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Assessment of Breeding Strategies in Genomic Breeding Programs

Sven König[1], Hermann H. Swalve[2]

[1]Institute of Animal Breeding and Genetics, University of Göttingen, Germany
[2] Institute of Agricultural and Nutritional Sciences, University of Halle, Germany

Today's dairy cattle breeding programs

1. Shift from production to functionality in the overall breeding goal

2. Shift from indicator traits (e.g. SCS, conformation…..) to the traits of interest (e.g. mastitis, hoof disorders….)

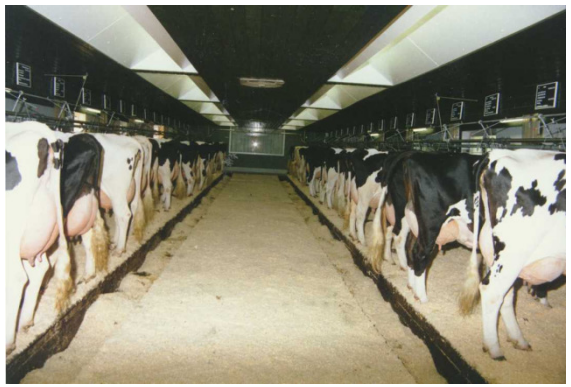
3. Genomic breeding values (GEBVs)

Aim of the study

To evaluate selection strategies in genomic breeding programs with a focus on improving functional (health) traits

How to collect functional traits?

1. On bull dams (BD) kept on station
   Examples in Germany:
   Donor test station in Osnabrück (since 1988)



   Station in Karkendamm (since 2001)

2. Progeny testing (PT)
   Examples in Germany:
   Large-scale dairy farms in East Germany

Do we need BD-Testing and PT in the genomic era?

Evaluation of genomic breeding programs via selection index theory (Dekkers, 2006)

$$b = \mathbf{P}^{-1}\mathbf{G}w$$

Evaluation criteria

$$r_{TI} = \frac{\sigma_I}{\sigma_T} = \sqrt{\frac{b'Gw}{w'CW}}$$

$$RSR = \frac{\Delta G_{\text{without SNP information in the index}}}{\Delta G_{\text{including SNP information in the index}}} * 100$$

Formulae to set up the necessary matrices

(Lande and Thompson, 1990; Falconer and Mackay, 1996)

