

## **BREEDING, SELECTION AND SOMATIC CELL COUNTS: WHERE ARE WE TODAY?**

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Genetic evaluations for Somatic Cell Score [SCS] were published by the USDA Animal Improvement Programs Laboratory [AIPL] for the first time in 1994 (Schutz et al., 1995; Shook and Schutz, 1994). Despite the high economic cost of mastitis and the strong correlation between mastitis and SCS, these genetic evaluations have not attained a high profile among producers or within the AI industry. Recent changes related to genetic evaluations for SCS make this a good time to increase the understanding of these evaluations, review recent research, and anticipate future developments. Also, it is timely to re-emphasize the value of genetics as a tool for preventing mastitis and reducing SCS.

### Description of SCS Data Used in Genetic Evaluation

Genetic evaluations are computed from performance records of about 1.8 million cows in Dairy Herd Improvement [DHI] herds throughout the country (AIPL, 2000e). More than 90% of these cows are on somatic cell testing (AIPL, 2000c). The DHI laboratories perform monthly somatic cell counts [SCC] among other tests on milk samples of individual cows. Each SCC observation is converted to SCS using a base 2 logarithmic function (Ali and Shook, 1980; Shook, 1993). Individual SCS values are averaged over all months of lactation and adjusted for effects of age, stage of lactation, and month of calving (Schutz et al., 1995). The adjusted average SCS for each lactation of each cow is used in the genetic analysis.

Selected SCS and SCC values are shown in Table 1 to illustrate the nature of the conversion. A one point increase [or decrease] in SCS corresponds to a doubling [or halving] of SCC. The scores exhibit a number of advantages over somatic cell counts (Shook, 1993):

- 1) Heritability, the portion of variation among animals that is due to genetics, is higher for SCS; the ability to distinguish genetic from environmental effects is improved;
- 2) The relationship between SCS and milk yield loss is linear for SCS;
- 3) SCS has a Normal frequency distribution – the familiar bell shaped curve; SCC has a strongly skewed frequency distribution in which the mean is higher than the median;
- 4) Mean SCS can be interpreted as a median; mean SCC is often much higher than the median and there is no consistent relationship between the mean and median;
- 5) The standard deviation of SCS is consistent among cows within herds or among daughters within sires; this makes it possible to use the same standard deviation within all herds or sires, and the mean by itself characterizes the differences among herds or sires;
- 6) The power to distinguish between diseased and healthy cows is greater for SCS than SCC (Berning and Shook, 1992).

Table 1. Somatic cell counts [cells/  $\mu$ l] associated with selected values of somatic cell score.

SCS	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
SCC	25	35	50	71	100	141	200	283	400	566	800

### Predicted Transmitting Ability for SCS

Genetic evaluations for dairy cattle in the United States are called Predicted Transmitting Ability [PTA]. PTA's are published for cows and bulls for the yield traits – milk, fat, and protein – SCS, productive life, and several type traits. Although PTA's are computed for both cows and bulls, this discussion will focus largely on bulls because more than 90% of genetic improvement is due to sire selection. New evaluations are published four times each year in February, May, August, and November. With each new evaluation, some AI bulls are removed from active service, new AI bulls are added, and additional daughters are included in the bulls' PTA's.

*The difference between the PTA's for two bulls is a prediction of the difference in average performance of the bulls' future daughters.* For example, PTA's for two well-known bulls are listed in Table 2; the bulls differ by 633 lb milk and .40 points SCS. Within any given herd-year-season, future daughters of Formation are expected to produce 633 lb more milk and average .40 points lower SCS than future daughters of Leif. In simple terms, PTA is an expression of the expected performance of a bull's or a cow's future daughters. Also, PTA does not predict the average actual performance of bulls' daughters, because daughter performance is influenced by herd management and other environmental factors. Instead, PTA should be used to forecast differences between bulls' or cows' future daughter averages.

Table 2. PTA's for two widely used Holstein bulls and the differences between them.

