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Improving Food Security in Africa by Genetic Enhancement of More Resilient Poultry

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Feed the Future Innovation Lab for Genomics to Improve Poultry

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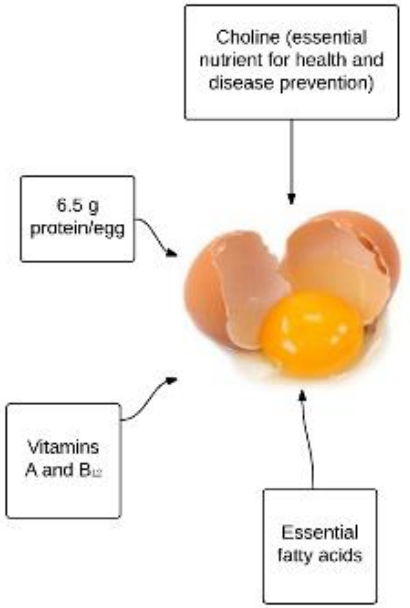
Importance of poultry for livelihoods, food security, and sociocultural significance in developing countries

- Smallholder poultry production is often the primary source of income and sustenance.
  - Poultry (meat and eggs)
    - Eggs rich in both micro- and macro-nutrients
    - Meat provides protein, potassium, zinc and iron
  - A living savings bank
  - Less water consumption and land usage
  - High feed efficiency
- Developing countries
  - Affect marginal dietary proteins in both quality and quantity
  - Human health



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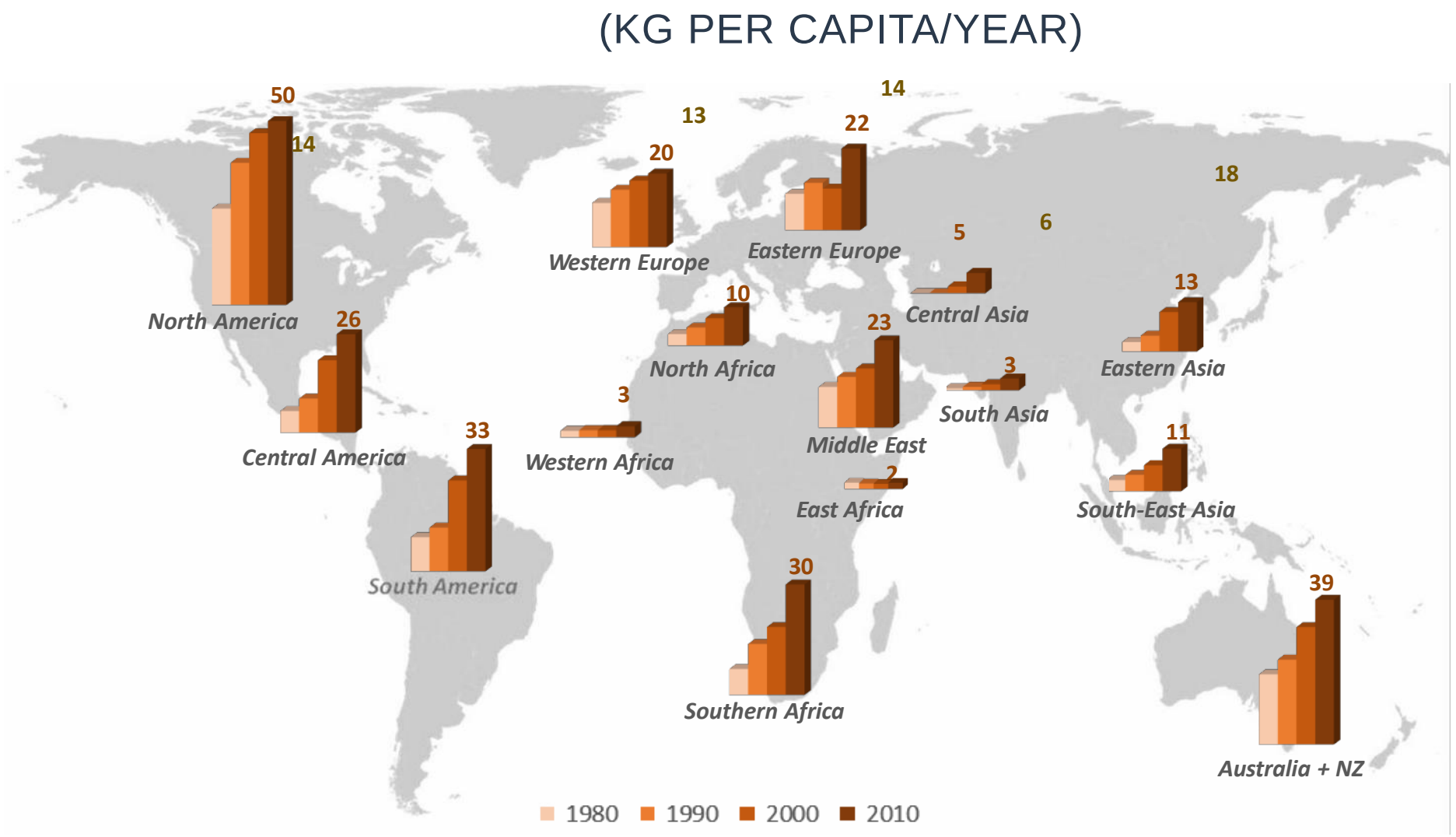
Poultry meat consumption



