In most places of the world, ideal meat animal production systems involve some type of “crossbreeding.”

The ideal type of animal (or management) for one production environment may be a wreck in others.
Mating Systems

**Straightbreeding**
- All animals are of the same breed
  - “Typical” purebreds
  - Linebreeding
  - Outcrossing

**Crossbreeding**
- At least two breeds are involved
  - Terminal
  - Continuous
  - Combination

What are some advantages and disadvantages to straightbreeding/purebreeding systems?

What does “relationship” mean?

- Depends on what groups are being compared
  - Full brothers and sisters share 50% of their genetics
  - People and chimpanzees have over 96% of the same DNA.

- Relationship in the “pedigree” sense

Different groups share different amounts of DNA/genes:

- All mammals have this part in common
- All ruminants have this part in common
- All sheep and goats have this part in common
- All Rambouillet sheep have this part in common

This part is where livestock pedigree relationship and inbreeding are measured

Not drawn to scale.
**Why would someone want to use inbreeding in livestock?**

If your family tree don’t branch, you might be a redneck....
- Jeff Foxworthy

**Genetic uniformity within a breed comes from homoygosity of genes**

- There are different forms of genes called “alleles.”
- Animals that are ___% more inbred are ___% more homozygous than non-inbred animals in that breed.
- Non-inbred animals are heterozygous (AaBbCcDdEeFf) for most genes.

**Structured inbreeding systems**

- Linebreeding
- Full-sib (or other close relative) mating
- Self-fertilization
- Breeding back to same ancestor

Line 1 Hereford bulls at the USDA-ARS research station in Miles City, MT.

Closed line since late 1930s.

*Goal of linebreeding – maintain relationship to admired ancestor(s) but with minimal inbreeding accumulation*

Linebred to:

- one grandparent
- one great grandparent
- one great great grandparent

12.5% 6.25% 3.1%

Inbreeding percentages

There is no set “structure” to linebreeding in general across all situations, and it may vary considerably in level of inbreeding due to breeder preferences.
Why would someone want to cross different breeds of animals?

Crossbreeding major concepts:
1. Blending of breed characteristics – *The foundation*
2. Hybrid vigor (heterosis) for direct and maternal effects – estimated from gene loci heterozygous for breed alleles
3. Some crossbred progeny may be made more than one way, and some ways can make more sense than others
4. Sustainability – population size, replacements, market acceptance

Be careful of the term “F1 type” in advertisements…. The F₁ is genetically unique because of how it is made.

Figure 3.6 When crossing two breeds (A and B), the mid-parent value is halfway between the purebred means. The amount of deviation of the crossbred population mean from the mid-parent value is the amount of heterosis.
Relative potential for hybrid vigor and inbreeding depression for some traits

<table>
<thead>
<tr>
<th>Type of trait</th>
<th>Heterosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female fertility, lamb/kid survival, overall health</td>
<td>High (15-20%)</td>
</tr>
<tr>
<td>Male fertility, growth, early life body size, milk production, gain efficiency</td>
<td>Moderate (10%)</td>
</tr>
<tr>
<td>Product-type traits, loineye area, fat depth, mature size, linear body measurements</td>
<td>Low (5%)</td>
</tr>
</tbody>
</table>

Inbred animals tend to breed better than they perform, crossbred animals tend to perform better than they breed...

Some crossbreeding concepts

Terminal breeds/types:
- Breeds or animals that are more useful as sires or as market animals

Maternal breeds/types:
- Breeds or animals more useful as females in breeding flocks/herds

Direct hybrid vigor:
- Increased performance of progeny because they are crossbred

Maternal hybrid vigor:
- Increased performance of dams because they are crossbred

Terminal vs. Continuous crossbreeding

Terminal:
- Progeny are genetically different than either parent type (no replmts)
- Most potential for heterosis (but not for all crosses)
- Most potential to use complementarity (different specialized sire and dam types)

