Considering multiple trait selection strategies; why indexes work best

考虑多性状选择策略，为什么指数最有效？

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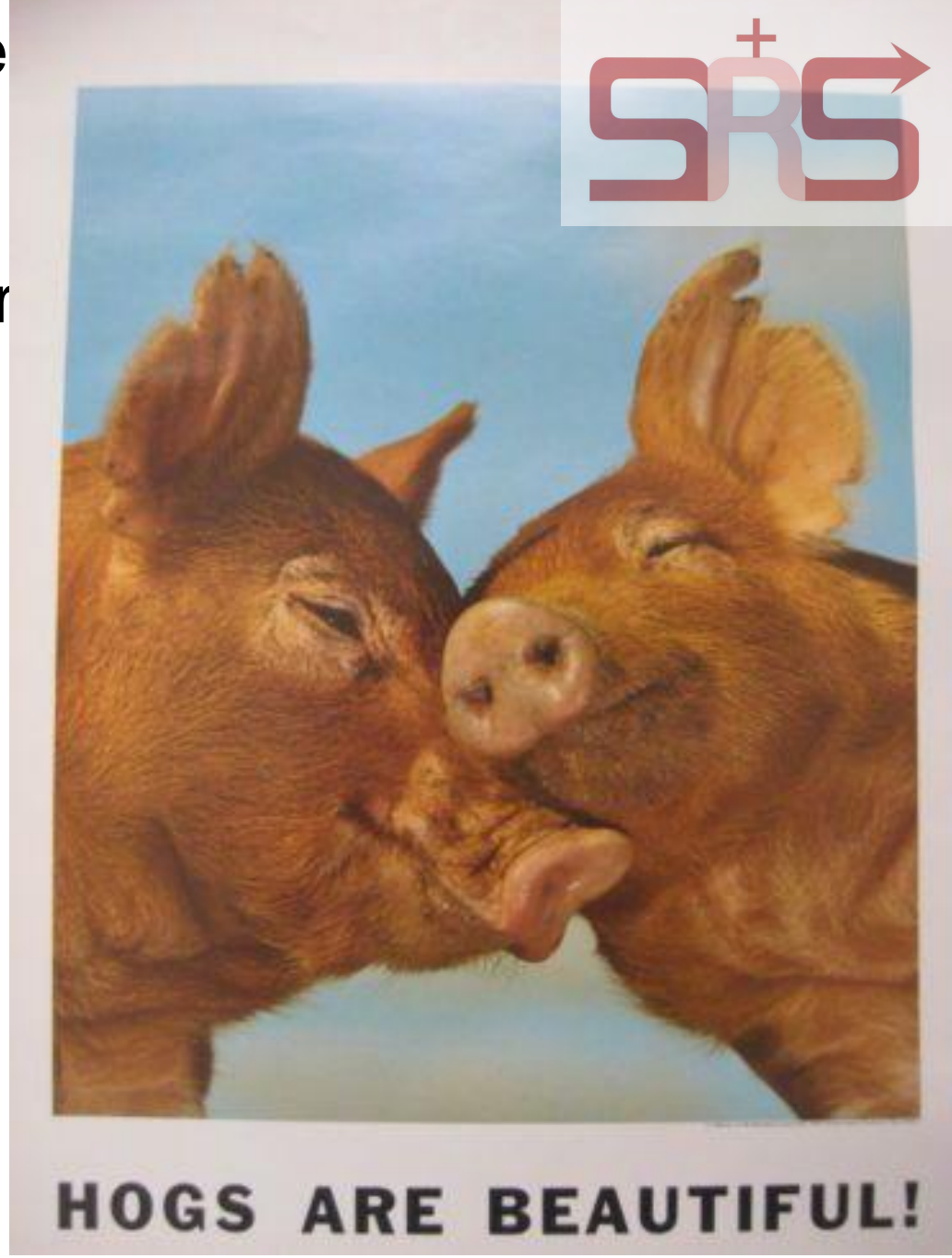
“Most scholars agree there were two separate domestication events …of the wild boar (*Sus scrofa*). …the process began with local hunter-gatherers hunting wild boars, then over a period of time began managing them, and then purposefully or unconsciously keeping those animals with smaller brains and bodies and sweeter dispositions.”

“大多数学者都同意野猪（*Sus scrofa*）有两个独立的驯化事件……。这个过程始于当地的狩猎采集者捕猎野猪，然后在一段时间内开始管理它们，然后有意或无意识地让这些野猪拥有更小的大脑和身体，更温顺的性情。”



History of Livestock Improvement
畜牧业改良史

- ~10,000 years ago domestication
- 约一万年前驯化
- Select animals to serve humans
- 选择一些动物来为人类服务
- Regional selection resulted in landraces
- 区域选择导致了地方品种
  - Locally adapted populations 适应当地的品种
- Landraces with pedigrees led to breeds
- 有血统的地方品种为不同品系的建立打下基础

Evolution of Breeding
育种的进化

- Breeds vary in performance traits
- 不同品种的表现性状也有所不同
- Specialization of sire lines vs dam lines
- 父系与母系的专门化
- Crossbreeding used to capture heterosis (hybrid vigor)
- 用于获取杂种优势的杂交育种（杂种优势）

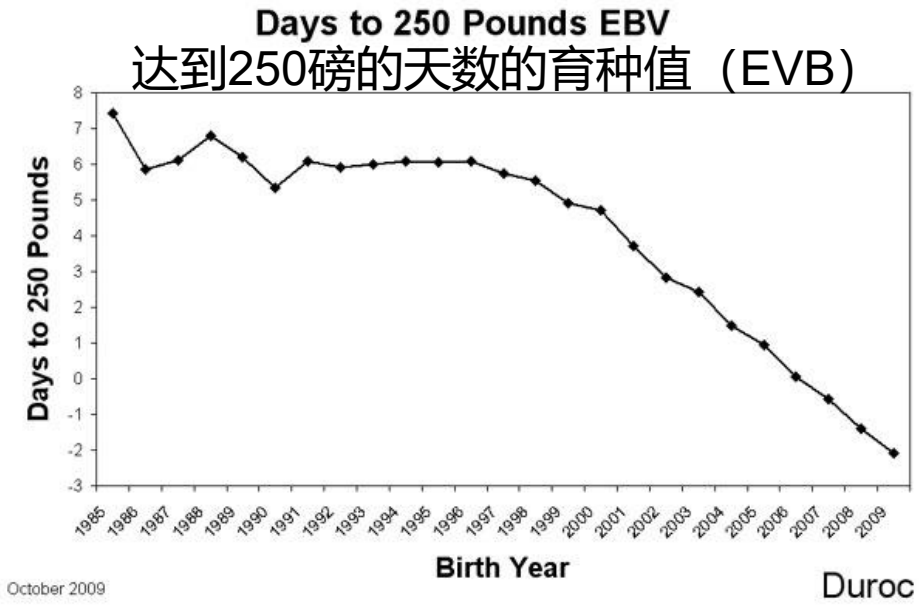
Selection History 选择历史

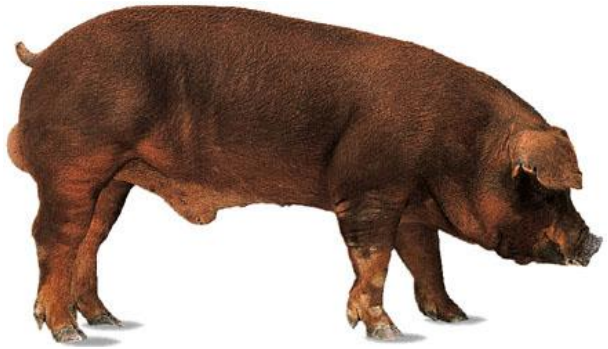
- Selection on phenotype 表型选择
- Selection on phenotype enhanced with relatives' data
- 亲缘数据增强了表型的选择
- Selection enhanced by adjusting for environment
- 通过调整环境来增强选择
- Selection enhanced with Marker Assisted Selection
- 通过标记辅助选择增强了选择
- Transgenic technology tested 转基因技术测试
  - Introducing DNA from one species to another 将DNA从一个物种引入到另一个物种
  - Largely refused by public and not used in livestock 主要被公众拒绝，也没有用于牲畜中

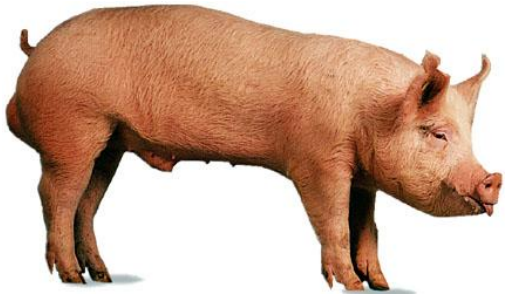
Specialized Sire and Dam Lines
专门化的父系和母系

