Using Conformational Anatomy to Identify Functionality & Economics of Dairy Cows

Gordon Atkins [1], Jay Shannon [2] and Bethany Muir [2]

[1] Atkins Veterinary Services Ltd., 248 Varsity Estates Link NW, Calgary AB T3B 4C9
Email: atkinsg@shaw.ca
[2] Holstein Association of Canada, P.O. Box 610, Brantford, ON N3T 5R4
Email: jshannon@holstein.ca

Take Home Messages

- Genetic selection is a powerful tool that has dramatically changed both the external appearance and internal anatomy of dairy cows over the past 100 years.
- The influence of modern confinement management has changed the dairy cow's environment, created a more energy rich diet and greatly increased her productivity.
- Continual increase in milk output is only sustainable with corresponding improvements in functional conformation.
- With modern confinement management, many cows are culled from herds before they have an opportunity to fully express their milk producing genetic potential and poor functional conformation is an important factor in premature culling. Cows with better overall conformation maximize their milk producing potential and produce at a higher level for more lactations.
- Important functional conformational traits are: udder conformation, locomotion resulting from desirable feet and leg conformation, dairy strength, and desirable rump structure.
- Udder and feet and leg traits have been shown to have the greatest relative impact on dairy cow longevity.
- A balanced breeding program that selects for production and functional conformation is optimal for achieving high production from cows that last for many lactations.
- Herds that classify have significant advantage over herds that do not classify with regard to higher production per cow, greater survivability, and resulting higher profits per lactating cow.

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Introduction

Today's dairy cow handles some of the greatest challenges ever faced in the history of the dairy industry. These challenges include the demands associated with unprecedented levels of production, the expectation for superior reproductive performance, the use of high energy rations, and exposure to other stresses associated with modern confinement management. The length of a cow's productive life directly affects the profitability of that herd; longer herd life reduces replacement costs and increases the proportion of lactations from higher yielding, mature animals. Therefore, it is paramount that we increase the cow's chance of surviving longer in the herd.

Dairy cow survival is influenced by many genetic and non-genetic factors. Non-genetic factors include stall size and barn design, bedding type, milk quota restrictions and the availability and affordability of replacement heifers. Genetic factors include the capability for high production and desirable milk components, the functional conformation necessary for a cow to express her productive and reproductive potential, the ability to maintain adequate body condition to resist metabolic disorders and maximize immune status, and the ability to move with sound locomotion.

Many cows never have the opportunity to express their full genetic potential because they don't live in an environment that maximizes the non-genetic factors. Therefore if a cow is not provided with the ideal environment, care, and housing that is necessary to achieve the full expression of her genetic potential, she will likely under-perform and leave the herd prematurely.

In the past, the primary focus of the classification system was overall Final Class. Attention was placed on the individual animal and her most direct ancestors and whether members of this family scored Good Plus, Very Good or Excellent. In contrast, today's classification emphasis is placed on the detailed appraisal of individual functional traits, an approach recognized by large herd owners as an effective tool to predict longevity. The classification system better addresses the needs of commercial dairy herds by providing a detailed and reliable assessment of individual functional traits that can be used as a herd improvement tool to improve longevity and enhance a cow's ability to express her genetic productive and reproductive potential.

The heritability of milk production and associated milk components is relatively consistent and is considered to be moderate to high around 0.40 (Muir et al., 2004). However, conformation traits have a wide range of heritability (Kistemaker and Huapaya, 2006) from 0.08 to 0.53, with many conformation traits having a heritability in a similar range or higher than milk production. Though there is variability in functional trait heritabilities, by studying superior cows over the past century, it is evident that incredible

genetic and phenotypic progress has been made particularly with regard to udder conformation and dairy strength.

Today's dairy businesses are more commercially oriented (i.e., many larger dairy herds) with less focus on the individual animal and a greater focus on overall herd performance and profitability. In the midst of this change, generating interest in breed improvement programs such as classification can be challenging, mainly because there is only a small component of scientific literature devoted to studying the association between improvement in functional conformation and improvement in longevity and profitability (Caraviello et al., 2004; Sewalem et al, 2004; Larroque and Ducrocq, 2001). To address this deficiency, Holstein Canada initiated a project to analyze the anatomy and physiology of the internal mechanics of a dairy cow in relation to the functional conformation characteristics. The project also analyzed the relationship between the profitability of a dairy operation and the functional conformation and longevity of cows within that operation (Holstein Canada, 2007).

