THE GENETIC SUPERCOW ISN’T IN SIGHT

Chad Dechow

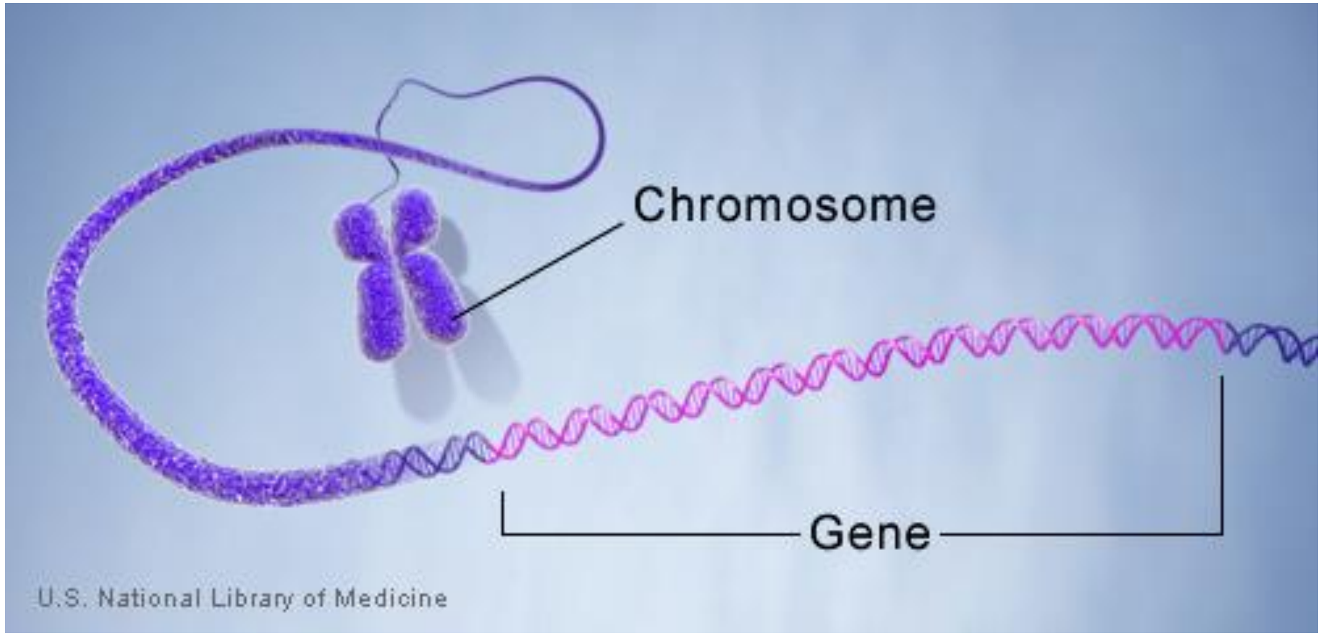
PennState
College of Agricultural Sciences

TOPICS

- **Selection limits**
- **Locked and lost genetic variation**
- **Selection goals**
- **How do we get there?**

SELECTION LIMIT ESTIMATES IN DAIRY CATTLE

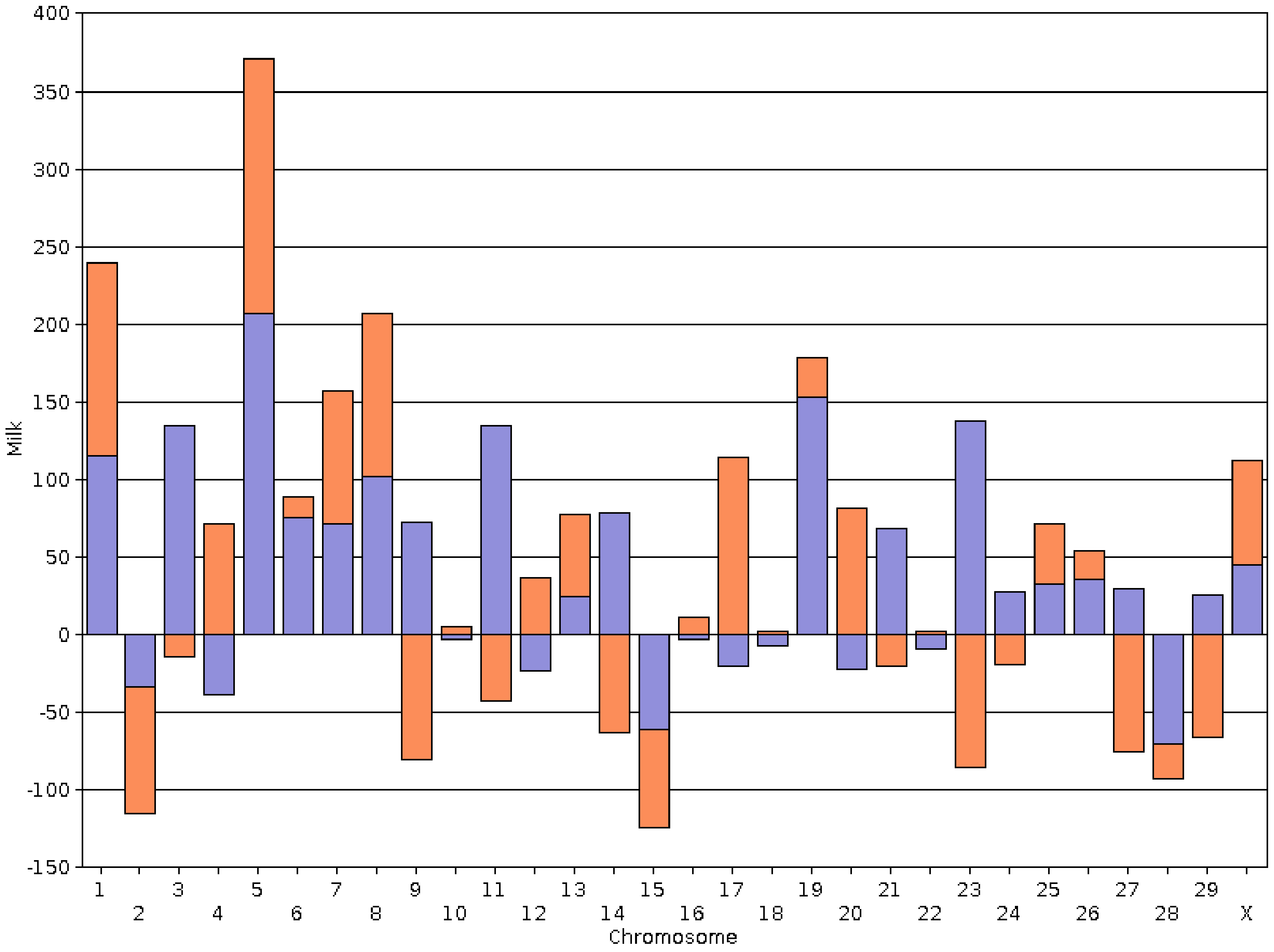
- **USDA scientists evaluated genotypes for Holstein, Jersey and Brown Swiss**
- **Pluck the best chromosomes**
  - Lower limit
- **Pluck the best gene**
  - Upper limit



