JACOB SHEEP BREEDERS ASSOCIATION

INSPECTION COMMITTEE FACT SHEET

HORN ISSUES

April 2020

DEFINITIONS FROM THE JSBA GUIDEBOOK

Narrow Horn Set: Horn set that is close to the head. In the two-horned ram they will be close to the cheek at maturity. As the horn continues to grow in width, it will crush the facial bones or grow into the skin causing infection. This may be heritable in the naturally two-horned ram, i.e. horns not formed by the fusing of four horns. In the four-horned ram the lower set may curl in towards the face, neck or jaw. This may be a heritable trait, or it may occur as a result of injury to the lower horn during the lamb's first 6 to 9 months of age.

Polled: Having naturally no horns. Polled Jacobs are disqualified from registration.

Polycerate: Having the ability to produce more than one pair of horns.

Scur: Scurs are incompletely developed horns which are generally loose and moveable beneath the skin, not attached to the skull. They range in size from small scab-like growths to occasionally almost as large as horns. Because the gene for scurs is transmitted separately, it has no effect on the presence or absence of horns.

Fused horn: Horn(s) which grow together. One can usually find the seam along the point of fusion. The tips of the horns may remain separated giving a split effect. Horns may fuse in a balanced form giving a two-horned appearance, or unbalanced form such as a three-horned appearance.

LANGUAGE FROM THE BREED STANDARD – HORNS

Desirable – Rams

- Any number provided they are well-differentiated (cleanly separated) and balanced
- Flesh between horn bases
- Two-horned rams should have wide, well-spaced horns with good clearance of cheeks, nose, and mouth at maturity
- Lower horns should be well-spaced from face, cheeks and neck

Desirable – Ewes

- Horns firm, fine-featured with femininity, balanced, and well-differentiated

Acceptable – Rams

- Fused, even horns
- Slightly forward-tipping horns which do not impair grazing
- Insufficient spacing between upper and lower horns (must be differentiated and balanced though flesh may not be present)

Acceptable – Ewes

- Unbalanced horn set
- Fused horns
- Multiple-horned ewes having normal, securely attached primary horns, but with scurs in the lower horn position only. (It is fully acceptable for a ewe with 4 or more strong, balanced horns to have additional scurs or horn buds.)

Unacceptable/Disqualifying – Rams

- Two-horned rams having small, weak, feminine-looking horns
- Multiple-horned rams having fewer than four, strong horns, with scurs in the upper or lower horn position. (It is fully acceptable for rams with at least 4 or more strong, balanced horns to have additional scurs or horn buds.)
- Narrow or close horns on two-horned rams that lack space between growing horns and his neck or jaw encumbering his well-being
- Undifferentiated and unbalanced set to four-horned ram, i.e., fused in an irregular pattern on one or both sides

Unacceptable/Disqualifying – Ewes

- Two-horned ewes having small or weak horns
- Multiple-horned ewes having scurs in the primary/top horn position

Unacceptable/Disqualifying – Rams and Ewes

- Polled sheep, or sheep with scurs only
- Solid white horns
- Forward-pointing horns curling toward the eyes, or growing over the nose impairing the ability to graze naturally
- Lower, lateral horns that grow into the face, cheek, or neck

DISCUSSION AND ILLUSTRATIONS

WHY IS THE STRUCTURE OF HORNS AN ISSUE?

Their amazing horns are one of the defining characteristics of Jacob sheep. When we see references to "Four-Horned Jacob Sheep" we should remember that a *polycerate* sheep is one that can *produce* four horns; our two-horned animals are equally important. In order to maintain the traditional characteristics of the breed, we need to ensure that our registered animals have horns that are consistent with the established Standard.

Given the numerous provisions of the Breed Standard, confusion can result unless the list of characteristics found in the Standard are taken as a whole. For example, "fused, even horns" are defined as "acceptable" for rams, but horns "fused in an irregular pattern on one or both sides" are unacceptable. All provisions must be considered to understand the line that is drawn between acceptable and unacceptable animals. Even considering the full language of the Standard, uncertainties can occur given the range of horn structures that exist and the extent to which horns change over time. The following discussion attempts to clarify typical inspection decisions to the extent possible, but often waiting for a lamb to mature is the best course of action.

The Breed Standard addresses these types of concerns with horns:

- Horn structure that can impact the health of the animal. Most often, this includes horns that are too close to the jaw (in two-horned rams) or growing in a potentially harmful direction (toward the cheek, face and eyes, shoulder, or back toward the neck).

