DEPARTMENT OF

DAIRY SCIENCE

University of Wisconsin-Madison

  

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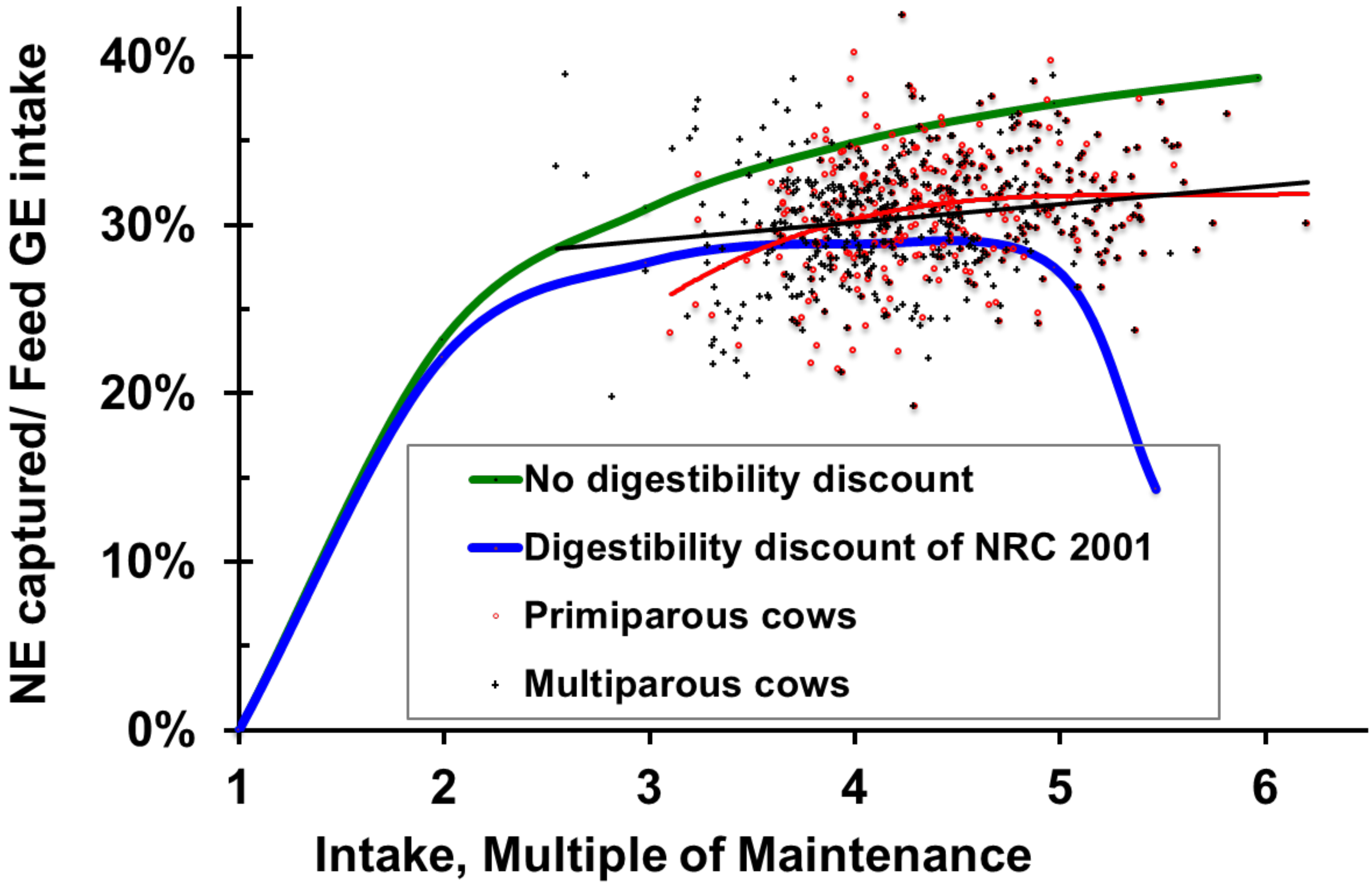
Genomic Selection for Improved Feed Efficiency

Dr. Kent A. Weigel
Department of Dairy Science
University of Wisconsin – Madison

Selection for Improved Feed (Energy) Efficiency

Milk Production versus Efficiency



VandeHaar, 2013



Selection for Feed Efficiency – Why Now?

