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Where Next for Livestock Innovation?

Chris Warkup
Director

Biosciences
Knowledge Transfer Network

Oxford Farming Conference 2011

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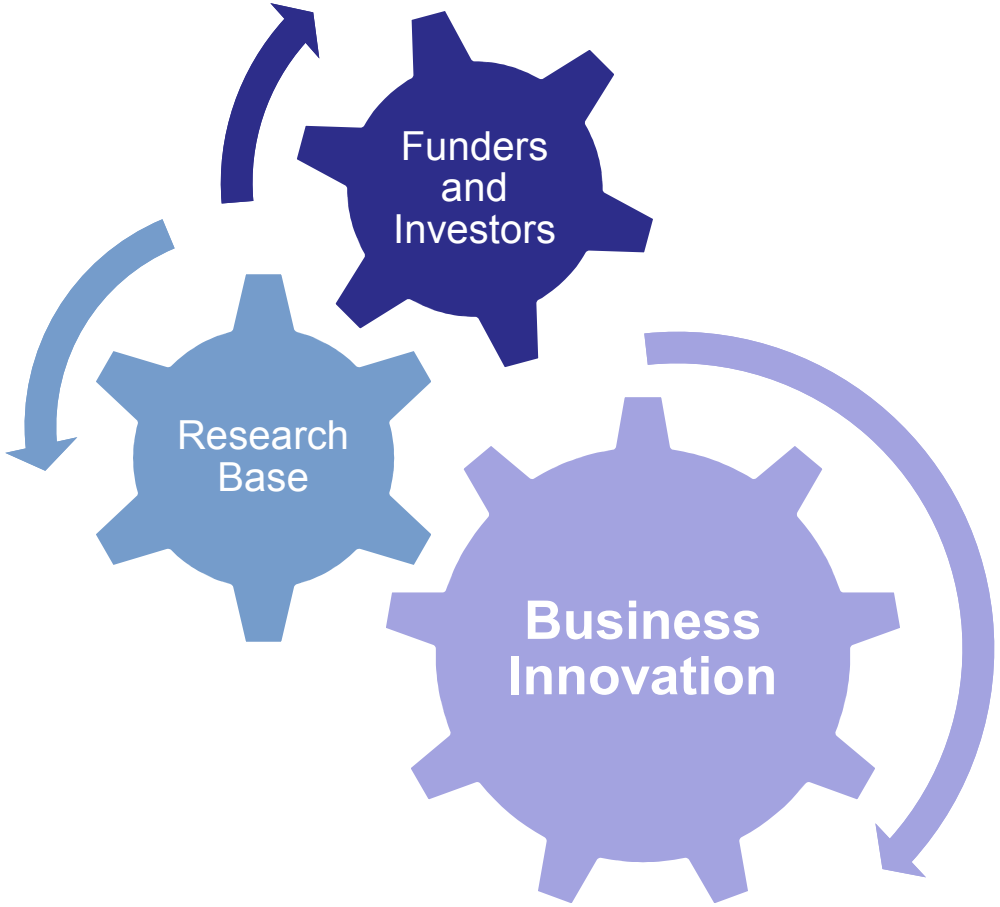
‘To Connect and Catalyse’



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"Since prehistory humans have been dependent on animals."

"We still are."

Prof. Maggie Gill

Chief Scientific Adviser, Rural Affairs and Environment, Scottish Government

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"Over the next 50 years, the world's farmers and ranchers will be called upon to produce more food than has been produced in the past 10,000 years combined, and to do so in environmentally sustainable ways."

Jacques Diouf, FAO Director General, 2007

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"…the biologically based industries move into a new era as different from contemporary production as today's methods are from those of the eighteenth century."

Prof. Sir John Marsh, 2001

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Overview

- The breadth of past innovations
- Some impacts
- Things happening right now
  - Breed improvement
  - Other innovations from genomics
  - Advanced reproductive technologies
  - GM
- Where next?