Source: FAOSTAT

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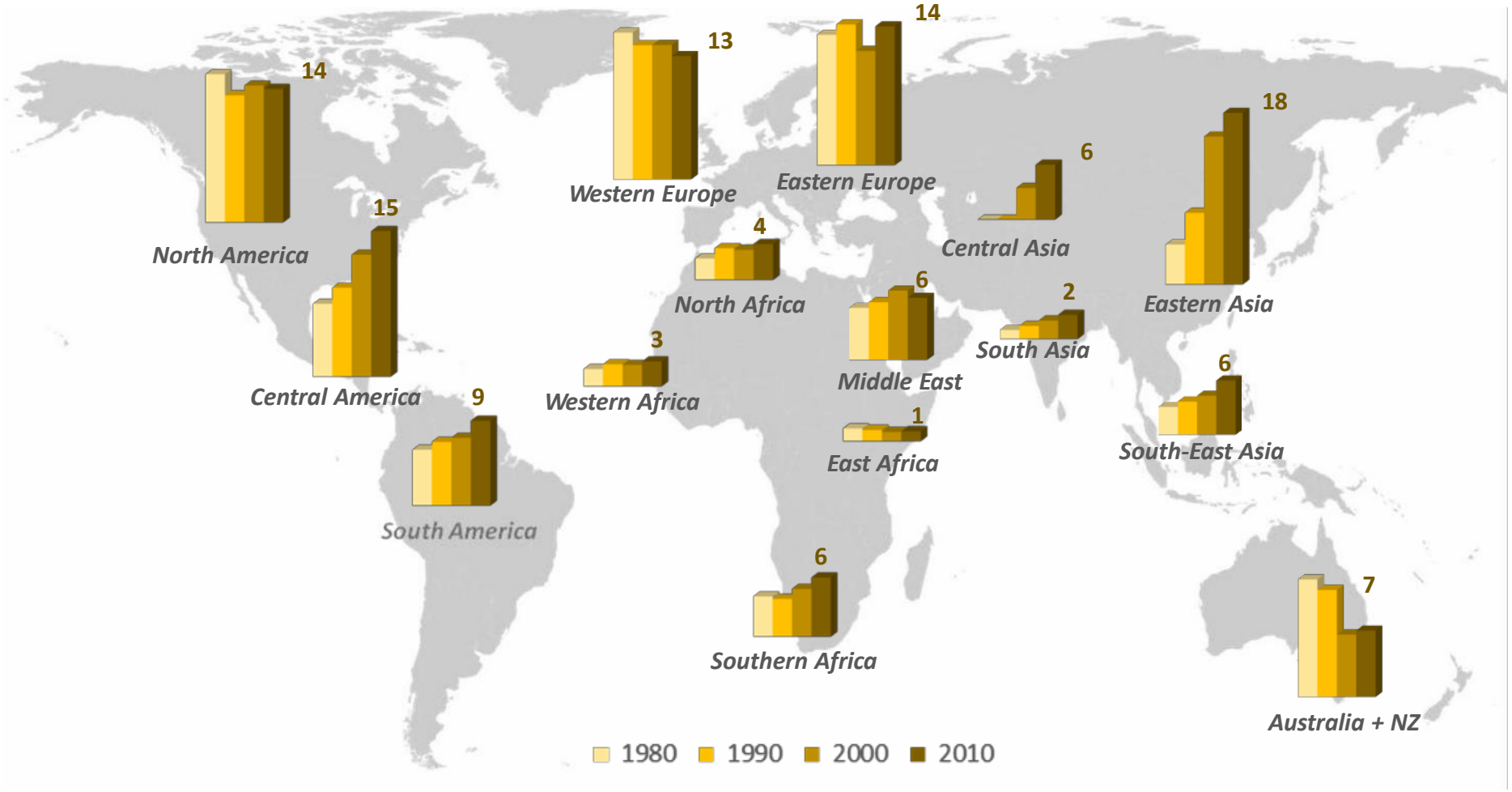
Eggs consumption

(KG PER CAPITA/YEAR)



Source: FAOSTAT

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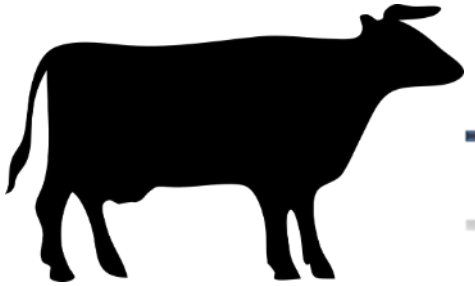
Global animal production projection, 2005-2050

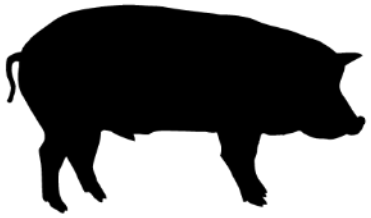

+121%


+65%


+92%

+62%


+66%


+43%

Source: Alexandratos & Bruinsma, 2012

Major challenges for smallholder poultry production in rural Africa

- Infectious diseases
- Systems with low biosecurity
- Limited "cold chain" for vaccination
- Limited available feed
- Inadequate extension support
- Harsh climate

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Multidisciplinary research team

Breeding and Genetics
Genomics
Bioinformatics
Statistic genomics
Quantitative genetics
Poultry virology
Poultry epidemiology
Genetic diversity
International development
Poultry disease
Agricultural economy

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ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE
Sokoine University of Agriculture

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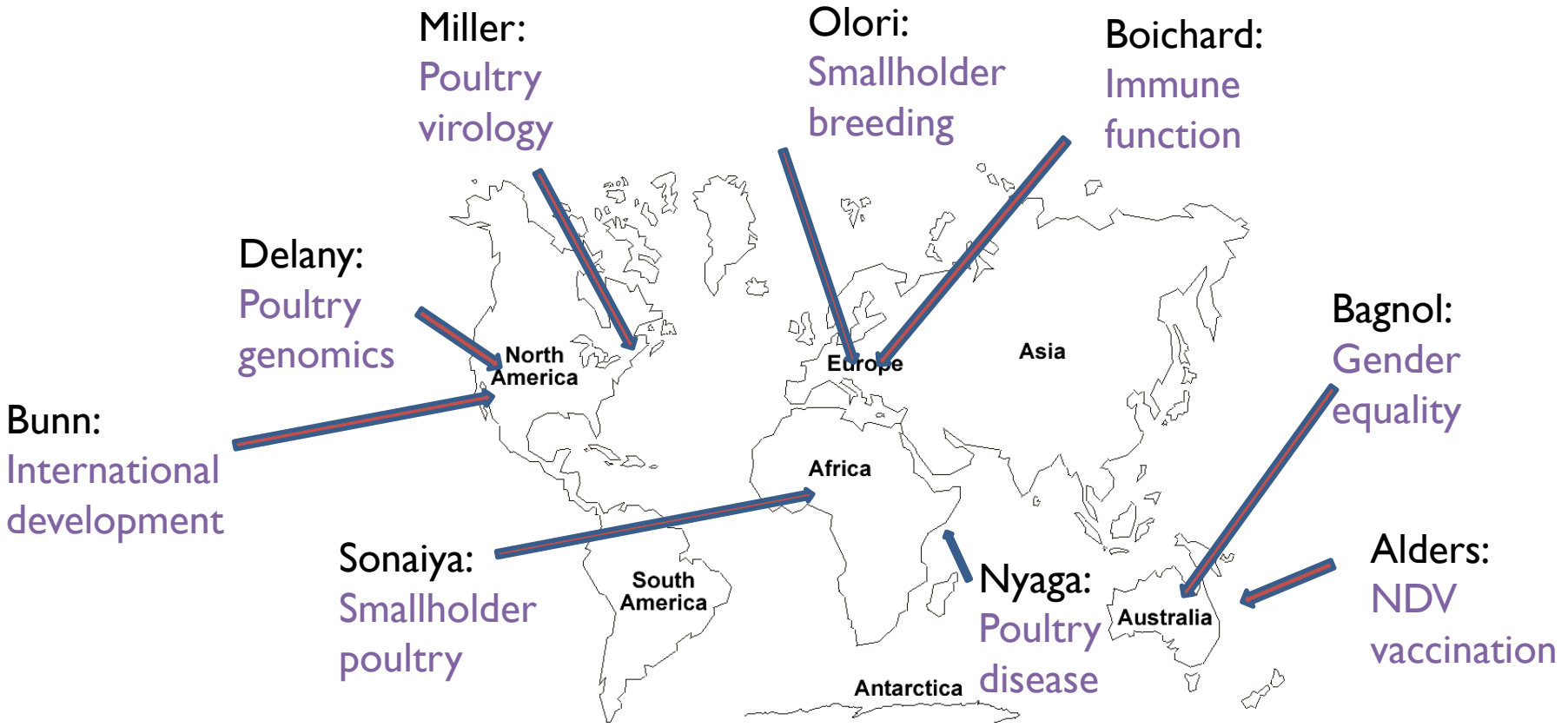
Research Advisory Committee



Resolving two of the most significant factors

1. Disease resistance

2. Adaptation to environmental stresses of Africa (i.e. heat stress)

Why NDV and heat stress?