Before Genomics

- Measurement for 1 cow = $300
- Young bulls per year = 1,500
- Daughters per bull = 100
- Cows per year = 150,000
- Cost per year = $45 million
- Generation interval = 5 years

$30,000 per bull

After Genomics

- Measurement for 1 cow = $300
- Cost per genomic test = $45
- No. reference cows = 25,000
- Young bulls per year = 5,000
- Cost per year = $1.1 million
- Generation interval = 2 years

$218 per bull



Feed Efficiency Project Partners

- Iowa State University (Ames, IA)
- Michigan State University (East Lansing, MI)
- University of Florida (Gainesville, FL)
- University of Wisconsin-Madison (Madison, WI)
- United States Dairy Forage Research Center (Madison, WI)
- USDA Animal Genomics & Improvement Lab (Beltsville, MD)
- Virginia Tech (Blacksburg, VA)
- Purina Animal Nutrition Center (Grays Summit, MO)
- Miner Agricultural Research Center (Chazy, NY)
- University of Alberta (Edmonton, AB, Canada)



Summary of Feed Efficiency Data

Animals:

- 16,219 bulls without phenotypes
- 3,522 cows with phenotypes

Phenotypes:

- Residual feed intake (RFI): kg / d
- Dry matter intake (DMI): kg / d
- Metabolic body weight (MBW): $kg^{0.75}$
- Net energy in milk (Milk NE): Mcal / d

Genotypes:

- 57,055 SNPs per animal

Definition of Residual Feed Intake

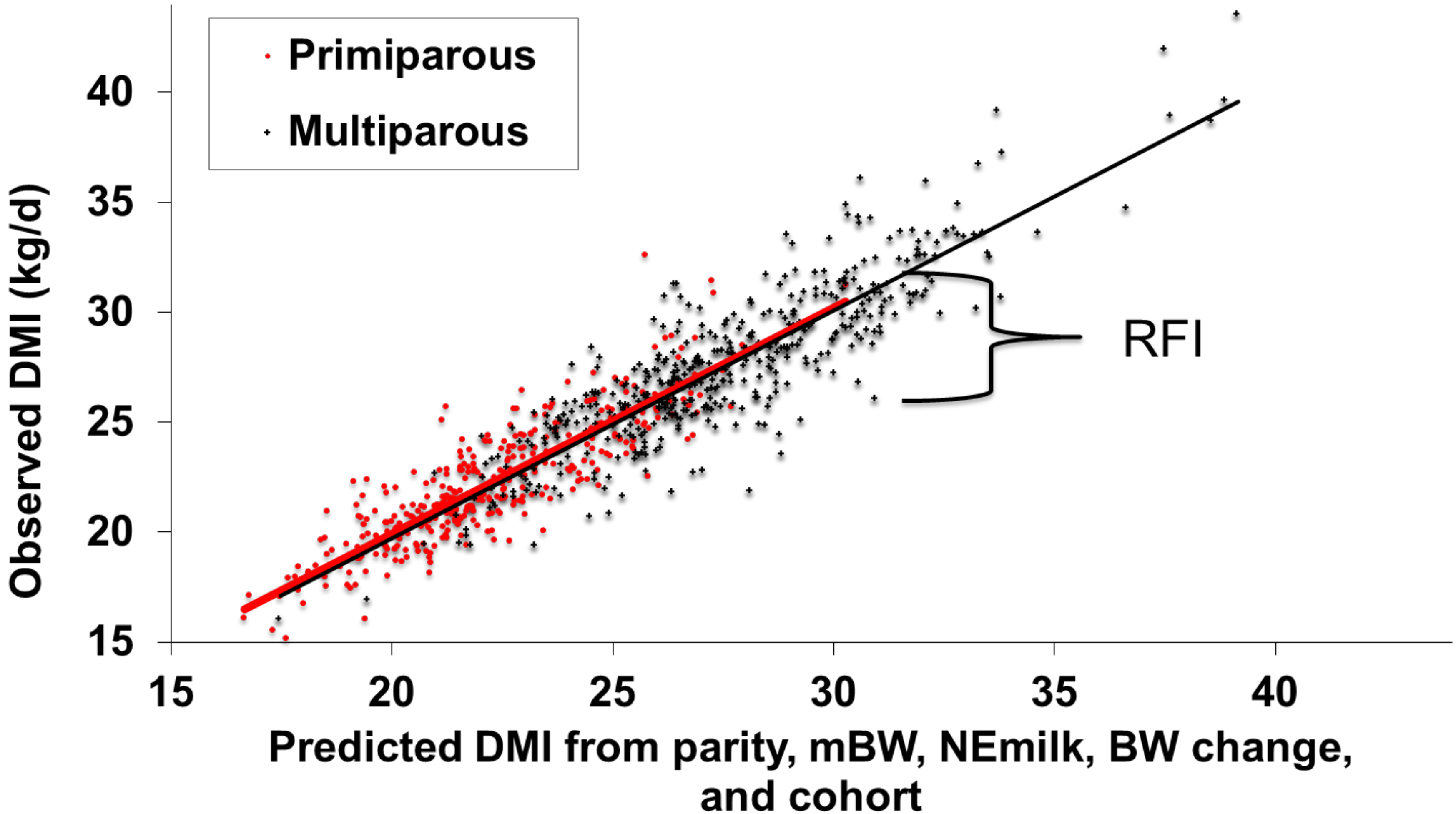
RFI = Observed DMI - Expected DMI

where:

Expected DMI = Average intake of cows in the same cohort or contemporary group, after adjustment to a constant level of milk production, milk composition, body weight, and body weight change



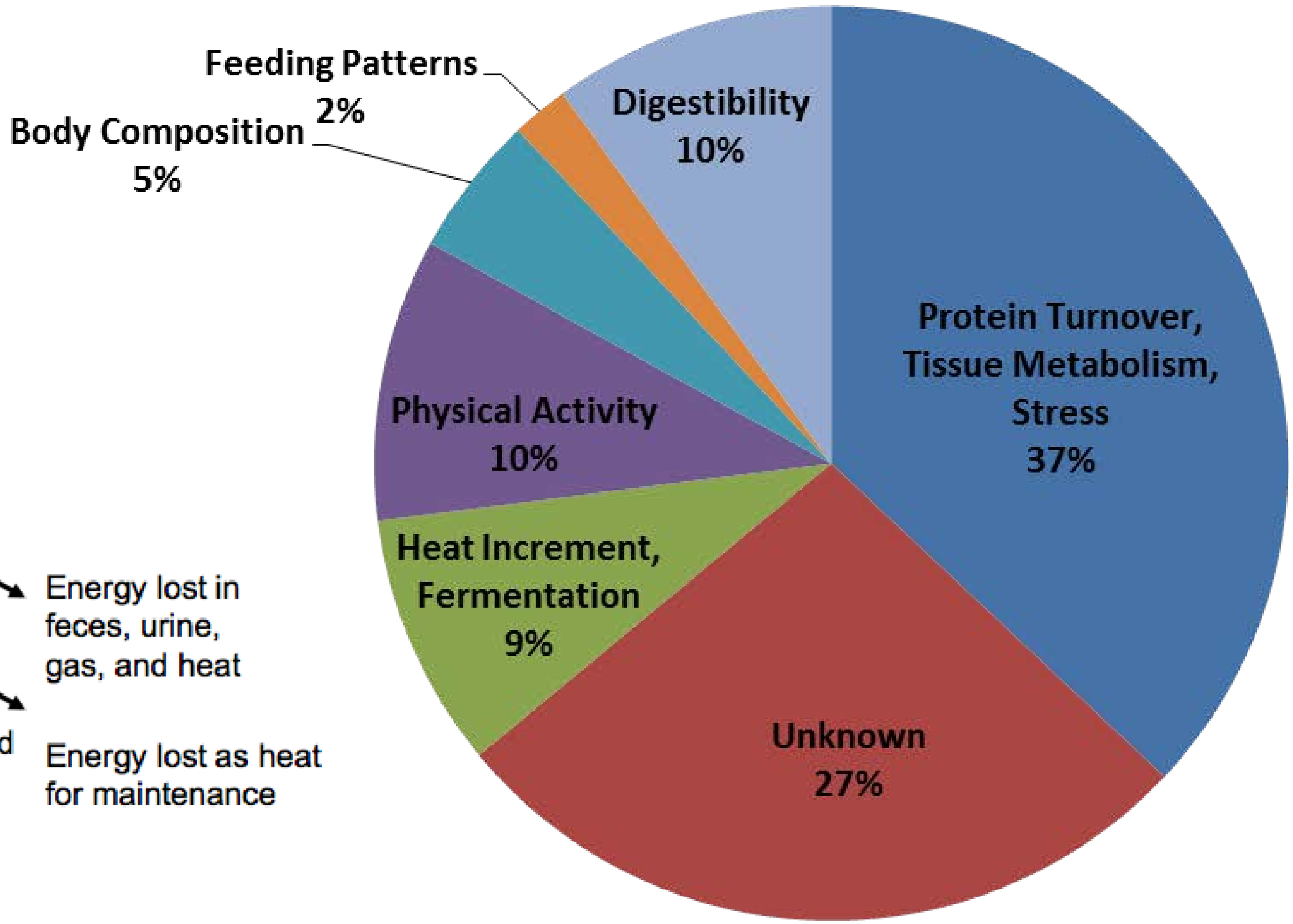
Definition of Residual Feed Intake

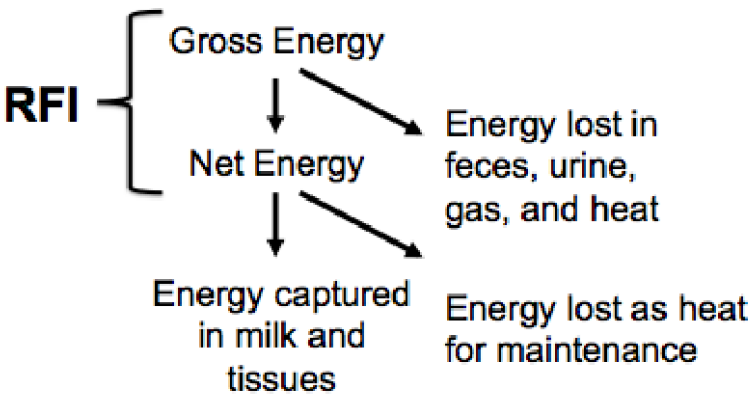


VandeHaar, 2013



What is Residual Feed Intake (RFI)?