Chromosomal PTA for EVER-GREEN-VIEW MY 1326-ET (HOUSA000061853387, F)

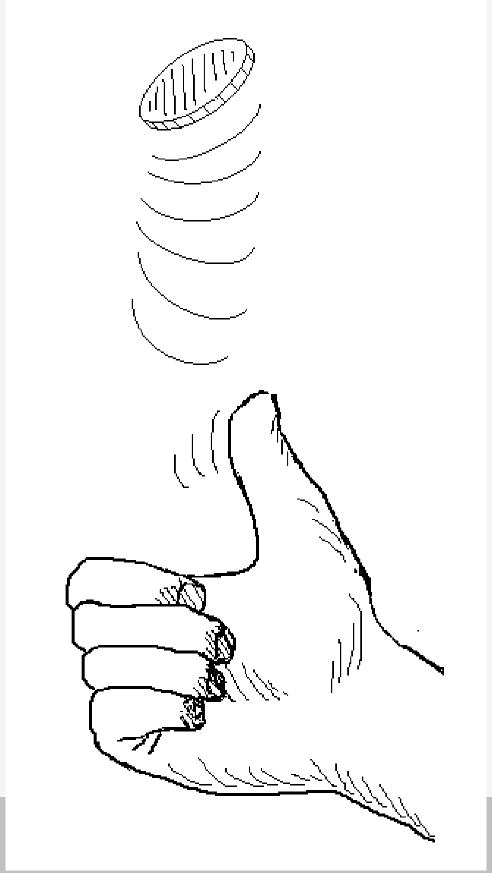
PTA Milk (lbs.): +504, **Rel Milk:** 85%

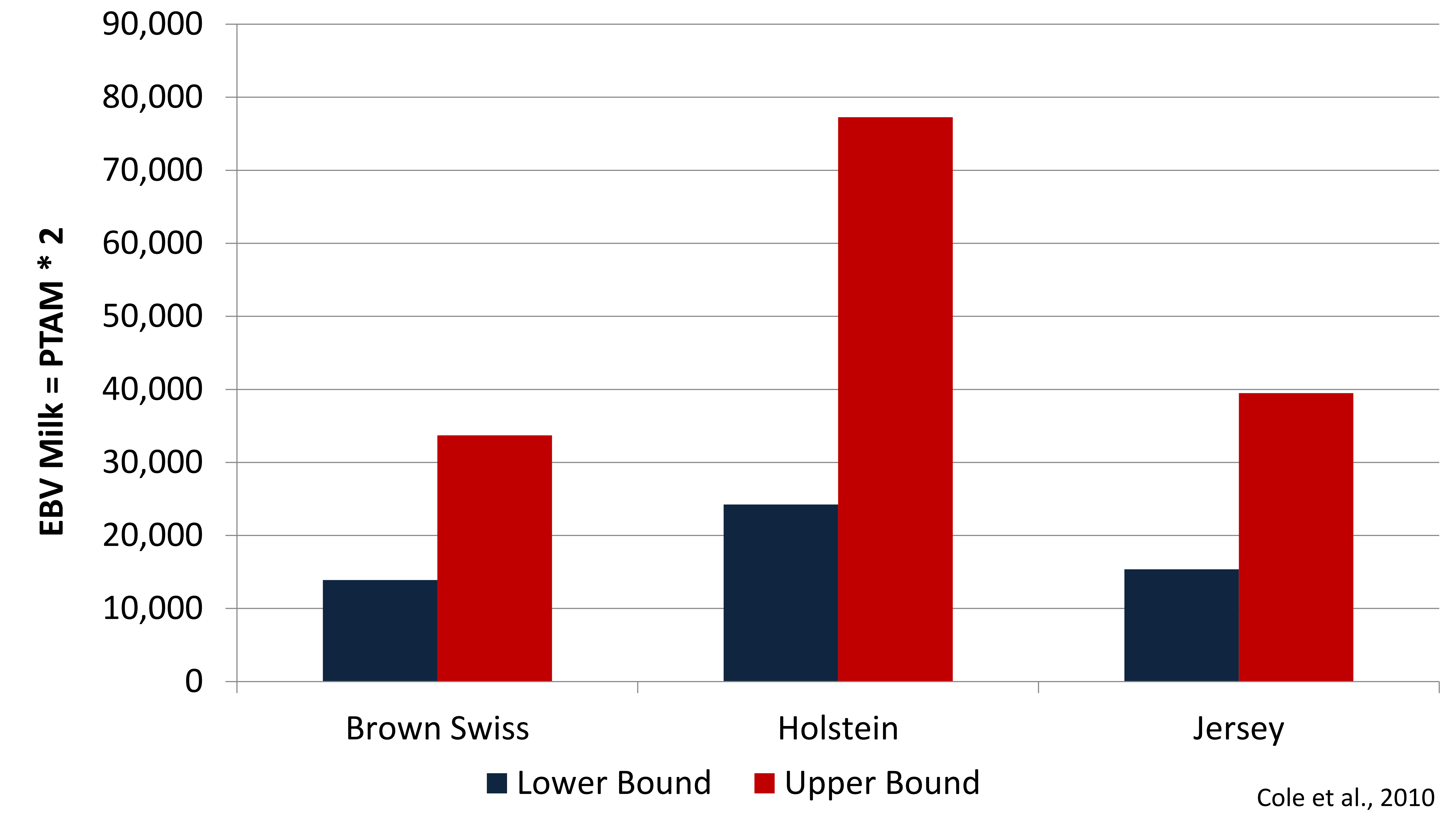
How do I interpret and use the values in this figure?



GOOD LUCK!!

- **2 copies of each chromosome (one from sire, one from dam)**
- **Chance of passing the best of each?**
  - $(½)^{30}$ = 0.00000009%
  - One in 1,073,741,824
  - Bulls: 1 in 536,870,912
- **Assumes no recombination**




EBV Milk = PTAM * 2
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Brown Swiss
Holstein
Jersey
Lower Bound
Upper Bound
Cole et al., 2010

