Basic Concepts of Applied Genetics

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Concepts
- Population
- Traits
- Environmental Effects
- Genetic Effects
- Genetic Evaluation Models
- Computational Procedures
- Selection
- Mating Strategies
- Genetic Trends
- Future Developments

Population

Group of purebred and (or) crossbred animals that interbreed

Unibreed
Multibreed

More Examples of Populations

Traits

Calves Cattle
- Calving Ability ($)
- Daughter Pregnancy Rate (%)
- Milk Yield (lb)
- Fat Yield (lb)
- Protein Yield (lb)
- Somatic Cell Score (0 to 9)
- Productive Life (mo)
- Net Merit ($), Cheese Merit ($), Fluid Merit ($)

Beef Cattle
- Calving Ease (% unassisted births on heifers)
- Maternal Calving Ease (% unassisted births 1st calf)
- Birth Weight (lb)
- Weaning Weight (lb)
- Maternal Wean Weight (lb)
- Maternal Milk (lb)
- Yearling Weight (lb)
- Yearling Traits: Marbling, REA, Shear Force, YG
- Stayability (% daugh in herd at 6 yr age)
- All Purpose Index ($), Terminal Index ($)

Environmental Effects

Herd
Year
Season

Sex of Calf
Management Group
Age of Dam
Age of Calf
Days Open
Contemporary Groups
**Unibreed Contemporary Groups**

- **Herd-Year-Season**
- **Sex Calf**
- **Age Calf [± 90 d]**
- **Breed Group**

**Multibreed Contemporary Groups**

- **Herd-Year-Season**
- **Sex Calf**
- **Age Calf [± 90 d]**

**Connectedness**

| Herd-Year-Season | 1 | X | X | 2 | X | X | 3 | X | X | 4 | X | 5 | X | 6 | X | X | 7 | X |

**Genetic Effects**

- **Breed of Sire**
  - **Heterosis**
  - **Additive**
  - **Intrabreed**
- **Breed of Dam**
  - **Recombination Loss**
  - **Nonadditive**
  - **Interbreed**

**Breed**

- **Breed of Sire**
- **Breed of Dam**
- **Purebred Populations**
  - **Model**
  - **Fractions of component breeds**
  - \( \frac{3}{4} \) Jersey \( \frac{1}{4} \) Holstein

**Heterosis**

- **Model**
  - **Prob (allele breed 1/allele breed 2)** in one locus
Recombination Loss
Loss of productivity in crossbreds due to recombination in gametes

Model
Prob (recombinant gametes) considering two loci

Additive Genetic Effects
Transmissible across generations
Cumulative effect of all genes involved

Model
Breed of Sire and Dam (0 <= p <= 1)
Animal, Sire, and Dam effects (1,0)

Nonadditive Genetic Effects
Non-transmissible across generations
Recreated during meiosis

Model
Heterosis (0 <= p <= 1)
Recombination Loss (0 <= p <= 1)
Sire x BGDam Heterosis (0 <= p <= 1)
Sire x BGDam Recomb Loss (0 <= p <= 1)

Direct and Maternal Genetic Effects
Direct Genetic Effects
Own ability to perform

Maternal Genetic Effects
Influence of dams on progeny
Genetic to the dam
Environmental to the progeny

Dairy Genetic and Environmental Effects

Chart of Genetic Effects
Additive
Direct
Maternal
Nonadditive
Intrabreed
Interbreed
Intrabreed
Intrabreed
Intrabreed
Intrabreed
Intrabreed
Intrabreed
Intrabreed

Chart of Residual Effects

- Additive (Direct + Maternal)
  - Intrabreed
  - Interbreed
- Nonadditive (Direct + Maternal)
  - Intrabreed
  - Interbreed

Genetic Evaluation Models

- Type of Population
  - Unibreed
  - Multibreed

- Type of Trait
  - Categorical
  - Continuous

Dairy Unibreed Model

- Pre-Corrected Milk Yield
  - Herd-Year-Season
  - Parity x Dam Calving Age
  - Registry Status
  - Genetic Group (Unknown parents by year)

- Animal Additive Genetic Effect
  - Herd x Sire
  - Permanent Environment

- Residual

Dairy Multibreed Model

- Milk Yield
  - Herd-Year-Season
  - Dam Calving Age (Regression on H)
  - Holstein Fraction (Regression)