Herd & Arthur, 2014



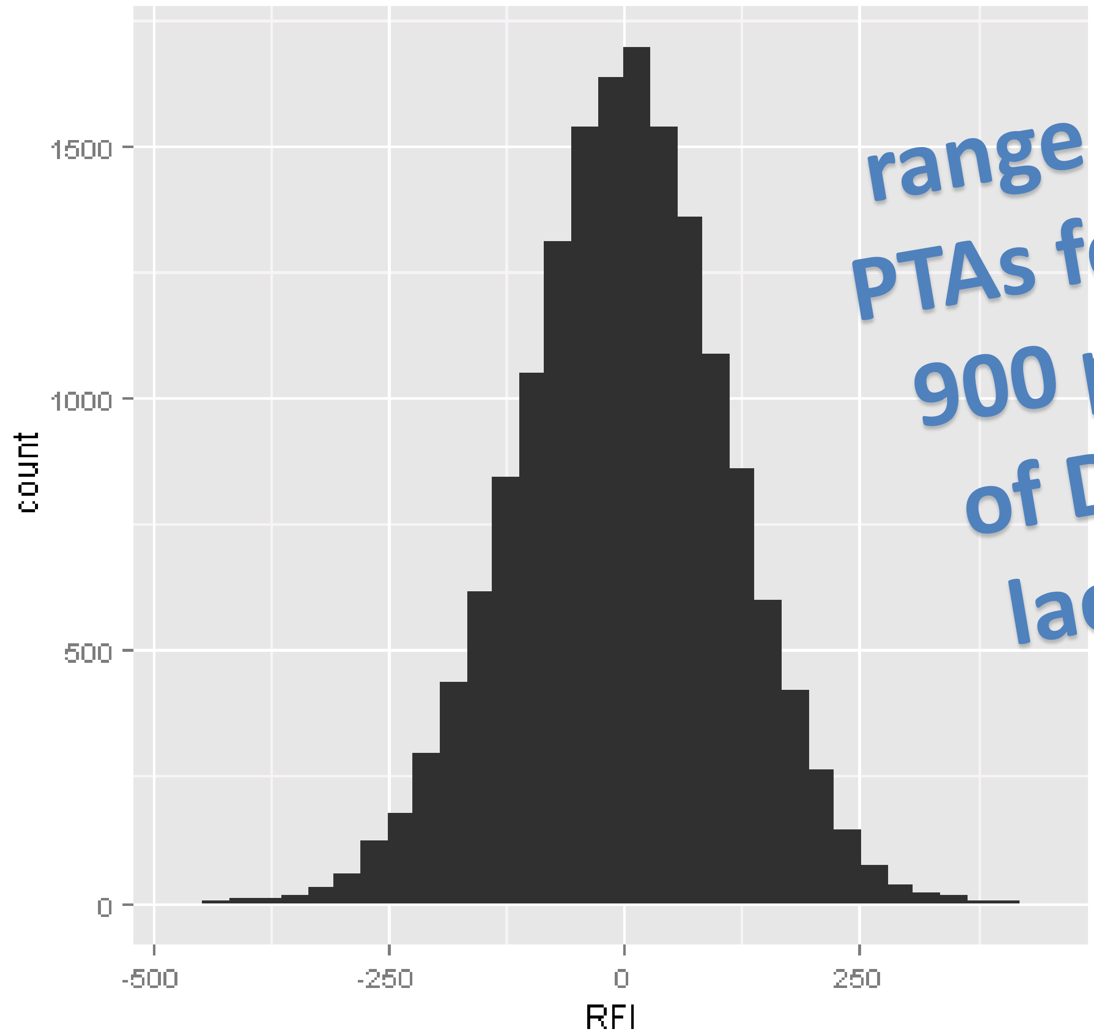
Genomic Estimated Breeding Values

Genomic BLUP to predict genomic estimated breeding values (GEBV)