If one likens a dairy cow to a piece of machinery in a factory, it is clear that a continual increase in output is only possible if we continue to improve the function and durability of the machine as well as the environment in which it operates. Advances in management, housing, nutrition and genetics have raised our expectations for dairy cow production. It then remains a constant challenge to improve the structure (conformation) of the animal to match her production potential so she remains resilient to the stresses of modern confinement systems and can remain trouble free over a long lifetime.

The Canadian Classification system identifies the following conformational categories as the most important traits with known relationships to functionality and longevity:

- udder conformation,
- feet and leg conformation and the relationship with locomotion,
- thoracic and abdominal body conformation (dairy strength),
- rump and loin structure

■ Relationship between Conformation and Longevity

Udder traits and feet & leg traits are the most important functional conformation traits in relation to survivability (see Figure 1). Although there exists a strong relationship between conformation and survivability, a significant proportion of genetic variation in longevity remains unexplained by existing production and conformation traits. Actual culling and fertility data are needed to explain the remainder of the story. Health and daughter fertility traits are becoming much more prominent in genetic evaluations as we seek accurate predictors of longevity and profitability. These traits are dependent not only on conformation and productivity but also on the general health and physiology of the cow, as well as the cow's resiliency to the stress of high production and confinement housing.

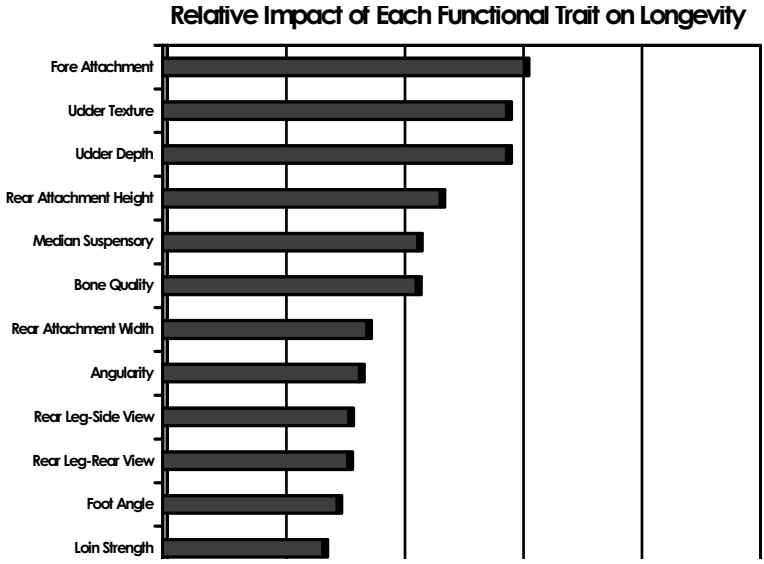

Figure 1. Descriptive trait significance in relation to longevity based on herd survival data for cows classified during first lactation between November 1998 and June 1999.

■ Economic Benefits of Classification

Classification can be a powerful early culling tool. Appraisals of strengths and weaknesses early in a cows' life are informative for both breeding and early culling decisions. Herds that classify regularly are able to make corrective mating decisions to develop more functional animals with solid feet and legs,

better udders and rumps and more dairy strength. Over time, continual management decisions based on classification build more functionality and healthier cows that have the resilience to survive in their environments.

Classifiers travel to thousands of farms across Canada each year to provide unbiased conformation assessments for all dairy breeds. They bring a wealth of skill and experience to each herd and utilize precisely defined reference and measurement points to facilitate objective, congruent and accurate assessments across animals, across classifiers and over time.

When a herd starts to classify, several methods of improvement are initiated. As early as after the very first classification visit, each animal's conformational strengths and weaknesses can be identified. Directly from this information, culling decisions can be made. Problem cows can be easily identified and culled. Alternatively, if an animal's weaknesses do not warrant removal, the producer gains valuable information for managing and breeding the cow in the future.

Decisions made on an animal-by-animal or group basis are possible from information gained on classification day. At every classification visit, in addition to individual animal reports, overall herd conformational strengths and weaknesses are provided. Over time, trends in functional sub-traits and overall conformation are given so that herds can monitor progress or deterioration, as the case may be. For instance, herds with feet and leg weaknesses can focus on improving foot health and foot conformation and hopefully manage the herd's environment to maximize their genetic potential.