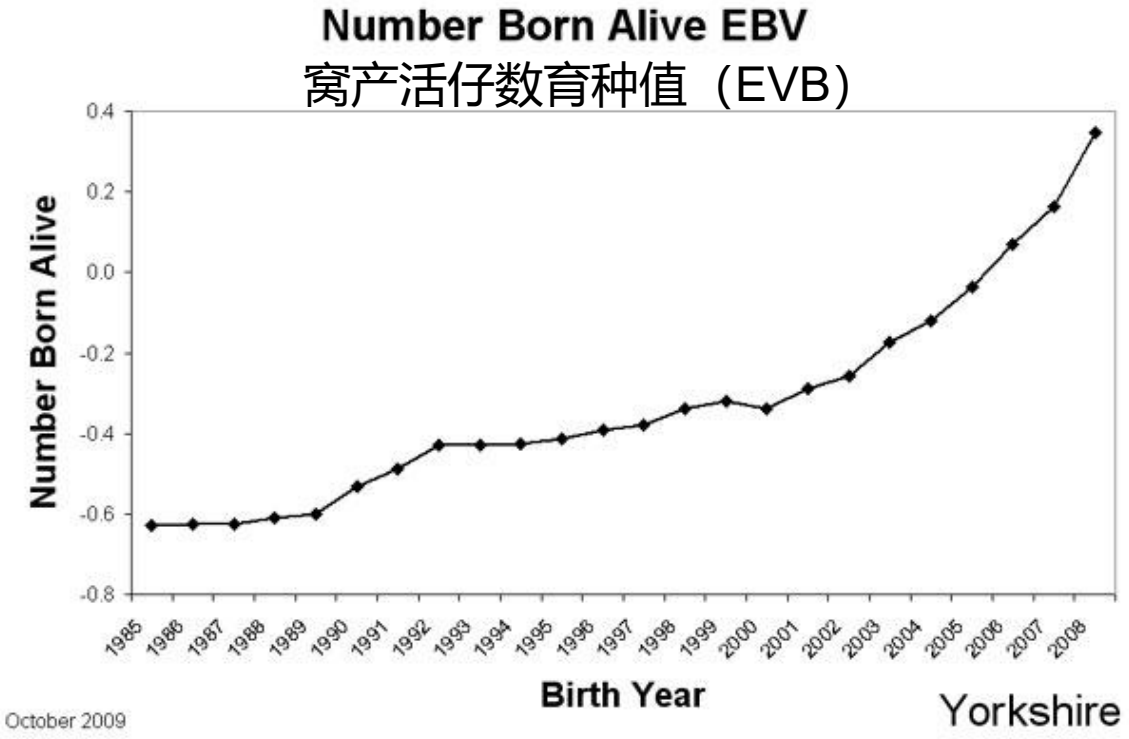
- Growth rate 生长速率
- Feed:Gain 饲料：增重
- Carcass composition 胴体组成
- Meat quality 肉类品质
- Testes size 睾丸大小
- Feet and legs 脚和腿

- Age at puberty 初情期年龄
- Litter size 窝仔猪数多少
- WEI 断奶发情间隔
- Longevity 寿命
- Milk production 母乳生产
- Nipples 乳头
- Vulva 外阴


Days to 250 Pounds EBV
达到250磅的天数的育种值（EVB）
Days to 250 Pounds
Birth Year
October 2009
Duroc






Number Born Alive EBV
窝产活仔数育种值（EVB）
Number Born Alive
Birth Year
October 2009
Yorkshire

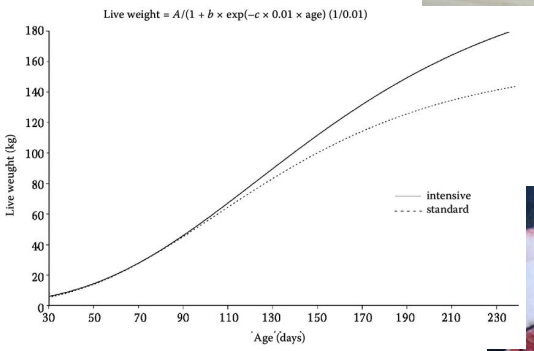
Phenotype = Genotype + Environment
表型=基因型+环境

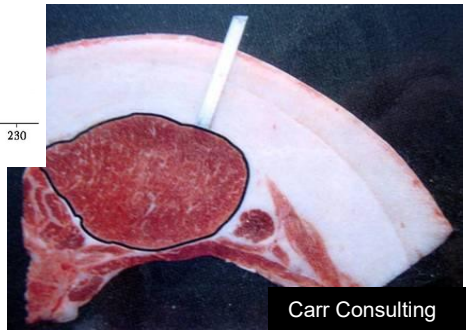
Heritability is the proportion of phenotypic variation due to genetics (remainder of variation due to environment) 遗传力是指由遗传引起的表型变异的比例（环境造成的剩余变化）

population specific 群体特异性

varies by trait type 因性状类型而异

繁殖和适应度较低	reproduction/fitness	low
生长转化能力适中	growth/conversion	moderate
胴体和肉类品质高	carcass/meat	high





Heritability estimates of some traits
某些性状的遗传力估计

特征	Trait	Heritability遗传力
活产仔数（NBA）	*Number Born Alive (NBA)*	0.10
窝出生体重	Litter Birth Weight	0.29
修正的21天体重（21dwt）	Adj. 21 d weight (21dwt)	0.15
第21天时的仔猪数	Number piglets at 21 d	0.06
到113公斤的天数	*Days to 113kg*	0.30
背膘探针（脂肪）	Backfat probe (fat)	0.40
饲料效率	Feed efficiency	0.30
平均日增重（ADG）	Average Daily Gain (ADG)	0.30
瘦肉率（胴体）	*% lean (carcass)*	0.48

NSIF, 2002

Response to Selection
对选择的响应

- **ΔG = heritability x selection differential**
  ΔG = 遗传力x选择差异

  - h^2 = proportion of phenotypic variation due to additive genetic variance
  - h^2 = 加性遗传变异引起的表型变异比例
  - SD = difference between population mean and mean of individuals selected as replacements
  - SD = 群体平均值和被选为后备猪的个体平均值之间的差异
    - The *variance* and *selection intensity* 变异和选择强度

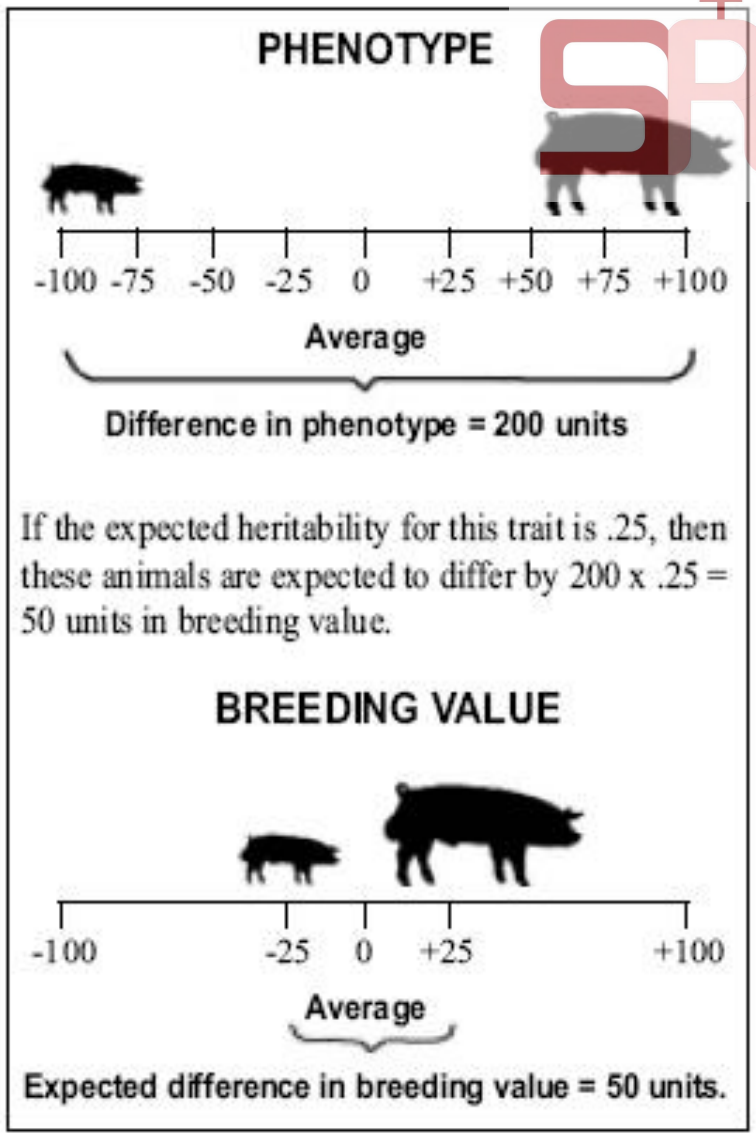
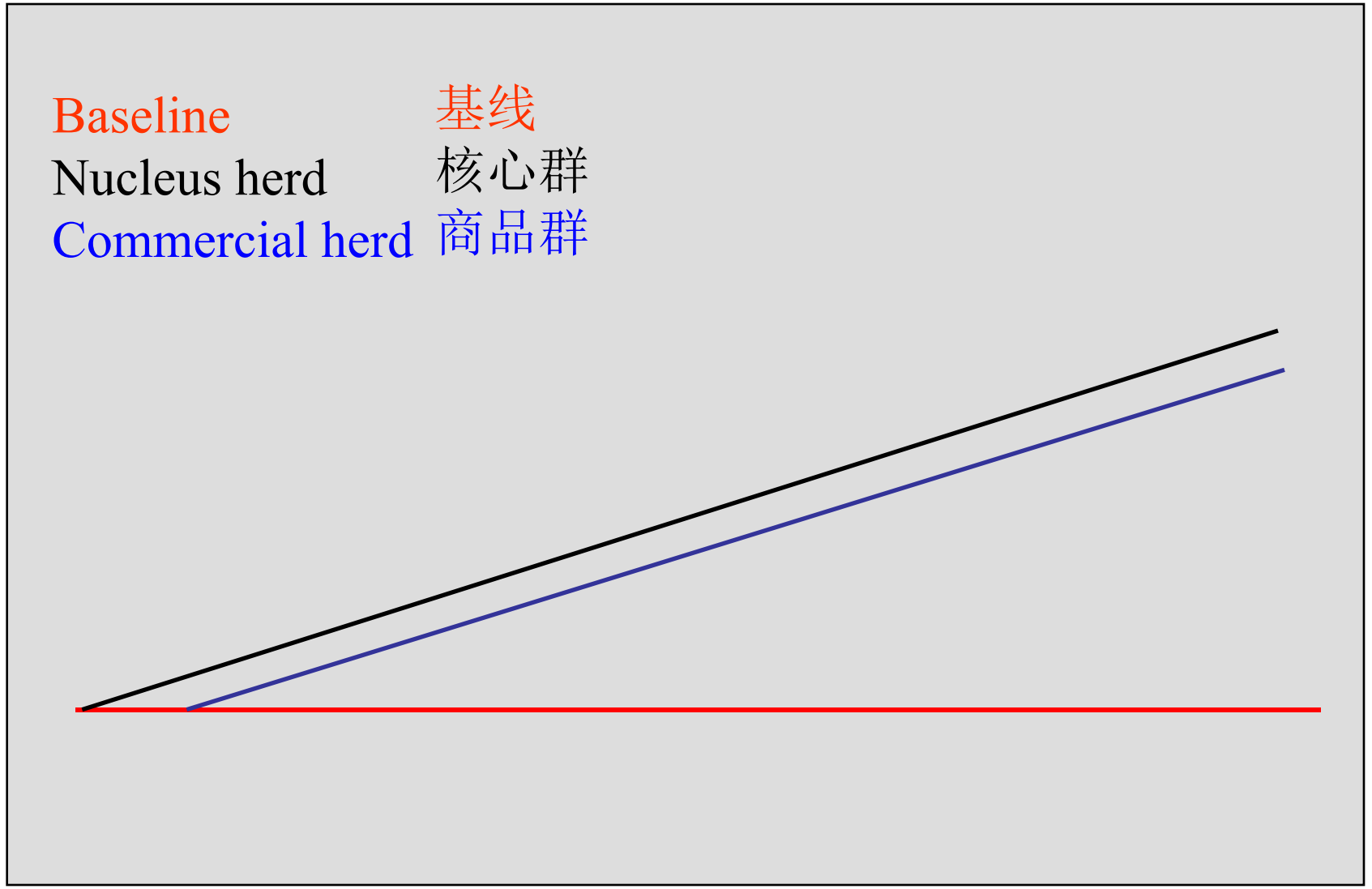


