% of People in the World at Different Poverty Levels

80% $<10/day

Source: World Bank Development Indicators 2008
Livestock are often the most important asset for the poor.
Over 700 Million Poor (<$2/day) Livestock Keepers in SSA and SA.

Source: ILRI 2008
Challenges for Livestock Development

1. Short term ‘pilot’ projects without the scale or sustainability.
2. Reluctance to commit significant resources to livestock even after CAADP.
3. Competition from cheap imports (intensively produced chicken costs 50% more in Ghana compared to US imports).
4. Lack of private sector participation and institutional coordination.
5. Lack of breeding strategies in livestock with fewer, weaker players in genetics.
6. Very low adoption of livestock innovations and inputs.
7. Poor infrastructure and access to input/output markets.
8. Inadequate capacity in animal genetics and health.
9. No excess grain for intensive and semi-intensive feeding, and cost of imported feed.
Value Chain Investing: where, who, how, when, expected impact?

**Policy and statistics**

<table>
<thead>
<tr>
<th>Genetics</th>
<th>R&amp;D and Delivery</th>
<th>Value Chains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve genetic material of animals</td>
<td>Managing quality and quantity of feed</td>
<td>Storage, aggregation, transportation and agro-enterprise</td>
</tr>
<tr>
<td></td>
<td>Prevent and treat animal diseases to reduce mortality rates</td>
<td>Processing</td>
</tr>
<tr>
<td></td>
<td>Managing other farm inputs and management practices to maximize benefit from breed, feed and health initiatives</td>
<td>Enabling access to local, regional and global markets</td>
</tr>
<tr>
<td></td>
<td>On farm maintenance</td>
<td>Connecting smallholder farmers to the formal sector and increasing benefits from the informal sector</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processing raw products – ranging from minimal and major value addition</td>
</tr>
</tbody>
</table>

- **Consumers**
Investing in both animal health and genetics is critical for sustainable productivity growth.

Indigenous, backyard chicken

40 eggs/yr.
30% mortality

Health

Genetics

40 eggs/yr.
5% mortality

120 eggs/yr.
30% mortality

120 eggs/yr.
5% mortality

Health & Genetics

Investing in both animal health and genetics is critical for sustainable productivity growth.
Health and genetics are the greatest opportunities.

Animal genetics provides the largest opportunity across all geographies.

There is also opportunity in animal health, particularly in SSA.
LIVESTOCK GENETICS
There are immediate productivity gains from crossbred animals.

Indigenous
Adapted to harsh conditions but low-yielding even when environment improves

Crossbreds/tropically-adapted breeds
Better adapted than exotics and produce more milk than indigenous cows even in “poor” environments
*Slightly lower disease tolerance than indigenous*

Exotic
Low survival in harsh environments; high yields only with “good” feed and management – not feasible for most smallholders
Making crossbreeding work for poor dairy farmers in India and East Africa: Realized productivity opportunity

<table>
<thead>
<tr>
<th>Country</th>
<th>Daily Milk Yield, Kg/d</th>
<th>2014</th>
<th>2022</th>
<th>2030</th>
<th>Productivity of local animals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethiopia</td>
<td>8.20</td>
<td>2.00</td>
<td>1.75</td>
<td>2.50</td>
<td>Red</td>
</tr>
<tr>
<td>Tanzania</td>
<td>6.56</td>
<td>2.00</td>
<td>1.75</td>
<td>2.2</td>
<td>Green</td>
</tr>
<tr>
<td>Uganda</td>
<td>7.41</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>6.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kenya</td>
<td>6.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Productivity of local animals**

- Non-descript cows = ~300-500 Kg/Lactation
- Crossbred cows = ~1,500 Kg/Lactation
- Long-term genetic gains = 3,000 Kg/Lactation

Indian poor smallholder starting with single nondescript cow / buffalo over 10 years

<table>
<thead>
<tr>
<th>Description</th>
<th>2014</th>
<th>2022</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Breeding and net Heifer rearing cost</td>
<td>$100.0</td>
<td>$290.9</td>
<td>$338.9</td>
</tr>
<tr>
<td>Lactation Yield, Kg</td>
<td>$450.0</td>
<td>$1,650.0</td>
<td>$1,650.0</td>
</tr>
<tr>
<td>Total Revenue over productive life of first cow</td>
<td>$719.4</td>
<td>$2,407.8</td>
<td>$3,009.7</td>
</tr>
<tr>
<td><strong>Net revenue over productive life of first cow</strong></td>
<td>$180.7</td>
<td>$1,118.2</td>
<td>$1,227.5</td>
</tr>
</tbody>
</table>

- Crossbred cow from **Unsorted Semen-AI**
- Crossbred cow from **Sorted Semen-AI**