Bull	PTA-Milk	PTA-SCS
Formation	1,648	2.79
Leif	1,015	3.19
Difference	633	-.40

Producers and milk quality specialists are more familiar with SCC than SCS. Using SCS in the genetic evaluations may be a barrier to use of PTA-SCS in sire selection. How can the differences among bulls in PTA-SCS be expressed in terms that are more familiar to producers and milk quality specialists? Two methods are illustrated using the multipliers in Table 3. The SCC ratio in Table 3 is the ratio of the geometric mean SCC for daughters of the high PTA-SCS bull to the geometric mean for daughters of the low PTA-SCS bull. Geometric means are discussed in detail elsewhere (Shook and Ruegg, 1999); although the procedures discussed here are technically geometric means, little is lost by disregarding this technicality. The clinical mastitis ratio in Table 3 is the ratio of the incidence of clinical mastitis for daughters of the higher bull to the incidence of clinical mastitis for daughters of the lower bull. These ratios are from the recent research of Nash, et al. (2000). Two examples will be used with each

method: One example is the two bulls shown in Table 2; the other example is based on the fact that the difference between the best and worst bulls for PTA–SCS is usually about 1 point.

Table 3. Multipliers to express the PTA–SCS difference between two bulls in terms of the ratio of geometric mean SCC and the ratio of clinical mastitis incidence of their daughters.

PTA–SCS Difference	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
SCC ratio <sup>1</sup>	1.07	1.15	1.23	1.32	1.41	1.52	1.62	1.74	1.87	2.00
Clinical mastitis ratio <sup>2</sup>	1.06	1.12	1.18	1.25	1.32	1.40	1.48	1.57	1.66	1.75

<sup>1</sup>Shook, 1993

<sup>2</sup>Nash et al., 2000

The mean SCC for daughters of the higher PTA bull is the mean SCC for daughters of the lower PTA bull times the SCC ratio in Table 3 that corresponds to the difference between PTA–SCS for the two bulls. Assume, for example, that in a particular herd the mean SCC of daughters of Formation is 200 cells / $\mu$ l; the mean SCC of daughters of Leif are expected to average  $200 \times 1.32 = 264$  cells / $\mu$ l. In a herd in which Formation’s daughters average 500 cells / $\mu$ l, Leif’s daughters would be expected to average  $500 \times 1.32 = 660$  cells / $\mu$ l. In these examples, the SCC ratio, 1.32, corresponds to the PTA–SCS difference of .4 in Table 3. For the extreme high and low PTA–SCS bulls for which the difference is 1 point, average SCC for daughters of the highest bull is expected to be twice the average SCC of daughters of the lowest bull in any given herd. For example, if daughters of the lowest bull averaged 125 cells / $\mu$ l, daughters of the highest bull would be expected to average 250 cells. In a high SCS herd, if the daughters of the lowest bull averaged 350 cells / $\mu$ l, daughters of the highest bull would be expected to average 700 cells / $\mu$ l.

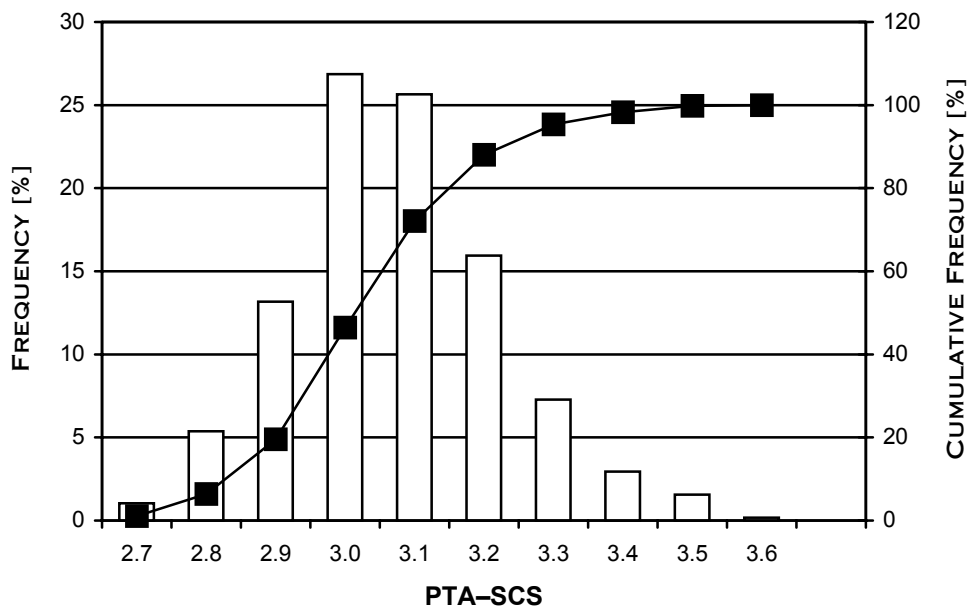
The incidence of clinical mastitis among daughters of a higher PTA bull is the incidence of clinical mastitis for daughters of a lower PTA bull times the clinical mastitis ratio in Table 3 that corresponds to the difference between PTA–SCS for the two bulls. For example, assume that in a given herd 20% of Formation’s daughters have clinical mastitis; using the clinical mastitis ratio in Table 3 that corresponds to a PTA–SCS difference of .4,  $20\% \times 1.25 = 25\%$  of Leif’s daughters would be expected to have clinical mastitis. In a herd with higher levels of mastitis incidence, if 32% of Formation’s daughters had clinical mastitis,  $32\% \times 1.25 = 40\%$  of Leif’s daughters would be expected to have clinical mastitis. In the extreme case in which the difference in PTA–SCS between bulls is 1 point, the incidence of clinical mastitis among daughters of the highest bull would be expected to be 75% higher than among daughters of the lowest bull. For example, if clinical mastitis incidence for the lowest bull is 16%, incidence for daughters of the highest bull is expected to be  $16\% \times 1.75 = 28\%$ . In a herd with higher levels of mastitis, if 32% of daughters of the lowest bull had clinical mastitis,  $32\% \times 1.75 = 56\%$  of the daughters of the highest bull would be expected to have at least one case of clinical mastitis per lactation.