- Newcastle Disease Virus is the number one disease constraint to rearing poultry in Africa
  - 80% mortality in unvaccinated village flocks
  - Highly contagious
- Why not just vaccinate?
  - Challenges with ensuring cold chain
  - Counterfeit vaccines
  - Costs of revaccination in scavenging system
- Heat stress reduces productivity

Why genetic and genomic approaches?

BROILERS

ACRBC (1957)Males – 2001 Feed

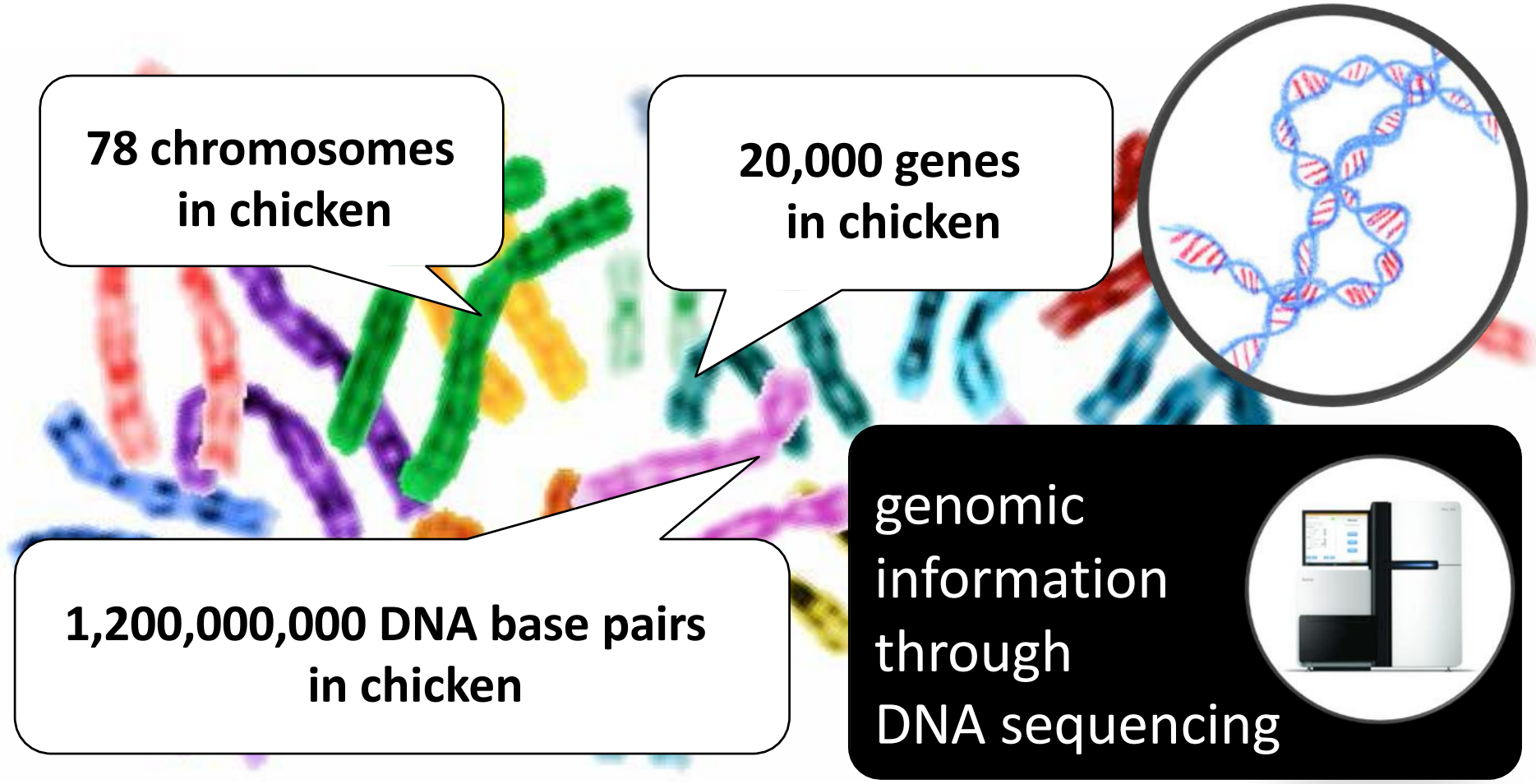
Ross Males (2001) – 2001 Feed

Day 43 **Day 57** **Day 71** **Day 85**

Havenstein and Qureshi, 2004

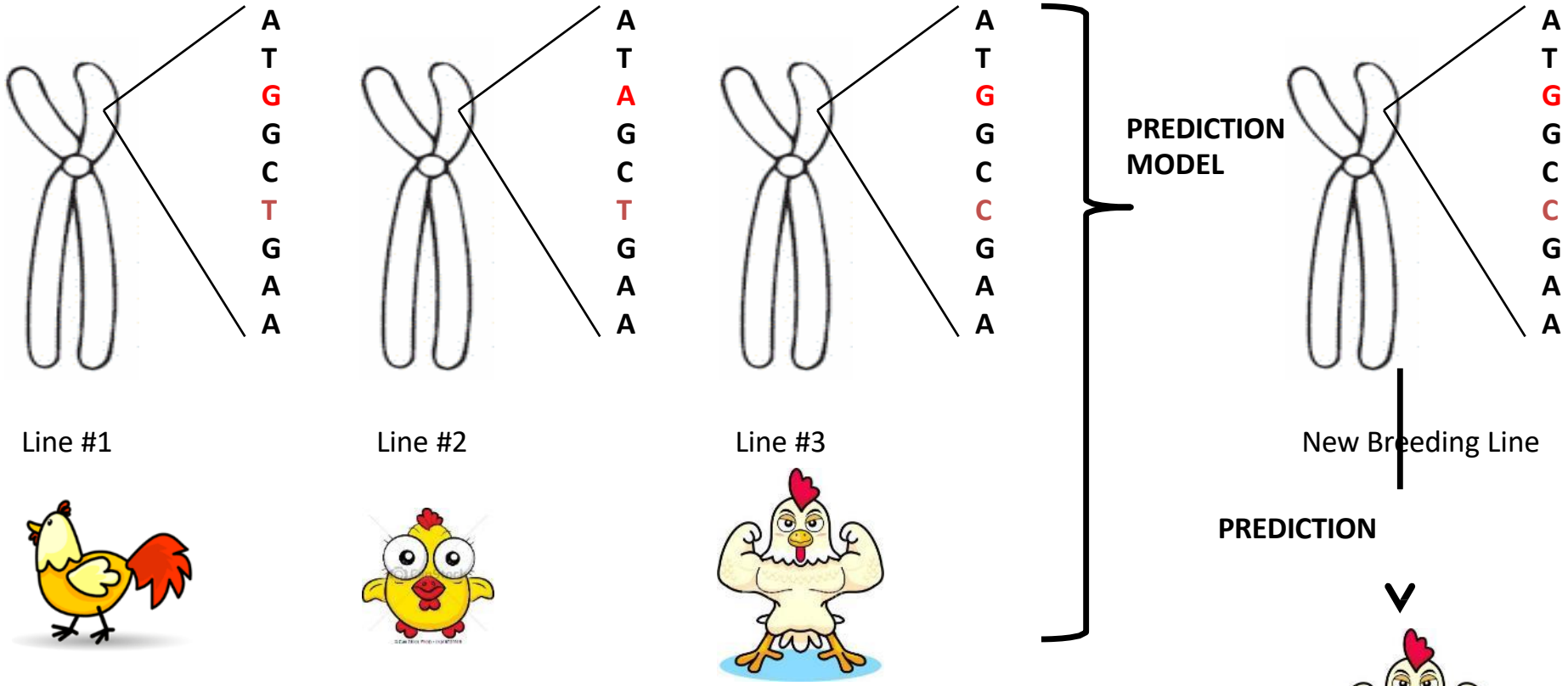
What are additional benefits?