Continuous:
- Progeny can be used as replacements for at least one parent type
- Typically less heterosis, but not always with only 2 breeds involved
- Less potential for use of specialized sire and dam types (less complementarity)

Some “terminal” crossbreeding terms

- **F₁ cross:**
  - First cross between two pure breeds:
    \[
    A \times B \rightarrow \frac{1}{2}A \frac{1}{2}B \text{ F₁}
    \]

- **Backcross:**
  - When F₁ is bred back to one parent breed:
    \[
    A \times \frac{1}{2}A \frac{1}{2}B \text{ F₁} \rightarrow \frac{1}{2}A \frac{3}{4}B
    \]
    \[
    \frac{1}{2}A \frac{1}{2}B \text{ F₁} \times A \rightarrow \frac{1}{4}A \frac{3}{4}B
    \]

- **F₂ cross:**
  - The parents are both the same F₁ crosses:
    \[
    \frac{1}{2}A \frac{1}{2}B \text{ F₁} \times \frac{1}{2}A \frac{1}{2}B \text{ F₁} \rightarrow \frac{1}{2}A \frac{1}{2}B \text{ F₂}
    \]

- **Reciprocal cross:**
  - Some crosses can be made more than one way
    Suffolk x Rambouillet
    Rambouillet x Suffolk
Some other terminal crosses

• Three-breeding terminal cross:
  – Purebred sires bred to F₁ dams (no overlap of breeds)
    \[ C \times \frac{1}{2}A \frac{1}{2}B \times \frac{1}{2}C \frac{1}{4}A \frac{1}{4}B \]

• Four-breeding terminal F₁:
  – Sires and dams are both F₁ of different breeds
    \[ \frac{1}{2}C \frac{1}{2}D \times \frac{1}{2}A \frac{1}{2}B \rightarrow \frac{1}{4}C \frac{1}{4}D \frac{1}{4}A \frac{1}{4}B \]

Terminal vs. Continuous crosses

• Is it possible for someone’s (or some flock’s) terminal cross to be someone else’s (or some other flock’s) replacement animals?

• Are there some scenarios where at least some terminal crosses must be made to eventually get to a continuous system?

Types of continuous crosses

• Two-breeding rotation
• Three-breeding rotation
• Four-breeding rotation

The number of sire breeds is also the number of breeding groups needed.

Two-breeding rotational (criss-cross) crossbreeding system

\[ \frac{2}{3}A \frac{1}{3}B \times \frac{2}{3}B \frac{1}{3}A \rightarrow \text{Ewes sired by breed A rams are bred to breed B rams.} \]

\[ \frac{2}{3}B \frac{1}{3}A \times \text{Ewes sired by breed B rams are bred to breed A rams.} \]
Table 3.11: Initiation and development of a two-breed rotation.

<table>
<thead>
<tr>
<th>Sires</th>
<th>Dams</th>
<th>Progeny</th>
<th>%A in progeny</th>
<th>%B in progeny</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>1/2A 1/2B</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>B</td>
<td>1/2A 1/2B</td>
<td>3/4B 1/4A</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>B</td>
<td>5/8A 3/8B</td>
<td>11/16B 5/16A</td>
<td>31.25</td>
<td>68.75</td>
</tr>
<tr>
<td>A</td>
<td>11/16B 5/16A</td>
<td>21/32A 11/32B</td>
<td>65.6</td>
<td>34.4</td>
</tr>
<tr>
<td>B</td>
<td>21/32A 11/32B</td>
<td>43/64B 21/64A</td>
<td>32.8</td>
<td>67.2</td>
</tr>
<tr>
<td>A</td>
<td>43/64B 21/64A</td>
<td>85/128A 43/128B</td>
<td>66.4</td>
<td>33.6</td>
</tr>
<tr>
<td>B</td>
<td>85/128A 43/128B</td>
<td>171/256B 85/256A</td>
<td>33.2</td>
<td>66.8</td>
</tr>
</tbody>
</table>

This example illustrates how a 2-breeding rotation (breeds A and B) starts as a cross of pure breeds and progresses over several generations toward a 2/3, 1/3 ratio at equilibrium.