Figure 1. A diagrammatic representation of the proportion of phenotypic differences, which are expected to be due to differences in breeding value for a trait with a heritability of 0.25.

Performance over time with selection, say ADG
随着时间的推移，选择对生产成绩的影响，例如ADG



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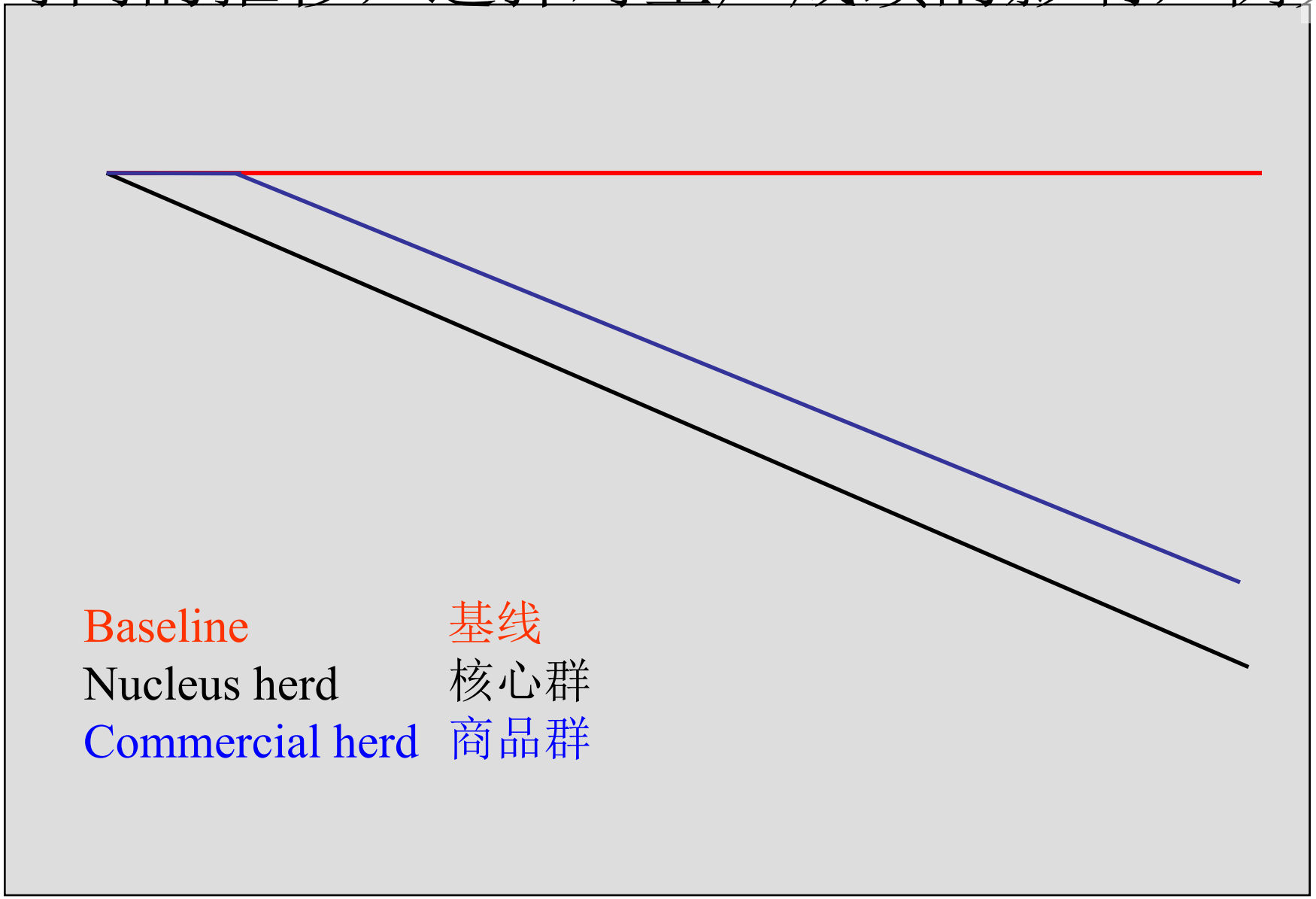


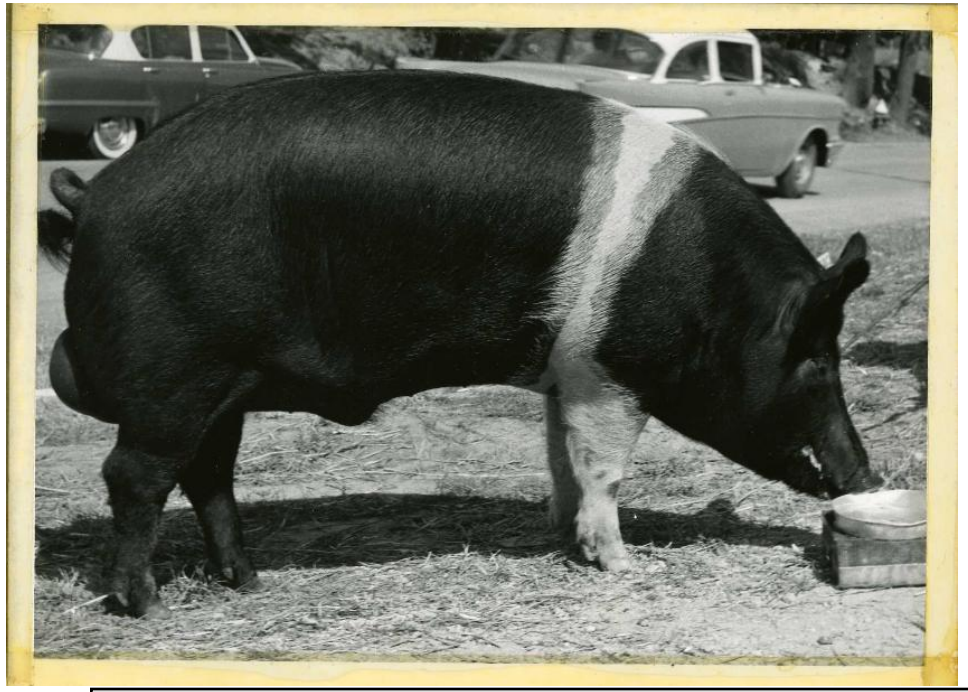
Multiple Trait Selection
多性状选择

- Indirect through correlated traits 间接地通过相关的特征
- Tandem Selection串联选择
  - Alternate traits selected each generation 每一代选择交替性状
- Independent Culling Levels 独立的淘汰水平
  - Threshold for each trait of interest 每个感兴趣的特征的阈值
- Index Selection 指数选择
  - Using economic value and genetic/phenotypic correlations to combine all traits of interest into one number
  - 利用经济价值和遗传/表型相关性，将所有感兴趣的性状组合成一个数字