None would argue that these differences among bulls in SCC and clinical mastitis are insignificant. Yet the narrow point scale used to measure SCS may give the illusion that differences among bulls in SCS are not important.

Figure 1 shows the frequency distribution of PTA-SCS for active AI Holstein bulls from the November 2000 genetic evaluation run. The range of PTA-SCS was 2.72 to 3.68, a difference of nearly 1 point. Notice in Figure 1 that 80 % of PTA's lie in the middle four classes; a relatively low percentage of bulls are at the low and high extremes. This is due to the low heritability of SCS [10%] and comparatively low reliability of PTA-SCS. Increasing the numbers of cows on SCS testing and increasing the numbers of daughters per bull in young sire testing programs would contribute to increasing the percentage of bulls in the extreme PTA-SCS categories. The low percentage of extreme bulls limits the opportunity for genetic improvement of SCS.

*Bulls with PTA-SCS 3.3 and higher should be avoided as herd sires unless they are truly superior for the economically important yield traits [see Figure 1]. This eliminates the worst 10% of bulls without affecting the opportunity for improvement in other traits. Upon inspection of a list of these high PTA-SCS bulls one will find several that have large numbers of daughters, many of which are not exceptional for any important traits. The economic cost of mastitis among daughters of these bulls is considerable and it could have been avoided. Also, this group of high PTA-SCS bulls includes some of the top bulls for yield and other traits. Some of these may be worth using in spite of their high PTA-SCS. On the other hand, other bulls with similar genetic merit for the most important traits may be found that have lower PTA-SCS; these could be used in favor of the high PTA-SCS candidates.*

Fig. 1



Frequency [bars] and cumulative frequency [line] of PTA-SCS for active AI Holstein bulls in November 2000. (Compiled from NAAB. <http://www.naab-css.org/db/>. Accessed November 20, 2000).

Reliability of PTA is a measure of the accuracy of PTA. In statistical terms, reliability is the squared correlation between PTA and true transmitting ability. Reliability depends on heritability of the trait, the amount of performance information used in computing PTA, and the genetic relationship of the individual being evaluated with the animals involved in the performance measure. Reliability for bulls increases as additional daughters are included in successive genetic evaluation runs. In the November 2000 active AI Holstein sire summary, the reliability for PTA–Milk ranged from 52 to 99% and averaged 87%; for PTA–SCS reliability ranged from 31 to 99% and averaged 72% (NAAB, 2000). Reliability is higher for PTA–Milk because milk yield has a higher heritability than SCS [30% vs. 10%] and because more cows are recorded for milk than for SCS. When a bull's reliability is low, say less than 65%, there is some chance that his PTA will increase or decrease as more daughters are included in future evaluations; when reliability is high, say above 90%, subsequent PTA's are likely to change very little from their current values. *Producers should use high reliability bulls more heavily and low reliability bulls sparingly. Reliability should not be used as a basis for deciding which bulls to use.* Too often, producers will choose a bull with high reliability and low PTA in preference to a higher PTA bull with lower reliability; these decisions result in lower genetic value and poorer performance in the next generation of herd replacements.

