Crossbreeding

crossbreeding - mating of individuals
from different breeds

actually
spectrum of mating systems

inbreeding
linebreeding
linecrossing
crossbreeding
hybridization

Inbreeding - mating of related individuals
Linebreeding - mating of individuals with a special type of relationship
Linecrossing - mating of members of different lines within a breed
Crossbreeding - mating of members of different breeds
Hybridization - mating of members of different species

As mates are closer in relationship
homozygocity is increased

As mates are more distant in relationship
heterozygocity is increased

close matings tend to decrease performance

distant matings tend to increase performance.

Benefits of crossbreeding

heterosis
advantage of the crossbred compared to the average of the component purebreds

breed complementarity
optimum combination of breeds
use strengths of breeds and hide the weaknesses

Dominance model of heterosis

```
                         one gene pair
                              |   another gene
pair
                              |     |
Purebreed  "A"      Genes from sire: A  A  A  A  A  A  A  A
                    Genes from dam : A  A  A  A  A  A  A  A

                    Heterosis expression = 0%


F1  cross "A x B"   Genes from sire: A  A  A  A  A  A  A  A
                    Genes from dam : B  B  B  B  B  B  B  B

                    Heterosis expression = 100%
```

Dominance model of heterosis

```
3 breed cross       Genes from sire:   C  C  C  C  C  C  C  C
 "C x (AxB)"        Genes from dam :   A  B  A  B  A  B  A  B

                    Heterosis expression = 100%


 Backcross          Genes from sire:   A  A  A  A  A  A  A  A
 "A x (AxB)"        Genes from dam :   A  B  A  B  A  B  A  B

                    Heterosis expression = 50%


F2  cross           Genes from sire:   A  A  B  B  A  A  B  B
"(AxB) x (AxB)"     Genes from dam :   A  B  A  B  A  B  A  B

                    Heterosis expression = 50%
```

Heterosis

individual heterosis
advantage of the crossbred offspring

maternal heterosis
advantage of the crossbred dam

paternal heterosis
advantage of the crossbred sire .

Paternal heterosis

operates differently than individual or maternal

sire is not physically present when offspring is there

crossbred sires cause
<u>higher conception rate</u>
earlier sexual development
higher libido

Paternal heterosis

advantage of crossbred sire

stops at conception

no difference in

- littersize
- growth rate
- carcass merit

Heterosis in Beef Cattle

Trait	Heterosis (%) Individual	Maternal
Calving %	3.4	6.6
Calf survival	1.7	2.0
Birth weight	2.7	1.6
Weaning weight	4.7	4.2
Postweaning ADG	3.9	-1.4
Yearling weight (feedlot)	3.8	2.9
Loin eye area	2.8	
Fat thickness	2.3	
Quality grade	.7	
Dressing %	.6	
Cutability %	.6	

Heterosis in Sheep

Trait	Heterosis (%) Individual	Maternal
birth weight	3.2	5.1
weaning weight	5.0	6.3
preweaning growth rate	5.3	
postweaning growth rate	6.6	
adult body weight	5.2	5.0
conception rate	2.6	8.7
litter size	2.8	3.2
survival to weaning	9.8	2.7
lambs born per ewe exposed	5.3	11.5
lambs reared per ewe exposed	15.2	14.7
wt of lamb per ewe exposed	17.8	18.0

Heterosis Values for Dairy Cattle

Trait	Heterosis %
milk yield	5.1
fat %	- .3
SNF %	-1.1
Protein %	-1.5
age first calving	.2
lactation length	1.0
persistency	2.3
lb FCM/mcal intake	1.5
calf survival 0-3 months	4.6
% survival to first calving	6.2
days open	1.7
calving interval	2.7
% pregnant (90 days)	5.0
calving difficulty	1.3
birth weight	5.7

Crossbreeding parameters...

- ***Direct additive effects*** A_{d1}, A_{d2} ***and*** A_{d3} Additive For yearling weight, they relate to the ability to grow quickly.

- ***Maternal additive effects*** A_{m1}, A_{m2} ***and*** A_{m3} Additive purebreeds as expressed by the dams of the crossbred individuals under consideration. They probably relate to milk production and rearing ability. Note that these effects add to zero - they describe performance of each pure breed.

- ***Direct dominance effect*** D_d The effect of individuals, when fully expressed, as in an F1 cross.

- ***Maternal dominance effect*** D_m The effect of crossbreeding in the dam, when fully expressed, as in

Estimating crossbreeding parameters...