$$h_m^2 = 1 \qquad [1]$$

$$\sigma_m = r_{mg} * \sigma_a \qquad [2]$$

$$\sigma_{am} = a_{ij} * r_{mg}^2 * \sigma_a^2 \qquad [3]$$

Scenario I

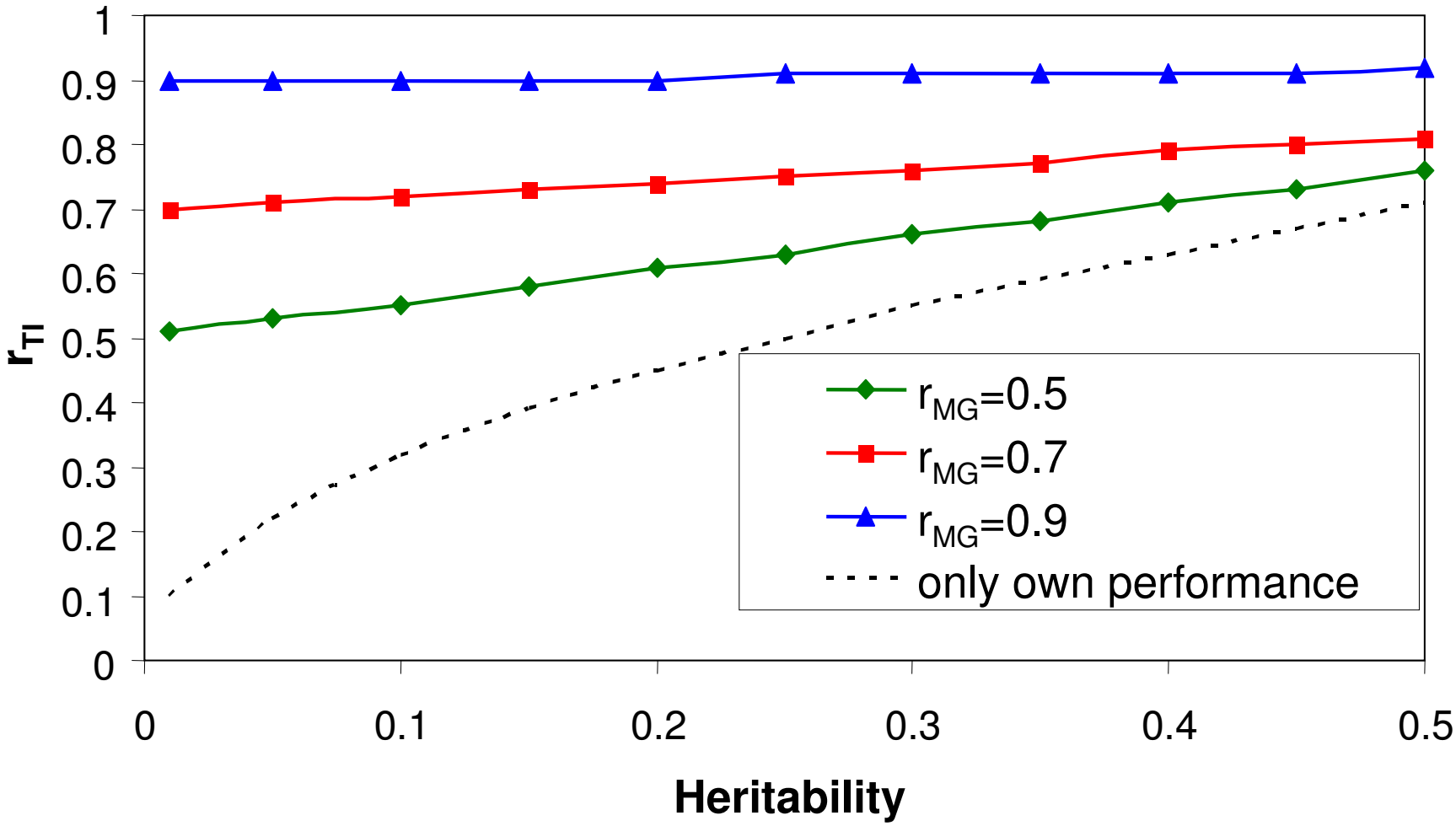
genotyped BD (marker m), own performance of BD (y)

$$\mathbf{P} = \begin{bmatrix} \sigma_y^2 & \sigma_{am} \\ \sigma_{am} & \sigma_m^2 \end{bmatrix}$$

$$\mathbf{G} = \begin{bmatrix} \sigma_a^2 & \sigma_{am} \\ \sigma_{am} & \sigma_m^2 \end{bmatrix}$$

$$\mathbf{w} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

Scenario I: Results in terms of r_{TI}



Scenario II

genotyped sire (marker m), daughter performances (y)