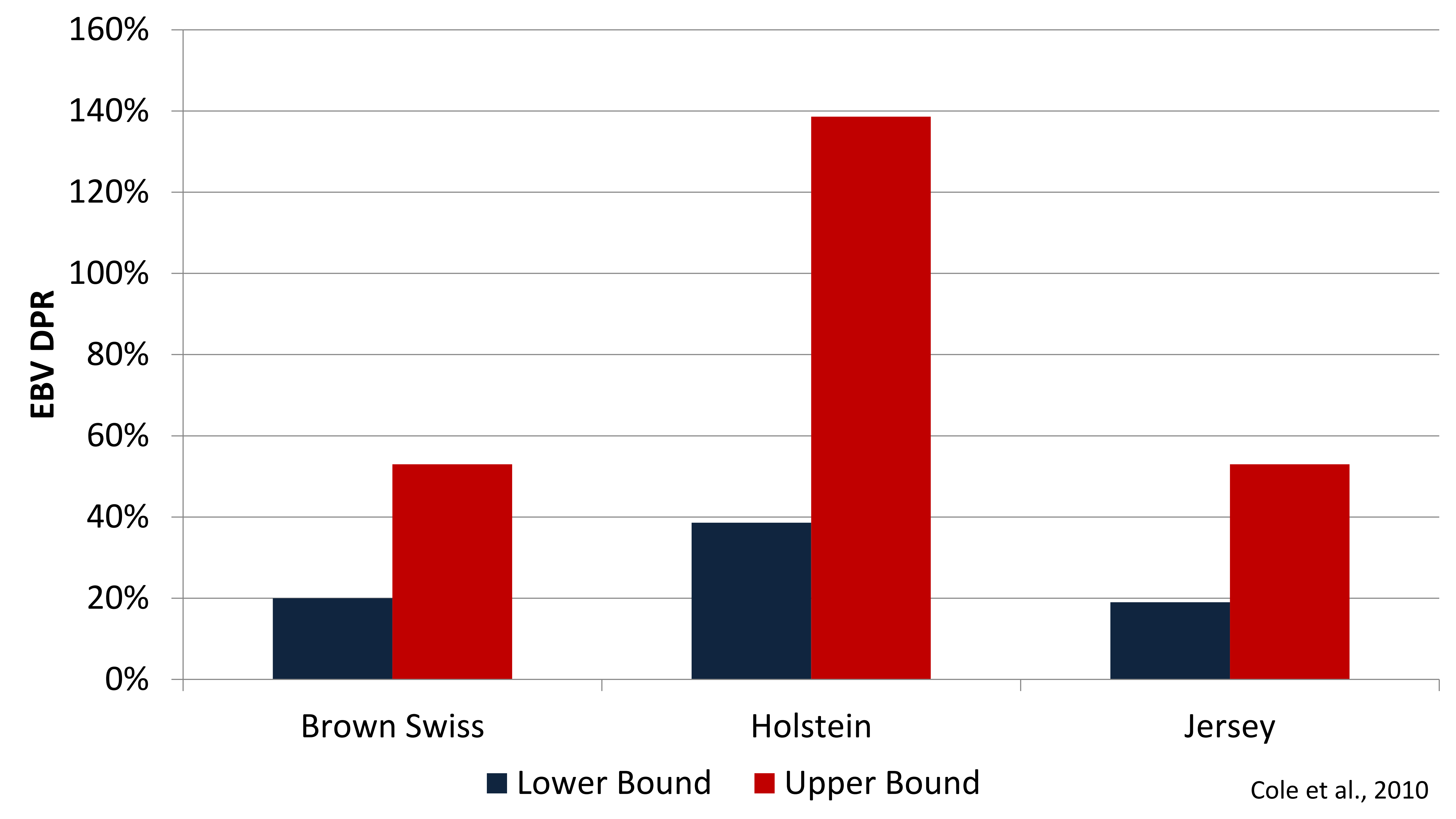
GLASS HALF FULL?