Cross Table (Yearling weight)

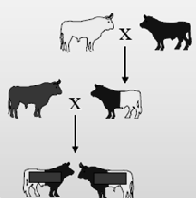
3 Breeds | New Row | Reset Table | Breed / Trait | Update | Defaults | Close | Calculate

Effects:		Ad1	Ad2	Ad3	Am1	Am2	Am3	Dd	Dm	Merit	
Value (Kg)		300	280	260	-6	-1	7	20	10		
1	1 x 1	1	0	0	1	0	0	0	0	294	☑
2	2 x 2	0	1	0	0	1	0	0	0	279	☑
3	3 x 3	0	0	1	0	0	1	0	0	267	☑
4	1 x 2	0.5	0.5	0	0	1	0	1	0	309	☑
5	1 x 23	0.5	0.25	0.25	0	0.5	0.5	1	1	**318**	☑
6	1 x 12	0.75	0.25	0	0.5	0.5	0	0.5	1	311.5	☑
7	2 Br Bal Comp	.5	.5	0	.5	.5	0	.5	.5	301.5	☑
8	3 Br Bal Comp	.3333	.3333	.3333	.3333	.3333	.3333	.667	.667	299.982	☐
9	2 Br Opt Comp	.63	.37	0	.63	.37	0	.47	.47	302.55	☐
10	3 Br Opt Comp	.57	.31	.12	.57	.31	.12	.56	.56	302.91	☐
11	2 Br Rotation	.5	.5	0	.5	.5	0	.667	.667	306.51	☐
12	3 Br Rotation	.3333	.3333	.3333	.3333	.3333	.3333	.86	.86	305.772	☐

Crossbreeding:

More ‘structure’ gives more merit ...

In general ...



The shorter the breed pedigree back to purebred parents:

- the more heterosis can be expressed.
- the more sire-dam complimentarity can be expressed

BUT: The more expensive the operation is to run

Prediction of performance in crossbreeding programs

general mean (average of breeds as purebreds)
+ direct effects of breeds in offspring
+maternal effects of breeds in dam
+individual heterosis
+maternal heterosis

heterosis values are added as % advantage

breed	direct	maternal	
Hereford	10	-5	
Angus	-5	10	general
Limousin	50	-20	mean = 500
Jersey	-55	15	
heterosis%	4.5	4.7	

Angus

500 + (-5) + 10 = **505 lb**

No heterosis added

breed	direct	maternal	
Hereford	10	-5	
Angus	-5	10	general
Limousin	50	-20	mean = 500
Jersey	-55	15	
heterosis%	4.5	4.7	

Hereford x Angus

500 +.5 (10) + .5 (-5) + 10 = 512.5

512.5 + .045 (512.5) = **535.56 lb**

No maternal heterosis

breed	direct	maternal	
Hereford	10	-5	
Angus	-5	10	general
Limousin	50	-20	mean = 500
Jersey	-55	15	
heterosis%	4.5	4.7	

Limousin x Hereford - Angus

500 +.5(50) +.25(10) +.25(-5) +.5(-5) +.5(10) = 528.75

528.75 + .045 (528.75) = 552.54

552.54 + .047 (552.54) = **578.51 lb**

Utilization of heterosis

not all matings are fully purebred or fully crossbred

backcross

Duroc x Duroc-Yorkshire

male and female are partly from different breeds

Hereford x Hereford Angus

calf	dam
H H	H A
H H	H A
H H	H A
H H	H A
H A	H A
H A	H A
H A	H A
H A	H A
3/4 H:1/4 A	1/2 H:1/2 A
1/2 ind heterosis	all mat heterosis

breed	direct	maternal	
Hereford	10	-5	
Angus	-5	10	general
Limousin	50	-20	mean = 500
Jersey	-55	15	
heterosis%	4.5	4.7	

Hereford x Hereford-Angus

500+.75(10) +.25(-5) +.50(-5) +.50(10)=508.75

508.75 + (.5) .045 (508.75) = 520.20

520.20 + (1) .047 (520.20) = **544.65 lb**

Limousin x Angus(Angus-Jersey)

calf	dam
L A	A A
L A	A A
L A	A A
L A	A A
L A	A J
L A	A J
L J	A J
L J	A J
1/2L:3/8A:1/8J	3/4 A:1/4 J
all ind heterosis	1/2 mat heterosis

breed	direct	maternal	
Hereford	10	-5	
Angus	-5	10	general
Limousin	50	-20	mean = 500
Jersey	-55	15	
heterosis%	4.5	4.7	