#### Recent Changes in PTA–SCS Procedures

New genetic bases were introduced for all traits in August 2000. PTA–SCS values decreased with the new base. PTA's are measured against a genetic base that is analogous to the freezing point of water as a base for Celsius temperature readings. Each breed has its own genetic base, so PTA's are not comparable between breeds. *The genetic base is determined from the average of cows born in a specified year.* In August 2000, the base year was updated to cows born in 1995; the base year is updated each five years, so the previous base was determined from cows born in 1990. Updating the base each five years serves to keep the average PTA near current breed averages as genetic improvement raises the level in each breed. For most traits, the base value is set to zero; as an example, the average PTA for milk yield for cows born in 1995 is set to zero. The PTA for all cows and bulls for milk yield, then, is expressed as a difference from the average cow born in the base year which is set at zero.

For SCS, the base is not set to 0; instead it is set equal to the average first lactation SCS of cows born in the base year. Table 4 shows breed averages for the 1990 and 1995 base years. Changes in breed average are due both to improvements in management and changes in genetics. Genetic change was calculated from the average PTA–SCS for cows born in 1995 minus the average for cows born in 1990; results are shown in Table 4. The desired genetic change for SCS is negative. Genetic change has been negligible in all breeds except Jersey; the Jersey breed continues to show a long term, slow, and unmistakable increase in genetic level of SCS (AIPL, 2000b). The changes in management from 1990 to 1995 shown in Table 4 indicate that producers are continuing to improve their management of udder health as measured by SCS. This improvement in management was the major reason for the lower genetic base for PTA–SCS.

Table 4. Breed averages for the previous [1990] and current [1995] genetic base years, genetic change in PTA–SCS from 1990 to 1995, and management change in PTA–SCS by breed [data from AIPL, 2000a].

<u>Breed</u>	<u>Breed Average</u> <sup>1</sup>		<u>Genetic</u>	<u>Management</u>
	<u>1990</u>	<u>1995</u>	<u>Change</u>	<u>Change</u>
Ayrshire	3.15	2.92	.01	–.24
Brown Swiss	3.22	3.08	.00	–.14
Guernsey	3.35	3.21	–.01	–.13
Holstein	3.20	3.10	.00	–.10
Jersey	3.30	3.31	.04	–.03

<sup>1</sup> Breed average of first lactation SCS for cows born in the indicated base years

The second significant change in genetic evaluation methods in August 2000 was the introduction by USDA–AIPL of a new Lifetime Net Merit [LNM] index and the Holstein Association’s new formulation for Type-Production Index<sup>TM</sup> [TPI] (AIPL, 2000d; Holstein Association, 2000; VanRaden, 2000). Lifetime Net Merit is a lifetime profit index that replaced Net Merit \$ [NM\$] which was formulated on single lactation performance. The Holstein Association, for the first time, included PTA–SCS as a component of TPI. These two indexes are perhaps the most widely used by producers for screening lists of dairy bulls. The indexes are an easy way to characterize and rank bulls while giving consideration to several traits simultaneously. An index considers a bull’s strengths and weaknesses for several traits to arrive at a single value that represents the bull’s overall merit. Ideally, the weights applied to the several traits in an index reflect the real economic values of the traits. Economic values for the yield traits are relatively well defined; for the non-yield traits, these values are more subjective. The LNM equation and its derivation are given elsewhere (AIPL, 2000d; VanRaden, 2000). Index weights for the traits in NM\$ and LNM are given as dollars per unit of the trait. The formula for TPI is in Holstein Type-Production Sire Summaries (Holstein Association, 2000). Index weights for the traits in TPI are arbitrary TPI points per unit of the trait. The index weights are listed in Table 5. The weights on SCS are negative because high SCS are undesirable. Also shown in Table 5 are the standard deviations of transmitting ability [SDTA] for each trait.