- Accelerate genetic improvement
- High accuracy and efficiency
- Reduced environmental footprint
- Sustainable improvements
- Animal health → human health
- Integrate genomics and biology: holistic approach
- In addition, simultaneously improve vaccine efficacy (complementary to vaccination approach)

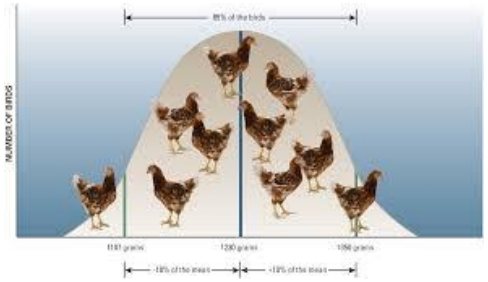


Genome … millions of A, C, T, and Gs…

Genomic prediction models

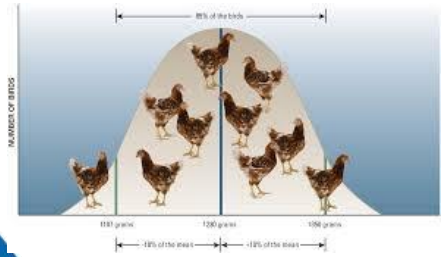


The Breeding Cycle

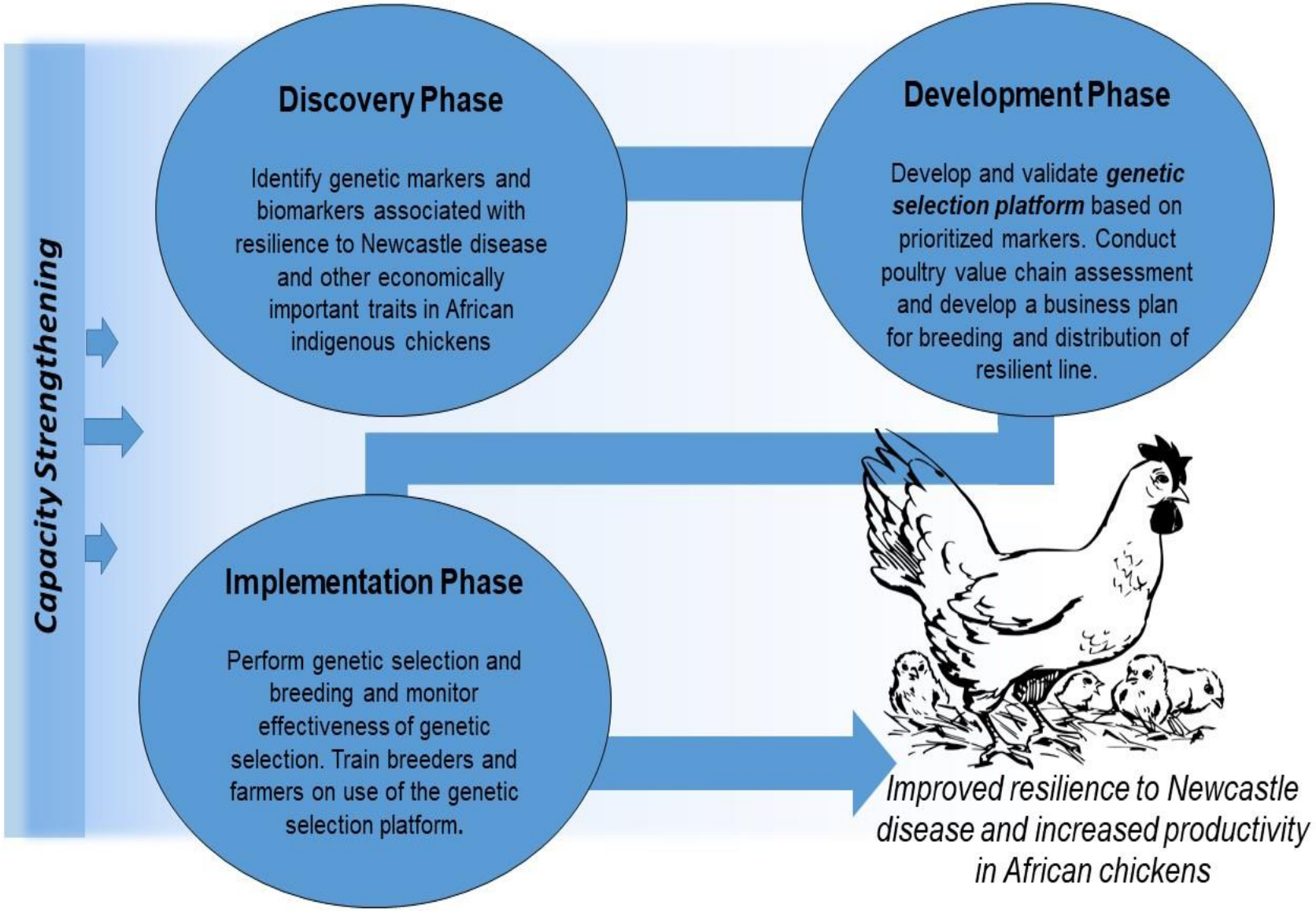


Modified from Poland 2016

(accelerated) The Breeding Cycle

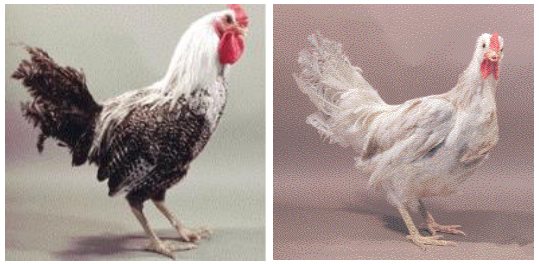


Modified from Poland 2016


Capacity Strengthening
Discovery Phase
Identify genetic markers and biomarkers associated with resilience to Newcastle disease and other economically important traits in African indigenous chickens
Development Phase
Develop and validate genetic selection platform based on prioritized markers. Conduct poultry value chain assessment and develop a business plan for breeding and distribution of resilient line.
Implementation Phase
Perform genetic selection and breeding and monitor effectiveness of genetic selection. Train breeders and farmers on use of the genetic selection platform.
Improved resilience to Newcastle disease and increased productivity in African chickens