A comprehensive genetic mating service is offered through several Artificial Insemination centers. These programs give producers the ability to make mating decisions based on classification information. The best functional cows in the herd can be selected to develop the herd genetically. The optimal sire can be chosen for each cow to maximize the genetic potential in the offspring. These kinds of decisions can be made after every classification visit. Over time, the herd improves genetically and in conjunction with better management practices, great progress can be made in the development of a more functional herd of cows.

To begin to quantify these benefits, production and classification results for animals classified in first lactation from January until August 2007 were investigated. Animals were grouped in 5 point increments according to their Final Score and the average milk production of each group was compared. As Final Score increased so did 305-d yields of milk, fat, and protein as well as BCA for milk, fat, and protein (Table 1). There was a 1,225 kg difference in 305-d milk yield between the high and low scoring groups. Animals that scored higher had a better opportunity to express their full genetic potential and produced more milk.

Table 1: Average production by Final Score group.

	60–64	65–69	70–74	75–79	80–84	85–89
305 Milk (kg)	8,129	8,257	8,390	8,580	8,787	9,354
305 Fat (kg)	300	303	309	316	323	353
305 Protein (kg)	260	264	269	275	282	303
BCA Milk	209	210	212	215	217	228
BCA Fat	208	207	209	213	217	231
BCA Protein	210	210	212	216	219	231
Deviation Milk	-7.0	-3.0	-0.5	1.9	3.9	10.0
Deviation Fat	-8.5	-3.4	-1.8	0.8	2.7	8.2
Deviation Protein	-6.1	-3.2	-0.4	2.4	4.3	10.3

Classification score can also serve as an early predictor for cows that will achieve maximum longevity in herds. Animals that were classified for the first time from November 1998 until June 1999 were followed to determine the length of time they produced before leaving the herd through culling or dying. Animals were grouped in 5 point increments based on their classification final score as first lactation heifers. The average productive life for each group was calculated in the number of lactations and the results are shown in Table 2. Results showed that there was a 2.1 lactation difference between the high and low scoring groups.

From both analyses we can summarize that high scoring cows make more milk and last longer in the herd. Herd owners can determine which cows will produce milk profitably over a long lifetime by using information gained on classification day.

Table 2: Average length of productive life by Final Score group for animals classified from November 1998 until June 1999.

Final Score in First Lactation	Average Number of Lactations (Productive Life)
85 – 89	3.81
80 – 84	3.20
75 – 79	2.71
70 – 74	2.24
65 – 69	2.06
60 – 64	1.75

There may only be marginal impact in the bottom line for a herd that classifies

for the first time, however, sustained use of classification information to make management decisions initiates a cycle of increased revenue and profits over time as the functional conformation improves in the herd. Herds that classify use the information to make timely, educated decisions for culling, breeding, and overall herd management. The net result is an increased profit that far out-weighs the cost of investment.

To quantify the financial benefits achieved by herds that classify, average milk production in herds that participate in milk recording in Canada were compared between herds that participated in classification (at least the last 3 consecutive rounds) and those that did not participate. (see Table 3). Results showed that herds that classify had an average production of 1,293 kg more milk per cow per lactation than those herds that did not classify. Even within the top 10% production herds, classifying herds outperformed non-classifying herds by 1089 kg per cow/lactation.

The average lactation number (as a snapshot from the current active milking herds) was slightly higher in classifying herds. However, in the top 10% production herds, classifying herds had 0.6 more lactations/cow than non-classifying herds. This would seem to indicate that, at higher production levels, the cows with more desirable functional conformation are able to achieve greater longevity. Therefore, this data indicated that, not only do herds that are regularly classified have higher milk production and components per cow, but also these herds have cows that last longer since they are more durable and functional.

Table 3: Average milk production and lactation number in classifying and non-classifying herds (Holstein Canada Functional Conformation CD).

	Classifying Herds		Non-Classifying Herds	
Trait	All	Top 10%	All	Top 10%
305-d Milk (kg)	9,294	11,149	8,001	10,060
305-d Fat (kg)	346	413	298	375
305-d Protein (kg)	296	355	253	320
Lactation Number	2.43	2.81	2.38	2.21

Approximate revenue and costs for these two groups of herds were calculated. Although classifying herds produce more milk on average, they would subsequently incur more costs associated with producing that extra milk. The costs associated with additional feed, milk transportation, hydro, labour, insurance and the additional quota were all accounted for. When the increased costs were compared to increased revenue from the added longevity and milk sales, classifying herds made $429.25 more profit per cow

per year than non-classifying herds. Although one must recognize that the higher revenue from classifying herds is due to a multiple number of factors, classification itself can account for a considerable portion of the increased profit.