In one way, the selection index weights in Table 5 are easy to interpret because they show the values that are applied to the PTA for each trait in calculating a bull’s index value. In fact, the index value is obtained by multiplying the index weight for a trait by the PTA for that trait and summing the products over all traits. In another way, the index weights are potentially misleading and difficult to interpret because the genetic variability of the traits varies widely from one trait to another. Genetic variability is shown in Table 5 as standard deviation of transmitting ability (SDTA). Comparing the weights for protein yield [\$4.76/ lb] and SCS [\$154/ point] in LNM, for example, it might appear that SCS is weighted very heavily in relation to protein. Multiplying the index weight for each trait by the SDTA for that trait shows that one standard deviation of change in protein has a value of \$119 while one standard

deviation of change in SCS has a value of only \$30. Genetic change is proportional to SDTA. Therefore, it is appropriate to use the product of index weight times SDTA for each trait as a measure of the relative importance of each trait in the index. The Holstein Association uses standard deviations of PTA which are somewhat smaller than those shown here; the Holstein assumptions are shown in the Holstein Type-Production Sire Summaries (Holstein Association, 2000).

Table 5. Standard deviation of transmitting ability [SDTA] and selection index weights for Net Merit \$ [NM\$], Lifetime Net Merit [LNM], and Type-Production Index (TPI).

Trait, units	Units:	SDT A <sup>1</sup>	NM\$	LNM	TPI
		Trait units/SD	\$/ Trait unit	\$/ Trait unit	Points/ Trait unit
Milk, lbs/ 305 d		832	.0217	.018	--
Fat, lbs/ 305 d		32	.56	2.14	2.29
Protein, lbs/ 305 d		25	1.40	4.76	6.76
Productive Live, mos		1.96	11.30	28.00	45.00
SCS, pts		.195	-28.22	-154.00	-4.50
Type, pts		.700	--	--	64.29
Size, pts		.935	--	-14.00	--
Udder, pts		.784	--	29.00	37.12
Feet and Legs, pts		.829	--	15.00	18.00

<sup>1</sup>Standard Deviation of Transmitting Ability (from VanRaden, 2000)

Table 6. Relative index weights for Net Merit \$ (NM\$), Lifetime Net Merit (LNM), and Type-Production Index (TPI).

Trait	NM\$	LNM	TPI
Milk	.52	.13	--
Fat	.51	.58	.40
Protein	1.00	1.00	1.00
Productive Life	.63	.46	.32
SCS	-.16	-.25	-.03
Type	--	--	.35
Size	--	-.11	--
Udder	--	.19	.23
Feet and Legs	--	.10	.12

The relative selection index weights in Table 6 show the importance of each trait in the three selection indexes relative to protein yield. These were obtained as the ratio of economic value per standard deviation for each trait to the economic value per standard deviation for protein yield. In this way, it is quite easy to see the relative influence of traits on the index. The new LNM index gives 25% as much weight to SCS as it does to protein. This is about 55% more relative emphasis than the NM\$ index that LNM replaces. Because the yields of milk, fat and protein are highly correlated, the effect of the yield traits on the indexes is greater than the sum

of their weights would imply. As a result, the non-yield traits actually have less influence on the indexes than these results suggest. The inclusion of SCS in TPI was introduced for the first time in August 2000. Although this was a step in the right direction, the influence of SCS on the index is negligible as shown by the relative index weights in Table 6.

The assignment of index weights to SCS is controversial due to the lack of a comprehensive economic analysis of the association of SCS with mastitis prevention and treatment costs. Specifically, the need is for a documentation and analysis of the extent to which mastitis prevention and treatment costs change per unit of increase in SCS. Costs that should be included in such an analysis are: drugs used in treatment of clinical mastitis, veterinary treatment and diagnostic costs, milk discarded after antibiotic treatment, and herd labor involved in treatment and diagnosis. Among geneticists it is generally agreed that most of the yield losses from clinical and subclinical mastitis are reflected in measures of milk yield; for that reason, including yield loss in the index weight for SCS would be redundant. In addition to these real costs, there are some intangibles that would justify even greater economic weight to SCS in the selection indexes. These intangibles include improved animal well being, reducing the need for antibiotic treatments, and the nuisance of dealing with diagnosis and treatment of mastitis. In the absence of good information, the industry has taken a conservative approach to weighting SCS in the selection indexes. In my view, TPI considerably undervalues SCS. Although the new LNM index increases the weight on SCS compared to the previously used NM\$ index, doubling the weight used in LNM may be justifiable. This would not seriously reduce the genetic improvement for the yield traits, and it would create real improvement in genetic resistance to mastitis.