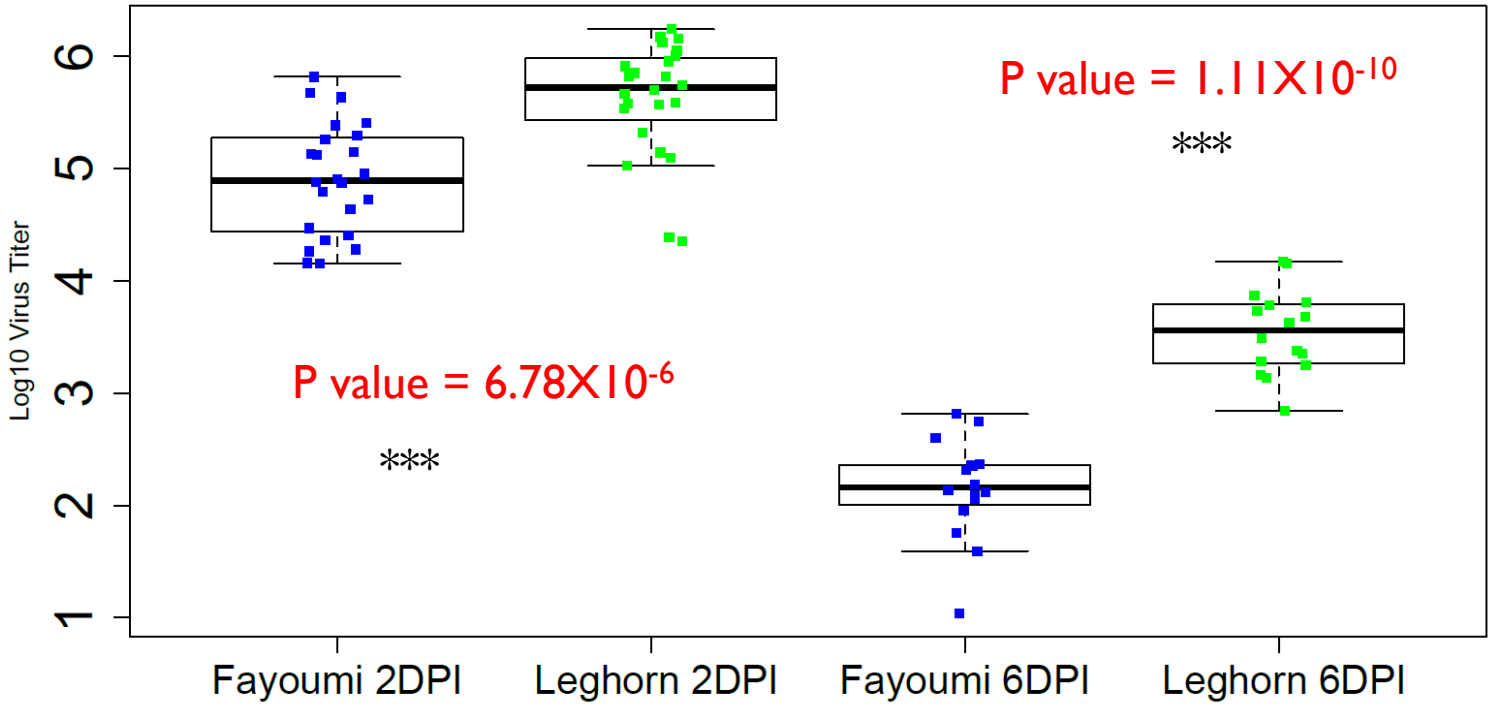
Experimental populations in the US

- University inbred lines
  - Fundamental scientific discovery platform
  - Established NDV resistance-susceptibility model
  - One of inbred lines: Fayoumi line was from Egypt, similar to African ecotype
  - To identify genes and signal pathways associated with NDV resistance and heat tolerance in chickens



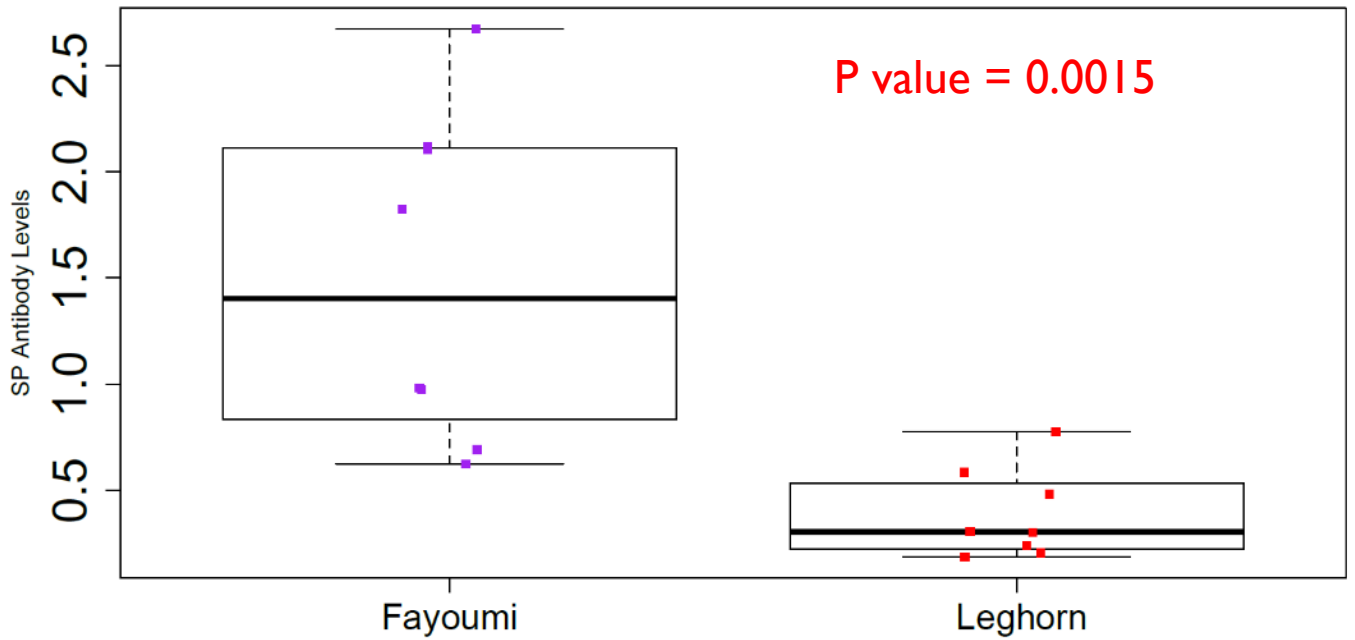
- Hy-Line Brown Line
  - Major line for larger-scale African producers, more adapted to hot climate environment with high egg production
  - Can be challenged in controlled environment in the US
  - Rapid translation into application

Virus load between Fayoumi and Leghorn lines



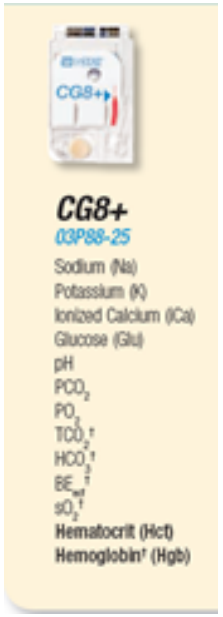
Village-type chicken had lower viral load