	RFI	DMI	Milk NE	MBW
Heritability	0.19	0.25	0.19	0.49

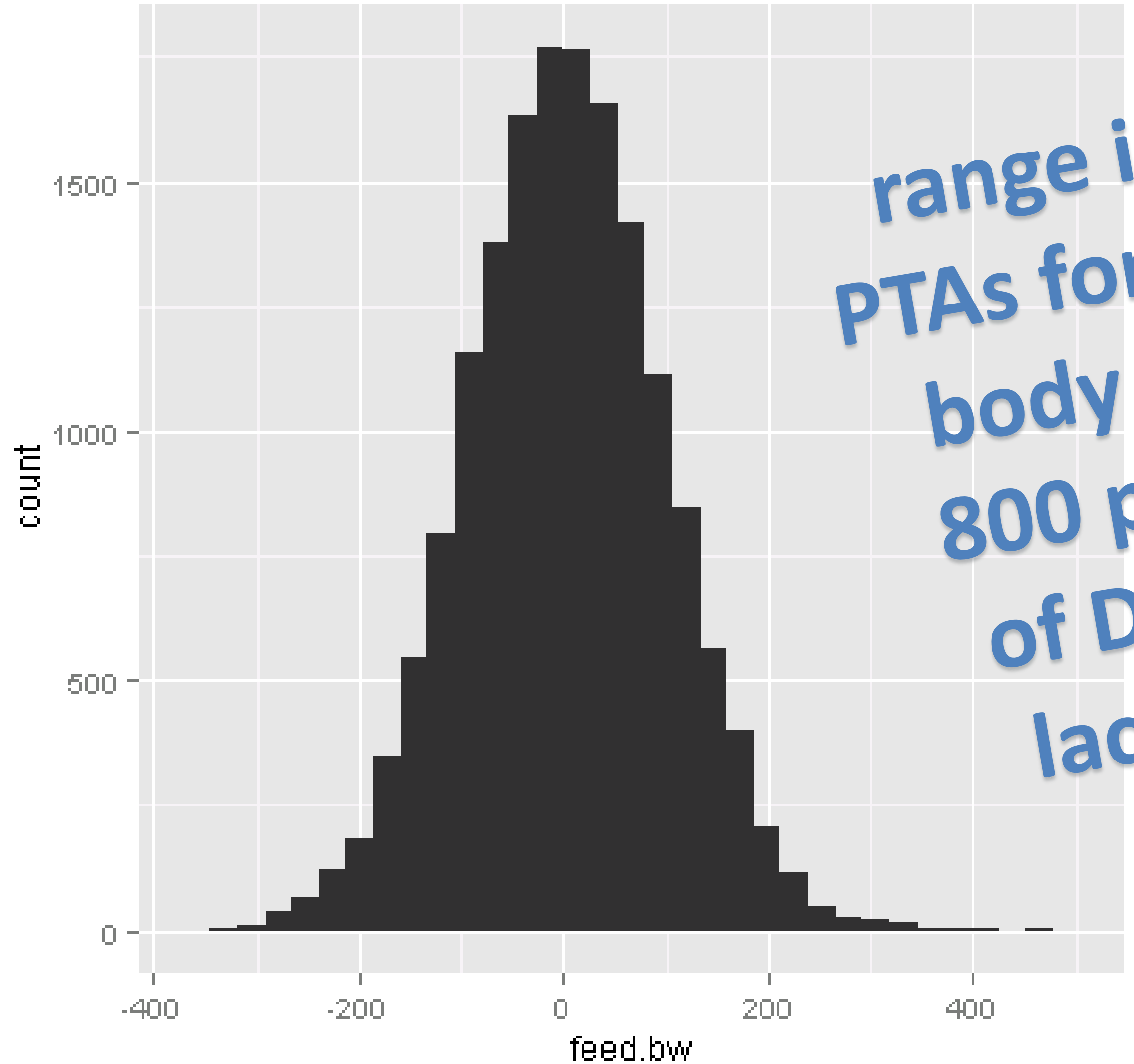
- **GEBV for RFI, DMI, and Milk NE were converted to a lactation basis by multiplying daily GEBV by 305 days**