### Recommendations for Using PTA-SCS

Although PTA-SCS was introduced seven years ago, producers have shown rather little interest in this information. While mastitis is an important problem in dairy herds, it is only one of many concerns producers face. Also, the process of sire selection suffers from information overload; the large number of traits with genetic evaluations, measures of reliability, inbreeding, and other issues contribute to this problem. The use of a selection index consolidates much of this information into a single quantity. It has been observed that producers sometimes lose sight of the big picture regarding milk quality. Their focus is too often limited to lowering SCS for the purpose of gaining quality premiums from the milk processor. The costs associated with clinical mastitis are frequently forgotten as the greater benefit from improving milk quality.

From the perspective of the AI industry, the availability of PTA-SCS may do more to hinder than to enhance the marketing of bulls. A bull with desirable, low PTA-SCS and otherwise favorable genetic evaluations may not generate the additional revenue needed to offset the potential loss of sales from a bull with undesirable, high PTA-SCS that is outstanding in other respects. The AI industry does respond to market forces. Currently producers' interest in type, even more than production, drives the semen market. Only a strong interest in PTA-SCS on the part of producers will raise the profile of PTA-SCS among decision-makers in the AI industry.

Veterinarians and milk quality specialists could be helpful in encouraging use of PTA-SCS by producers. Genetics is an area in which these professionals do not normally work, so the comfort level with using genetic information is, understandably, quite low. Conversely, milk quality issues are almost never the concern of semen distributors. The following recommendations are provided to enable all segments of the industry to make appropriate use of PTA-SCS.

Recommendation 1: Include sire selection as a point on the check list when consulting with herds for mastitis and milk quality. Recognize that sire selection is a long term, not a short-term solution to improvement. For this reason, sire selection will not be a high priority for herds facing loss of their milk market, but it should be part of the long-term outlook. Also, because genetic improvement is a long-term process, every herd, even those with excellent udder health programs, should avoid sires with high PTA-SCS.

Recommendation 2: Herds with low average SCS should give the same attention to PTA-SCS in sire selection as herds with high average SCS. Genetic differences among bulls' daughters are expressed to the same extent in both high and low SCS herds (Banos and Shook, 1990). Consider for example two bulls whose PTA-SCS differ by .80 points. If the daughters of the low bull have average SCS of 2.0, daughters of the high bull will average 2.8; in a herd in which the daughters of the low bull average 5.0, daughters of the high bull will average 5.8. Although few daughters of the high bull would be above the regulatory limit in either of these herds, that bull's daughters will experience a higher incidence of mastitis in both herds.

Genetic improvement is a cumulative process. Using consecutive generations of sires with low PTA-SCS will produce future generations of cows with increasingly lower levels of SCS. The costs of diagnosing and treating mastitis can be reduced, even in well managed herds, when low SCS sires are used generation after generation.

Recommendation 3: Producers who can manage artificial insemination successfully should use AI bulls. A wealth of genetic information and true genetic superiority are available through AI that is not available for non-AI bulls. Producers who cannot manage AI, should purchase bulls from dams with favorable USDA-AIPL genetic evaluations and sired by well-qualified AI bulls. The tools used for selecting AI bulls should be applied to selecting the sires and dams of non-AI bulls.

Recommendation 4: Use the LNM index as an initial screening for selecting AI bulls. This will provide a moderate amount of selection emphasis on PTA-SCS. Producers should create a 'long list' of candidate bulls using the LNM index. TPI, which is favored by many producers, has an insignificant amount of emphasis on PTA-SCS. If TPI is used in the initial screening, special consideration must be given to PTA-SCS.

Recommendation 5: Include PTA-SCS among the criteria for selecting a 'short list' of service sires from the 'long list'. Avoid the 5 to 10% of bulls with the highest PTA-SCS; for the current genetic base in Holsteins, these are the bulls with PTA-SCS 3.3 and higher. Other

traits to consider in forming the short list are calving ease, genetic defects, type, fertility, and semen cost.