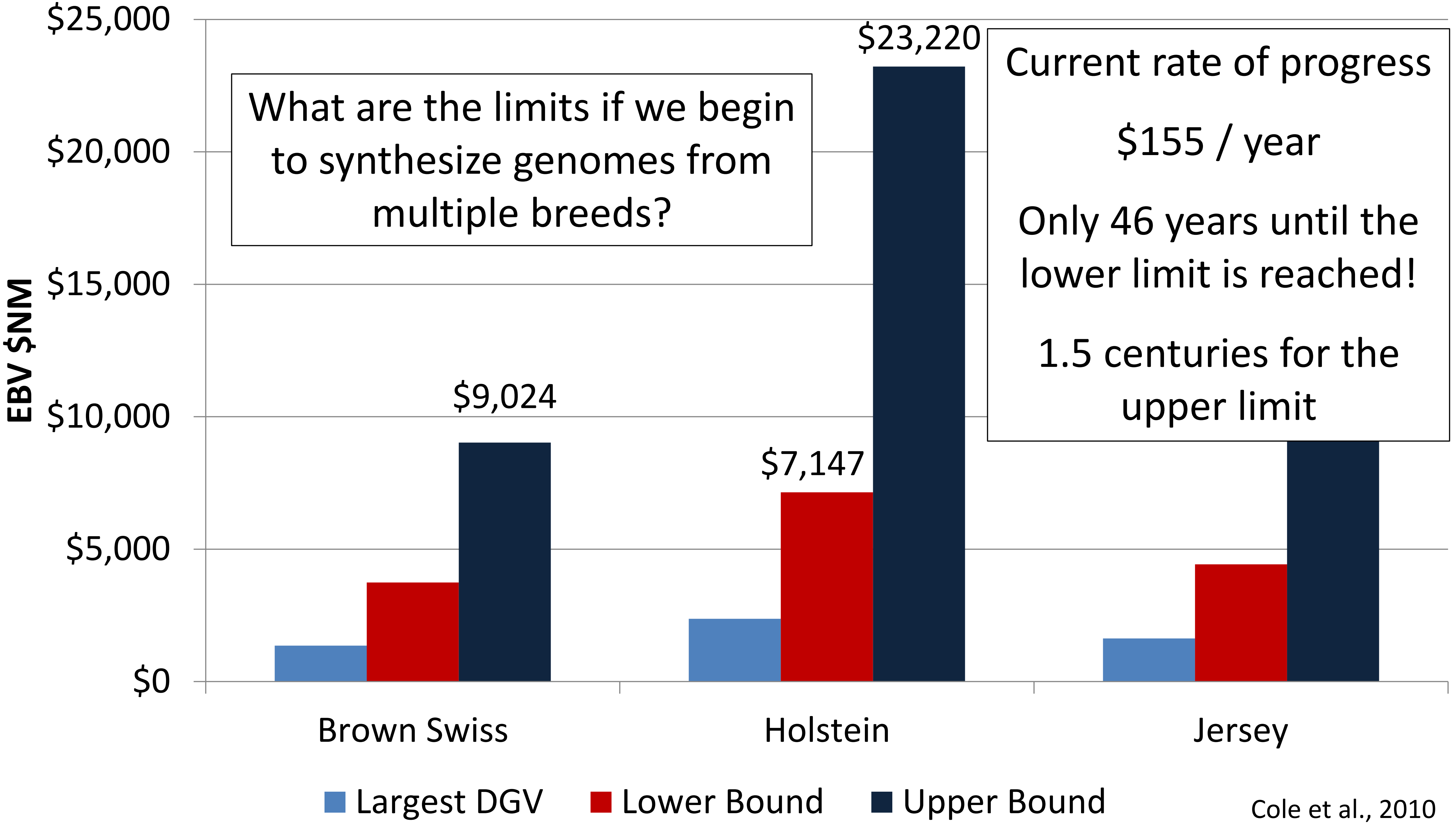
PTA Milk = 503
EBV Milk = 1006

78,170 + 76,262 = 154,432
Lower bound = 101,392

PTA Milk = 475
EBV Milk = 950

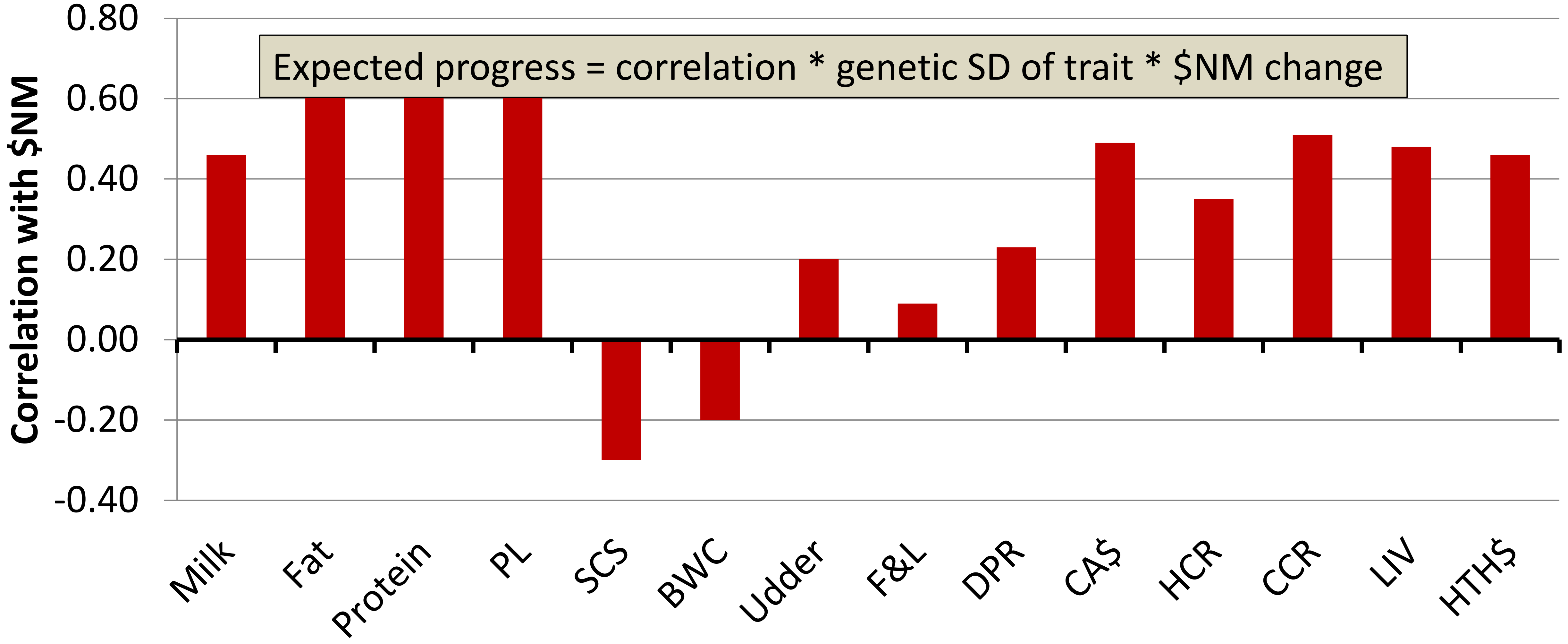
77,480 + 76,318 = 153,798
Lower bound = 101,758


160%
140%
120%
100%
80%
60%
40%
20%
0%
EBV DPR
Brown Swiss
Holstein
Jersey
Lower Bound
Upper Bound
Cole et al., 2010


What are the limits if we begin to synthesize genomes from multiple breeds?
Current rate of progress
$155 / year
Only 46 years until the lower limit is reached!
1.5 centuries for the upper limit
EBV $NM
$25,000
$20,000
$15,000
$10,000
$5,000
$0
$9,024
$7,147
$23,220
Brown Swiss
Holstein
Jersey
Largest DGV
Lower Bound
Upper Bound
Cole et al., 2010

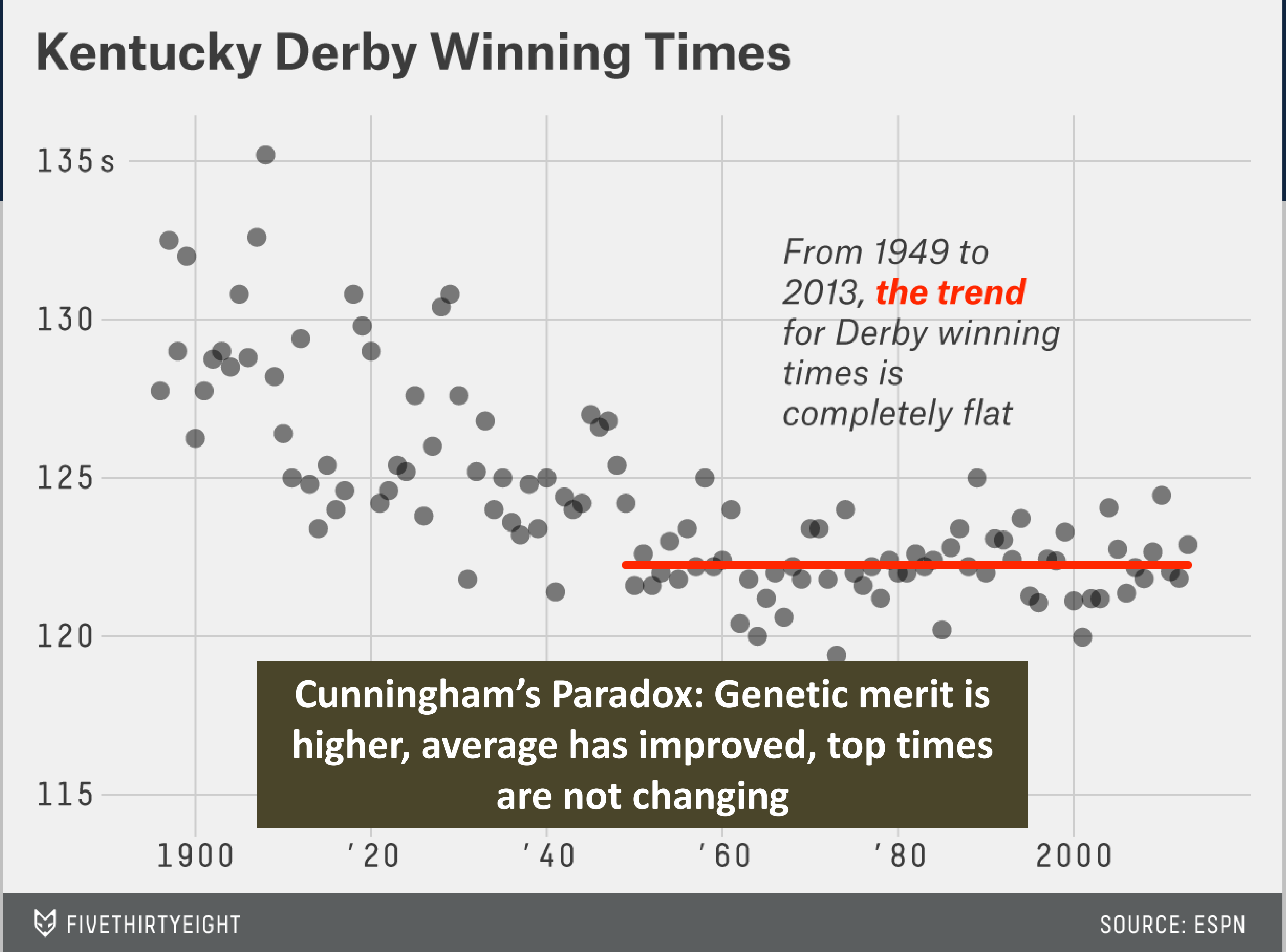
- + 60,630 lbs EBV Milk
  88,500 lbs milk
- + 3,032 lbs EBV Fat
  4,100 lbs fat (4.6%)
- + 2,274 lbs EBV Protein
  3,150 lbs pro (3.6%)
- Hold the line on everything else
- **EBV $NM = $20,000**
  - **PTA $NM = $10,000**

