How Genomic BLUP Works
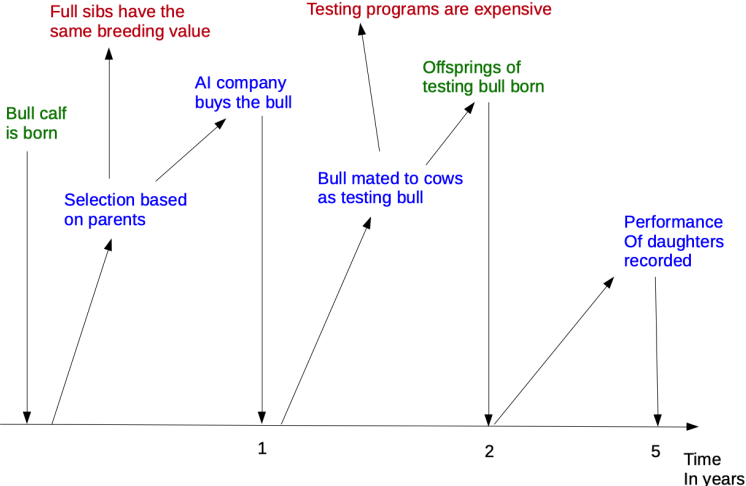
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Advantage of Genomic Selection

- Big advantage of genomic selection: **shorter generation interval**
- Old days: selection mainly based on performance tested sires
  - fine in species where generation inverval is low, e.g. pigs
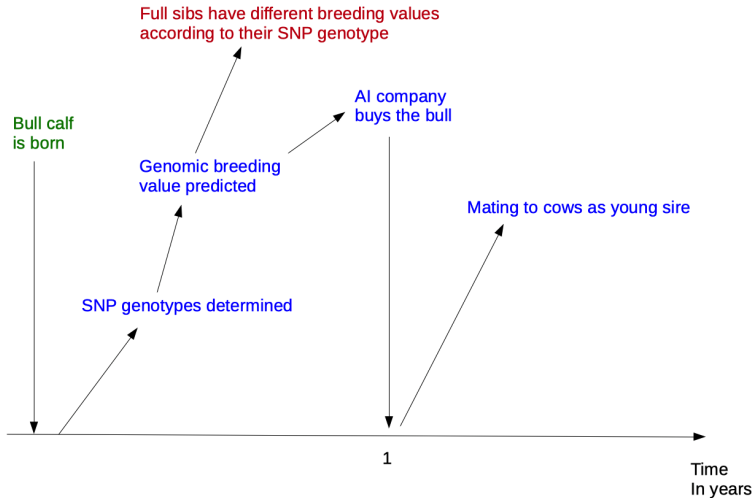 - problem when generation interval is long like cattle

Performance Testing

Genomic Selection

- SNP Genotype can be determined when calf is born
- Genomic Breeding value can be computed as soon as SNP genotype is determined
- Full sibs get different genomic breeding values $\rightarrow$ increase accuracy

Genomic Selection (II)

Full sibs have different breeding values
according to their SNP genotype

Bull calf
is born

AI company
buys the bull

Genomic breeding
value predicted

Mating to cows as young sire
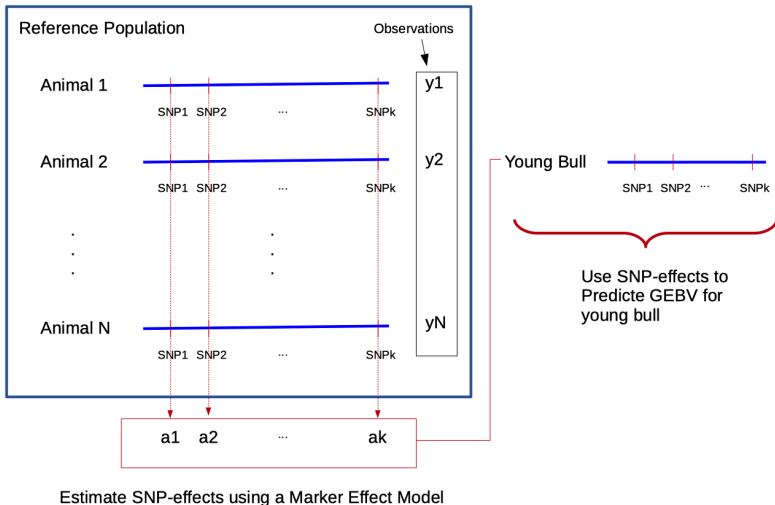
SNP genotypes determined

1

Time
In years

Prediction of Genomic Breeding Values

Genomic breeding values can be predicted using either

- Two step approach or
- Single step GBLUP

Two Step Approach

Estimate SNP-effects using a Marker Effect Model

Single Step GBLUP

- Use a mixed linear effect model
- Genomic breeding values g are random effects

$$y = Xb + Zg + e$$

with

- $E(e) = 0$, $var(e) = I * \sigma_e^2$
- $E(g) = 0$, $var(g) = G * \sigma_g^2$
- Genomic relationship matrix G

Solution Via Mixed Model Equations

- All animals have genotypes and observations

$$\begin{bmatrix} X^T X & X^T Z \\ Z^T X & Z^T Z + \lambda * G^{-1} \end{bmatrix} \begin{bmatrix} \hat{b} \\ \hat{g} \end{bmatrix} = \begin{bmatrix} X^T y \\ Z^T y \end{bmatrix}$$

with $\lambda = \sigma_e^2 / \sigma_g^2$.

Animals Without Observations

- Young animals do not have observations
- Partition $\hat{g}$ into
  - $\hat{g}_1$ animals with observations and
  - $\hat{g}_2$ animals without observations
- Resulting Mixed Model Equations are (assume $\lambda = 1$)

$$
\begin{bmatrix}
X^T X & X^T Z & 0 \\
Z^T X & Z^T Z + G^{(11)} & G^{(12)} \\
0 & G^{(21)} & G^{(22)}
\end{bmatrix}
\begin{bmatrix}
\hat{b} \\
\hat{g}_1 \\
\hat{g}_2
\end{bmatrix}
=
\begin{bmatrix}
X^T y \\
Z^T y \\
0
\end{bmatrix}
$$

Predicted Genomic Breeding Values

- Last line of Mixed model equations

$$
G^{(21)} \cdot \hat{g}_1 + G^{(22)} \cdot \hat{g}_2 = 0
$$

Solutions

- Solving for $\hat{g}_2$

$$\hat{g}_2 = -(G^{(22)})^{-1} \cdot G^{(21)} \cdot \hat{g}_1$$