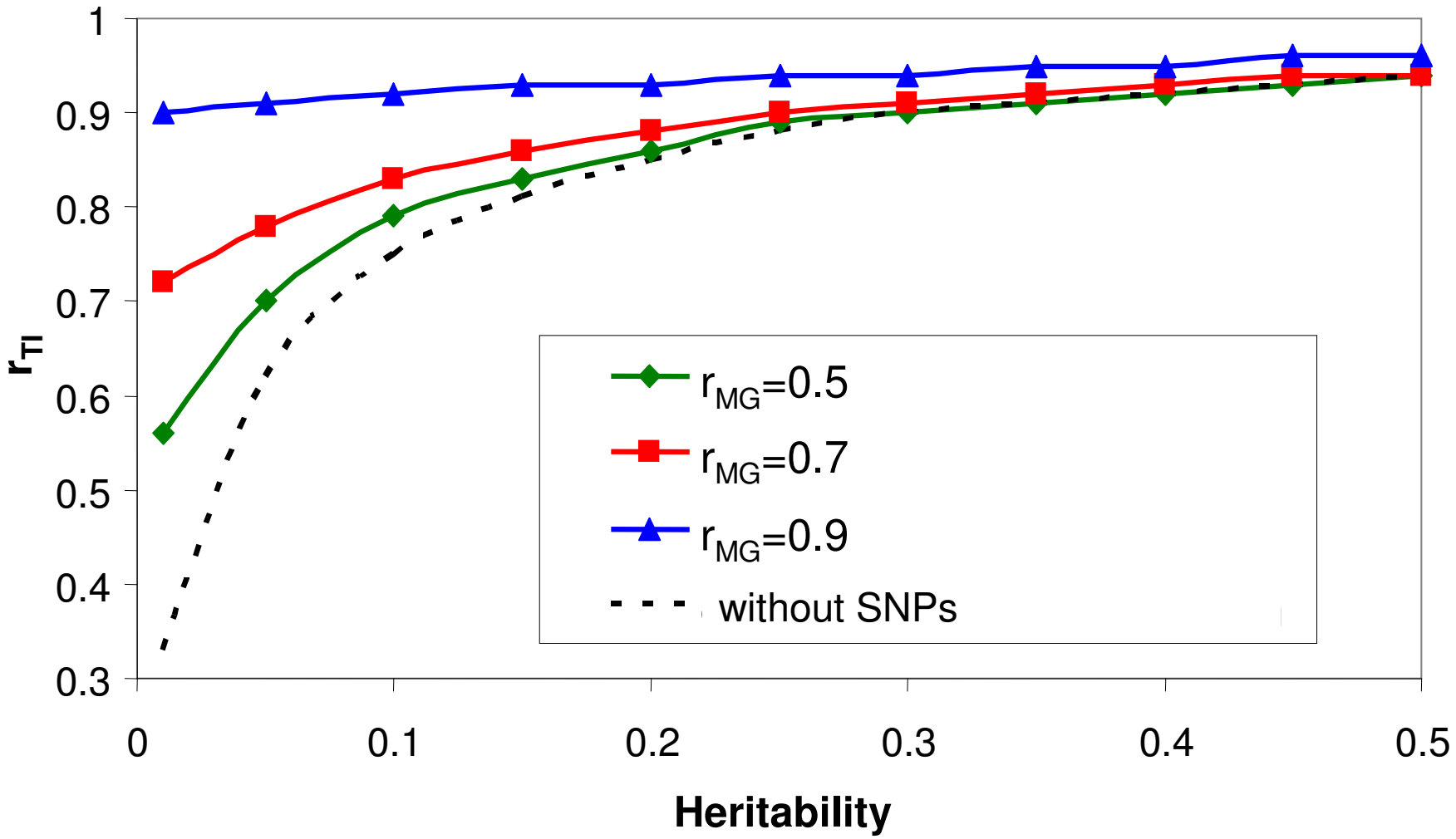
$$\mathbf{P} = \begin{bmatrix} \frac{\left(1+(n-1)*0.25*h^2\right)}{n}\sigma_y^2 & 0.5\sigma_{am} \\ 0.5\sigma_{am} & \sigma_m^2 \end{bmatrix}$$

$$\mathbf{G} = \begin{bmatrix} 0.5\sigma_a^2 & 0.5\sigma_{am} \\ \sigma_{am} & \sigma_m^2 \end{bmatrix}$$

$$\mathbf{C} = \begin{bmatrix} \sigma_a^2 & \sigma_{am} \\ \sigma_{am} & \sigma_m^2 \end{bmatrix}$$

$$\mathbf{w} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

Scenario II for 50 daughters: Results in terms of r_{TI}



Scenario II: No. of daughters required to achieve a pre-defined r_{TI}

	Accuracy of GEBV (r_{MG})							
	r_{MG}=0.5		r_{MG}=0.7		r_{MG}=0.9		only daugthers	
h^2	r_{TI}=0.8	r_{TI}=0.95	r_{TI}=0.8	r_{TI}=0.95	r_{TI}=0.8	r_{TI}=0.95	r_{TI}=0.8	r_{TI}=0.95
0.01	581	3561	330	3310	0	1993	710	3694
0.05	115	705	65	656	0	395	141	732
0.10	57	348	32	324	0	195	70	361
0.15	38	230	21	213	0	129	46	238
0.20	28	170	16	158	0	95	34	176
0.25	22	134	13	125	0	75	27	139
0.30	18	111	11	103	0	62	22	115
0.35	16	94	9	87	0	53	19	97
0.40	13	81	8	75	0	45	16	84
0.45	12	71	7	66	0	40	15	74
0.50	11	63	6	59	0	35	13	65

Scenario III

own performance of BD for 2 traits (MILK, CTFS)
genotyped BD for 2 traits (MILK_M, CTFS_M)