Limousin x Angus(Angus-Jersey)

500 +.5(50) +.375(-5) +.125(-55) +.75(10) +.25(15)=527.5

527.5 + (1) .045 (527.5) = 551.24

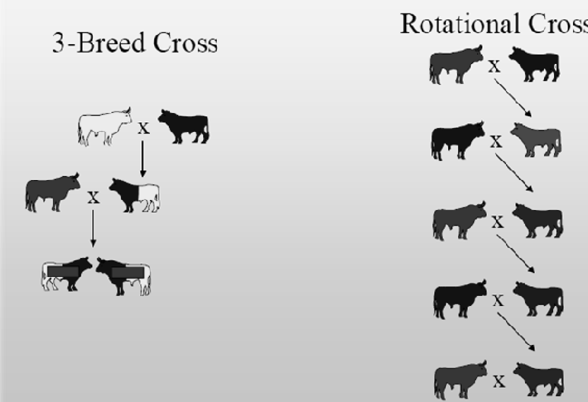
551.24 + (.5) .047 (551.24) = **564.19 lb**

Crossbreeding systems

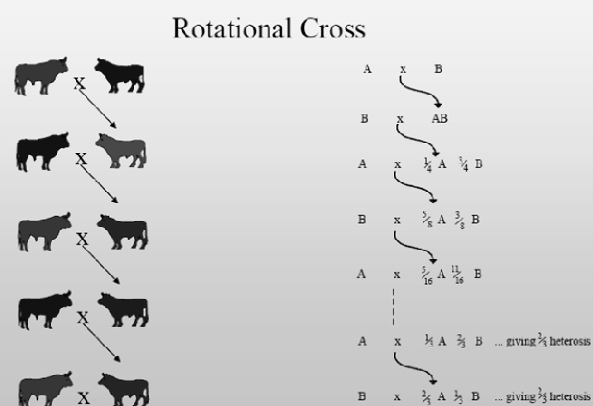
terminal
- specific breed(s) of sire mated
  - to specific breed(s) of dam

rotation
- sire breeds used in a cycle
- replacement females kept
  - from each generation

Loss of heterosis and complimentarity ...



Loss of heterosis and complimentarity ...



Rotational systems

two breed

Hereford bulls	Angus bulls
Angus sired cows	Hereford sired cows
A	H
AH	HA
A(HA)	H(AH)
A(H(AH))	H(A(HA))
A(H(A(HA)))	H(A(H(AH)))

heifers retained from each group mated to the opposite breed

Rotational systems

2 breed
- 1/2 each direct breed effect
- 1/2 each maternal breed effect
- 2/3 individual heterosis
- 2/3 maternal heterosis

Rotational systems

three breed rotation

Hereford bulls Limousin sired cows	Angus bulls Hereford sired cows	Limousin bulls Angus sired cows
L	H	A
LA	HL	AH
L(AH)	H(LA)	A(HL)
L(A(HL))	H(L(AH))	A(H(LA))
L(A(H(LA)))	H(L(A(HL)))	A(H(L(AH)))

heifers retained from each group mated to the next breed

Rotational systems

2 breed
- 1/2 each direct breed effect
- 1/2 each maternal breed effect
- 2/3 individual heterosis
- 2/3 maternal heterosis

3 breed
- 1/3 each direct breed effect
- 1/3 each maternal breed effect
- 6/7 individual heterosis
- 6/7 maternal heterosis

4 breed
- 1/4 each direct breed effect
- 1/4 each maternal breed effect
- 14/15 individual heterosis
- 14/15 maternal heterosis

breed	direct	maternal	
Hereford	10	-5	
Angus	-5	10	general
Limousin	50	-20	mean = 500
Jersey	-55	15	
heterosis%	4.5	4.7	

Hereford - Angus rotation

500+.50(10) +.50(-5) +.50(-5) +.50(10)=505

505 + (2/3) .045 (505) = 520.15

520.15 + (2/3) .047 (520.15) = **536.45 lb**

breed	direct	maternal
Hereford	10	-5
Angus	-5	10
Limousin	50	-20
Jersey	-55	15
heterosis%	4.5	4.7

general mean = 500

Hereford - Angus - Limousin rotation

500 +1/3(10)+1/3(-5)+ 1/3(50)+1/3(-5)+1/3(10)+1/3(-20)=513.33

513.33 + (6/7) .045 (513.33) = 533.13

533.13 + (6/7) .047 (533.13) = 554.61 lb

Crossbreeding systems

Terminal

2 breed
purebred sire x purebred dam

3 breed
purebred sire x crossbred dam

4 breed
crossbred sire x crossbred dam .