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Some Historical Innovations

- Genetics
  - Breed substitution
  - Within breed improvement
- Reproduction
  - Oestrus synchronisation
  - Induced parturition
  - MOET etc.
  - Wider use of AI
  - Sexed semen
  - Pregnancy scanning
  - SCNT cloning
- Growth modifiers
  - Hormone implants
  - β-agonists
  - Ionophores
  - pST
  - bST (Posilac™)
- Animal health
  - SPF/high health
  - Diagnostics
  - Vaccines (including food safety applications)
  - Disease resistance

- Nutrition
  - Formulation for requirements
  - In-feed
    - Synthetic amino acids
    - Enzymes
    - Synthetic and/or bioavailable vitamins & micronutrients
    - Pre- and probiotics
    - Bypass protein
    - Immune modifiers
- Other biotechnologies
  - GM
    - Agricultural traits
    - Pharmaceuticals (Atryn™,
  - Improvac™ taint vaccine
- Post-farm-gate
  - Controlling meat eating quality
  - Extended shelf-life
  - HACCP
  - Traceability/authenticity

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Selective Breeding is a Powerful Tool

Photo by Chris Muiden

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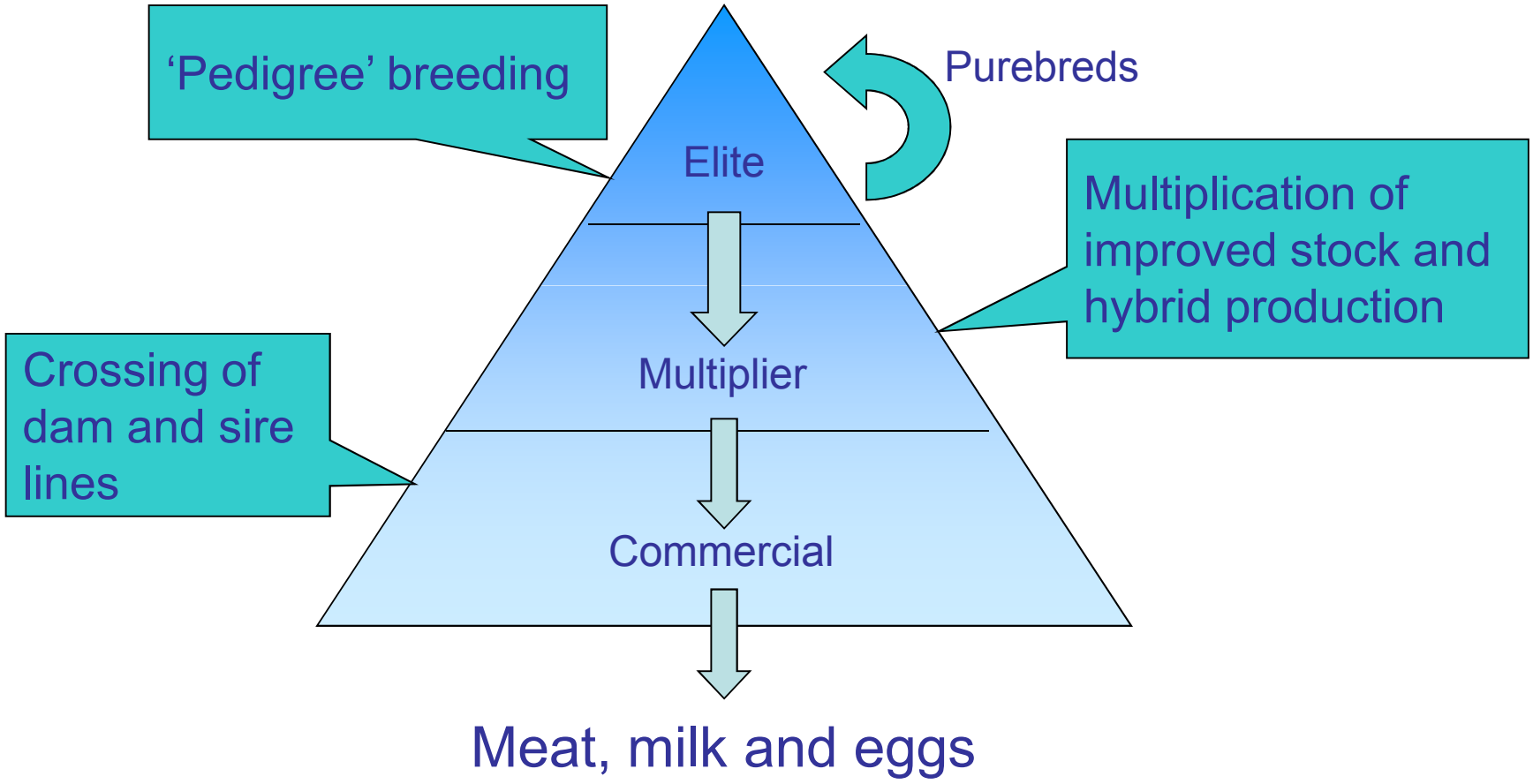
Classical Breeding Pyramid