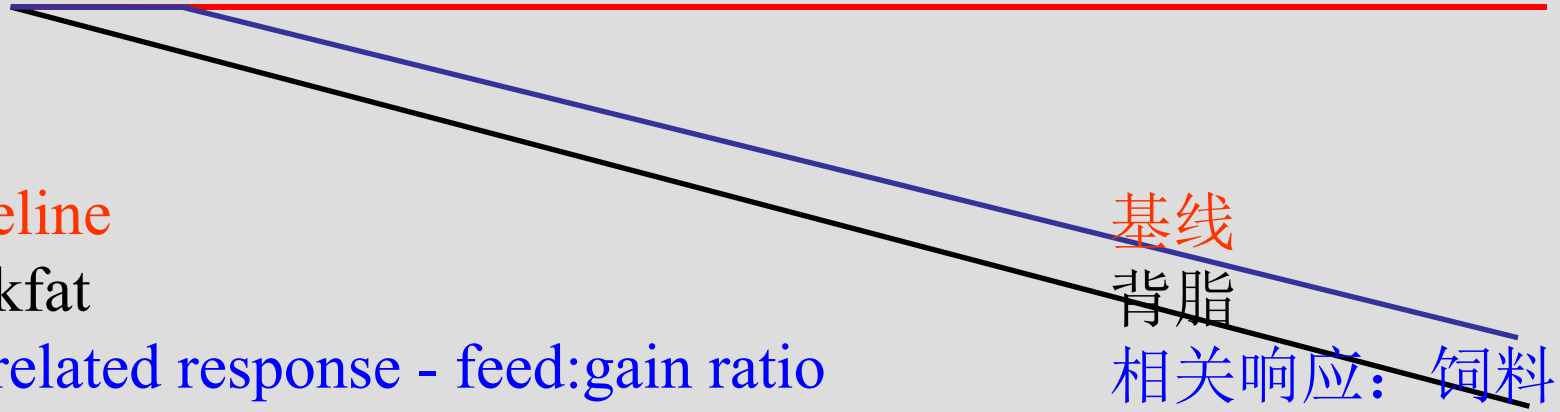
Genetic correlations of male fertility traits with progeny performance traits (within a line)
雄性生育性状与子代表现性状的遗传相关性（在一个品系内）

	Average Daily Gain平均日增重	Backfat hickness 背膘厚度	Muscle Depth 肌肉深度
Volume 体积	-0.21	-0.19	-0.94
Concentration 浓度	0.30	-0.21	-0.49
Motility 流动性	-0.62	0.34	
#sperm cells 精子细胞	0	0.35	-0.93

Safranski, 2008

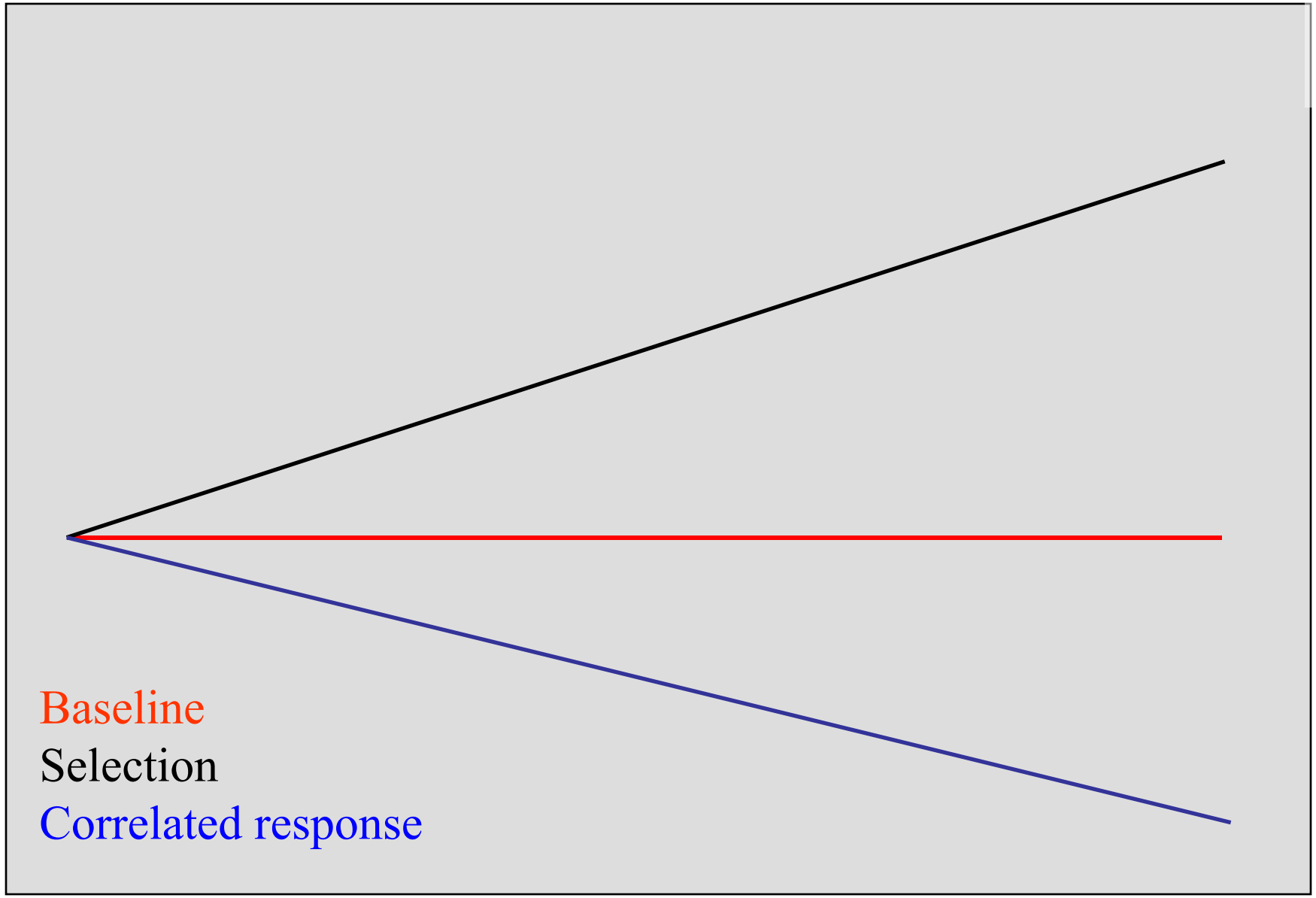


provided by National Swine Registry



Baseline
Backfat
Correlated response - feed:gain ratio
Correlated response - average daily gain
Correlated response - feed intake

基线
背脂
相关响应：饲料：增重比
相关响应：平均日增重
相关响应：饲料采食量



基线
选择
相关响应

Relative response in one trait from selection for multiple traits assuming equal heritability and no genetic correlation.
(Relative Response 1/√n where n=number of traits.)
在遗传力相同且无遗传相关的多个性状选择中，一个性状的相对反应。
（相对响应1/√n，其中n=性状数量。）

性状数量 # of Traits	相关反应 Relative Response
1	1.0
2	.71
3	.58
4	.50
5	.44
10	.31
20	.22