Example of a two-breeding composite:

- Dorper – Dorset Horn and Persian Blackhead are foundation breeds.
- Columbia - Rambouillet and Lincoln

The foundation animals (breeds and individuals) are very important, and the amounts of breed influence are important.

Heterozygosity in Composites

The interbreeding of crossbred animals is the foundation of a composite breeding program. The amount of heterozygosity in F2 and later generations is a function of: (1) number of breeds, (2) amounts of the breeds, and (3) level of inbreeding.

Rams and ewes are 5/8 Suffolk and 3/8 Lincoln (5/8 S 3/8 L x 5/8 S 3/8 L)

The breed combinations expected to be heterozygous are 30/64, or 47%.

Meatmaster composite in South Africa
(Based on Damara and Dorper cross foundation)
How do I have more hybrid vigor retained in a composite?

- More foundation breeds (2, 3, 4, etc.)
- Foundation breeds that are different types (fine wool, medium wool, hair, fat tail, etc.)
- Equal distribution of breeds
- Avoid inbreeding

Gametes from dam:

<table>
<thead>
<tr>
<th>P(A) = 1/4</th>
<th>P(B) = 1/4</th>
<th>P(C) = 1/4</th>
<th>P(D) = 1/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(AA) = 1/16</td>
<td>P(AB) = 1/16</td>
<td>P(AC) = 1/16</td>
<td>P(AD) = 1/16</td>
</tr>
<tr>
<td>P(BA) = 1/16</td>
<td>P(BB) = 1/16</td>
<td>P(BC) = 1/16</td>
<td>P(BD) = 1/16</td>
</tr>
<tr>
<td>P(CA) = 1/16</td>
<td>P(CB) = 1/16</td>
<td>P(CC) = 1/16</td>
<td>P(CD) = 1/16</td>
</tr>
<tr>
<td>P(DA) = 1/16</td>
<td>P(DB) = 1/16</td>
<td>P(DC) = 1/16</td>
<td>P(DD) = 1/16</td>
</tr>
</tbody>
</table>

Gametes from sire:

<table>
<thead>
<tr>
<th>P(A) = 1/4</th>
<th>P(B) = 1/4</th>
<th>P(C) = 1/4</th>
<th>P(D) = 1/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(AA) = 1/16</td>
<td>P(AB) = 1/16</td>
<td>P(AC) = 1/16</td>
<td>P(AD) = 1/16</td>
</tr>
<tr>
<td>P(BA) = 1/16</td>
<td>P(BB) = 1/16</td>
<td>P(BC) = 1/16</td>
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</tr>
<tr>
<td>P(CA) = 1/16</td>
<td>P(CB) = 1/16</td>
<td>P(CC) = 1/16</td>
<td>P(CD) = 1/16</td>
</tr>
<tr>
<td>P(DA) = 1/16</td>
<td>P(DB) = 1/16</td>
<td>P(DC) = 1/16</td>
<td>P(DD) = 1/16</td>
</tr>
</tbody>
</table>

Figure 3.7 Expected levels of breed combinations in progeny of a composite that has equal amounts of four breeds is 12/16, or 75% (assuming no inbreeding).
Comparing different breeding programs*