### Where to Find PTA-SCS Evaluations

Often the best source of information for genetic evaluations is the internet. Printed lists of bulls in the popular dairy magazines and AI company publications sometimes list PTA-SCS evaluations, but many do not. While each of the AI companies maintains a website with sire information, the genetic evaluation data aren't always complete at these sites. Three sites that provide comprehensive genetic evaluation data are outlined here.

The National Association of Animal Breeders is the trade organization of the artificial breeding industry in the US. Their site, <http://www.naab-css.org/>, provides the option to create a customized list of bulls that meet the user's criteria. You may also download the complete list of active AI bulls as a comma delimited text file and place it into a spreadsheet or other personal computer application. Genetic evaluations for production, SCS, calving ease, and type traits are included in these files.

The USDA-AIPL computes genetic evaluations for yield traits, SCS, and productive life for all cows and their sires. The AIPL website, <http://aipl.arsusda.gov/>, provides extensive information about the genetic evaluation system and genetic improvement in the US. Results for both AI and non-AI bulls are available at the AIPL site. Facilities are provided to obtain complete information for individual cows and bulls and to obtain lists of bulls in various forms. Type data are not available at the AIPL site. A useful feature of the AIPL site is its extensive list of links to the breed associations, domestic and international AI companies, DHI organizations, and others.

The "Dairy Bulls dot Com" site, <http://www.dairybulls.com/>, provides genetic evaluations on AI bulls for SCS as well as all production and type traits. This site allows the user to look up information on individual bulls and to create ranked lists of bulls that meet user specified criteria.

### Genetic Relationship Between SCS Clinical Mastitis

Including SCS among the criteria for sire selection is driven by the desire to improve genetic resistance to mastitis. Using SCS as a proxy for clinical mastitis in breeding programs is justified by the fact that the major factor affecting SCS is the presence of intramammary infections (Harmon, 1994). Several studies have shown a positive, unfavorable genetic correlation between milk yield and clinical mastitis (Emanuelson et al., 1988; Rogers et al., 1998, Shook, 1993); this implies that genetic improvement for milk yield is accompanied by increases in genetic susceptibility for mastitis. Therefore, it is important to place some selection emphasis on udder health traits to offset the undesirable genetic trend in mastitis susceptibility. Clinical mastitis treatments are routinely recorded in the Scandinavian countries, and these records are used in genetic evaluation programs (Emanuelson, 1988; Ruane et al., 1997). In the US, clinical mastitis records are not maintained as part of the DHI

program, but SCC data are available for more than 90% of cows (AIPL, 2000c). How effective is SCS as a proxy for clinical mastitis in genetic improvement programs? The answer to this question hinges mostly on the genetic correlation between SCS and clinical mastitis. Earlier reviews have summarized the findings (Emanuelson et al., 1988; Mrode and Swanson, 1996, Nash et al., 2000; Shook, 1993); the focus here will be on two recent studies.

The relationship of cows' clinical mastitis episodes in first and second lactations with their sires' PTA-SCS was investigated for 1,860 cows in eight herds (Nash et al., 2000). Results consistently showed the lowest incidence of clinical mastitis and the fewest numbers of mastitis episodes occurred among daughters of bulls with lowest PTA-SCS, and the mastitis measures increased with increasing PTA-SCS. A one-point difference in the sire's PTA-SCS was associated with a 75% increase in daughters' mastitis incidence in both first and second lactation.

Rogers et al. (1998) examined genetic correlations between daughters of Holstein bulls recorded in the US for SCS and daughters of the same bulls recorded in Denmark and Sweden for clinical mastitis. The study involved 80 bulls in the US-Denmark data and 85 bulls in the US-Sweden data. These bulls had >60% reliability for SCS in the US [average was >95%] and at least 50 daughter equivalents for clinical mastitis in Denmark or Sweden. The genetic correlations of SCS with clinical mastitis were .66 in Denmark and .49 in Sweden. Within the Swedish Holstein population, the correlation between SCS and clinical mastitis has been estimated at .70 (Philipsson et al., 1994). In the Danish portion of the study, the regression of clinical mastitis on PTA-SCS was  $.0972 \pm .0163$ ; a one point difference between PTA-SCS of two bulls is associated on average with nearly a 10% higher rate of clinical mastitis. In the Swedish data, the regression of PTA-SCS on an index of clinical mastitis was  $9.58 \pm 2.95$ . This statistic is difficult to interpret in terms of the rate of clinical mastitis in bulls' daughters because the trait is scaled to have a mean of 100 and standard deviation of around 6.