Crossbreeding systems

advantages of terminal systems
- maximum use of breed complementarity
- maximum use of heterosis
- single breeding groups

disadvantage of terminal systems
- must purchase replacements.

Crossbreeding systems

advantages of rotation systems
- generates replacement females
- uses some heterosis

disadvantages of rotation systems
- no breed complementarity
- loss of heterosis
- multiple breeding groups
- variation between generations.

Combination system

advantages

uses breed complementarity

more heterosis than straight rotation

generates female replacements

disadvantage

only works with 250+ females .

Starting a crossbreeding system with an existing herd

1. Determine genetic makeup of herd
2. Cull animals that cannot fit plan
3. Choose sires to produce female replacements
4. Build herd of females that fit the environment
5. Determine market possibilities
6. Choose some sires that will produce offpring (with the females) that will match the market

Structure for a breeding population

must be a sufficient purebred industry to support crossing program

terminal vs rotational
Which needs more purebreds?

How many purebreds are needed?

Rotational crossbreeding

purpose of purebreds?
produce purebred males

purebred herds must produce enough males for own use and for the commercial herds

Terminal crossbreeding

purpose of purebreds?
- produce purebred males
- produce purebred and crossbred females

purebred herds must produce enough males for own use and for the commercial herds

must also produce enough females for own use and for the commercial herds

Breed development

much interest in composite breeds

also called synthetic breeds

technically almost all breeds are composite breeds

generally term is reserved for breeds developed during 20th century.

Composite breeds

examples are the numerous Brahman-derivative breeds

Santa Gertrudis	Brangus
Braford	Beefmaster
Bralers	Simbrah
Charbray	Brahmousin
Gelbray	Brahmaine

most are 3/8 Brahman:5/8 base breed

Composite breeds

how to build 5/8 A: 3/8 B

A x B	1/2 A:1/2 B
A x AB	3/4 A:1/4 B
AB x A(AB)	5/8 A:3/8 B .

Composite breeds

when is a breed a breed?

After *inter se* matings
matings between animals
with common breed
Makeup

Retention of heterosis

what happens to heterosis
as breed is developed

A x B	100 % heterosis
AB x AB	50 % heterosis
subsequent generations	? heterosis

heterosis remains at 50%

Retention of heterosis

why is there not further loss of
heterosis?

Hardy - Weinberg Law

genotypic frequencies
remain constant

proportion of heterozygocity
remains constant

What happens after breed is developed?

Selection to improve and
increase uniformity

as selection proceeds some heterosis
will be lost

Can a person be successful in building a new breed?

Must have large population to avoid buildup of inbreeding (n>300)
Must have genetically superior animals
Must have need for new breed
Must have marketing system
Must be prepared to supply customers with needed services

Which crossing system to adopt?

PUREBREED	when no cross is better.
F1 CROSS	when direct heterosis is important.
3 BREED CROSS	when both direct and maternal heterosis are important.
4 BREED CROSS	when paternal heterosis is important as well.
BACKCROSS	when only 2 good parental breeds are available and/or when direct heterosis is not important.
ROTATIONAL CROSSES	when females are too expensive to either buy in or to produce in the same enterprise.
OPEN OR CLOSED COMPOSITE	when both males and females are too expensive. A few initial well judged importations establish the synthetic (or 'composite'), and it can then either be closed (which helps to establish a breed 'type'), or left open to occasional well judged importations.

Patterns of use of crossbreeding

Industry	Fecundity	Typical crossing systems
Poultry	highest	4-breedcrosses
Pigs	↓	3-breed crosses;back crosses
Meat sheep		3-breedcrosses
Wool Sheep		purebred*
Dairy		purebred*
Temperate Beef		rotations;composites
Tropical Beef	lowest	composites

*Wool sheep and dairy industries are exceptions due to availability of an outstanding pure breed in each.

Typical outcomes.

Conditions	Outcome
Direct and maternal heterosis high	3- and 4-breed crosses
Female import costs high	Rotation crossing
Male import costs also high	Import sires for some generations then closed composite
Within breed genetic variance high	Opportunistic crossing

We will re-visit this Tactical Approach in lecture 21/22