<table>
<thead>
<tr>
<th>Name</th>
<th>Hybrid vigor potential</th>
<th>Production of replacements</th>
<th>Other aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional straightbreeding</td>
<td>Very low</td>
<td>Yes, males &amp; females</td>
<td>Required for registration &amp; to produce F1 animals.</td>
</tr>
<tr>
<td>Linebreeding</td>
<td>Lowest of all</td>
<td>Yes, males &amp; females</td>
<td>More uniformity, selection needed to offset inbreeding</td>
</tr>
<tr>
<td>Terminal crossing</td>
<td>Highest of all</td>
<td>No</td>
<td>Can utilize specialized sire &amp; dam types, can have uniformity</td>
</tr>
<tr>
<td>Rotational crossing</td>
<td>Medium to high (# breeds)</td>
<td>Yes, females only</td>
<td>Multiple breeding groups needed</td>
</tr>
<tr>
<td>Composite</td>
<td>Medium to high (# breeds &amp; distribution)</td>
<td>Yes, males &amp; females</td>
<td>Can have uniformity</td>
</tr>
</tbody>
</table>

*Choosing the right type of animals for the production environment and market is the true foundation of any breeding program. Knowing pedigree information is critical.

Grading up
(The transition over time from crossbreeding to straightbreeding)

- The scheme where two breeds are crossed, and each progeny generation is bred back to the same parental breed.
  - *This strategy does not automatically imply inbreeding*

Table 3.10 Concepts of grading up

<table>
<thead>
<tr>
<th>Sires</th>
<th>Dams</th>
<th>Progeny</th>
<th>%A in progeny</th>
<th>%B in progeny</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>1/2A 1/2B</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>A</td>
<td>7/8A 1/8B</td>
<td>15/16A 1/16B</td>
<td>93.75</td>
<td>6.25</td>
</tr>
<tr>
<td>A</td>
<td>15/16A 1/16B</td>
<td>31/32A 1/32B</td>
<td>96.9</td>
<td>3.1</td>
</tr>
<tr>
<td>A</td>
<td>31/32A 1/32B</td>
<td>63/64A 1/64B</td>
<td>98.4</td>
<td>1.6</td>
</tr>
<tr>
<td>A</td>
<td>63/64A 1/64B</td>
<td>127/128A 1/128B</td>
<td>99.2</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Repeatedly breeding successive crossbred generations back to the same breed (breed A in this example) over several generations produces animals that are essentially purebreds.

Heterosis considerations associated with grading up

<table>
<thead>
<tr>
<th>Sires</th>
<th>Dams</th>
<th>Progeny</th>
<th>% progeny heterozygosity</th>
<th>% dam heterozygosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>1/2A 1/2B</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>A</td>
<td>1/2A 1/2B</td>
<td>3/4A 1/4B</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>A</td>
<td>7/8A 1/8B</td>
<td>15/16A 1/16B</td>
<td>12.5</td>
<td>25</td>
</tr>
<tr>
<td>A</td>
<td>15/16A 1/16B</td>
<td>31/32A 1/32B</td>
<td>6.25</td>
<td>12.5</td>
</tr>
<tr>
<td>A</td>
<td>31/32A 1/32B</td>
<td>63/64A 1/64B</td>
<td>3.13</td>
<td>6.25</td>
</tr>
</tbody>
</table>

Repeatedly breeding successive crossbred generations back to the same breed (breed A in this example) over several generations produces animals that are essentially purebreds.
Breeding Strategies & Questions

**Purebred**
- Who buys my lambs (kids)?
- How can I get paid more for added value?
- What extra information will help me the most?
- What is the ideal type of animal for (a) my flock and (b) my customers?

**Commercial**
- Who buys my lambs (or kids)?
- How can I get paid more for added value?
- What extra information will help me the most?
- What is the ideal type of animal for (a) my flock and (b) my customers?

*Commercial producers should buy seedstock from purebred breeders that share the same philosophies…*

People want simple answers to complex questions...

*Not the best strategy for livestock breeding programs…*

Overall recommendations

- Know what causes differences in value (and in costs of production) among your animals
- Have realistic long-term goals
- Be able to trace/identify genetic influences for family lines
- Keep things as simple and as enjoyable as possible
- Combinations of genetics-environment-management-market make for success, not just any one of these factors

Can you recommend a good contractor for my fixer-upper?

*People want simple answers to complex questions…*