Antibody response in Fayoumi and Leghorn lines



Village-type chicken had stronger immune response

Blood parameters for heat stress



Chemistries/Electrolytes (4)

- Sodium (Na); Potassium (K); Ionized Calcium (iCa); Glucose (Glu)

Blood Gases (7)

- pH; PCO2; PO2; TCO2; HCO3; Base Excess (BE); sO2

Hematology (2)

- Hematocrit (Hct); Hemoglobin (Hb)

Heat stress-related biomarkers in blood

	Beneficial Response	Heat Stress (HS) vs. Non-Treated (NT)					
		Fayoumi			Leghorn		
		4 hr	6 d	9 d	4 hr	6 d	9 d
Na^+	+	NS	NS	NS	-	NS	NS
K^+	+	NS	+	NS	-	-	NS
iCa^{2+}	+	NS	NS	NS	+	NS	+
Glu		NS	NS	NS	+	NS	+
pH	-	+	+	-	NS	NS	-
PCO2	-	-	-	NS	NS	NS	NS
TCO2	-	NS	-	-	NS	NS	NS
HCO3	-	NS	-	-	+	NS	NS
BE	-	NS	NS	-	NS	NS	NS
PO2	+	NS	+	+	-	NS	NS
sO2	+	+	+	NS	-	+	-
Hct		NS	-	NS	NS	-	NS
Hb		NS	-	NS	NS	-	NS

- The heat-resilient Fayoumis maintained a relatively well-balanced acid-base balance
- The Leghorn line had significant acute responses with disrupted acid-base balance and metabolic disorders

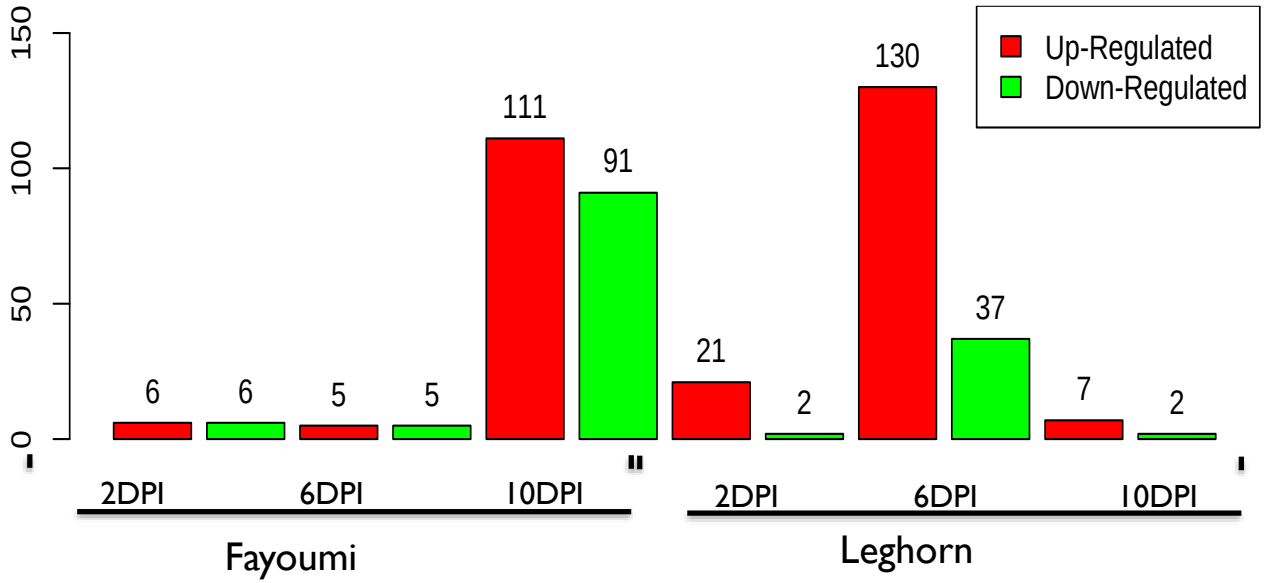
(Poultry Science, Wang, et al., 2017)

Advanced genomic approaches

RNA-seq: identify genes and signal pathways associated with NDV and heat stress resistance

Genome-wide association study: identify natural variation associated with NDV and heat stress resistance

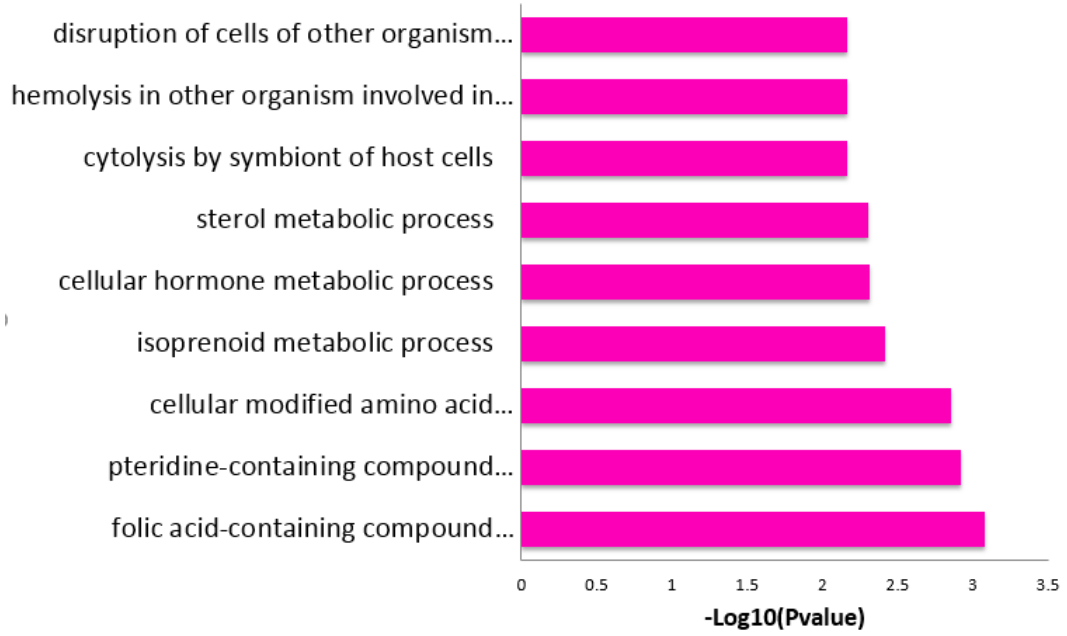
Genes associated with immune function and disease resistance by RNA-seq