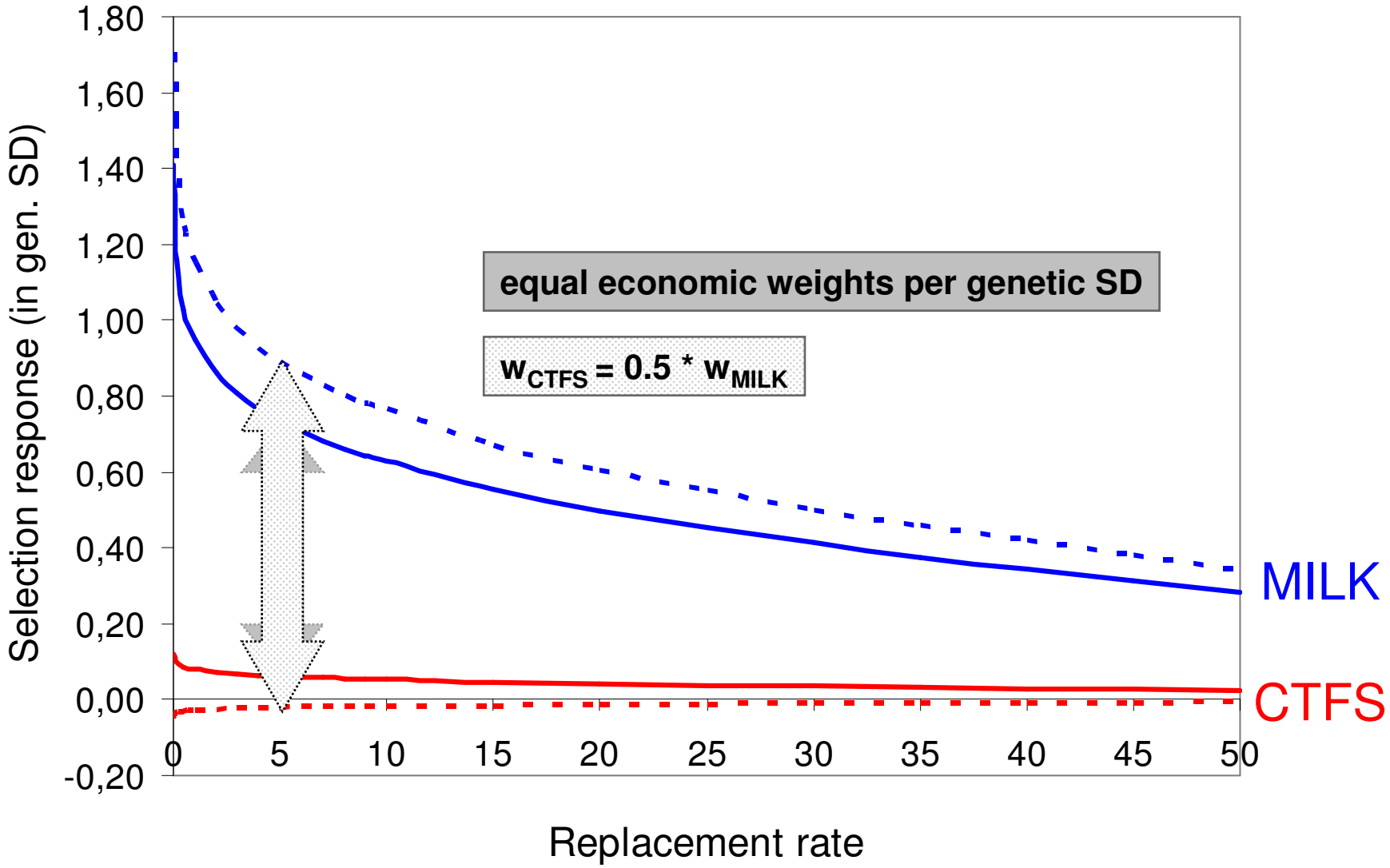
$$h^2_{MILK} = 0.30 \qquad h^2_{CTFS} = 0.05$$

$$r_{p_{MILK:CTFS}} = -0.20 \qquad r_{g_{MILK:CTFS}} = -0.20$$

$$r_{MG_{MILK}} = 0.8 \qquad r_{MG_{CTFS}} = 0.5$$

$$\mathbf{w} = \begin{bmatrix} w_{MILK} \\ w_{MILK\_M} \\ w_{CTFS} \\ w_{CTFS\_M} \end{bmatrix} \begin{matrix} \text{variation} \\ =0 \\ \text{variation} \\ =0 \end{matrix}$$

Scenario III: Results



Breeding strategies

Traditional breeding scheme: 4-paths of selection
(Robertson and Rendel, 1950)