PATH WE'RE CURRENTLY TAKING



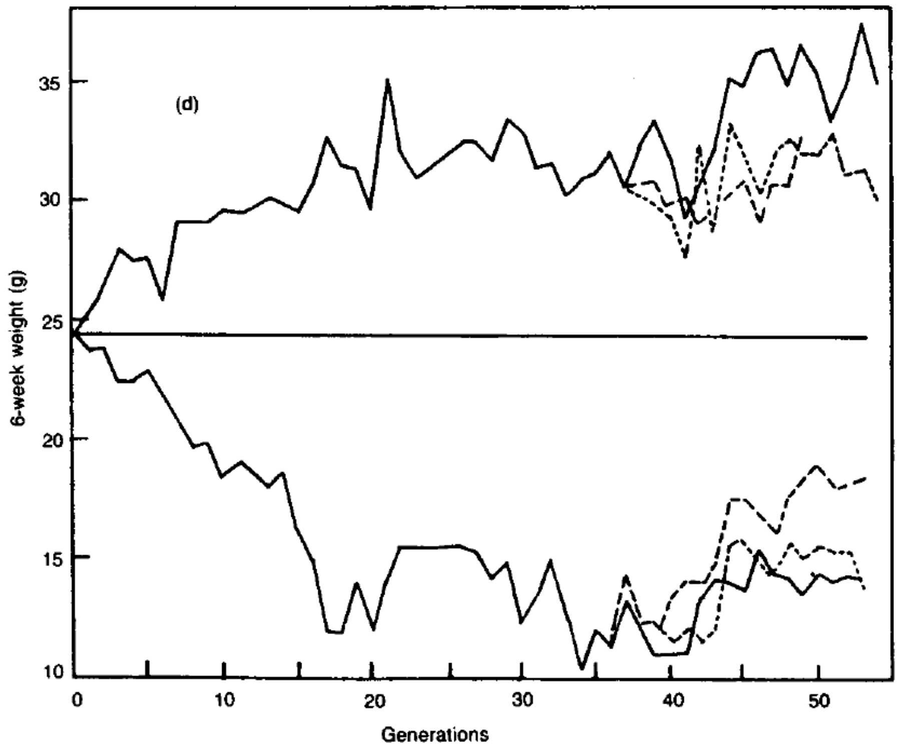
Trait	Lower Limit of $NM	Upper Limit of $NM
Milk	11,215	36,433
Fat	653	2,121
Protein	418	1,358
PL	60	195
SCS	-2	-7
BWC	-8	-26
Udder composite	7	21
Feet/leg composite	3	11
DPR	19	62

Genetic Limits
vs
Biological Limits



Cunningham's Paradox: Genetic merit is higher, average has improved, top times are not changing

WHAT IS THE BIOLOGICAL LIMIT?