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Very Significant Improvements in Efficiency

Species	Trait	Indicative performance		
		1960s	2005	% Change
Pigs	Pigs weaned /sow/year	14	21	50
	Lean %	40	55	37
	Kg lean meat/tonne feed	85	170	100
Broiler chickens	Days to 2 Kg	100	40	60
	Feed conversion ratio	3.0	1.7	43
Layer hens	Eggs per year	230	300	30
	Eggs/tonne feed	5000	9000	80
Dairy cows	Milk/cow/lactation (Kg)	6000	10,000	67

Modified from van der Steen, Prall and Plastow, 2005 J. Anim Sci 83: E1-E8

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Life Cycle Analysis Modelling - % change in emissions per tonne product through genetic improvement (1988-07)

	Methane	Ammonia	Nitrous Oxide	GWP_{100}
Layers	-30	-36	-29	-25
Broilers	-20	10	-23	-23
Pigs	-17	-18	-14	-15
Dairy	-25	-17	-30	-16
Beef	0	0	0	0
Sheep	-1	0	0	-1

Project for Defra by Genesis Faraday and Cranfield University (AC0204), 2008
These figures exclude and post-farm-gate efficiencies such as reduced waste.

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Breeding Goals Now More Balanced

- Traditional breeding goals
  - Growth
  - Yield
  - Efficiency
  - (quality)

- Current breeding goals
  - Growth
  - Yield
  - Efficiency
  - Fitness
  - Fertility
  - Food quality
  - Food safety
  - Disease resistance
  - Welfare
  - Emissions
  - Robustness
  - Behaviour
  - Managing diversity

DNA diagnostics and genomic selection have most value here

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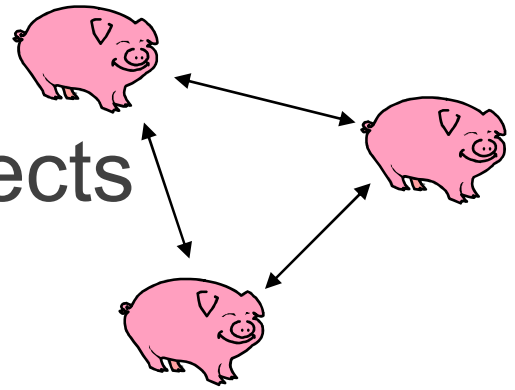
What's Happening Now in Breed Improvement

- Crossbred Breeding Values
- Accounting for social/group effects
- Many more DNA tools to:
  - aid selection
  - manage crossbreeding
  - detect and eliminate inherited diseases
  - measure and manage biodiversity
  - predict genetic merit at a young age



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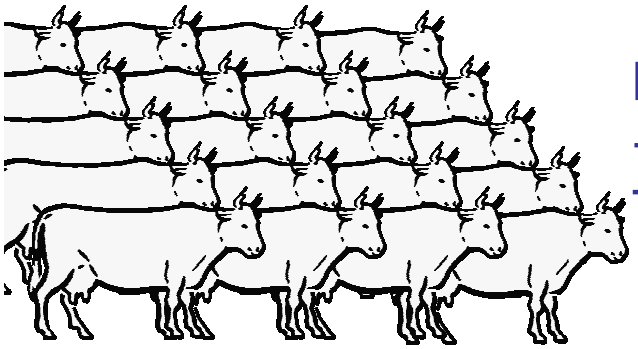
The Principle of Genomic Selection

Meuwissen, Hayes and Goddard, 2001 – Prediction of total genetic value using genome-wide dense marker maps. Genetics 157