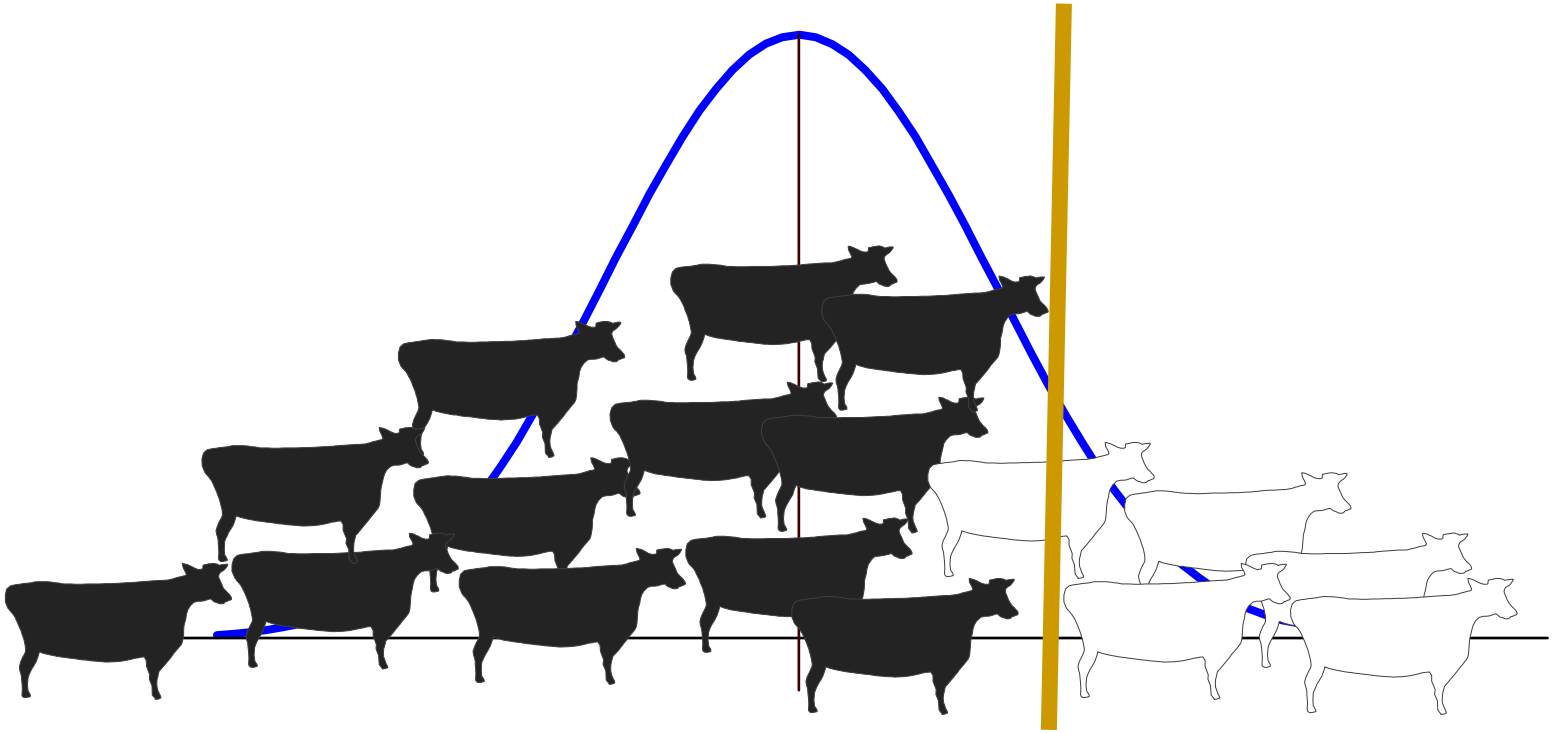
James M. Rendel
1915 - 2001

1. CS
2. CD
3. BS
4. BD

Alan Robertson
1920 - 1989

Bull dam selection: production

- efficient selection tools (conventional EBVs)
- EBVs have sufficient reliability
- practical BD selection is focussed on production