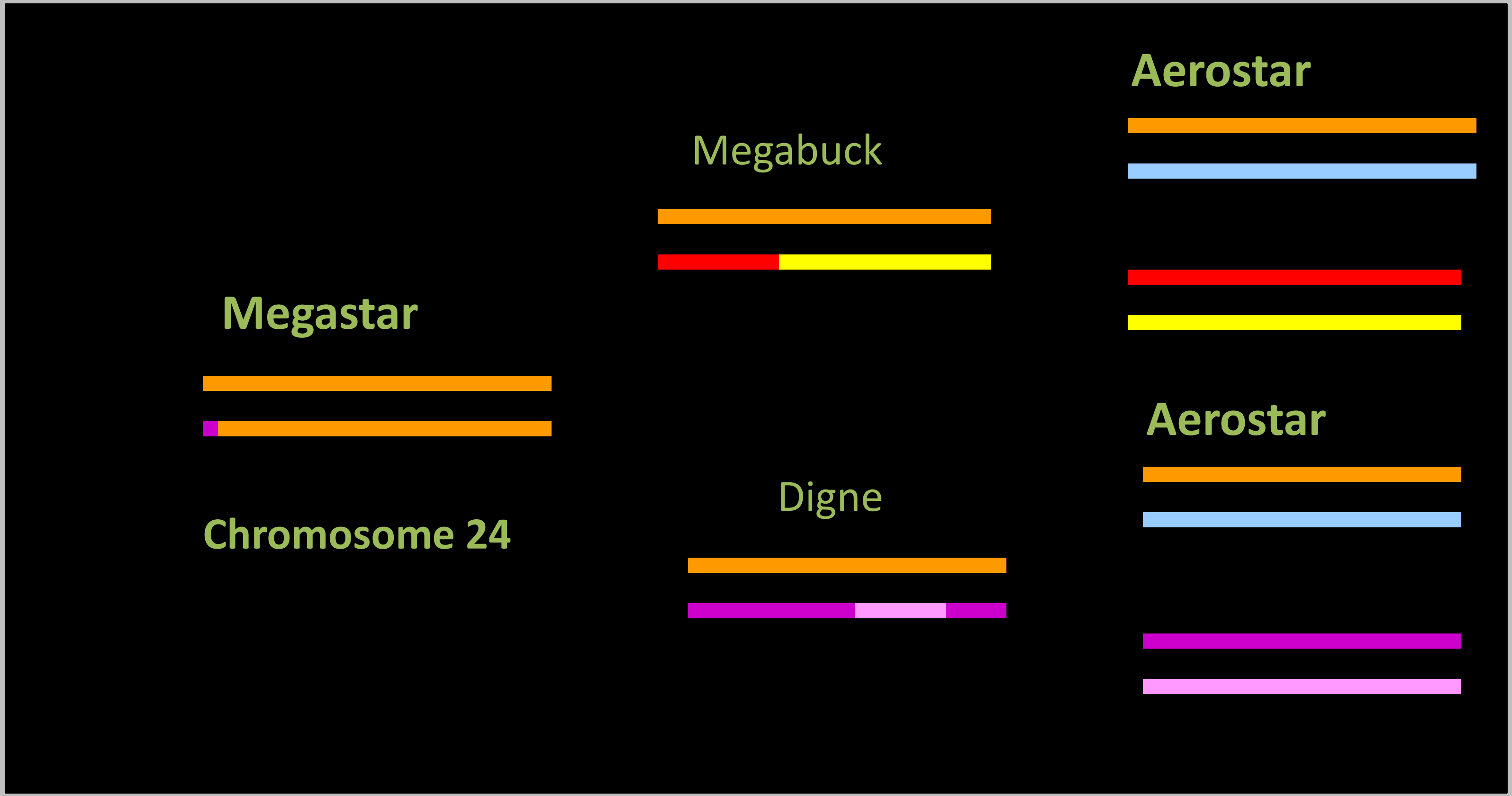


- **We won't know until long after we've arrived**
  - New mutations or recombination
- **Potential yield limits**
  - Limit to nutrient intake & digestive capacity
  - Metabolic capacity
  - Udder capacity
    - ➢More frequent milking can help overcome

LOCKED & LOST

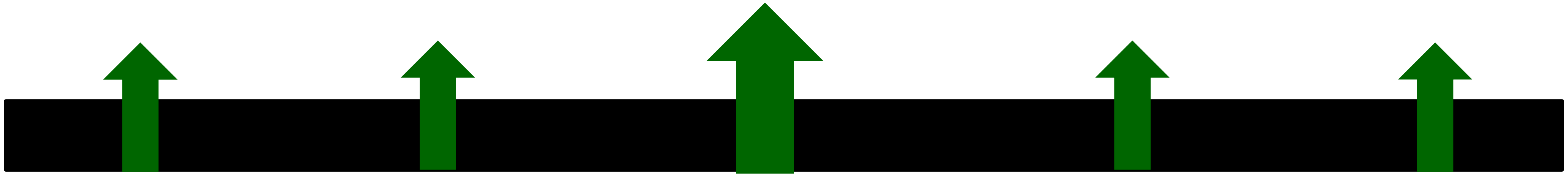
- **Some favorable genes are physically linked to unfavorable genes**
  - Need recombination to unlock
- **Eliminated from the population and we'll never know**
  - Short term versus long term selection response

AVERAGE NUMBER OF RECOMBINATION EVENTS = ONE / CHROMOSOME

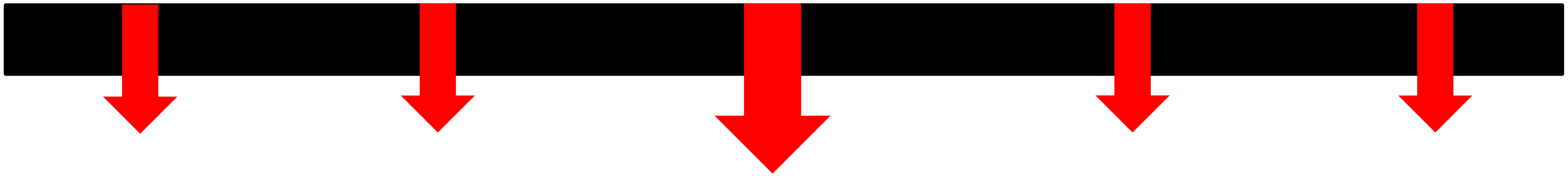


VanRaden, 2008

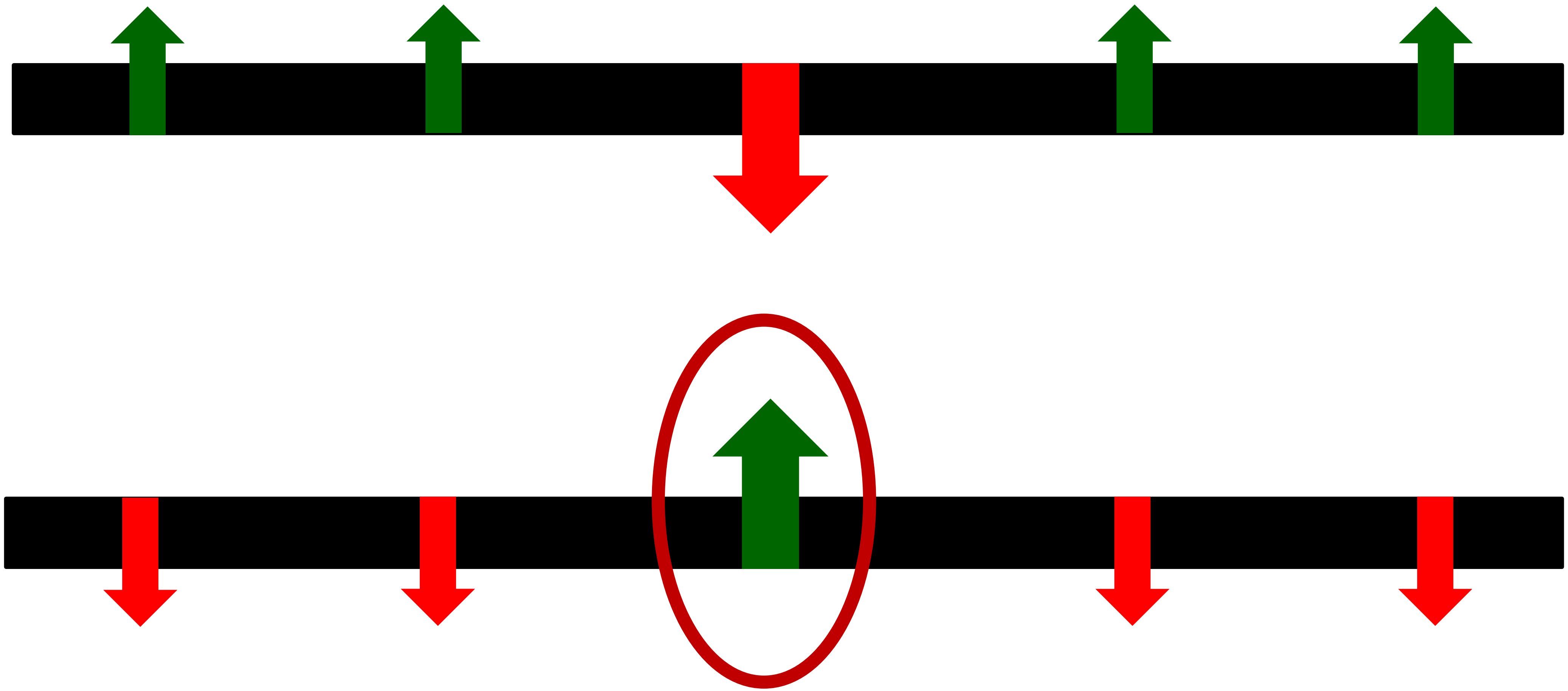
IDEAL CHOICE



OR



OUR OPTIONS



SELECT TO INCREASE RECOMBINATION RATE?