  Although the Standard refers sometimes to multiple-horned sheep and sometimes to four-horned sheep, we understand that in most instances the provisions for four-horned rams apply to all polycerate animals.

- Lack of horns (sheep that are polled or have scurs in the place of the primary horns) and are thus not consistent with the basic definition and image of a Jacob.

- Ram horns that are "undifferentiated and unbalanced" – as discussed below. While the health of these animals may not be threatened by their horns, they are not consistent with the normal two-horned or multiple-horned ideal and may be detrimental to the conservation and appearance of the breed.

Specific examples of each of these issues in ewes and in rams, and the difference between acceptable and unacceptable Jacobs, are included in the discussion below.

Although the Breed Standard defines limits on what is acceptable in Jacobs registered with JSBA, breeders are expected to have different preferences regarding horn structure. Maintaining the diversity in Jacob appearance and genetics is also important. Therefore, the Standard addresses not

only ideal or desirable horn structure, but also distinguishes other acceptable types of horns from those that disqualify an animal for registration. As always, knowledgeable breeders will differ on what they find most attractive, or why they decide to use a particular animal in their breeding program. For this reason, both "acceptable" and "unacceptable" horn types are discussed below.

IS HORN STRUCTURE HERITABLE?

The number of horns – that is, two versus four – is definitely hereditary, with four horns being dominant. Thus, breeding of a two-horned ram and a two-horned ewe will always result in two-horned offspring. Occasionally this is disputed, but we anticipate that reports of four-horned lambs from two-horned parents result from the use of a four-horned ewe or ram that is fully fused and that *appears* to be two-horned.

The observations of numerous breeders support scientific evidence that the structure and position of the horns is highly hereditary. Heredity may influence factors such as the width or spread of horns in two horned animals, spacing between upper and lower horns, and direction of growth. However, further investigations are needed to clarify the details of horn inheritance.

The photo posted below shows the results of a research project carried out at the University of California at Davis (Anderson, 2014). It shows identical twin Jacob rams that were produced by splitting an early embryo into halves and transferring the two half-embryos to recipient or surrogate ewes of a different breed for development to term. Although the primary purpose of the experiment was to compare color inheritance in identical twins, other factors were also noted. You will see that while the horns on the two rams are very similar, they are not absolutely identical. For example, the lateral horns of the ram on the right appear to curl more toward the face. This type of information is important to inspectors (and breeders) in making decisions regarding their lambs.

Figure 1. Horn structure on identical twin rams from UC Davis research project

Gary Anderson also provided a summary of recent research related to Jacob sheep horn genetics for the JSBA Newsletter in 2018; see Appendix A of this fact sheet for a reprint.

Of course, environment also plays a role in horn structure. A flock of Scottish Jacobs left untended on Butter Island off the coast of Maine for about seven years, for the most part, had strong, correct horns at the end of that period. Although this isolation was of limited duration, nature still had time to cull animals with horns that were detrimental (e.g. close to the jaw). Leaving sheep with faulty horns in a flock can have the opposite future influence.

WHY THE EMPHASIS ON RAM HORNS?

The Jacob Standard allows ewes with less than ideal horns greater latitude than rams because we recognize that a single ram can have a much greater impact than a single ewe on a Jacob flock, or on the breed as a whole. Thus, for example, a four-horned ewe is acceptable with scurs (instead of horns) in the lower position. In a ram, this would be unacceptable.

POLLED SHEEP

Polled sheep do not fit the fundamental description of a Jacob and are not eligible for registration. Sheep that are known to have been disbudded (de-horned) are *not* eligible for registration; they simply do not meet the basic description of the breed as a horned sheep.

SCURS

As noted in the Guidebook definition of scurs (see page 1), scurs are not the same as horns and thus cannot take the place of horns. A ram having scurs in place of primary horns – including lower horns for a four-horned ram – is not eligible for registration. Greater flexibility is allowed in the registration of four-horned ewes in that scurs may acceptably take the place of lower horns.

Note that scurs *in addition to* acceptable horns are fully acceptable in both rams and ewes.

STRUCTURE AND PLACEMENT OF HORNS IN TWO-HORNED JACOBS

Rams The most common concern in two-horned rams is with horns that curl close to the head, such that there will not be adequate clearance between the horn and the jaw when the horn achieves its full dimension with maturity. A horn that rubs against the jaw can initially cause ulcers on the skin, and may eventually interfere with eating or damage the jaw. The horn at this stage cannot be trimmed back enough to avoid the jaw without cutting the horn core and impacting the blood supply.