Table 4: Comparison of average revenue and expenses for classifying and non-classifying herds.

	Classify	Do Not Classify
Average Production (per cow)		
kg milk/305-d lactation	9294	8001
kg fat / 305-d lactation	346	298
kg milk/day	30.5	26.2
REVENUE (per cow)		
Sale of Milk ($0.70/litre)	6505.80	5600.70
Livestock sales	321.95	251.37
EXPENSES (per cow)		
Dairy, crop, overhead, livestock expenses	4200.38	3903.95
Extra Quota	250.00	
TOTAL EXPENSES	4450.38	3903.95
NET RETURNS (per cow)	2377.37	1948.12

■ Udder Conformation

Evaluation of udder conformation and the relative importance placed on each component trait has been modified over the years. Any discussion of udder conformation should include a detailed description of the udder's suspensory apparatus since this attachment to the ventral abdominal wall and the pelvic floor is fundamental to udder health and longevity. Many of the undesirable changes in the udder's exterior characteristics and location can be attributed to a weakness of the suspensory apparatus and these changes are usually irreversible. Normal maturity will cause the suspensory ligaments to stretch but excessive stretching or tearing can cause low, pendulous udders, which are more prone to injury and infection.

Historically, the udder was located in a more anterior position and was attached only to the abdominal wall much the same as with deer or elk. Udder shape, location, and strength of attachments are all heritable traits. The heritabilities of these traits were estimated to be between 0.14 to 0.42 (Kistemaker and Huapaya, 2006). Therefore genetic selection has the ability to alter anatomical structure of the cow's udder. Selection for increased production over the past 250 years has caused the udder to increase in size and mass. As a result the udder's centre of gravity has shifted caudal or posterior and the suspensory apparatus of the udder has been supplemented with additional suspensory attachment to the pelvic floor by means of the symphysial tendon (represented by "3" in the Figure below). Evaluating fundamental anatomical characteristics such as udder depth and suspensory udder strength has facilitated the development of a functionally sound udder to accommodate the stress of high production.

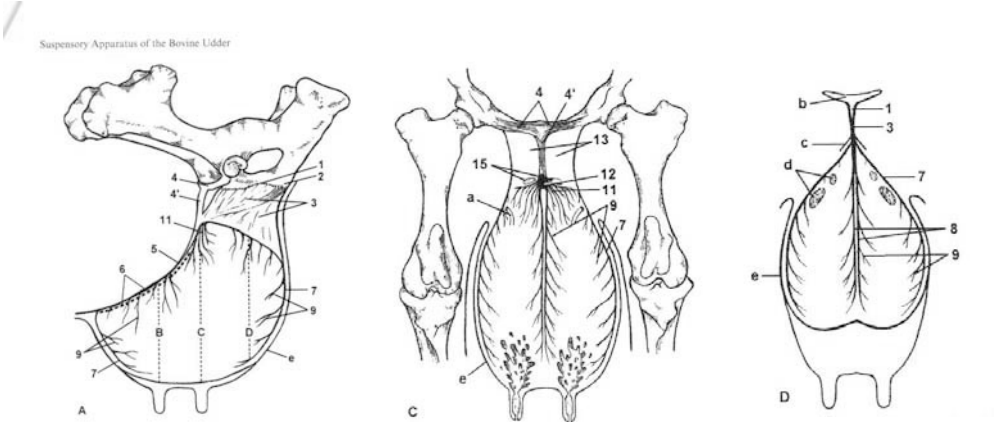

Figure 2. A diagrammatic representation of the suspensory ligaments of the udder. (Jalakas et al., 1999)

Several researchers have shown a consistent relationship between udder conformation and udder health and longevity. VanDorp et al., (1998) showed that cows with longer teats were genetically predisposed to a higher incidence of mastitis. In addition, cows may alter their gait if udders are deep and pendulous. Udder traits (especially the height of the udder above the hock) were found to positively influence the length of productive life. Udder depth and milking ease accounted for 84% of the total contribution of type traits to functional longevity (Larroque and Ducrocq, 2001). Recent Canadian data reported that rear teat placement, udder depth, and udder texture were udder traits that had a significant influence on functional survival (Sewalem et al., 2004).