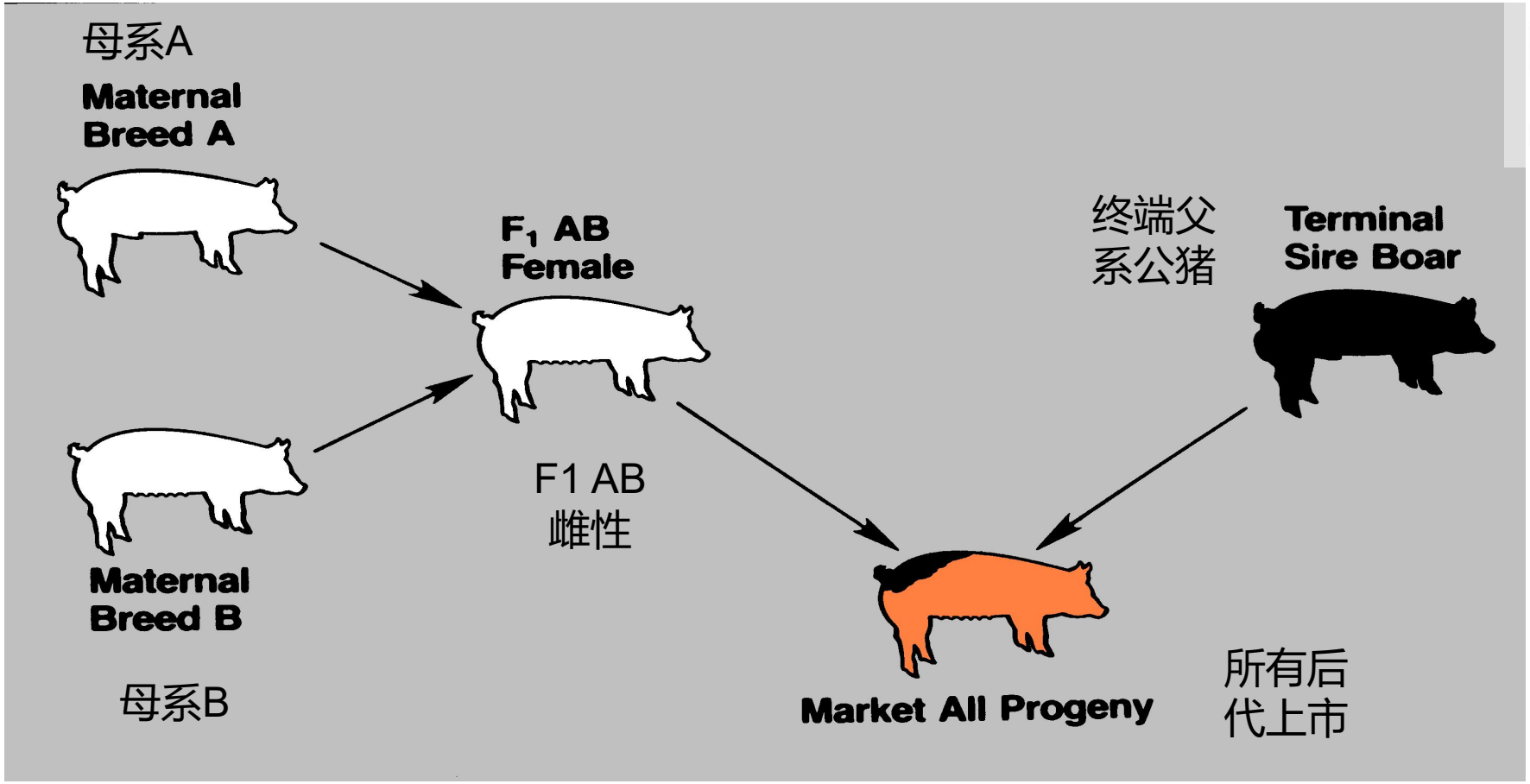
Adapted from NSIF

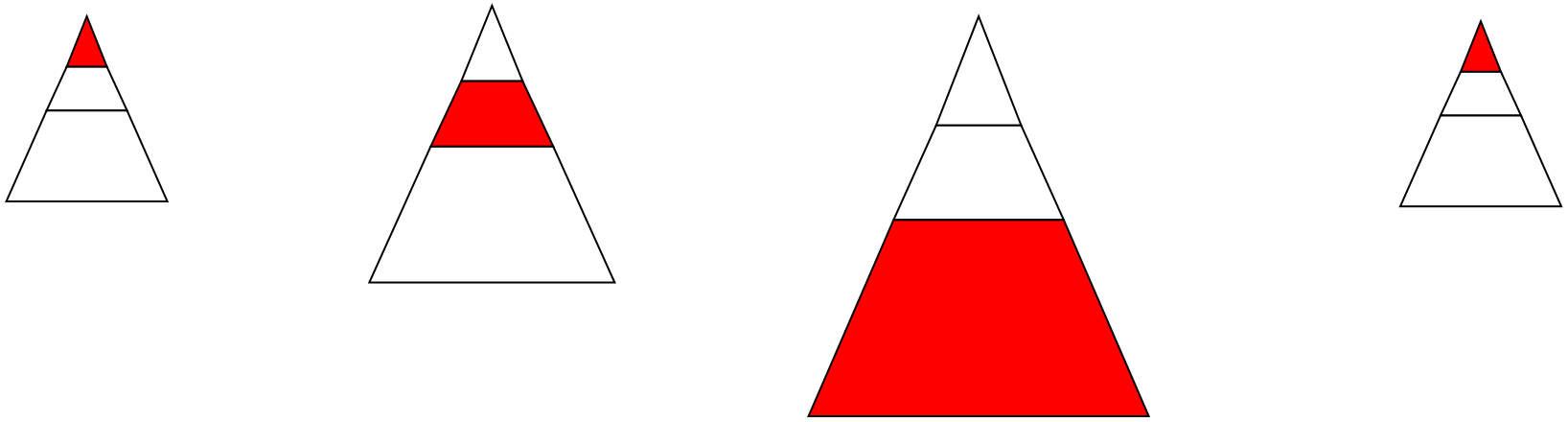
Relative economic improvement selecting for two vs three traits

两个VS三个性状的相对经济改善选择

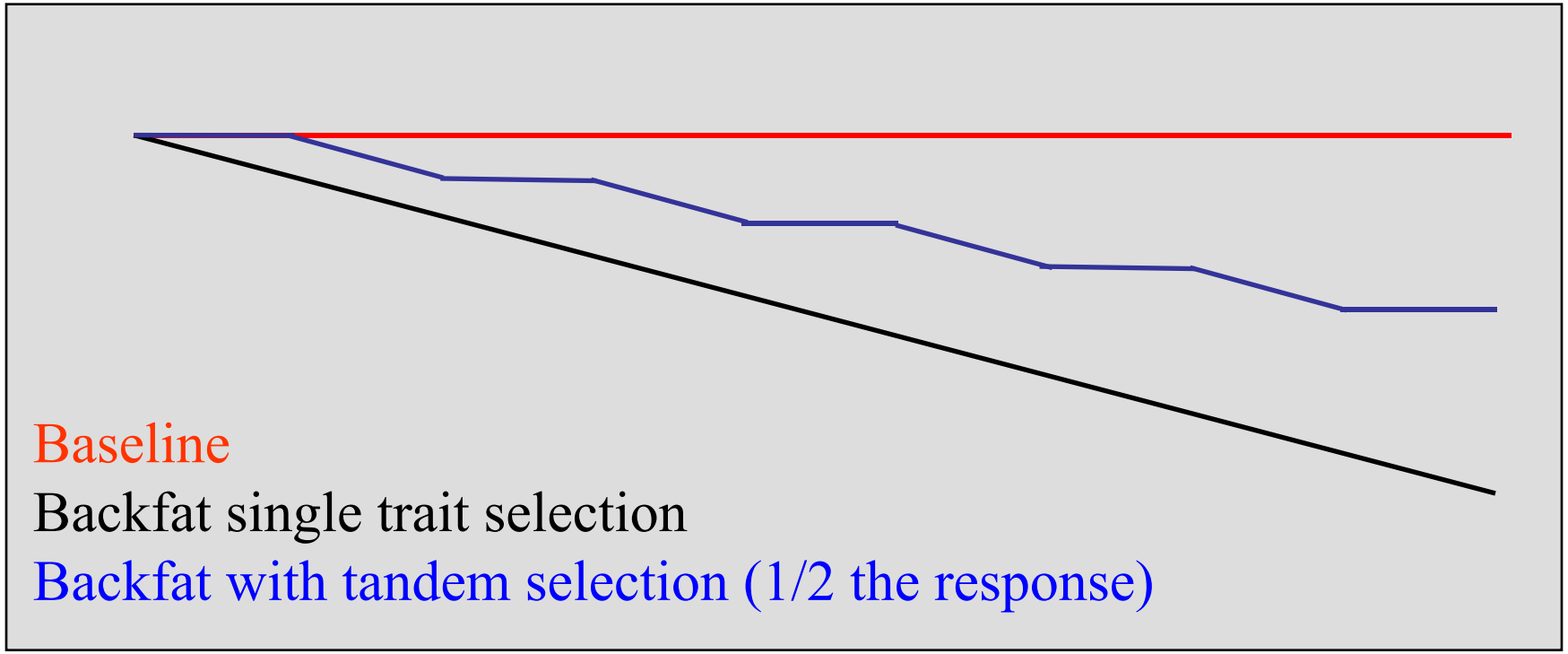
客观特点 Traits in Objective	值/单位 Value/Unit	响应 Response	响应价值 Value of Response
Days to market上市天数	-$.17/day	4.25 days	$.72
Backfat 背膘	-$1.04/0.1 in.	-.002 in.	$.002
			$.72/pig
Days to market上市天数	-$.17/day	-3.75 days	$.64
Backfat 背膘	-$ 1.04/0.1 in.	-.001 in.	$.001
# Born Alive 窝活产仔数	$15.50/pig/litter	.29 pigs/litter	$.51
			$1.15/pig

Adapted from National Swine Improvement Federation


母系A
Maternal
Breed A
F_1 AB
Female
F1 AB
雌性
终端父
系公猪
Terminal
Sire Boar
Maternal
Breed B
母系B
Market All Progeny
所有后
代上市