It can be difficult to determine the eventual position of the horn in a young lamb. This is why registration is delayed until the direction of the horn is at least somewhat developed. However, even after six months of age, change can occur. A horn that looks as if it is growing wide may curl back toward the cheek. Or, a horn that looks as if it may be close might curl away from the face. Registration decisions with a young two-horned ram rely on the judgement of the inspectors. If a ram lamb is questionable in this regard, the breeder may be well-advised to delay registration until the lamb is more mature.

Ram lambs that are submitted for registration before the direction of horn growth is clear will be evaluated by the registration committee, but the inspectors at that point must do their best to predict, based on their experience, whether the horns will grow wide of the head when mature. This can be straightforward where a lamb has obviously wide-growing horns, or by contrast, horns that appear already to be growing in a direction close to the head (see Figures 2 and 3 below). The final position of other horns may be much more uncertain. If the inspectors feel that they cannot pass a ram at the time of inspection given the likelihood that horns will adversely impact the animal, and if the breeder disagrees, the breeder may withdraw the application and wait until a later date to register the ram.

The inspectors may also err on occasion as horns that appear to be fully acceptable can curl back toward the jaw. The breeder obviously must decide at that point whether to continue to use such a ram or to remove him from use for breeding even though he has passed inspection.

Figure 2. The wide horns you want to see on a yearling ram. This ram would pass inspection at this age.

Figure 3. A yearling ram the same age as the ram above. There appears to be adequate space between the horns and cheeks, but it is quite likely that there will be insufficient space at maturity, and if presented for registration at this point would likely fail. If the ram lamb is otherwise desirable, the breeder may simply wait to see how he develops. However, a potential buyer would be taking a risk choosing this ram.

Ewes A two-horned ewe rarely (if ever) has horns close enough to the skull to cause health problems. However, experienced breeders are aware that the width of the ewe's horns contributes to the structure of the horns on her male offspring, including growth direction of lateral horns on 4-horned lambs. All else being equal, breeders are well-advised to select the ewe with the wider hornset, although this is not mandated by the Breed Standard.

Figure 4. A nice wide-horned adult ewe, and her two-horned ram lamb – also looking good at this point.

Figure 5. A very nice ewe, but without the wide horns that we'd like to see. All else being equal, the breeder might want to choose the ewe with wider horns. [This ewe was kept as a brood ewe for other reasons.]

STRUCTURE AND PLACEMENT OF HORNS IN FOUR-HORNED JACOBS

The JSBA guidebook includes several definitions as listed at the beginning of this fact sheet. Two additional terms are defined here to assist in understanding the Standard, as follows.

> **UNBALANCED** As used in the breed Standard, "balanced" and "unbalanced" refer to the appearance of an equal number of horns on the left and right sides. An animal with an uneven number of horns (e.g. two on one side and three on the other) is unbalanced. An evenly fused four-horned ram that appears the same as a two-horned ram has traditionally been considered balanced. Note that "balanced" does not refer to a *symmetrical* hornset where the position of the horns on each side closely mirrors the other.

Figure 6. An evenly fused four-horned ram that appears as a two horned ram is acceptable, having a balanced appearance.

UNDIFFERENTIATED Undifferentiated horns are fused horns where two or more horns are fused along a parallel line with no space between the horn bases. Sometimes there may be a slight differentiation at the tips, but the overall appearance is of horns fused together. This is different from horns that are close at the base, and that might show some right-angle fusing at the base. Compare the right and left horns of the ram in Figure 7.

Figure7. *A four-horned yearling ram, undifferentiated on right side (fused in an irregular pattern). This horn pattern is unacceptable. He also shows some fusing at the base on the left side, but this in itself would probably not be cause for failure.*

Figure 8. Two different skulls showing undifferentiated horns. Are there two, or three on each side? On an adult, they might appear as two or three fused horns. How many horn buds on the skull developed into these horns?

Acceptable and unacceptable horns in four-horned ewes As noted above, there is more flexibility in the definition of acceptable horns for ewes than there is for rams. It is *acceptable* for a ewe to have unbalanced horns (that is, a different number of horns on the left than on the right) and it is *also acceptable* for a ewe to have fused horns, and for a four-horned ewe to have scurs in the place of the lower horns. (She must have sound upper horns.) Additional scurs or horn buds are also acceptable. Again, it is up to the breeder to determine what is best for his or her flock regarding use of ewes with "acceptable" but less than ideal horns. For example, if a less desirable trait, such as scurs in the lower position, is becoming very common in a given flock, the breeder may avoid animals with that trait even though they are registered. Inspectors obviously cannot substitute their judgement for that of the breeder, but rather simply determine whether the Standard is met.