- Animal Additive Genetic Effect

- Residual

Beef Multibreed Model

- Contemporary Group
  - Age of Dam x Sex of Calf (Regr on breed fract)
  - Breed Group (Regr on breed fract)
  - Heterosis (Regr on p(b1/b2))

- Animal Additive Genetic Effect
  - Sire x BG Dam (Regr on p(b1/b2))

- Residual

Pre-Corrections

- Milk Yield
  - Age at Calving
  - Month
  - Times Milked per Day (2x)
  - Previous Days Open
  - Lactation Length (305 d)
  - Heterogeneous Variance

Computational Procedures

- **Type of Population**
  - Unibreed
  - Multibreed

- **Type of Trait**
  - Categorical
  - Continuous

- **Population Size**
- **Number of Traits**

Small Number of Equations -> Direct Procedures

Large Number of Equations -> Iterative Procedures

Genetic Predictions

- **Dairy Cattle**
  - Predicted Transmitting Abilities (PTA)
    - PTA = ½ EBV

- **Beef Cattle**
  - Expected Progeny Differences (EPD)
    - EPD = ½ EBV

Genetic Evaluations

- **Unibreed**
- **Multibreed**

- **Multitrait**
  - Quantitative Trait Loci (QTL)
    - (BLUP, Bayesian Methods)

Additive and Nonadditive Genetic Effects (Interbreed)

Genetic Bases

- **Dairy Cattle**
  - Mean Additive Genetic Value of Cows Born in 2000
- **Beef Cattle**
  - Mean Value of Simmental, Angus, Hereford, and Brahman genes in 1991

USA

- Milk, Fat, Protein
- PL, SCS, DPR, CAS

- Unibreed BLUP

Animal Model

Index

Single-Trait Repeatability Model

Traits and Profit Indexes [NMS, CMS, FMS]


http://www.holsteinusa.com/pdf/sire_%20information_how_to_read.pdf
Selection and Mating Strategies

Selection
- Unitrait
- Multitrait - Indexes

Mating Strategies
- Unibreed
- Multibreed

Dairy
- Milk
- Profit Indexes

Beef
- Weight Traits (D, M)
- Profit Indexes

Dairy Genetic Trends

Milk Yield
- Fat Yield
- Protein Yield
- Somatic Cell Score (SCS)
- Daughter Pregnancy Rate (DPR)

Genetic Trend - USA

http://www.aipl.arsusda.gov/eval/summary/trend.cfm
Genetic Trend - USA

Year

Genetic Trend - USA

Year

Genetic Trend - USA

Year

Beef Genetic Trends

Calving Ease Traits (CED, CEM)
Direct Growth Traits (BW, WW, YW)
Maternal Growth Traits (MILK, MWW)
Carcass Traits (YG, MARB, FAT, REA, CWT)

Future Genetic Evaluations

New Traits

Composite Traits

New Procedures

Integraton of QTL and Phenotypic Data

New Flow of Information

New Research Development Structure

New Traits

Traditional Traits

Traits

Molecular Physiological Nutritional

Genetic Material

Intracellular Extracellular Products

Biological Relationships

Cattle Genome - Milk Yield QTL

Cattle Genome – Yearling WT QTL

New Models

Basic Traits

Traditional Traits

Composite Traits

Linear Models

Biological Models

Systemic Models

Nonlinear Models
New Research Structure

Expensive Research Projects (Equipment, Personnel)

Private Companies Will Collect Most of the Genetic Information?

Role of National Organizations?

Role of Universities?

Role of Breed Associations?

Large Number of Simultaneous Measurements (Biochips)

Dairy Improvement Structure

Breed Associations
Phenotypes and DNA

Animal Improvement Program Laboratory (AIPL, ARS-USDA)

Genetic Evaluation Center

Private Companies
Sire Sampling
DNA Analysis

Dairy Herd Improvement Association (DHIA)
Milk Sampling

Universities
Basic and Applied Research

Beef Improvement Structure

Breed Associations
Phenotypes and DNA

National Beef Cattle Evaluation Consortium (NBCEC)

Genetic Evaluation Center

Private Companies
DNA Analysis

Universities
Basic and Applied Research

Research Centers
MARC

Current Flow of Information
Future Flow of Information

Universities
- Larger Integration with Private Sector
- Joint Basic and Applied Research with Private Sector
- Research Parks
- National Research Committees
- Participation in Product Development and Commercialization with the Private Sector

Globalization
- International Companies
- International Databases
- International Projects for Research and Development
- Regional Agreements
- Larger Genetic Changes
- Larger Economic Benefits