■ Feet and Leg Conformation

Locomotion is a qualitative evaluation of a cow's ability to walk normally. It measures not only the cow's conformation but also her motion biomechanics including her freedom from lameness and the desirability of the surface upon which she walks. Scoring locomotion directly is the most accurate determination of a cow's feet and leg soundness.

In addition to evaluating the magnitude of lameness, locomotion scoring has been initiated in several countries as part of the type classification system. In Canada, locomotion is being evaluated as a research trait in free stall herds. Locomotion evaluation involves observing a cow while walking and identifying important movement and step parameters including foot placement and length of stride as shown in Figure 3. Normal locomotion is characterized by a long fluid stride where the rear foot falls into the imprint produced by the front foot on the same side (no abduction or overlap). Undesirable locomotion may result in the rear foot being placed outside the imprint of the front foot as well as a shortened stride length, and a decrease in step angle and walking speed.

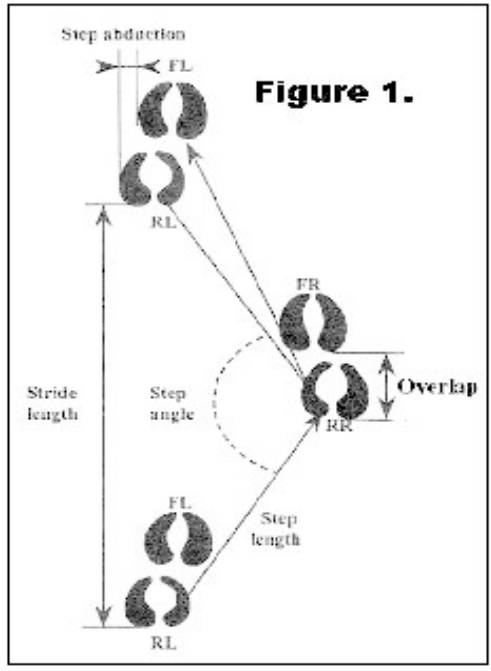

Figure 3. Holstein Canada's locomotion scoring parameters. (Telezhenko, 2003)

In the past, scoring of actual locomotion on the total population in Canada has not been practiced since many cows are still housed in tie stall barns. As a result, a selection index for locomotion was developed using the scored feet and leg traits and the genetic and phenotypic relationships between these traits and actual locomotion. The phenotypic correlation between feet and leg traits and locomotion was estimated using recent data collected in free-stall herds. Correlations ranged from 0.21 with Bone Quality to 0.59 for Rear Legs Rear View.

Since the locomotion index was proposed, Holstein Canada has initiated scoring actual locomotion (as a research trait) in free-stall herds in an effort to provide data to validate and further refine the locomotion index. It is anticipated that in the future a selection index for locomotion could be incorporated into the Canadian Lifetime Profit Index.

Studies have shown that 86% of all foot lamenesses involve the hind foot and that 85% of all hind leg lamenesses involve the lateral claw (Blowey, R.W. 1998). The hind legs are connected to the pelvis by a fixed and relatively inflexible ball and socket joint. While standing, the weight should be distributed equally on each hind leg and equally on each claw assuming good level trimming. During motion, the centre of gravity shifts from side to side and the weight bearing by each hind foot varies with the movement (Raven, 1989). The outer hind claw carries more weight and is more heavily stressed and this is consistent with the much greater incidence of lameness associated with the outer claw of the hind feet. The cow has responded to this by developing an outside claw that is larger and thicker in the sole and heel than the inside claw as seen in Figure 4. However, even with these adaptations, the increased stress on the outside claw still results in a significantly greater incidence of lameness.

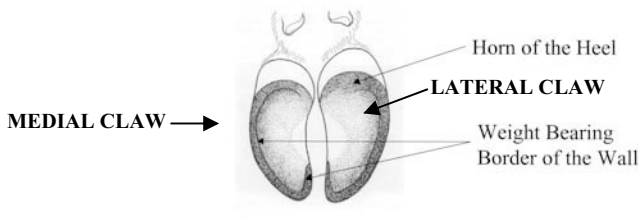

Figure 4. The larger lateral claw on the hind foot. (Blowey, R.W. 1998)

Several researchers have shown relationships between feet and leg traits and clinical lameness. Wells et al. (1993) showed that a 10-degree drop in foot angle resulted in an odds ratio of 2.4 to develop clinical lameness. The estimated heritability of feet and leg traits is low, ranging from 0.08 to 0.30

(Kistemaker and Huapaya, 2006), however, the most influential type trait on profit, after adjusting for production, was shown to be Feet and Legs (Perez-Cabal and Alenda, 2002).