Figure 9. A five-horned yearling ewe. Unbalanced horns are acceptable in a ewe even if partially fused. (These horns are fairly well-differentiated.) She is acceptable and is registered.

It is *unacceptable* for a four-horned ewe to have forward-pointing horns that curl toward the eyes, or lateral horns that curl into the face or cheek (unless a single limited trimming can address the issue as discussed below.) These animals can be entered in the Appendix Certified (AC) category on a case by case basis.

Figure 10. A four-horned yearling ewe with one horn curling directly toward her eye. (Her horn was trimmed immediately after this photo was taken.) Her breeder decided not to register her, given the very poor position of her horns. Note that her horns not only lean forward, but are positioned somewhat forward on her skull, just above the eyes. Ewes with forward curling horns may be considered for inclusion in the AC category.

Acceptable and unacceptable horns in four-horned rams Most breeders know what a *desirable ("ideal")* ram looks like in terms of horn placement. A desirable multi-horned ram has four (or more rarely six) strong horns, with space between them, growing up or out in a manner that will not interfere with the animal's health at maturity. Achieving the ideal horn placement in a multiple-horned ram is one of the greatest challenges in breeding Jacobs.

<u>Acceptable (although not desirable) horn patterns</u> A number of horn patterns that are less than desirable are *acceptable* for registration of a multi-horned ram. Again, the breeder has a significant role in determining whether an acceptable but less than ideal horn pattern is appropriate for addition to his or her flock, based on defined flock goals and the horn structure that already exists in the flock. Breeders may reasonably choose to use a ram with less than ideal horns for various reasons, e.g. to perpetuate a genetic line, or to take advantage of other outstanding characteristics. In general, however, given the number of outstanding Jacobs now available, owners are advised to set their own selection standard high for rams used in their flocks rather than making use of a ram that only arguably meets the Breed Standard.

Acceptable horn patterns can, in general, include the following:

- Distinct upper and lower horns may touch at the base or even show minor fusing. This is different from the linear fusing that occurs between horns arising from the same point on the skull as discussed below.

  In some instances, the amount of space between horns is influenced by the diameter of the

horns at maturity; large horns simply leave less room on the skull than finer horns. Breeders should be aware that close, touching horns may result in damage or distortion of the lower horn in particular as the ram matures.

Figure 11. Skull of a four-horned ram showing partial fusing at the base of the horns due to limited spacing.

The position of the horns is also distorting the lower horn. Limited fusing at the base due to lack of space is considered acceptable, although not desirable.

- The horns are *unbalanced* with a different number of horns (not counting scurs) on the right and left sides. This is the case with five-horned rams. This is *acceptable* <u>only if the ram has strong primary horns, and if the horns are *differentiated* – that is, the horns are not fused along their length and it is apparent that the horns arise from different locations on the skull.</u>

  This point can be confusing given the multiple provisions of the Breed Standard that all speak to horn structure. However, when all provisions are read together, it makes sense. For example, the Standard states that it is "fully acceptable for a ram with at least four or more strong horns…to have additional scurs or horn buds" – which allows for a five-horned ram to be acceptable. However, the Standard *further* states that if the horns are "fused in an irregular pattern on one or both sides" the animal is unacceptable. The animal must meet <u>all</u> provisions of the Standard to be acceptable.

  It should be noted that this provision applies to all polycerate (multi-horned) Jacob sheep.

Figure 12. A five-horned ram with five distinct horns (close at the base, but the overall appearance of five distinct horns.) These horns are unbalanced but differentiated and thus would be acceptable. (Note: this ram is registered).

Unacceptable horn patterns in four-horned rams Unfortunately, it is not uncommon to see a horn structure that is unacceptable/disqualifying. Such growth patterns may not be evident when the horns first emerge but typically become more pronounced as the animal matures. If horn structure is questionable at six months of age, the breeder is well-advised to postpone submitting a registration application until the final horn structure becomes more obvious.

Examples of unacceptable/disqualifying horn structure and placement include the following:

- Four-horned rams having fewer than four strong horns, including weak, feminine horns, or scurs in place of one or more primary horns.