Tandem Selection
串联选择

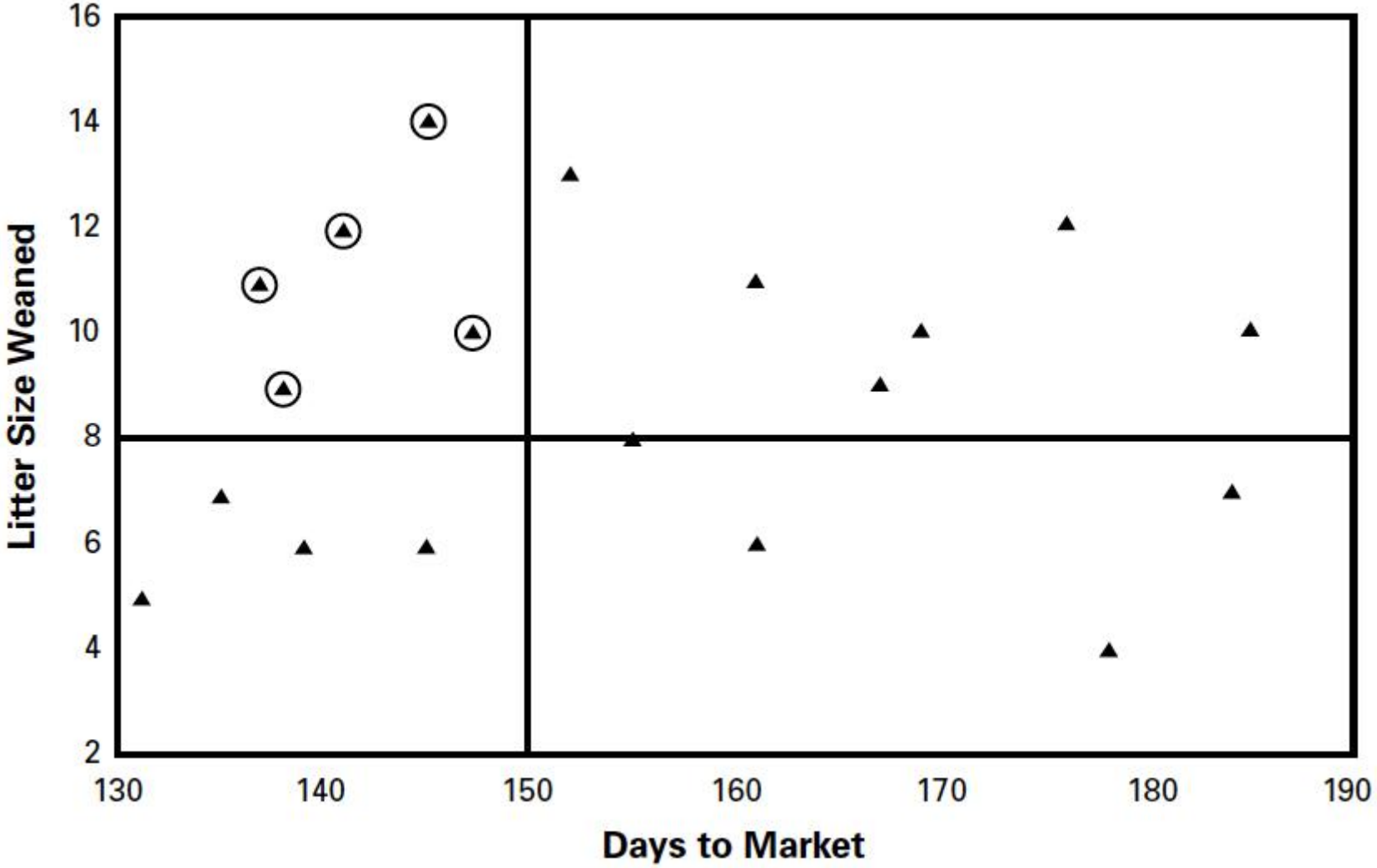


基线
背膘单性状选择
具有串联选择的背膘(1/2的响应)

Independent Culling Levels
独立的淘汰水平

- If 25% of animals are to be selected
- 如果要选择25%的动物
  - With equal weighting then the top 50% in each trait are selected
  - 在权重的情况下，选择每个性状的前50%
    - 50% X 50% = 25%
  - If one trait to be weighted 2x the other then top 35% in first trait and top 70% in second
  - 如果一个特征是另一个特征的2倍，那么第一个特征排名前35%，第二个特征前70%
    - 35% X 70% = 25%

Independent Culling Levels
独立的淘汰水平



Adapted from NSIF

Index Selection指数选择

- For each trait of interest matrix algebra used to include:
- 对于每个感兴趣的特征，矩阵代数用于包括：
  - Heritabilities 遗传性
  - Genetic and phenotypic correlations 遗传和表型的相关性
  - Economic value of a unit change 一个单位变动的经济价值

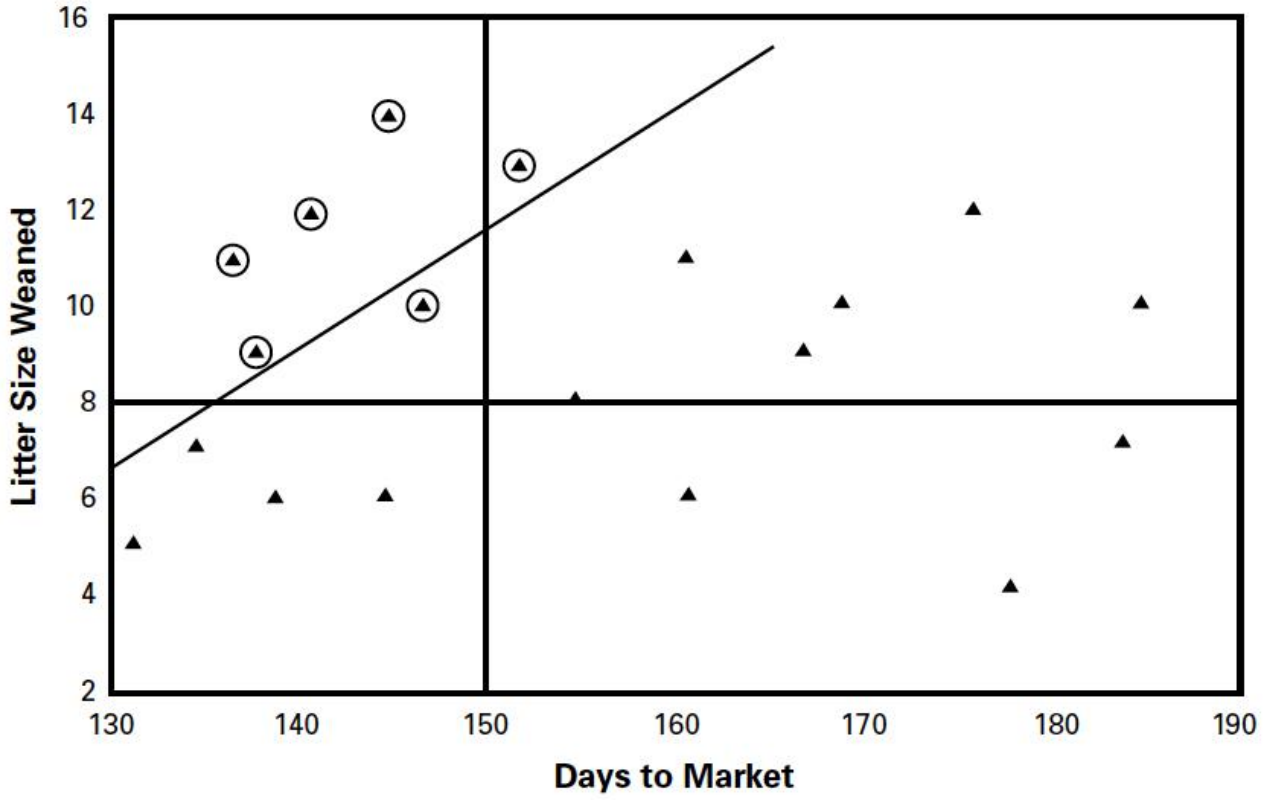
- Result is a single numeric value, typically relative dollar value
- 结果是一个单一的数值，通常是相对的美元价值

Index Selection指数选择

- All traits simultaneously included同时包括了所有的特征
- Correlations among traits accounted for
- 性状之间的相关性被解释了
- Economic values can be changed
- 经济价值可以改变的
- Overall value is criterion for selction
- 总值是选择的标准
  - Superior performance in one trait offsets deficiency in another
  - 一种性状的优越表现抵消了另一种性状的缺陷

NSIF Maternal Line Index NSIF母系指数

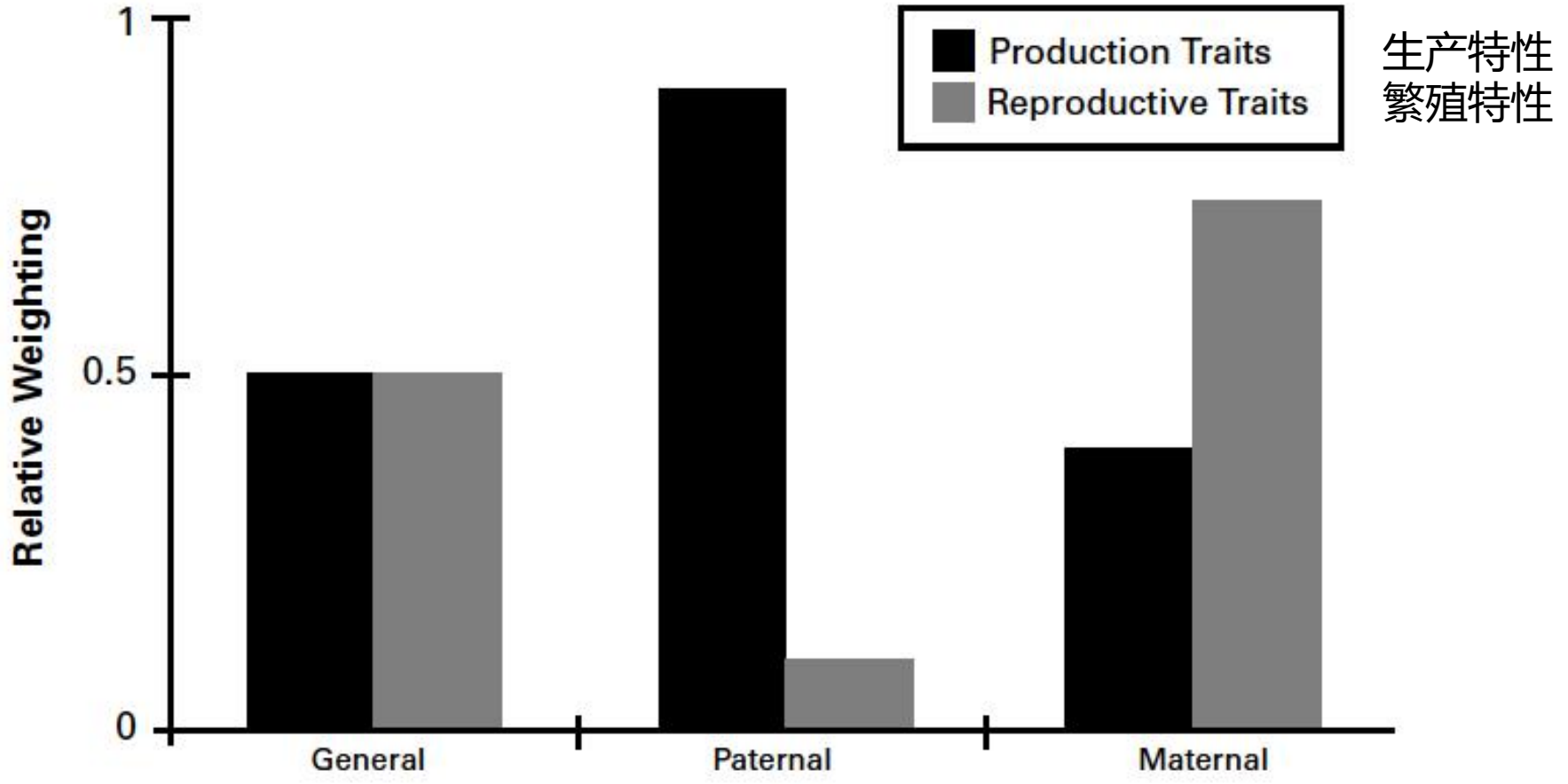
- MLI = 100 + 7(litter size 窝仔猪数) – 1.4(days to market 上市天数)