FOCUS ON GENETICS

Recombination—the Making of New Allele Combinations

The best combinations in the future will depend on a broad selection of cow and sire lines from our breed

BY TOM LAWLOR, Ph.D.

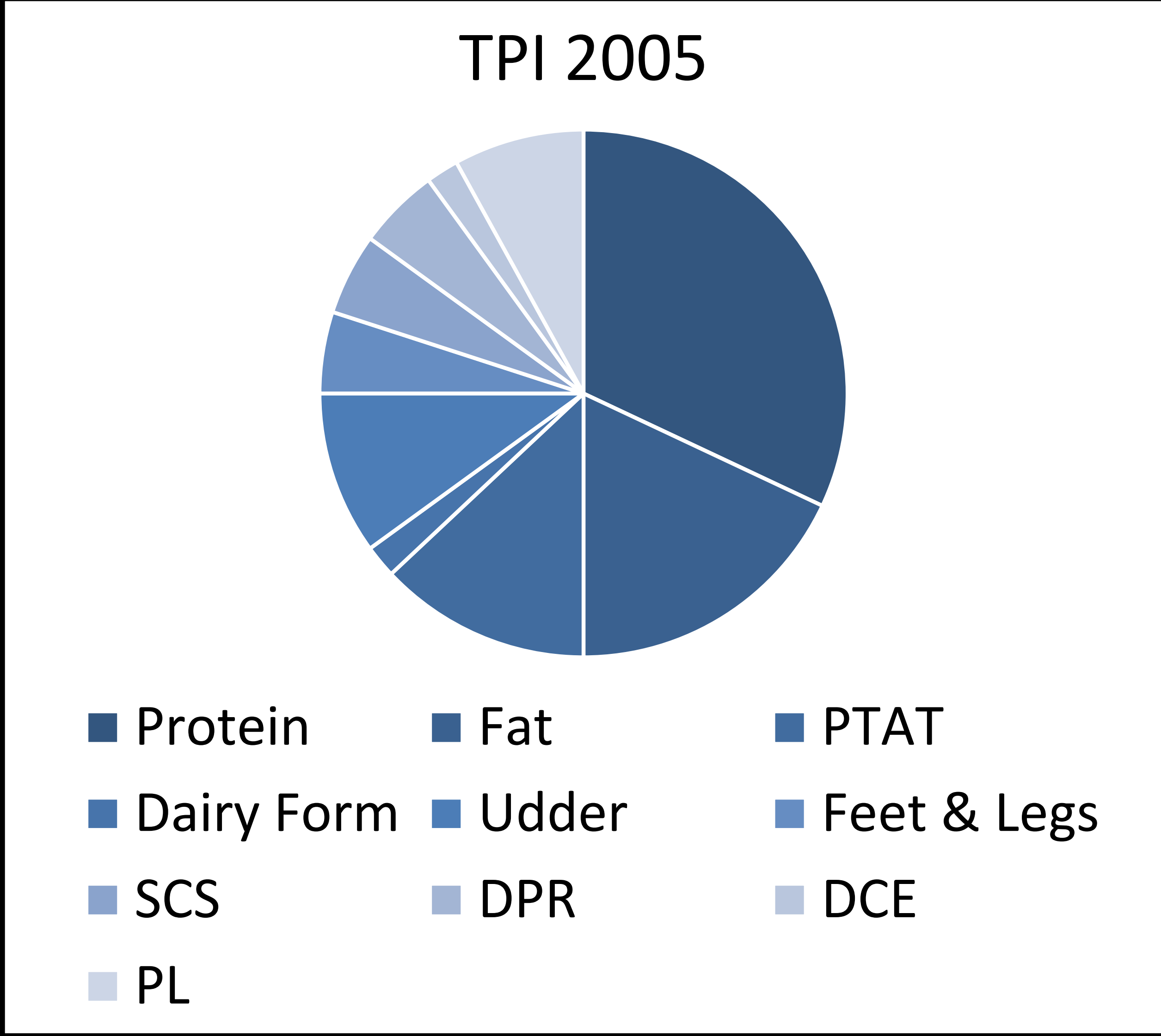
Part of the excitement of the holiday season is the thrill of unwrapping a beautiful present from under the Christmas tree. Often a gift will be packaged with fancy paper and a beautiful bow—and inside it'll contain something wonderful. Well, in dairy cattle breeding, we also need to think about how the genetics of our elite animals is presented to the next generation. The genetic merit of the animal, i.e., the sum of all of the alleles that the animal possesses, is the content of the package. The packaging of these alleles is done with

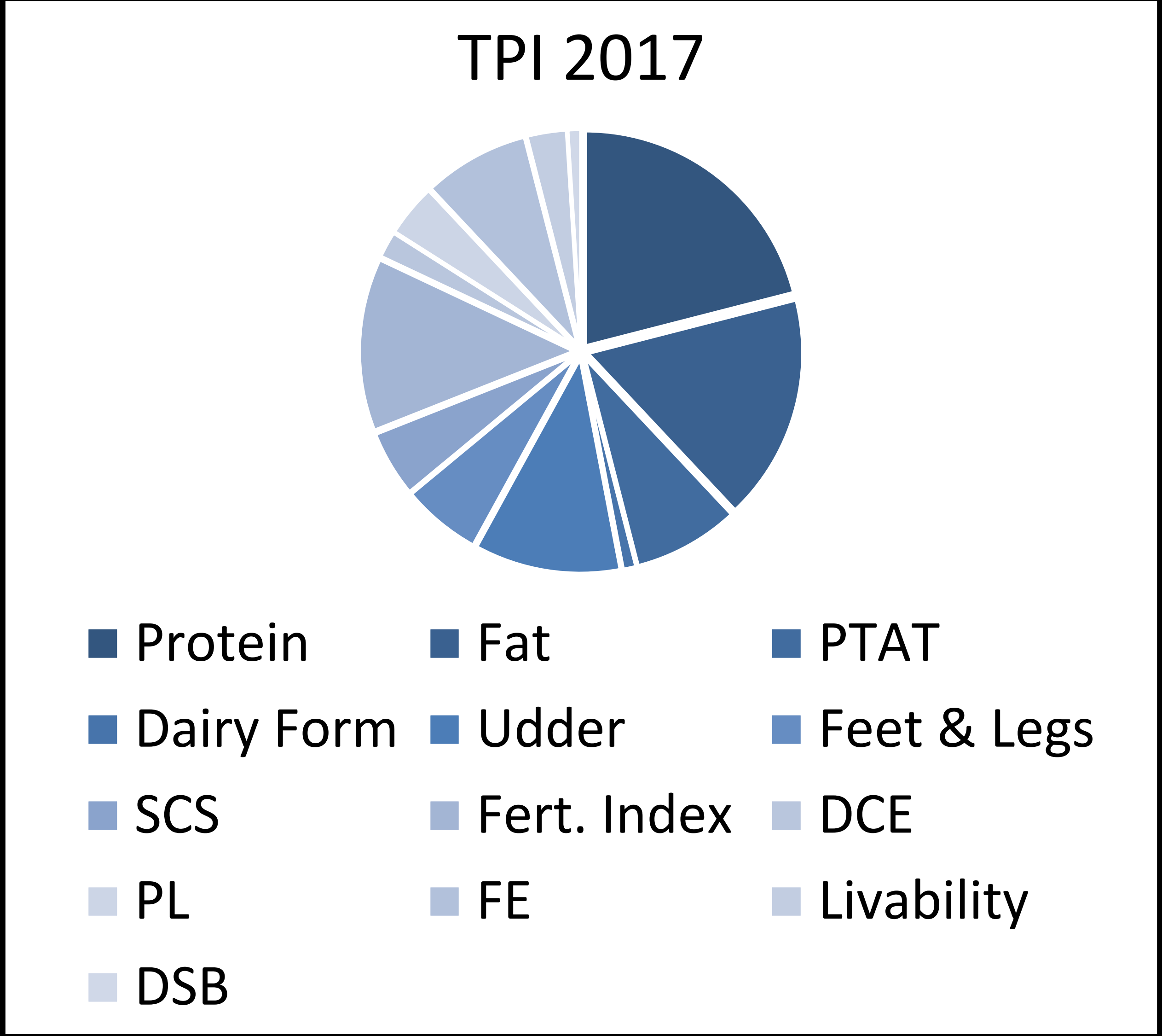
per pair of chromosomes. For example, with Chromosome 3, 41 percent of the time there will be one crossover between the inner pair of chromosomes; 27 percent of the time there will be 2 crossovers, and 9 percent of the time there will be 3 or more.