<table>
<thead>
<tr>
<th>Description</th>
<th>2014</th>
<th>2022</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull-bred nondescript cow / buffalo</td>
<td>$100.0</td>
<td>$290.9</td>
<td>$338.9</td>
</tr>
<tr>
<td>Lactation Yield, Kg</td>
<td>$450.0</td>
<td>$1,650.0</td>
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<td>$1,227.5</td>
</tr>
</tbody>
</table>

- Extra heifers over 10 years (Yrs/CI x Calving% x Sex Ratio)-(Repl-Rate)
- Net Revenue (Over 10-Years) if extra Heifers are sold
- Net Revenue (Over 10-Years) if extra heifers are retained to grow herd

<table>
<thead>
<tr>
<th>Description</th>
<th>2014</th>
<th>2022</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra heifers over 10 years (Yrs/CI x Calving% x Sex Ratio)-(Repl-Rate)</td>
<td>$2</td>
<td>$2</td>
<td>$4</td>
</tr>
<tr>
<td><strong>Net Revenue (Over 10-Years) if extra Heifers are sold</strong></td>
<td>$250.7</td>
<td>$1,866.1</td>
<td>$3,406.8</td>
</tr>
<tr>
<td><strong>Net Revenue (Over 10-Years) if extra heifers are retained to grow herd</strong></td>
<td>$980.0</td>
<td>$3,685.8</td>
<td>$6,577.3</td>
</tr>
</tbody>
</table>
**Poultry Genetics: Access to more productive chickens (>300%) adapted to the low-input systems in Africa**

**Lack of feed for intensive poultry keeping in Africa**
- Access to feed grains is a pre-requisite (feed = ~70% of variable cost) for intensive poultry production using productive exotics (300 eggs/year).
- There is NOT enough grain in Africa for poor farmers to feed their chickens. Exotic birds poorly survive the harsh low-input systems.
- India and Africa have many lines of improved tropically adapted chicken breeds created for low-input backyard poultry systems.

**Improve Household Nutrition**
- To increase individual bird productivity and hence poultry meat and or eggs supply to the household
- Integrate with nutrition programs that encourage regular consumption of meat and eggs thereby improving the animal protein intake of the rural poor

**Increase income, especially for poor women**
- Increase total output and value of birds thereby increasing the income-generating potential from sale of eggs and stock on a regular basis.
- Empower poor women chicken farmers to make their own choices on productive low-input chicken germplasm that works best for them

**Local and improved chicken populations by country (millions)**

- **Indigenous Chickens**
- **Improved Chickens**

<table>
<thead>
<tr>
<th>Country</th>
<th>Indigenous</th>
<th>Improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigeria</td>
<td>200</td>
<td>50</td>
</tr>
<tr>
<td>Tanzania</td>
<td>150</td>
<td>25</td>
</tr>
<tr>
<td>Ghana</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>75</td>
<td>5</td>
</tr>
<tr>
<td>Uganda</td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>Kenya</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

**Realized and potential genotype substitution effects for tropically-adapted low-feed input chickens**

- **2014**: 40 eggs
- **2022**: 180 eggs
- **2030**: 220 eggs

Source: Mwacharo et al 2008; Dessie et al 2011; Sonaiya and Swan 2004; MLFD 2013; FAO, 2008;2010; Semambo et al., 2013
1957 vs. 2001 Broiler Fed the Same 2001 Feed

Source: Havenstein – Lohmann
‘Omics-based’ tools: accelerate genetic gain and tropical adaptation

**Accelerated on-farm genetic gains**
- Digital platforms for on-farm performance tracking
- Decision-support and Farmer-to-Farmer performance benchmarking tools
- Genomics tools for selecting cattle and buffalo bulls to go into AI programs

**Economically relevant traits**
- Survival/Hardiness
- Milk Yield
- Mastitis
- Lactation persistency
- Parasites Repellence
- Feed/Fodder Efficiency
- Immune response
- Disease tolerance
- Adaptability Indices
- Reproductive Performance

**Genotype adaptation to local agro-ecology**
- Targeting of appropriate genotypes to the optimum agro-ecology
- Omics-based research on tropical livestock genetics and health adaptation
- Local feed/fodder resource use efficiency

**Development of synthetic breeds**
- “Eventually, Africa and India need to create breeds that are best suited to local agro-ecological conditions and the harsh to poor smallholder environment
- Genome editing biotechnologies

Sources: Silva et al., 2010; Zhao, 2013;

---

Accelerated genetic gains in tropical dairy cows
Milk yield improvement: Kg./lactation