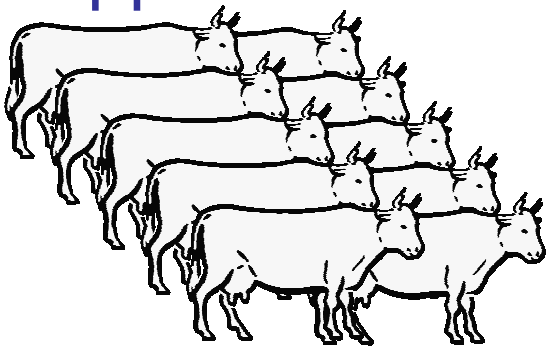
Training



Measured traits
+
Thousand of markers

} Prediction equations

Application



Thousand of markers
+
Prediction equations

} mEBV

Genomic Selection in Dairy Cattle

- Adopted in several countries for Holstein cattle in the
  - U
  - U
    b
- Car
- Less accurate but shorter generation interval means gain per year increases by about 60%

Opportunities in beef cattle and other species, but

- In principle can be applied to those difficult traits
- Major limitation is access to LARGE numbers of animals with relevant trait records
- Some limitations not yet clear
- Opportunity for 'public' breeding programmes and international collaboration

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Other Innovations from Genomics

- Improved diagnostics
- Molecular epidemiology
- Rational vaccine design
- Host–pathogen molecular biology
  - Breeding for disease resistance
  - Optimal breeding stock/vaccine combinations
  - GM disease resistance
- New therapeutics
- Gene ‘therapy’
- DNA tools for traceability, parentage assignment/verification and authenticity testing

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Reproductive and cell technologies

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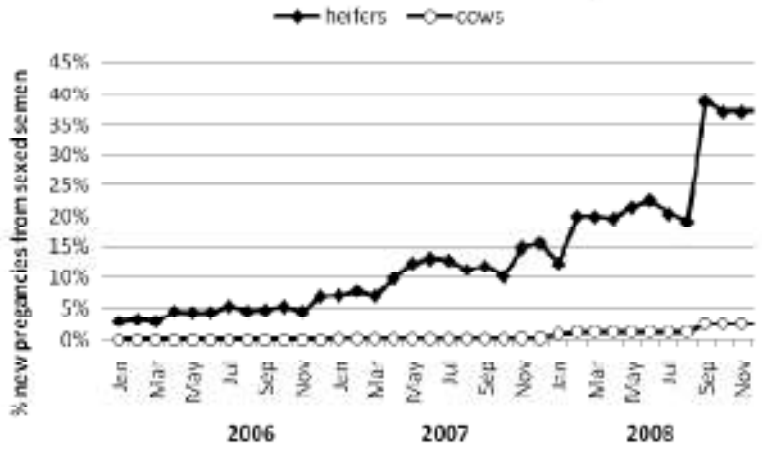
Semen Sexing - Impact

- 1999 sexed semen available in the UK
- De Vries et al, 2009 estimate 3.7m doses sexed semen in the US in 2009 and that by late 2011 10% of replacement heifers will be born from sexed semen

"Compassion in World Farming and RSPCA believe that not only does using sexed semen make good business sense, but increased uptake of sexed semen will mean fewer male dairy calves killed on the farm shortly after birth or exported to continental veal systems."

Figure 3. Percentage of new pregnancies with heifer calves in the national population (heifers and cows) that result from inseminations with sexed semen from January 2006 to December 2008.



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Potential Applications of (SCNT) Cloning


Courtesy Roslin Institute

- Research – improving knowledge of biology
- Insurance – safeguarding valuable animals
- Recovery – obtaining animals from tissue
- Conservation – increasing animal numbers
- Biosecurity – international trade in genetics
- Dissemination of improved genetics
- Niche roles in breed improvement


Bull 86[2] at Texas A&M. Produced 3 years after Bull 86 died – cloned from cells frozen for 15 years


Clones of Yellow Jacket (left) and Panhandle Slim (right) both famous rodeo bulls [Photo credits: Candace Dobson]