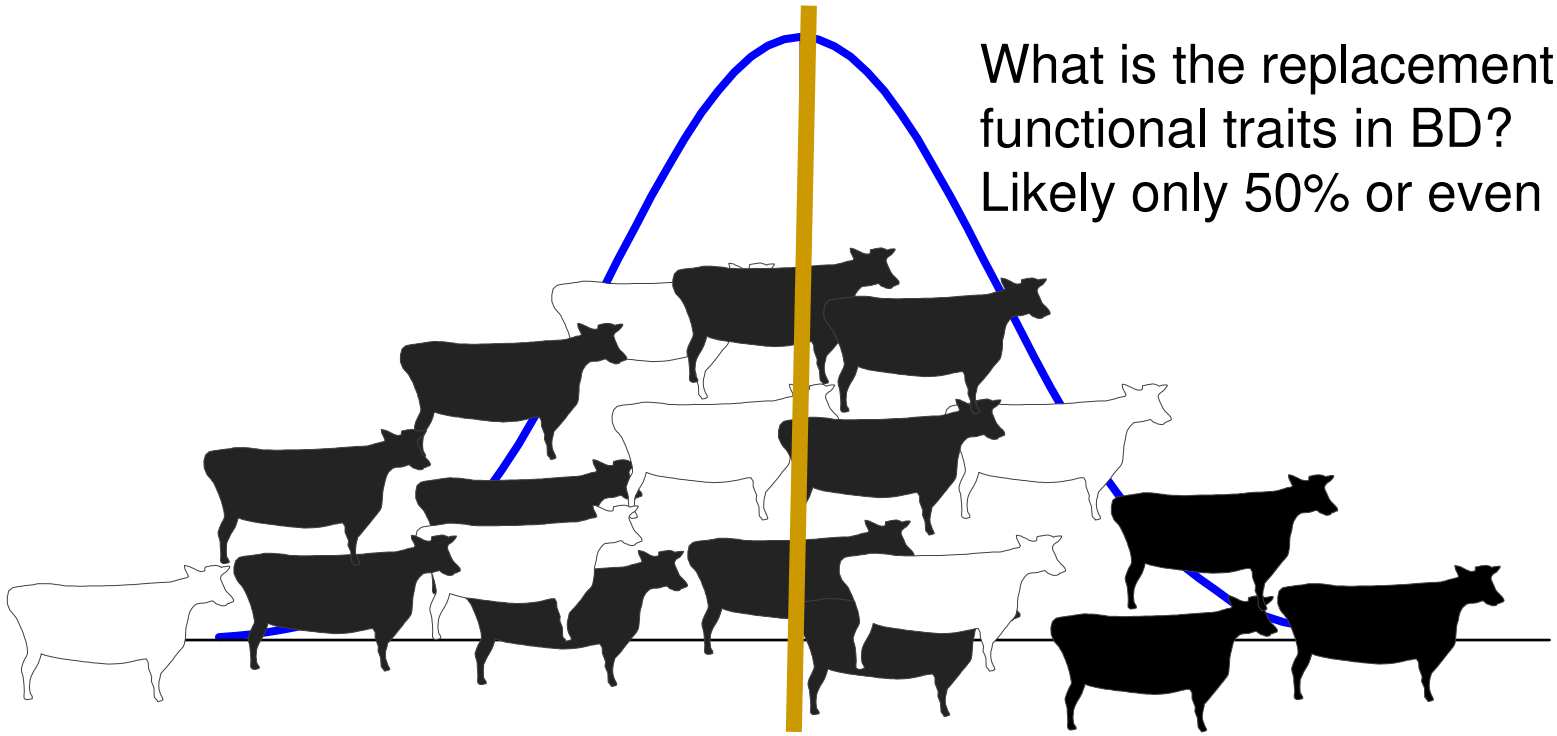


„true BV for production“ below the 5% threshold

„true BV for production“ above the 5% threshold

Bull dam selection: functional traits

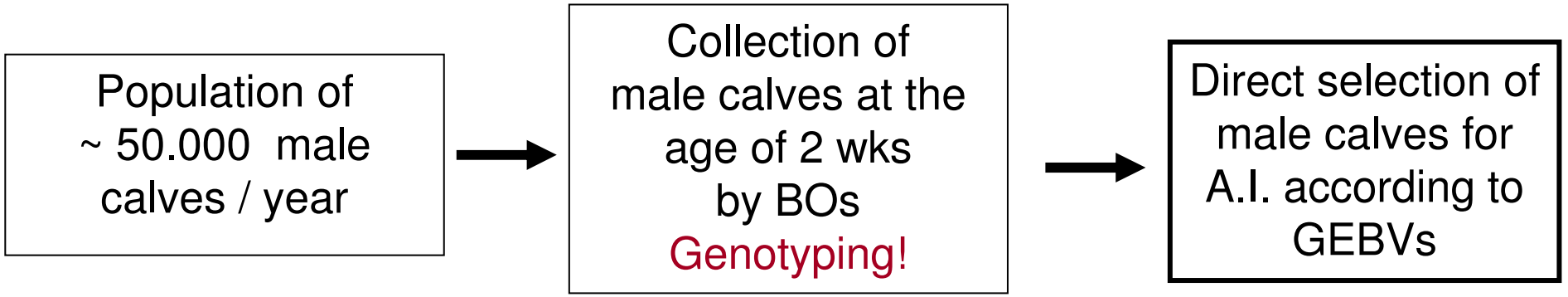
- limited selection tools
- EBVs have low reliability
- practical BD selection is focussed on production



What is the replacement rate for functional traits in BD?
Likely only 50% or even higher!