Genomic Breeding Values for RFI



range in sire PTAs for RFI is 900 pounds of DM per lactation

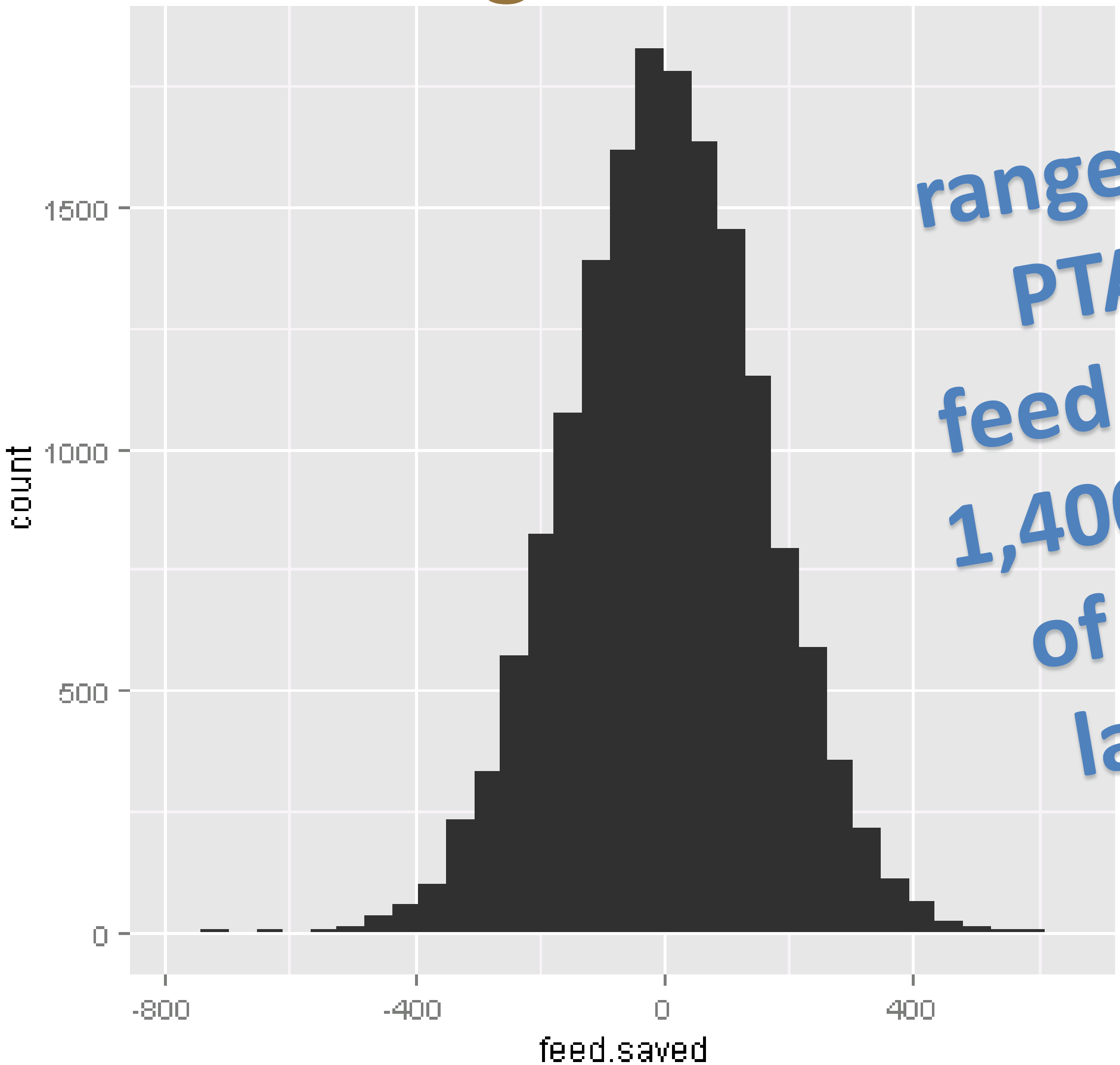
Genomic Breeding Values for Excess BW



range in sire PTAs for excess body size is 800 pounds of DM per lactation

(kg of dry matter per lactation)

Genomic Breeding Values for Feed Saved



(kg of dry matter per lactation)

range in sire PTAs for feed saved is 1,400 pounds of DM per lactation

Considerations in Selection for Improved Feed Efficiency



Breeding for Improved Efficiency - NLD

- Implemented in the Netherlands (Veerkamp, 2014)
- Published as DMI breeding value (kg/day)
  - Includes actual DMI data of about 3,000 cows
  - Includes predicted DMI based on: live weight
    milk yield
    linear type traits

CRV

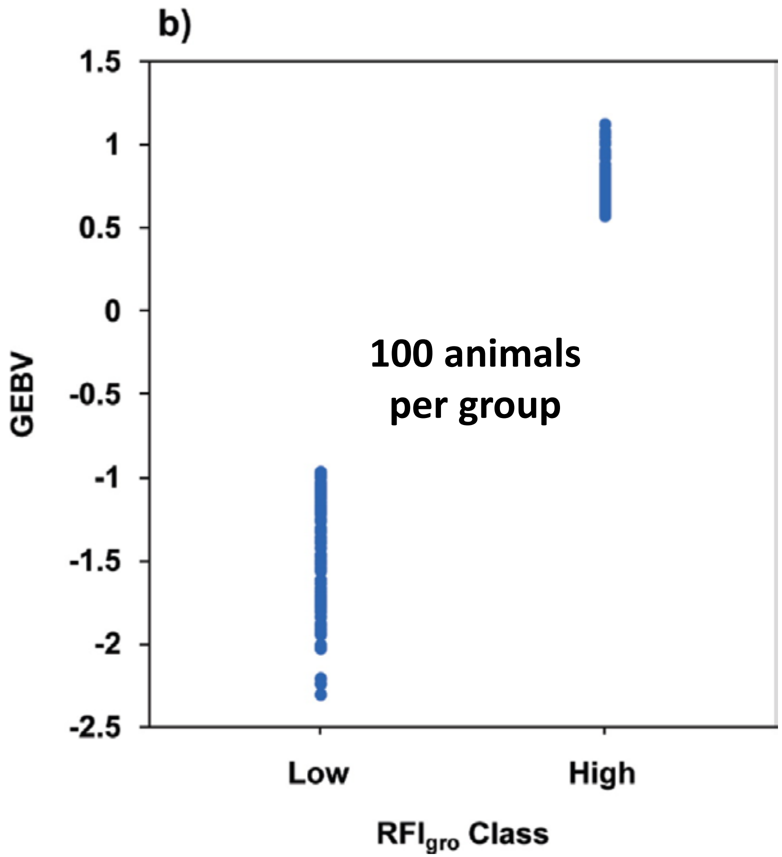
- Accuracy is improved by indirect traits, but we already had genetic predictions for milk and type traits
- Daughters of efficient bulls produce 2.5% more milk per kg of feed intake (~750 kg “free milk” during lifetime)