Year of Development of synthetic breeds

<table>
<thead>
<tr>
<th>Year</th>
<th>Milk Yield (Kg./lactation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>1,400</td>
</tr>
<tr>
<td>1981</td>
<td>1,800</td>
</tr>
<tr>
<td>1986</td>
<td>2,200</td>
</tr>
<tr>
<td>1991</td>
<td>2,600</td>
</tr>
<tr>
<td>1996</td>
<td>3,000</td>
</tr>
<tr>
<td>2001</td>
<td>3,400</td>
</tr>
<tr>
<td>2006</td>
<td>3,800</td>
</tr>
</tbody>
</table>
1. Technologies to accelerate the rate of tropical adaptation of high-producing cattle from temperate to tropical systems. EXAMPLE: Holstein made adaptable to Africa using genome editing
2. Technologies to match animal genotype to the appropriate agro-ecologies. EXAMPLE: Dairy Genetics East Africa phenotype & genotype
3. Technologies which improve reproductive performance. EXAMPLE: Sexed-specific sperm, sorted sperm, cold-chain-free AI systems, affordable heat detection technologies, cow-side diagnostic testing.
4. Low-input / high producing poultry lines. EXAMPLE: A tropically-adapted chicken that produces 150 eggs per year to produce 300 eggs per year, still under low-input systems.

5. Sexed-specific progeny using natural mating. EXAMPLE: Spermatogonial Stem Cells; Inactivated Y-carrying sperms

6. Efficient utilization of poor feeds in local agro-ecologies. Climate sensitive agriculture. EXAMPLE: microbiomics to increase digestibility of celluloses and hemi-celluloses

7. Acceleration of on-farm genetic gains. EXAMPLE: using multi-omics approaches such as genomics, transcriptomics, metabolomics & proteomics.
A ranking process to identify priority species

1. **Need and Relevance**
   - (# of animals and impact on smallholders)
   - Cow milk
   - Goat milk
   - Cattle meat
   - Chicken meat
   - Hen eggs
   - Goat meat
   - Buffalo milk
   - Buffalo meat
   - Pig meat
   - Sheep meat
   - Sheep milk
   - Bird meat
   - Camel milk
   - Cow hides
   - Duck meat
   - Turkey meat
   - Goose and guinea fowl meat
   - Other bird eggs

2. **Demand and Opportunity**
   - (current value of product, future VOP, yield gap)
   - Cow milk
   - Goat milk
   - Cattle meat
   - Chicken meat
   - Hen eggs
   - Goat meat
   - Buffalo milk
   - Buffalo meat
   - Pig meat
   - Sheep meat
   - Sheep milk

3. **Fit with Program Objectives**
   - (impact on women, nutrition, and environment)
   - SSA
     - Cow milk
     - Cattle meat
     - Hen eggs
     - Goat milk
     - Chicken meat
     - Goat meat
     - Sheep meat
   - SA
     - Cow milk
     - Goat milk
     - Hen eggs
     - Chicken meat
     - Buffalo milk (SA)
     - Cattle meat
     - Goat meat

**Final Selection**
- Cattle (dairy)
- Chickens
- Small ruminants

*NOTE: Aquaculture was omitted from this analysis because 1) it is a separate system with little relevance to land-based species and 2) research indicates that in SSA, aquaculture contributes only 5% of fish production and 10% of fish consumption (World Fish Center, 2009), and fish are expected to become more expensive compared with other food products (IFPRI 2003)*
## Diseases priorities: impact on smallholders, ROI, comparative advantage

14 Diseases prioritized based on global need

<table>
<thead>
<tr>
<th>Disease</th>
<th>Total Annual SH Loss (Africa)</th>
<th>Total Annual SH Loss (SA)</th>
<th>Total Annual SH Loss</th>
<th>Cattle</th>
<th>Small Ruminants</th>
<th>Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endoparasites</td>
<td>3332</td>
<td>1659</td>
<td>4992</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Peste des Petits Ruminants (PPR)</td>
<td>3611</td>
<td>NA</td>
<td>3611</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contagious Bovine</td>
<td>3274</td>
<td>NA</td>
<td>3274</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pleuropneumonia (CBPP)</td>
<td>1851</td>
<td>922</td>
<td>2773</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Foot and Mouth Disease</td>
<td>868</td>
<td>573</td>
<td>1441</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Trypanosomes (T. congolense, T. vivax and T. brucei)</td>
<td>1166</td>
<td>242</td>
<td>1409</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Contagious Caprine</td>
<td>1027</td>
<td>NA</td>
<td>1027</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pleuropneumonia (CCPP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newcastle disease‡</td>
<td>415</td>
<td>313</td>
<td>728</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goat Pox and Sheep Pox</td>
<td>479</td>
<td>234</td>
<td>714</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brucellosis (B. Abortus, B. Melitensis)*</td>
<td>344</td>
<td>314</td>
<td>659</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Lumpy Skin Disease</td>
<td>487</td>
<td>NA</td>
<td>487</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rift Valley Fever (RVF)*</td>
<td>477</td>
<td>NA</td>
<td>477</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Bovine Tuberculosis (TB)*</td>
<td>201</td>
<td>205</td>
<td>407</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Coast Fever†</td>
<td>286</td>
<td>NA</td>
<td>286</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 7 new products selected:
- **Feasibility / ROI**
- **What others are doing**
- **Unique advantage**