To make a Selection Index 创建选择指数

- Genetic and phenotypic correlations
- 遗传和表型的相关性
- Economic value of unit change in each trait
- 各性状单位变化的经济价值
- Ability to measure the trait
- 测量这个特质的能力
  - Remember correlated response?
  - 还记得相关反应吗？

Specialized Sire/Dam lines
专门化的父系/母系



Adapted from Pork Information Gateway

Translational Genomics For Improving Sow Reproductive Longevity (2013-2015)

提高母猪繁殖寿命的翻译基因组学（2013-2015）

University of Nebraska
Daniel Ciobanu
Stephen Kachman
Jean-Jack Riethoven
Matt Spangler

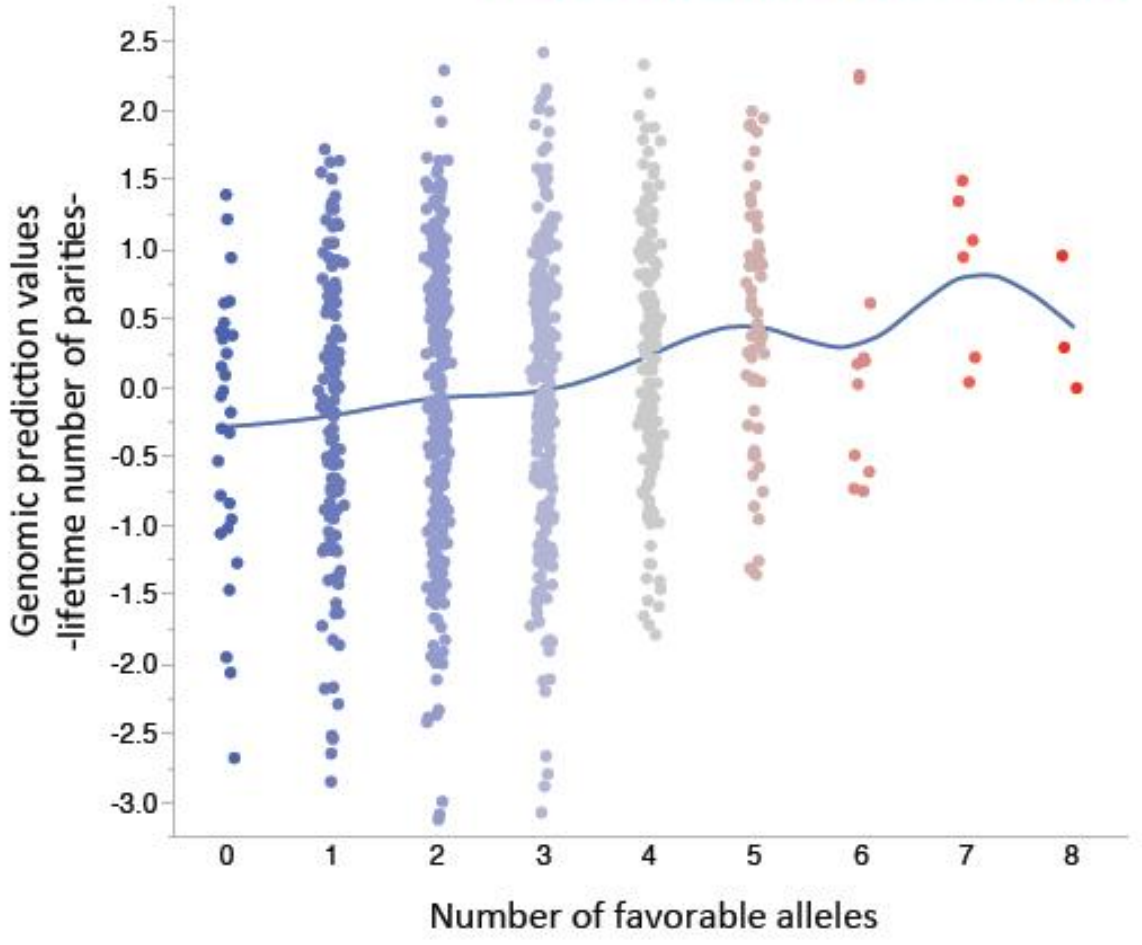
University of Missouri
Tim Safranski
Raymond Massey

USMARC
Clay Lents

Industry Participants
Pillen Family Farms
Smithfield
The Maschhoffs

有利等位基因数量的增加与更高的基因组预测寿命有关

An increase in the number of favorable alleles is associated with higher genomic prediction for lifetime number of parities (NP)



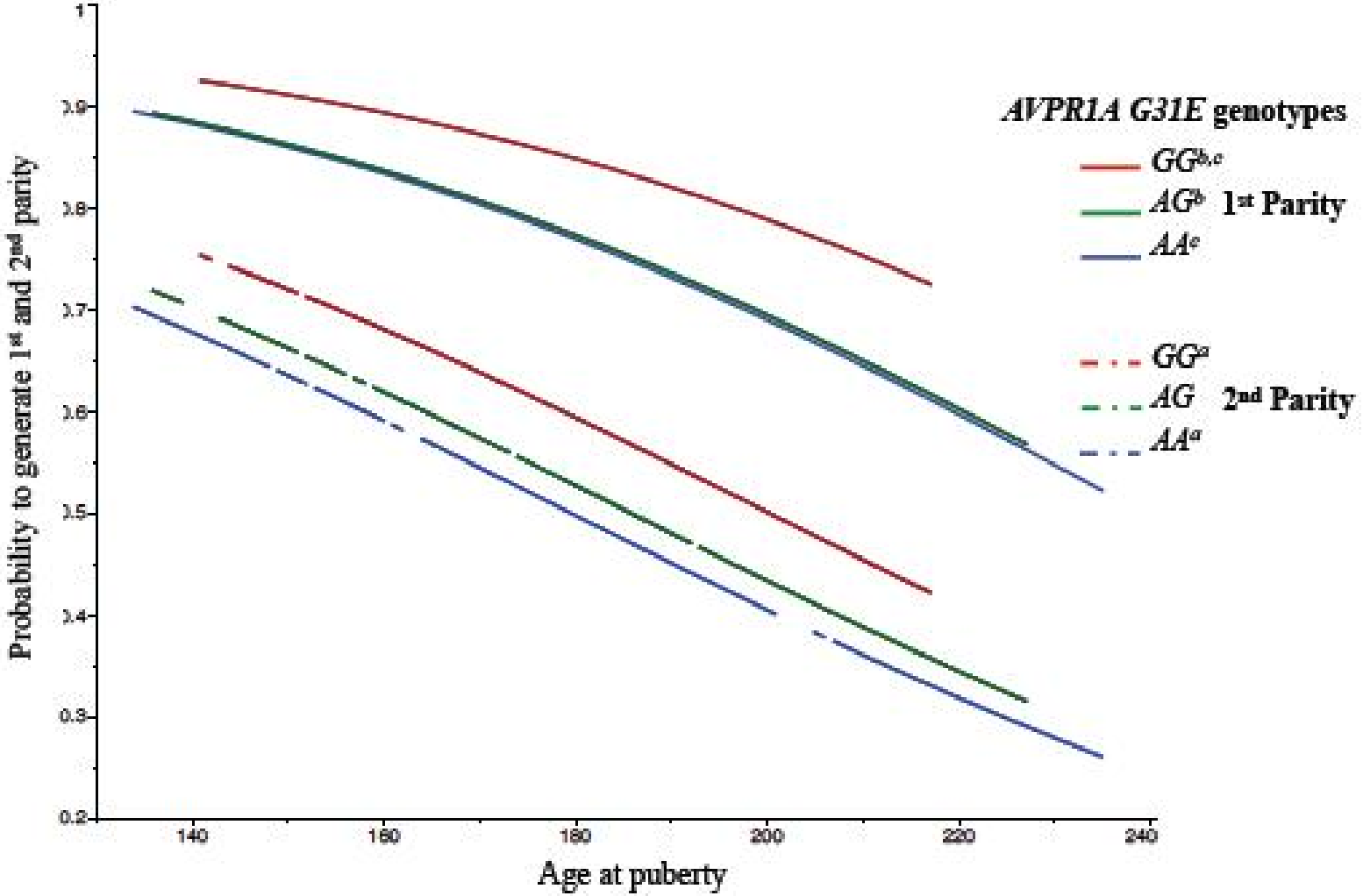
Traits	% of the Vp explained by SNPs
NP	0.16

Number of favorable alleles

0
1
2
3
4
5
6
7
8

Figure 2: The *GG* genotype of a SNP located in *AVPR1A* gene is associated with higher success rate of sows generating first two litters (a $P < 0.10$; b,c $P < 0.05$)