What's particularly fascinating about this repackaging of our genetic material is

Bulls	Crossovers per gamete	Category
BALISTO, O-STYLE, SUPERSIRE, KINGBOY, LITHIUM	28	High
MCCUTCHEN, MOGUL, FREDDIE, SHAMROCK, SUPERSTITION, PLANET	25	Medium
SHOTTLE, BOLTON, G W ATWOOD, TANGO, GOLDWYN	22	Low

SELECTION GOALS WILL CONTINUE TO EVOLVE





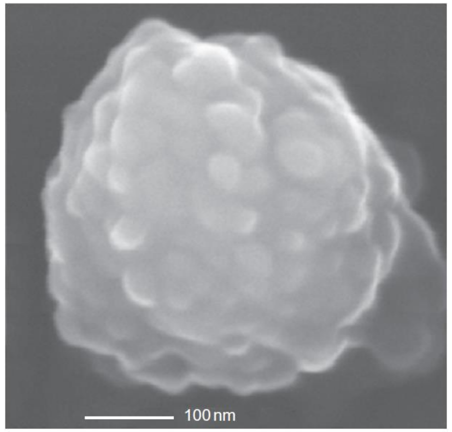
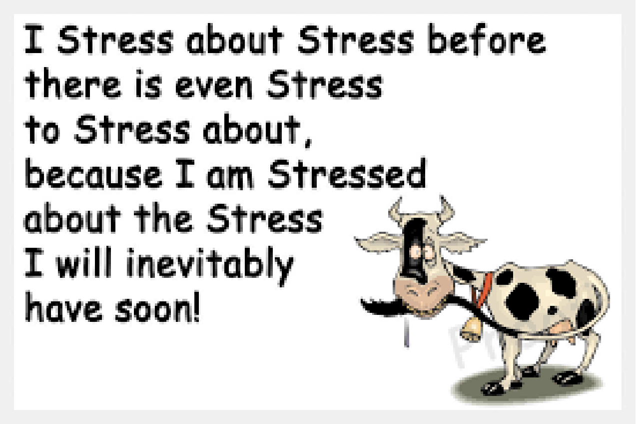


Fig. 3.9 Scanning electron micrograph of a casein micelle.

WHAT TRAITS WILL BECOME IMPORTANT ?

- **More precise feed utilization?**
- **Properties of milk?**
  - Processing characteristics
  - Human health
- **Immune function?**
- **Recombination & genome structure?**

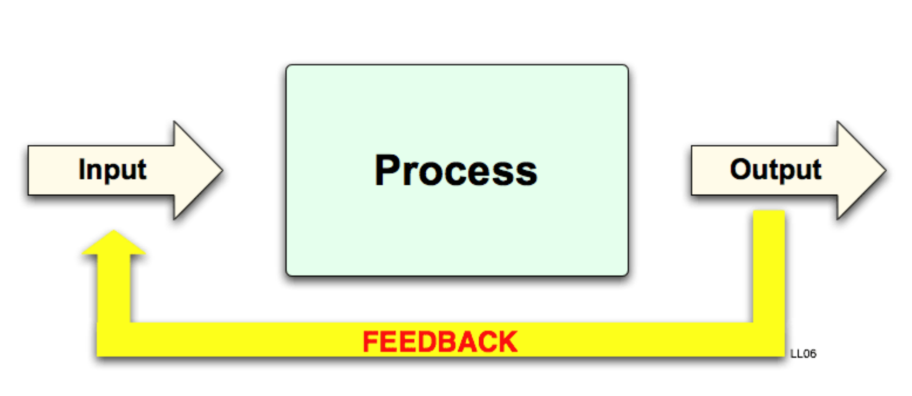


WHAT TRAITS WILL BECOME IMPORTANT ?

- **Stress resistance?**
  - Heat tolerance
- **Precise cows for precise management systems?**
- **Additional functional traits?**
  - Hoof health, mobility
- **Environmental sustainability?**

HOW WILL WE GET THERE?

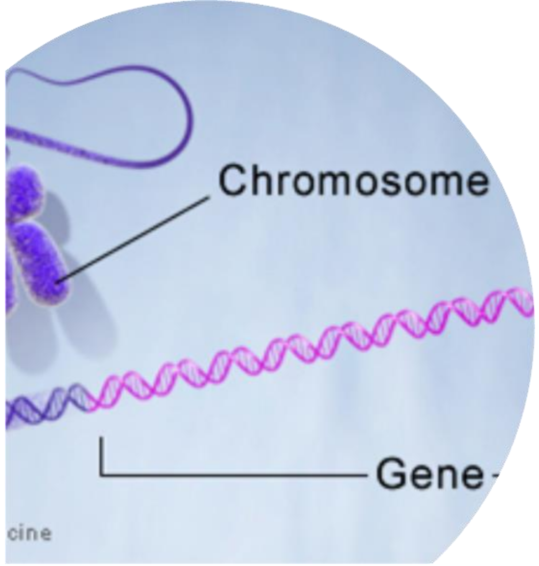
- **Gene Editing**
  - Suitable for traits such as polled, slick hair, A2
  - Yield is infinitely more complicated
- **Advances in genomic methodologies**
  - Whole genome sequence
  - Functional understanding of the genome



HOW WILL WE GET THERE?

- **Advanced embryo production technologies**
  - Embryos as parents of embryos
- **Beyond the DNA sequence**
  - Epigenetics
- **Recapturing lost genetic diversity**
- **Continued development of new traits**

THANKS FOR YOUR TIME!



WE’VE GOT A LOT OF WORK LEFT!