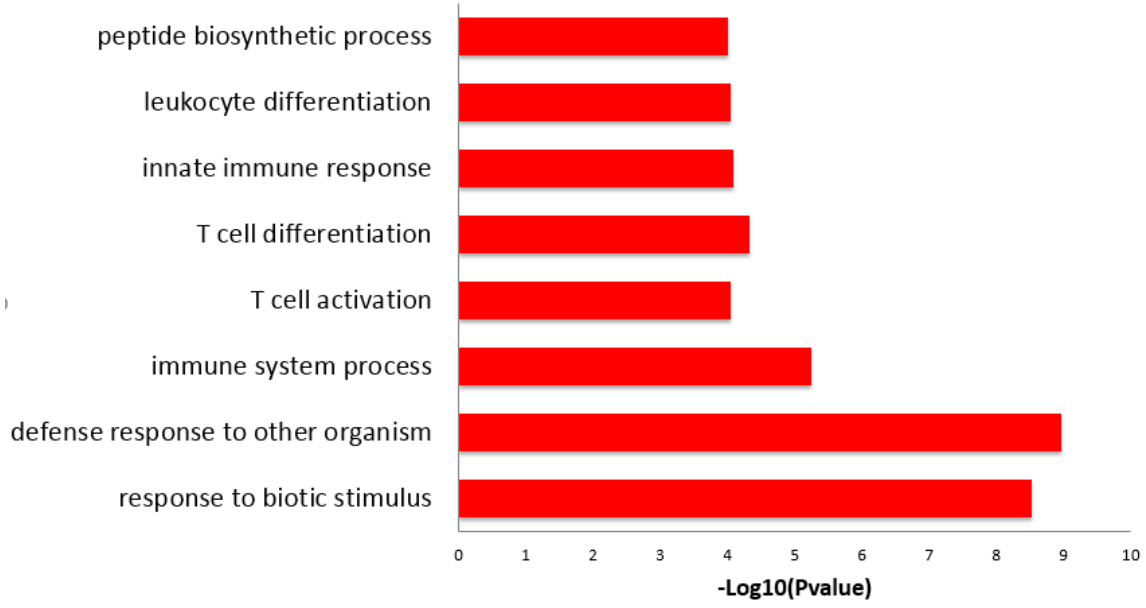
Distinct responses between Fayoumi and Leghorn lines during the different stages of infection

Distinct enriched signaling pathways between Fayoumi and Leghorn lines

Leghorn at 6 DPI



Fayoumi at 10 DPI



Metabolic related signaling pathways were affected in Leghorn line (susceptible)

Immune and defense related signaling pathways were activated in Fayoumi line (resistant)

Why African local ecotypes?

- Adaptability to the environment
  - Productive in local environment
  - Heat resistance: survival in harsh conditions, survival during long distance transportation
  - Local feed resource
  - Predatory escape
- Culturally relevant
  - Taste
  - Physical appearance

The African ecotypes allow us to meet the diverse needs of our final users

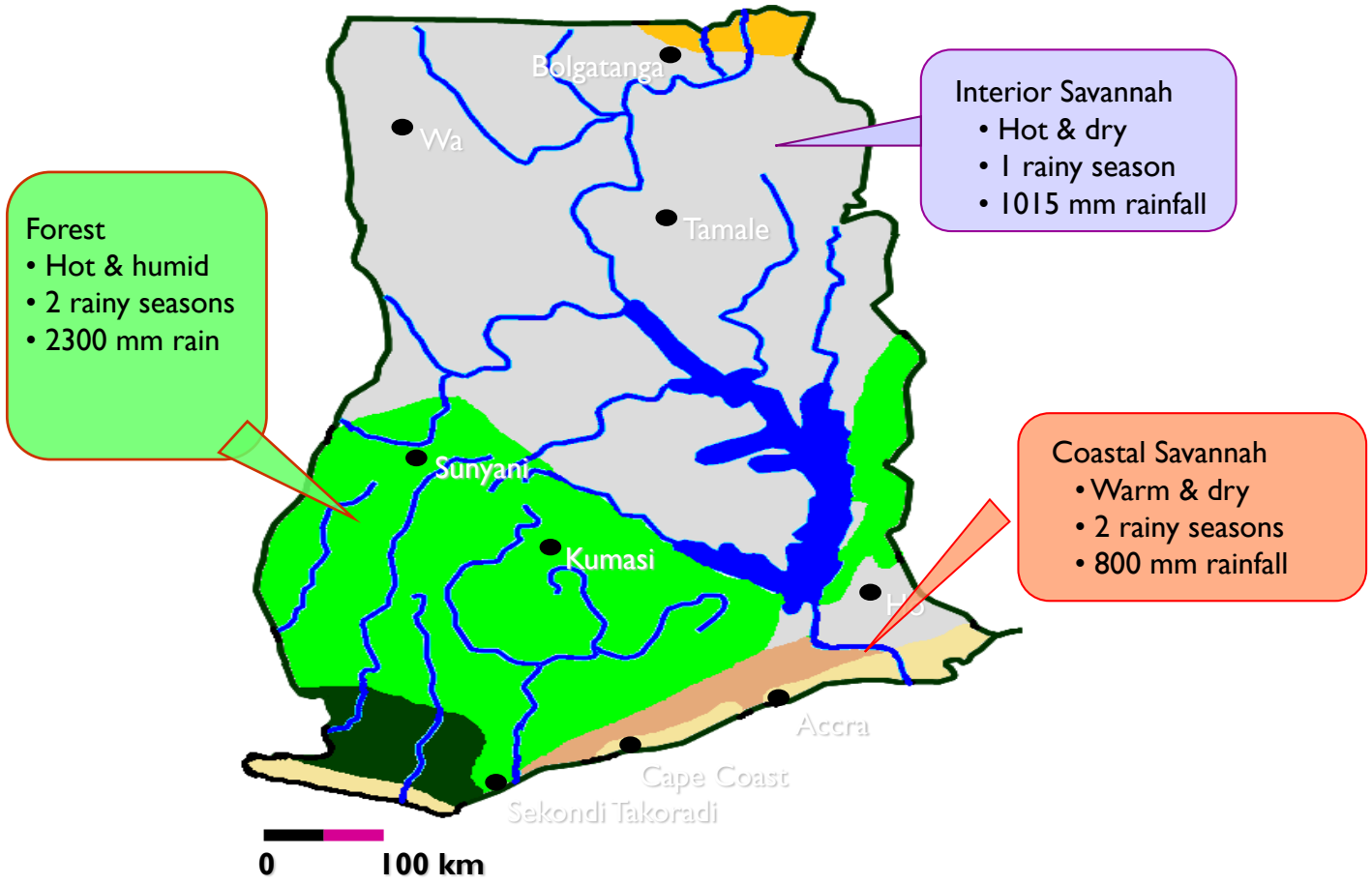
Three Ecotypes in Tanzania (East Africa)

Kuchi (Game-meat bird, desired characteristic)