„true BV for functionality“ below the 5% threshold
„true BV for functionality“ above the 5% threshold

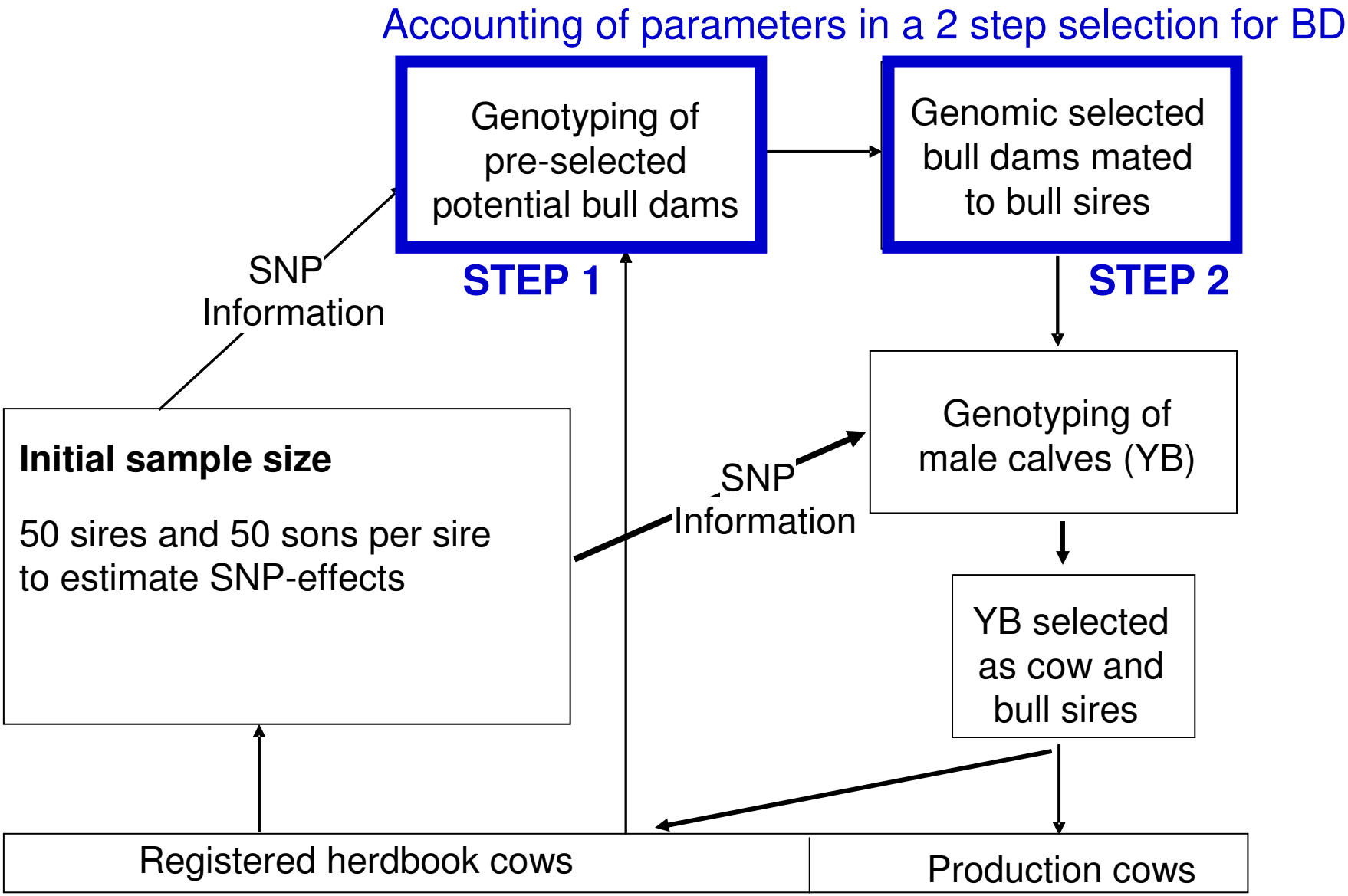
Alternative in the genomic era
2-pathway selection strategy



Comparison in terms of ΔG with:

4-pathway genomic breeding program (Schaeffer, 2006)