Genetic correlation estimates between clinical mastitis and SCS tend to have large standard errors, and the estimates vary rather widely due to their lack of precision. The several estimates that have been made are centered in the range of 65 to 70%. This is quite a strong association and indicates that selection of bulls for low SCS is effective as a means of producing new generations of cows that are genetically more resistant to mastitis. One should not expect these correlations to approach unity because clinical mastitis is measured subjectively and only the more severe cases of mastitis are treated and recorded. The research is quite clear that daughters of bulls with the lowest PTA-SCS have the lowest rates of clinical mastitis.

#### International Genetic Evaluations for SCS and Clinical Mastitis

In May 2001 Interbull, the International Bull Evaluation Service, will introduce international genetic evaluations for somatic cell score and clinical mastitis (Emanuelson, U., 2000, Personal Communication; Mark et al., 2000). International genetic evaluations for the yield traits have been computed since the early 1990's. Such international evaluations of dairy bulls are possible because some bulls have daughters in more than one country and because many

bulls have sons in several countries. These genetic ties across countries enable the use of performance records in all participating countries for genetic evaluation of bulls regardless of the bull's country of origin. Each country conducts its own domestic genetic evaluation. Interbull uses these various domestic evaluations, the pedigree relationships among bulls, and genetic correlations among countries to compile an international evaluation for all bulls. Because the genetic correlations between countries are less than 1.0, each bull has a separate evaluation in each country. The Interbull results are expressed on the same scale and in relation to the same genetic base as each country's domestic evaluation, i. e. each bull gets a different evaluation in each country. This makes it possible for producers and AI personnel to fairly evaluate the genetic merit of bulls regardless of the country of origin. In most countries, if the Interbull evaluation has a significantly higher reliability than the domestic evaluation due to a large number of daughters or sons proven in another country, the Interbull evaluation is published in place of the domestic evaluation.

At this time, nine countries conduct domestic genetic evaluations of Holsteins for SCS and will participate in the international SCS evaluations: Canada, Denmark, Finland, France, Germany, Great Britain, The Netherlands, Sweden and USA. Three countries conduct Holstein evaluations for clinical mastitis: Denmark, Finland, and Sweden. Ayrshire evaluations for SCS and clinical mastitis will involve only the Scandinavian countries. More countries and breeds will be included in this program as the data become available. Genetic correlations between countries for SCS are quite high. For example the genetic correlations between the US and other countries are: Canada, .93; Denmark, .88; Finland, .91; France, .92; Germany, .87; Great Britain, .93; The Netherlands, .90; and Sweden, .91 (Mark et al., 2000). These high correlations may make it possible to obtain higher reliability evaluations for SCS for some US bulls by using data from other countries. Current methodology does not allow the use of clinical mastitis data in one country to contribute to the genetic evaluation for SCS in another country; such methods are under development.

### Summary

Genetic differences among cows and bulls for clinical mastitis, SCS and SCC are substantial and economically important. Average SCC of daughters of the bulls with highest PTA-SCS is twice the average SCC of daughters of bulls with the lowest PTA-SCS. In terms of clinical mastitis, daughters of the highest PTA-SCS bulls have clinical mastitis rates 1.75 times daughters of the lowest PTA-SCS bulls in the same herd environment.

While management is most effective in the short term for correcting milk quality and mastitis problems, genetic improvement must be a component of any effective long-term strategy for improving milk quality and udder health. Producers who have achieved excellent milk quality and mastitis management will benefit from selecting bulls with low PTA-SCS to the same extent as those with troublesome rates of mastitis or poor milk quality. Genetic change is a slow, long-term process, so attention to PTA-SCS and other measures of genetic merit must be applied consistently year after year to maintain continuous improvement.

Genetic evaluations of bulls for SCS have been underutilized as a tool for reducing incidence of mastitis. Ultimately, the market demands of knowledgeable producers will drive the change toward greater emphasis on PTA-SCS as a criterion for sire selection by the AI industry. Veterinarians, milk quality specialists, and geneticists all have roles to play in promoting appropriate use of PTA-SCS by producers. It is incumbent upon animal health and milk quality specialists to become familiar with PTA-SCS in order to create knowledgeable producers.

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