This association can be attributed to the positive influence that sound Feet and Legs can have on reproduction and longevity. A favourable genetic correlation was estimated between Feet and Legs and non-return rate, suggesting that cows with good Feet and Legs were less likely to return to service (Wall 2005). Melendez (2003) explained that cows having foot and leg problems were less likely to show signs of estrous. Sewalem et al. (2004) reported that cows having extremely course bones, extremely shallow heels, low foot angle, and extremely straight or curved legs from the side view had decreased functional longevity.

■ Thoracic and Abdominal Body Conformation (Dairy Strength)

The Canadian Holstein has long been recognized around the world for her capacity, made possible by well sprung, open ribs, and for the unique combination of chest width and body depth that give rise to her characteristic angularity. Although extreme height and size in the show ring has been preferred historically, stature and size have been shown to have negligible or negative effects on longevity (Sewalem et al., 2004). The classification system in Canada has progressed alongside knowledge of relationships between body traits and longevity. As a result size is no longer evaluated and stature contributes less than 3% to the Final Score. In addition, extreme stature is now penalized in the Canadian system. A cow with desirable dairy strength in Canada is characterized by having an angular, open, well-sprung rib, with a wide chest floor and sufficient depth of body to have the capacity to convert large amounts of forage into high quality milk protein.

Studies have demonstrated the relationships between body shape and survival in dairy cows. Cows that were extremely short, small, and narrow-chested had a higher risk of being culled compared to cows intermediate for these traits. A clear relationship between angularity and longevity was observed, indicating that extremely non-angular cows (score of 1) were 2.47 times more likely to be culled than those with intermediate angularity (score of 5). Additionally, extremely angular cows (score of 9) were 1.28 times less likely to be culled than cows that scored 5 (Sewalem et al., 2004).

Holstein Canada recently introduced Body Condition Score (BCS) as a research trait. Although this trait currently does not contribute to Final Score, evaluation of daughters will enable calculation of sire proofs for body condition loss and perhaps predict future daughter reproductive performance

by incorporating BCS into the daughter fertility index. In addition, the scoring of body condition helps to establish the principle that dairy strength is a functional trait that should be evaluated independent of body condition score. Cows should not receive high scores for dairyness just because they are thin.

Relationships between body condition and reproductive performance are well documented. Cows with high genetic merit for BCS lost less body condition in early lactation, and therefore experienced less severe negative energy balance (Dechow et al., 2002). In addition, Dechow et al. (2002) reported that the genetic correlation between body condition loss and days to first service was 0.68 in first lactation and 0.44 in second lactation, indicating that as body condition loss became more severe, days to first service increased. Kadarmideen and Wegmann (2003) found similar favourable genetic correlations between fertility (days to first service and non-return rate) and BCS. Dechow et al. (2002) noted that selection for yield appears to increase body condition loss by lowering postpartum BCS. Cows that were thinner (lower body condition) had longer calving intervals (Pryce 2000).

Thoracic and abdominal capacity along with dairyness and femininity (angularity) are desirable attributes to facilitate the dairy cow's ability to process large volumes of roughage and sustain high production and desirable reproductive performance.

■ Rump and Loin Structure

A dairy cow's rump connects several other anatomical structures of significance through the pelvic region. The hind legs articulate with the pelvis at the thurls, the udder attaches to the abdominal wall which in turn attaches to the pelvis by way of the prepubic tendon (represented by "4" in Figure 5) and the rear part of the udder attaches directly to the pelvis floor by way of the suspensory ligaments (represented by "7" and "8" in the Figure below):