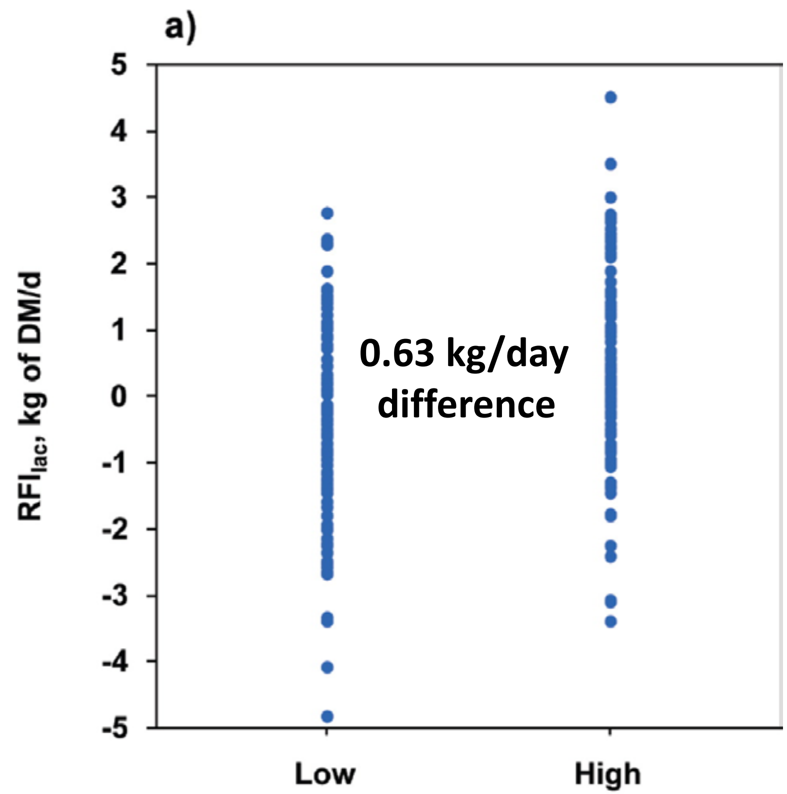


Breeding for Improved Efficiency - AUS

- Implemented in Australia (Pryce et al., 2015)
- Published as "feed saved" breeding value (kg/yr)
  - Includes actual RFI data of 2,000 cows + heifers
  - Includes predicted "excess DMI" for maintenance of large body size (based on linear type traits)
- Average reliability for Holstein bulls is 37%
- Can improve feed efficiency during the lactating, dry, and rearing periods
- Increases genetic gain in net profit by 3-4%

Feed Efficiency in Cows vs. Heifers - AUS





Genomic PTA as a Heifer

Feed Efficiency as a Cow

Davis et al., 2014

Proxies for Feed Efficiency

- **Holstein Association USA “Feed Efficiency” Index**
- **No cows were harmed (or even measured) during the creation of this feed intake index . . .**

U.S. Registered Holsteins
FOR MAXIMUM PROFIT
HOLSTEIN ASSOCIATION USA, INC.

FE = value of milk produced

- extra feed required to produce the milk

- extra maintenance costs due to large body size

- **Rewards high production and moderate body size**
  - **e.g., McCutchen +920 milk, +3.12 body size → $88 FE**
  - **e.g., Robust +946 milk, -0.76 body size → $156 FE**



Implementation in the National Genetic Improvement Program

Feed data vs. other trait data

- Top 100 **proven** HO bulls for NM$
  - Average 739 milk daughters, <0.1 RFI daus
  - GREL averages **94%** milk, **89%** NM$, **16%** RFI
- Top 100 **young** HO bulls for NM$
  - GREL averages **75%** milk, **71%** NM$, **12%** RFI
  - REL$_{PA}$ averages 35% milk, 33% NM$, 3% RFI

