wallace (US Vice President) to Rockefeller President Raymond B. Fosdick
  — “increasing the yield per acre will do more for Mexico than any other means”
Current Role of Philanthropy

THE ROCKEFELLER FOUNDATION

BILL & MELINDA GATES foundation

AGRA
Growing Africa's Agriculture
Why Penn State could have a major Role in subsistence farming

• Globalization
• We have a public mission
• We have world class science
• We have created an environment where the very best science can be integrated with goal orientated research and policy
• We understand evolution and disease better than most
The Cocoa/Cassava ant project in Ghana

Pesticides and attractants
Tom Baker PSU

Bio-Pesticides and Nina Jenkins PSU

Cocoa/Cassava Insect Research
Tony Cudjoe, CRIG Ghana

Plant genetics
Mark Guiltinan and Siela Maximova

Ant behavior
David Hughes PSU

Regional Education
Afreh Nuamah, U. Ghana, Ghana

RNAi and insect feeding
Cristina Rosa - PSU

Ghanaian Sociology
Francis Dodoo, PSU

Cassava Transformation
Willhelm Gruissem
ETH Zurich Switzerland
Conclusion

“Civilization and anarchy are only seven meals apart”  Spanish Proverb

“What has been will be again, what has been done will be done again; there is nothing new under the sun”  Ecclesiastes 1:9