Modification of Schaeffer's GBP

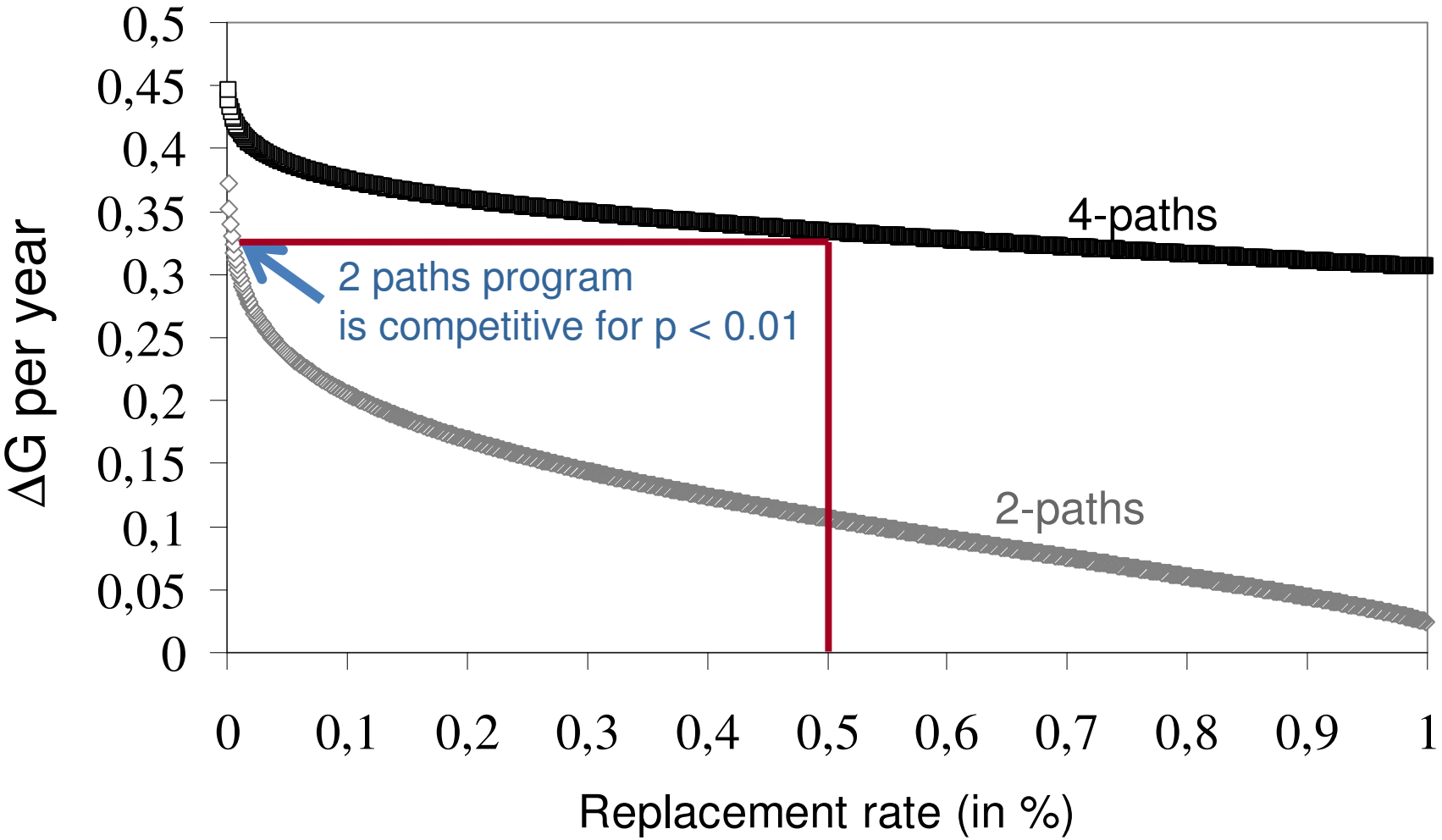


(Schaeffer, 2006)

Parameters to calculate ΔG

Pathway of selection	Replacem. (p in %)	Sel. intensity (i)	Accuracy (r_{TI})	Gen. int. (L)
4-pathway program				
BS	5	2.06	0.75	2.1
CS	10	1.40	0.75	2.1
CD	80	0.35	0.50	5.5
BD (step 1)	varied	varied	0.50	2.0
BD (step 2)	50	According to Fewson (1976)	0.75	2.0
2-pathway program				
CD	80	0.35	0.50	5.5
Male calves	varied	varied	0.75	2.1

ΔG: 2-paths vs 4-paths



Conclusions: Improvements for functional traits

1. There is no need for a central station test for BD in the genomic era

2. Genotyped bulls still need daughter performances
   ➔ setting up of co-operator herds for PT

3. Two-path selection strategy is an alternative when
   costs for genotyping decrease
   BOs are involved in trading of male slaughter cattle