<table>
<thead>
<tr>
<th>Disease / Pathogen</th>
<th>Product Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBPP</td>
<td>New vaccine</td>
</tr>
<tr>
<td>East Coast Fever</td>
<td>Vaccine</td>
</tr>
<tr>
<td>Ectoparasites</td>
<td>New formulations</td>
</tr>
<tr>
<td>Endoparasites</td>
<td>New formulations and vaccine</td>
</tr>
<tr>
<td>Trypanosomiasis</td>
<td>Vaccine</td>
</tr>
<tr>
<td>PPR</td>
<td>DIVA vaccine, Eradication in SSA</td>
</tr>
<tr>
<td>Newcastle Disease</td>
<td>Vaccine delivery improvements</td>
</tr>
</tbody>
</table>
Decision Framework

Potential Annual Impact on Smallholders

- Feasibility (technical, access)
  - High
  - Medium
  - Low

- Low ROI
- Medium ROI
- High ROI

- Bovine TB
- Brucellosis
- ND village vx strategy
- ND pilot vx market impact
- ND pilot chick vx
- CCPP vx production
- Tryps dx
- FMD vx bank
- CBPP vx bank
- ECF dx
- RVF vx bank
- RVF outbreak
- G/S Pox vx bank
- G/S Pox improve vx
- Brucellosis dx
- LSD dx
- LSD improve vx
- Adapt vx pkg
- CCPP dx
- FMD improve vx
- Tryps dx
- FMD improve vx
- CCPP improve vx
- Brucellosis ctrl strategy
- RVF multivalent vx
- Tryps dx
- FMD dx
- ECF dx
- Bovine TB improve vx
- RVF dx
- Bovine TB improve dx
- LSD vx bank
- LSD improve vx
- G/S Pox dx
- G/S Pox improve vx
- CCPP vx bank
- Bovine TB dx
- RVF dx
- Bovine TB dx
Livestock Vaccines are Important

• All animals and people can suffer from diseases, some of which are zoonotic.
• Prevention of a disease can be less expensive than treatment for the disease. It may also help ensure meat quality.
• A vaccine may help to prevent a disease by stimulating an innate or acquired immune response.
• Vaccine development in the “genomic era” can be guided by host gene expression signatures.*
• High throughput data models will drive faster discovery times.

*Pulendran et al.
Vaccines Technology is rapidly changing

FORWARD VACCINOLGY
Live vaccine (attenuated)
Killed vaccine
Subunit vaccine (non-recombinant)
Subunit vaccine (recombinant)
DNA vaccine

REVERSE VACCINOLOGY
Bio-informatics now allows us to use the information of the genome sequence of a pathogen.
We can now catalog all the protein antigens that a pathogen can express.
This approach relies heavily on the availability of high-throughput systems which can screen for protective immunity.
The host/gene expression signatures can now guide vaccine development.
Immune response signatures can now be quantified. (Pulendran, et al)
1. Global initiative for livestock vaccine discovery utilizing reverse vaccinology. EXAMPLE: Begin to build the livestock data base of immune response signatures for specific diseases.
2. Increase focus on specific neglected diseases. EXAMPLE: PPR Eradication follows Rinderpest.
3. Low cost, accurate diagnostic tests. EXAMPLE: Cell phone based, point of care diagnostics.
4. One Health partnerships. EXAMPLE: Public/private partners work on improved vaccines to benefit livestock and people.

5. Animal health public private partnerships to ensure sustainability. EXAMPLE: Stronger engagement by the private sector to ensure sustainable delivery.
CONCLUDING REMARKS

◆ Livestock are an important asset for the poorest of the poor.
◆ For sustainable improvement, focus on BOTH Genetics and Health.
◆ Genetic technologies: genomics, bio-informatics as well as reproduction.
◆ Climate/environmental sensitive adaptations using technology.
◆ Proper nutrition will be needed to “fuel” improved genotypes.
◆ Vaccination to prevent disease will replace treatment of disease.
◆ Reverse vaccinology shows great promise.
◆ Low cost diagnostic testing will also be key to making progress.

◆ THERE IS A LOT WE ALL CAN DO TO HAVE AN IMPACT!!