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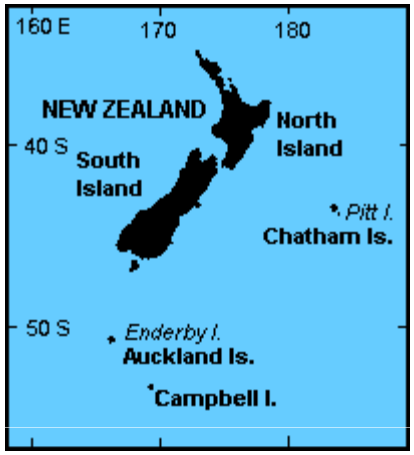
Enderby Island Cattle



- Imported onto Enderby Island 1894
- 47 feral animals culled by NZ Govt. in 1991
  (semen straws and oocytes collected, but poor quality)
- Two survivors found in 1992 (one died)
- Single female survivor produced one bull calf from 35 attempts at IVF with frozen semen
- One SCNT clone of the female in 1998, four more in 1999
- 13 Individuals by 2007

www.rarebreeds.co.nz/cattlepro.html

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Possible Inverted Breeding Pyramid

Elvis (2005) produced by Viagen from a Yield Grade 1 A crossbred steer carcass

Trait records and genotypes

Genomic Selection of the best allele combinations for that commercial environment

Multiplier

Elite

R&D Programmes and development lines

Crossing of dam and sire lines

+ sex ratio control

Multiplication of improved stock and hybrid production

+ sex ratio control

'Pedigree' breeding

Original ideas credited to Ken Laughlin and Theo Meuwissen

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Genomics with Cell Technologies

- 'Whizzo' Genetics (Haley and Visscher 1998) – *In vitro* gametogenesis coupled with 'Genomic Selection' could reduce generation intervals to < 1 month

Developmental Cell *11*, 125–132, July, 2006 ©2006 Elsevier Inc. DOI 10.1016/j.devcel.2006.05.010

In Vitro-Differentiated Embryonic Stem Cells Give Rise to Male Gametes that Can Generate Offspring Mice

Karim Nayernia,[1,7,*] Jessica Nolte,[1] Hans W. Michelmann,[2] Jae Ho Lee,[1] Kristina Rathsack,[1] Nadja Drusenheimer,[1] Arvind Dev,[1] Gerald Wulf,[3] Ingrid E. Ehrmann,[4] David J. Elliott,[4] Vera Okpanyi,[5] Ulrich Zechner,[5] Thomas Haaf,[5] Andreas Meinhardt,[6] and Wolfgang Engel[1]

mals, PGCs arise from
of the early embryo th
blood lineages of the e
Hage, 1994; Zhao and
PGCs migrate through
the developing fetal go
curs between E10.5 an

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Genetic Modification

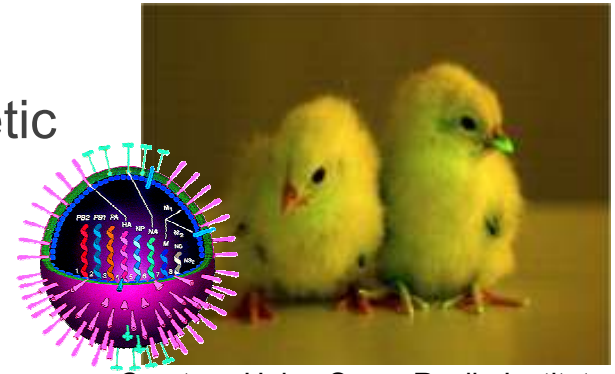
Enhancing diversity through GM

- Correction of defects
- Increased copy number
- Deletion
- Modified regulation
- Induced sex linkage
- Moving genes within a species
- True transgenesis
- Novel constructs/Synthetic biology

AquaBounty's AquAdvantage® Salmon

Enviropigs™, University of Guelph

Fao.org



Courtesy Helen Sang, Roslin Institute

Where Next?

Innovations

- Animal breeding progress will accelerate, but trait measurement remain critical
- Major opportunities from genomics combined with cell/reproductive technologies
- Even greater advances through GM
- Positive impacts on
  - Efficiency
  - Environment
  - Animal health and welfare
  - Food quality and safety
  - Human health

Regulation

- Technologies get better with use
- Assessment should be based on outcomes not on the technology used
- There are risks from inaction
- Need a systems approach to weigh up the pros and cons
- Rate of innovation in the EU likely to be slower than elsewhere due to regulatory and market conditions

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SEVENTH FRAMEWORK PROGRAMME