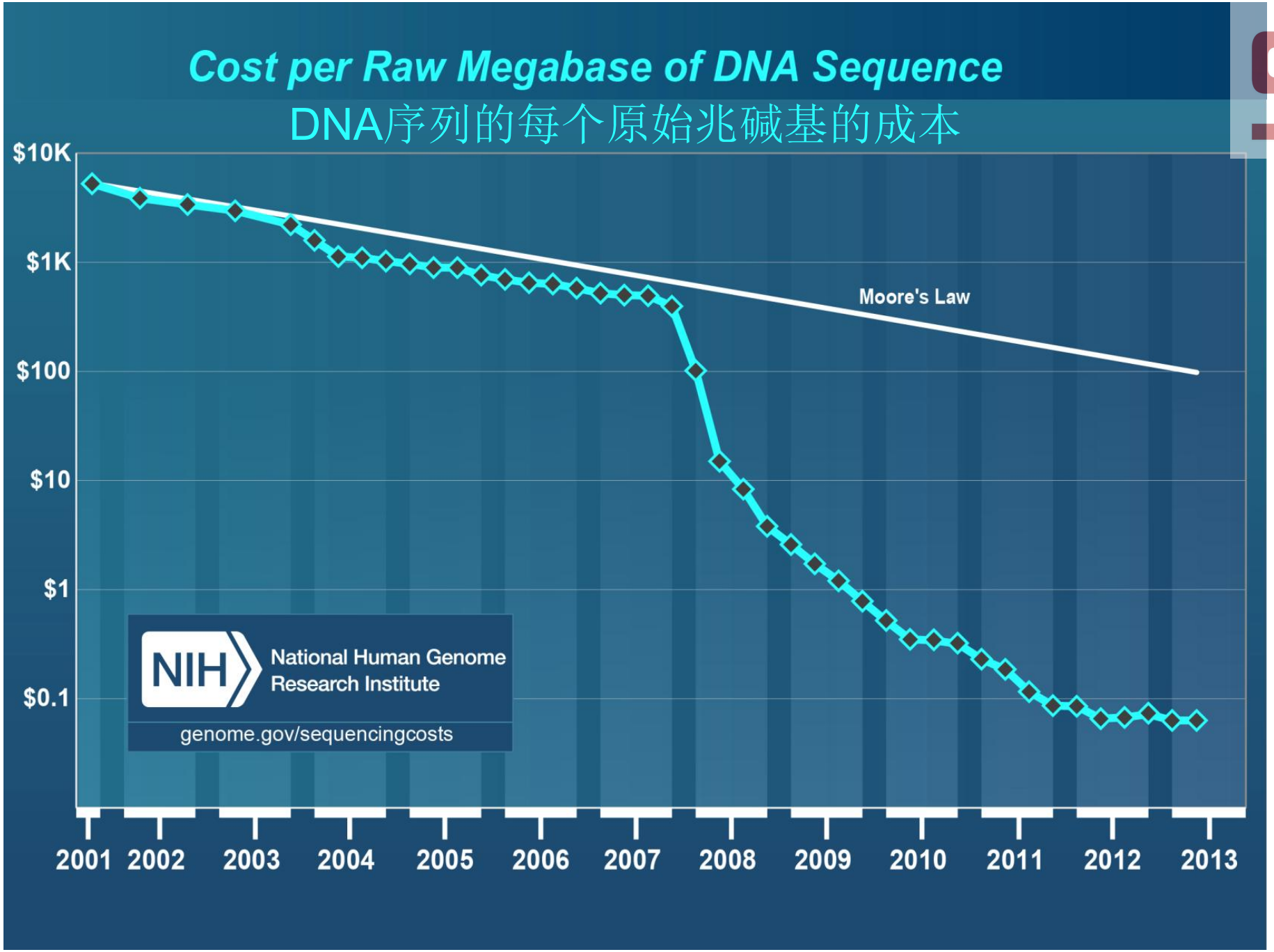
图2 位于*AVPR1A*基因的SNP的GG基因型与母猪前两窝的成功率较高有关



Using molecular genetic data
利用分子遗传数据

- Genomic prediction value = molecular breeding value
- 基因组预测值=分子育种价值
  - Breeding value based exclusively on genomic information
  - 完全基于基因组信息的育种价值

- Used in conjunction with conventional breeding value estimates to improve accuracy: e.g. 23% for SCC and 50% for fat% in dairy cattle;
- 与传统育种价值估计一起使用以提高准确性：例如，奶牛细胞计数为23%，脂肪为50%； (Weigel et al, 2010)


Cost per Raw Megabase of DNA Sequence
DNA序列的每个原始兆碱基的成本
$10K
$1K
$100
$10
$1
$0.1
Moore's Law
NIH
National Human Genome Research Institute
genome.gov/sequencingcosts
2001
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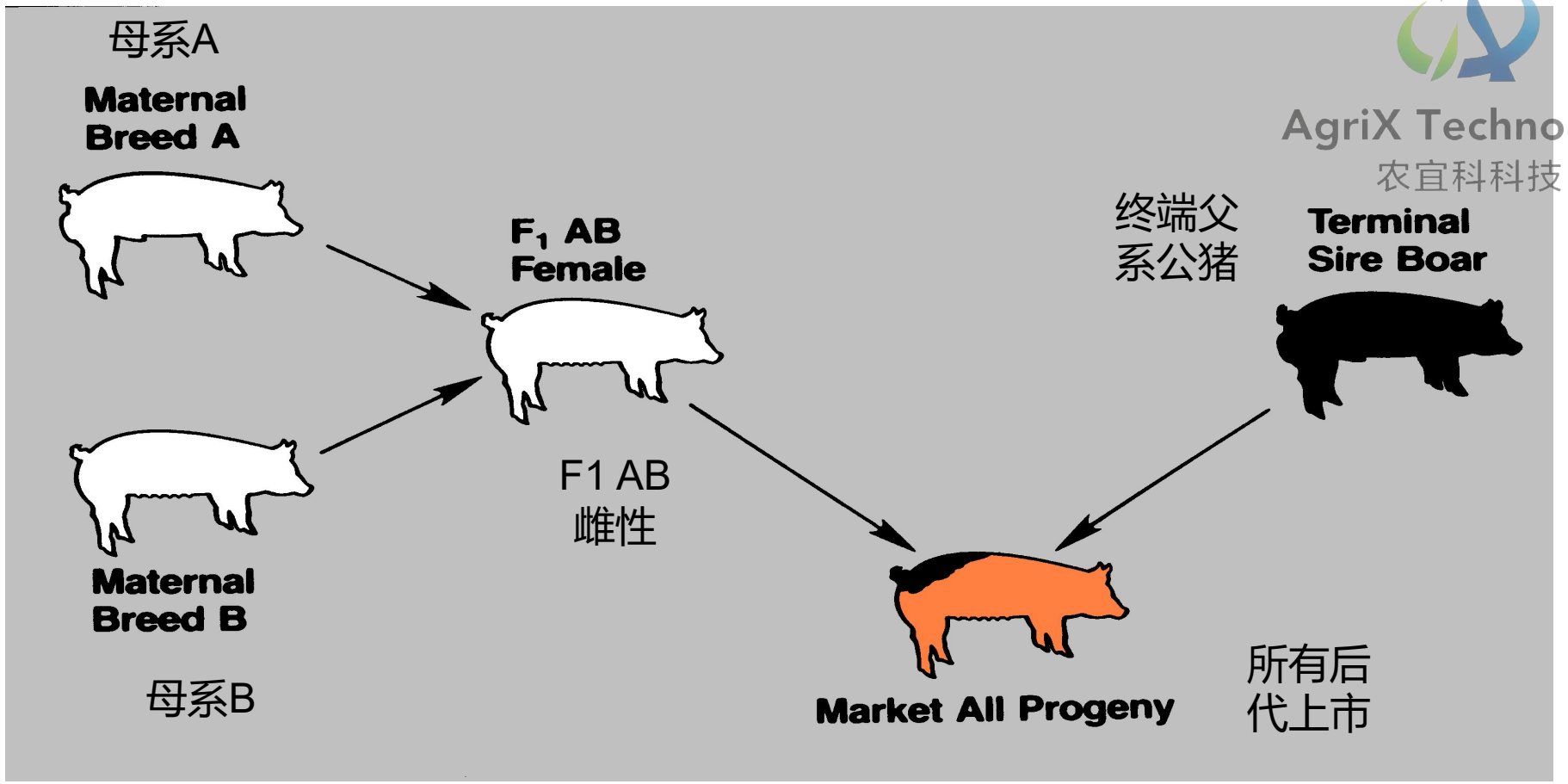

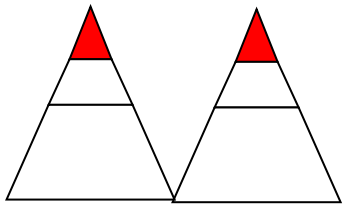

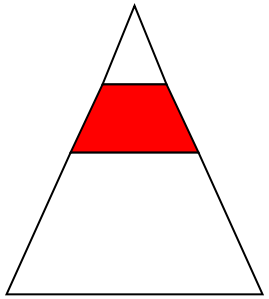

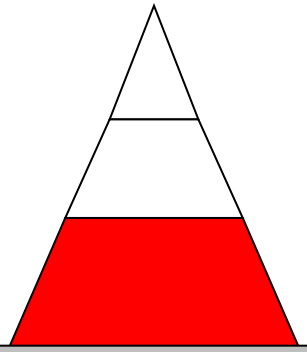

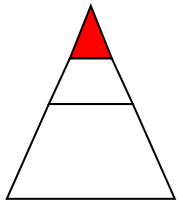

All reproductive traits 所有繁殖特征	physical features 物理特点	none 无	Growth and carcass traits 生长和胴体特征