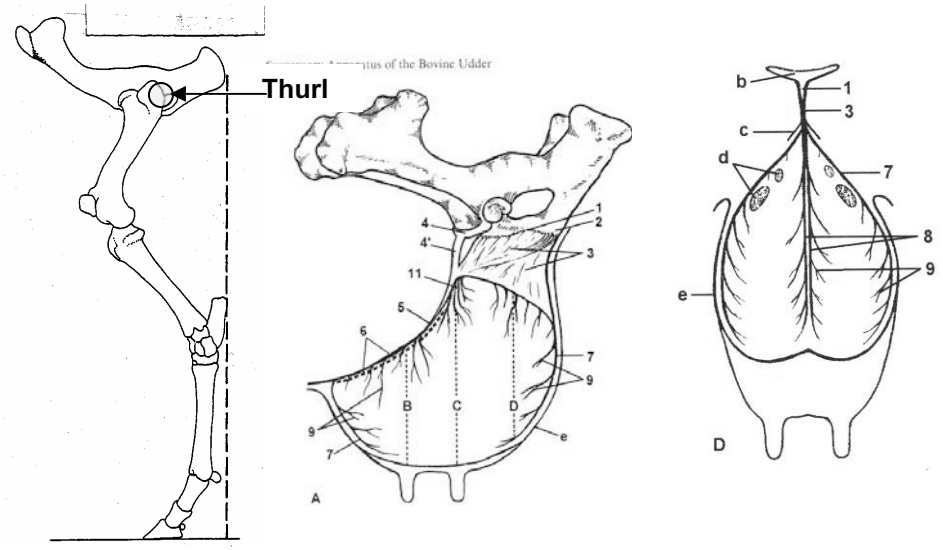

Figure 5. The importance of the rump (pelvis) with regard to the attachment of the hind leg, body wall, and udder. (Jalakas et al., 1999)

To complete the link, the loin is directly attached to the pelvis at the lumbo-sacral junction. Essentially, the rump and loin structures fasten the cow's abdominal and lumbar regions to her feet and legs and mammary system. Without adequate strength in this area, the productive life of a cow will be seriously compromised.

The position of the hook and pin bones define the allowable width of the pelvis to accommodate a desirably high and wide rear udder. A wide, correctly sloped rump is characteristic of pelvic structure that allows for easier passage for the calf at birth and necessary drainage of post-calving fluids in order to help prevent reproductive infections and related fertility problems. Ali and Schaeffer (1984) described the ideal rump phenotype for ease of calving as one having pin bones that are slightly lower than hook bones, a vulva

almost vertical when viewed from the side, collectively displaying a long and wide rump with a well-defined pelvic arch. Finally, absence of abnormalities such as advanced anus, advanced tailhead, and recessed tailhead are desired so that fertility is not negatively affected.

Higher pin bones are associated with an undesirable tilt to the vaginal canal causing it to lie at an inward sloping angle rather than lying flat. With this type of angle, the reproductive tract is more prone to infection since it lies deep within the abdominal cavity and the vagina is unable to drain effectively (Astis 2002). During parturition, the natural exit path for a calf is at a downward angle. Higher pins have a genetic association with inefficient longer calving intervals (Wall 2005). Research showed that animals with higher pin bones and narrower rumps are more likely to have difficult calvings (Cue 1990). In addition, cows with high and narrow pin bones had an increased genetic predisposition to retained placentas (VanDorp et al., 1998). VanDorp also showed that cows with lower scoring rumps were genetically prone to a higher incidence of lameness. In addition to its positive affect on reproduction, researchers have reported a strong link between a sloped wide rump structure and increased longevity. Animals with intermediate rump angles (slope of 1-2 inches from hook to pin) had a longer productive life (lower rate of culling) than animals with extremely low or extremely high pin bones in relation to hip bones (Pérez-Cabal and Alenda, 2002). Sewalem et al. (2004) showed that the relative risk of involuntary culling was lowest at intermediate rump angles.

■ Conclusion

The dairy industry faces a unique challenge to constantly improve functionality of the dairy cow to meet the needs of future production and reproduction demands. Today's Canadian classification program focuses on a comprehensive set of descriptive traits that describe the animal's strengths and weaknesses and that collectively depict overall functionality. Since conformation traits are heritable and are linked with functionality, selection for conformational traits is an effective tool to predict genetic improvement in functionality. In the constant efforts to advance genetic improvement, breed associations must continue to clarify the relationship between functional conformation and longevity and promote breeding programs emphasizing the functional conformation characteristics that increase longevity.

Dairy producers are equipped with more accurate selection and evaluation tools than at any time in the past. However, sound decision-making is still dependent on a fundamental balance between research and good common cow sense. These are the qualities that the dedicated breeders of the past have utilized to achieve the tremendous genetic progress that has been accomplished over the past hundred years. We must ensure that we apply

our genetic tools wisely as we strive to achieve continued genetic progress that maximizes functionality in the dairy cow in an environment of modern confinement management.

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