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Economic values

Statistic	Milk production (3.5% F, 3.0% P)	Dry matter intake	Residual feed intake
Lactation mean (pounds / lact)	25,000	16,600	0
Lactation SD (pounds / lact)	2,900	2,750	1,130
Price / pound	$0.17	$0.12	$0.12
Mean income or cost / lactation	$4,250	-$1,992	0
Lifetime value / pound (2.8 lact)	$0.253	-$0.336	-$0.336
Relative value (% of net merit)	36%		**-16%**

- Economic values for milk & body weight still subtract correlated feed consumption
- Subtraction of expected feed intake from milk yield is the “Net” in Net Merit $

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Reporting feed efficiency

- Feed efficiency expected from yield & weight
  - FE$ = (1 – .45) MFP$ – $.31 * 40 * BWC
  - Current definition used in TPI
  - New FE$ = FE$ – $.12 * 2.8 lacts * 305 * RFI lb/d
- Feed saved (used in AUS , also researcher proposal)
  - FS lb/lactation = – 305 * RFI lb/d – .20 * 40 *BWC
  - FS$/lifetime = –$.12 * 2.8 lacts * FS lb/lactation

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Conclusions of USDA Study

- Feed is the largest single expense of dairies
- Producers and researchers have always wanted to measure and select for feed efficiency
- Residual feed intake could get ~16% of relative emphasis in net merit, but low REL of ~12% for young animals will limit progress
- Genomics can multiply information from a few herds to thousands of other herds

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Future Considerations



Potential Impact on Efficiency and GHG

by Culling Inferior Calves

- Heifers born per year = 3.4 mln
- No. culled (15%) = 515,000
- Feed per heifer/year = 6,000 lbs
- Total feed saved ≈ 3.1 bln lbs

at \$0.08 and 8.1 g of CH_4 per lb of dry matter . . .

\$250 million and 25 gigagrams (g x 10^9) of CH_4 per year

by Selecting Efficient Cows

- No. milking cows = 9.2 mln
- Feed per cow per day = 60 lbs
- Change in feed intake = 1.5 lbs/d
- Total feed saved ≈ 5.1 bln lbs

at \$0.10 and 8.1 g of CH_4 per lb of dry matter . . .

\$540 million and 41 gigagrams (g x 10^9) of CH_4 per year



Future of Selection for Feed Efficiency

- Economic value of feed efficiency is very large
- Reliabilities of genomic predictions are low, but may improve
  - Measurement of more lactating cows and growing heifers
  - Focus on measuring close relatives of young AI bulls
  - Add data from other countries, if conditions are similar
  - Develop inexpensive proxies for DMI measurement
- Slow or reverse the trend toward increasing body size
- Improve calf health and transition cow health
- Implement efficient replacement management plans

Ongoing Data Collection at UW-Madison

- Insentec Roughage Intake Control (RIC) system
- 64 cows/trial x 5 trials/year x 5 years = 1,600 cows
- 42-day measurement period, after 7-day adaptation
  - DMI, NE_{Milk}, MBW, ΔBW → RFI
  - Control "herd" diet and/or nutrition experiments
  - Measure physiological parameters or feed intake proxies
  - Measuring intake of same cows during transition period
- Adding female relatives of AI bulls to UW-Madison herd
- All data flows to Council on Dairy Cattle Breeding



What About Feed Efficiency in Jerseys?

- **Building a large reference population is tough – in Holsteins!**
- **What are options beyond measuring DMI of 25,000 Jerseys?**
  - **Ratios of current traits, such as milk solids / body weight**
  - **Sensor-based proxies, like feeding behavior or rumination**
  - **Milk-based proxies, such as mid-infrared (MIR) spectrum**
  - **Group measurements, such as pens of paternal half-sisters**
  - **Definitive experiments on Jerseys vs Holsteins, other breeds**
- **Must find the right balance between correlation with actual energetic efficiency and cost + ease of measurement**



Take Advantage of Jersey's Uniqueness

- Relatively small "effective population size"
  - Identify the 4 to 6 most elite new sires of sons each year
  - Build large groups of paternal half-sisters
- Overrepresentation in large herds with multiple pens
  - Could organize pens by sire, with proper incentives
  - For example, 100 daughters each of bull A, bull B, bull C
  - Compute feed efficiency of the group, rather than each cow
  - Repeat across several different farms, with overlapping sires
  - Standard errors will be smaller by square root of N

Some Anecdotal Evidence to Take Home

Rosy-Lane Holsteins
Watertown, WI
~1100 cows

Metric	2008	2017
Health costs (dollars per cwt of milk)	$1.00	$0.31
Feed efficiency (energy-corrected milk / dry matter intake)	1.62	1.69
Δ Net profit per cow per year / .01 change in feed efficiency	$11	
Δ Net profit on 1100-cow dairy from ↑ health & feed efficiency	$325,000	

Mooving Forward.

DAIRY SCIENCE AT WISCONSIN

Questions?