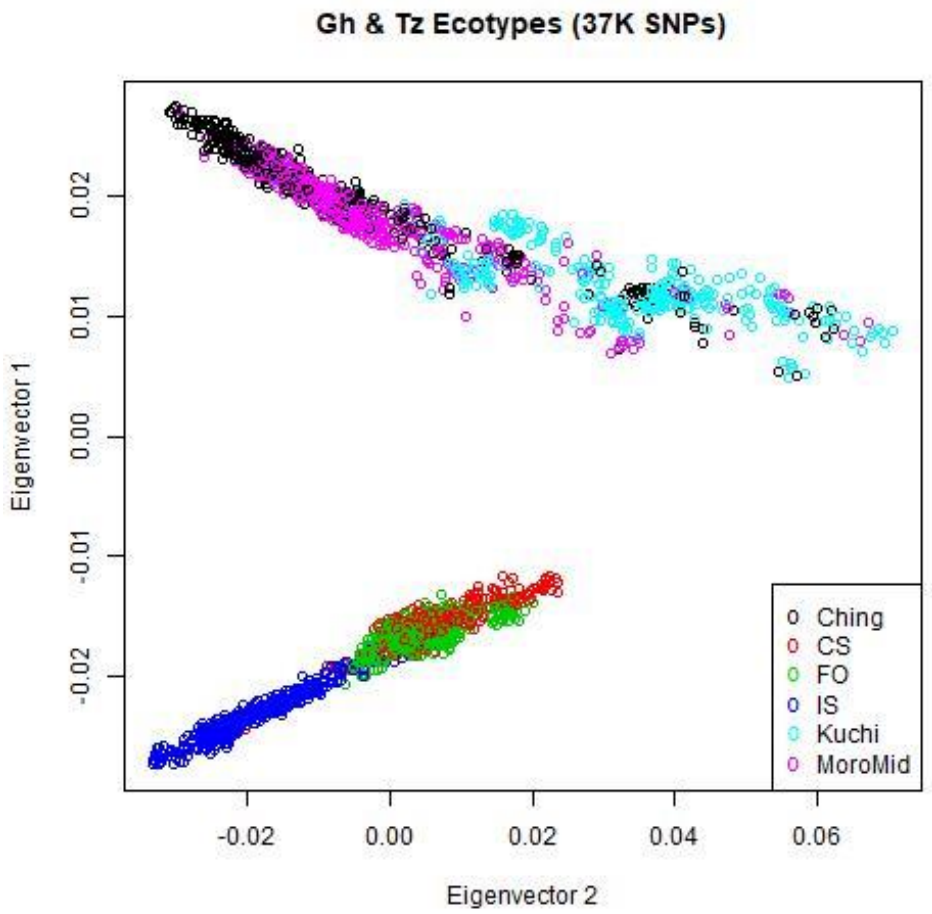
Ching'Wekwe

Morogoro

Three Ecotypes in Ghana (West Africa)



Genetic analysis of 6 African ecotypes



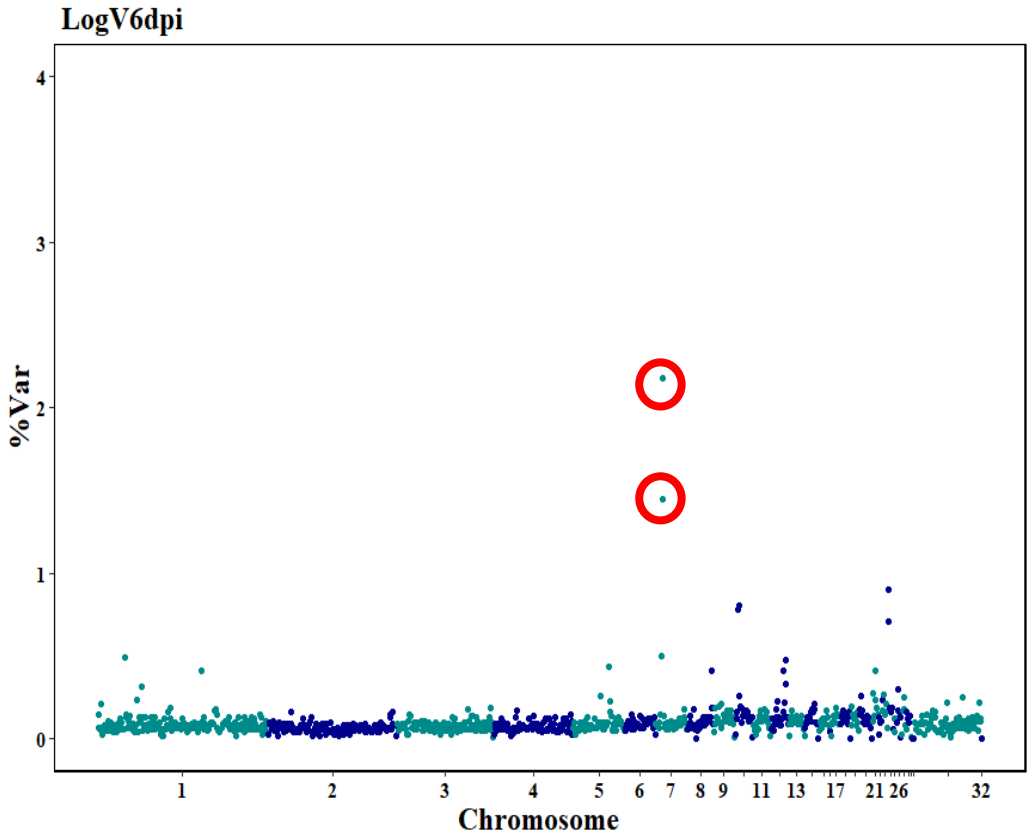
Distinct genetic variants between Tanzania and Ghana ecotypes

Genetic heritability (h^2) estimates

Trait	h^2	
	Gahna	Tanzania
Pre-infection growth rate	0.551	0.344
Post-infection growth rate	0.426	0.213
Log_{10}Antibody titer	0.286	0.216
Log_{10}Viral load, 2dpi	0.492	0.111
Log_{10}Viral load, 6dpi	0.233	0.262
Post-Challenge growth rate	0.09	0.344

Medium to high genetic heritablities in disease and growth related parameters suggest genetic improvement is a promising approach

Genetic variance in viral load



#SNPs		chr_Mb		%Genetic variance	
UOG	SUA	UOG	SUA	UOG	SUA
311	724	1_31	24_0	0.49	7.66
255	890	7_8	24_1	2.18	1.04
113	636	7_7	25_1	1.45	0.58
301		7_6		0.5	
601		10_4		0.81	
554		10_3		0.78	
814		24_1		0.9	
629		24_0		0.71	
			Total	7.82	9.28

Significant genetic variance controlling viral load

Summary

- Viral load and antibody response are important parameters for evaluating disease resistance
- Moderately high heritabilities of these parameters suggest genetic improvement is feasible and promising
- Selection on these traits can reduce viral load (10-12% in log/30-70% in original scale) and increase antibody response (4-5% in log/38-49% in original value) per generation
- Confirmed nature of polygenic control of disease resistance to NDV
- Hundreds of genetic markers associated with resistance can aid the development of diagnostic platform for genetic selection

Strengthening capacity for sustainable genetic improvement in Africa

Improving infrastructure of poultry research facilities and laboratories

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Training the next generation of poultry genetics and health researchers

Training students and staff on poultry handling, biosecurity, sample collection, laboratory analyses, and advanced genetics.

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Building partnerships with local private, governmental, and NGO poultry organizations and farmers.

Major Achievements

- Renovated breeding, challenge, and natural challenge facilities in Africa
- Established breeding and research flocks in Ghana and Tanzania
- Conducted poultry research trials and identified genetic markers associated with resilience in the face of NDV challenge and heat stress
- Developed preliminary selection platform (5,000 SNP panel) for genetic selection and breeding of birds with enhanced resilience

Launching the second phase (2018-2023)

- Assess correlations of crucial production traits with disease resistance traits: egg production, growth rate etc.
- Select and breed genetically enhanced local ecotypes
- Characterize circulating strains of NDV in Ghana and Tanzania
- Determine and monitor the effectiveness of genomic selection
- Conduct value chain assessment and business plan development
- Develop a training toolkit on application of genetic selection platform

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Acknowledgements

















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