- A ram that has forward-pointing horns that may impair the ability to graze at maturity, rear-curling horns than can impact the neck or shoulders, or lateral horns that curl toward the head and cannot be addressed with a single trimming. (See discussion of trimming at the end of the fact sheet.)

Figure 13. A yearling ram with forward-pointing horns that are likely to interfere with grazing at maturity and also with lateral horns that curl toward the cheeks.

Figure 14. A yearling ram with rear-curling horns that would impact his neck at maturity.

(His horns are also partially fused at the base on the left side.)

- Rams having horns that are *undifferentiated* – that is, *fused in an irregular pattern on one or both sides* – are considered unacceptable and are not eligible for registration. This horn pattern can vary greatly in appearance among rams. We show here only a few examples.

  In general, these rams have horns on at least one side that are fused in a linear manner – that is, not just at the base. (As noted above, fully-fused horns that result in a two-horned appearance have traditionally been considered acceptable.) If the skulls of animals with fused horns are examined, it becomes apparent that they often arise from the same part of the skull – or the same horn core. This core can divide into two or more branches that then fuse.

Figure 15 a and b. A ram with undifferentiated horns on the left and the same ram at a later date showing how horn distortions may advance.

Figure 16 a and b. A partially-fused, undifferentiated ram and ram with fully-fused horns on one side giving it a three-horned appearance. Both rams are undifferentiated and unacceptable.

Where more than four horns are present, fusing is also common. Five- and six-horned rams are acceptable *only if* they have well-differentiated horns. In some animals, unacceptable horns are apparent early on. In other rams, conformance with the Standard cannot be determined until the horns have more time to grow and develop.

Figure 17 a. and b. At three months of age (right), the problems with the horn structure of this ram are evident but may be difficult to describe.

At eleven months of age, fusing has progressed, and his horns are clearly unacceptable to most inspectors. This six-horned ram is fully and evenly fused on his right side, and almost fully-fused on his left side.

Figure 18. Three photos of the skull of the ram in figure 17 demonstrating the full extent to which his horns are undifferentiated. His horns are "fused in an irregular pattern on both sides."

Horn Inspection Issues and Recommendations

JSBA members can help inspectors to achieve timely, fair, and accurate decisions. Please consider the following:

- Submit your Jacob for registration only when it is old enough to evaluate horns as shown in your photos. While there is not a defined age for registration of ewe lambs, inspectors cannot evaluate very young ewe lambs that have insufficient horn grow to evaluate the horn pattern and structure. As noted above, it is even more important for rams to be old enough to evaluate horn growth, even if that delays registration beyond six months of age, especially if the horn structure is questionable.

  If you need registration to show a young lamb, please use temporary registration for this purpose if your lamb has very immature horn growth.

- Submit closeups and extra photos to clearly show the position and structure of horns. If photos are blurry or horns are not clearly visible, please take another one.

- When registering two-horned rams, especially in full fleece, we suggest that you use your hand or fist to show the clearance between the horn at the skull.

- Submit as many photos as needed, from different angles, to show the number, position and structure of the horns. For example, use photos from the side to assist the inspectors in evaluating the extent of forward- or backward-leaning horns.

- If horns have been broken, as they commonly are in ewe lambs, please note this in your application if it is not obvious in the photos. If possible, postpone registration until some regrowth has occurred, or provide earlier photos that show the horn that was broken, or

horns showing the remaining horn bud.

- Be careful in recording the number of horns and scurs on each side in the box on the application. This will assist the inspector in differentiating between horns and larger scurs in photos.

- Provide any other information that may influence a decision in your application, e.g. changes to a horn that resulted from an injury.

TRIMMING OF HORNS

Many Jacob breeders trim horns that are curling toward the cheeks, face, shoulders or neck, that may be harmful to the adult animal. In many instances, only a minor removal of the horn tip is needed. Often the need for trimming is not determined until after the lamb is registered. Moreover, as discussed under the heritability section, the direction of growth may not be identical even in identical twins. Injuries may also alter the direction in which a horn grows.

For all of these reasons, *limited* trimming of horns has been accepted by the inspection committee (and by the membership in general), provided that:

- Only the keratin portion of the horn is trimmed – that is, the horn core and the blood supply are not impacted;

- It is anticipated that a single trim will be sufficient to address the issue (the horn will not need to be repeatedly cut back).

It is not acceptable to greatly reduce the size of the horn, cut back the horn on two-horned rams to avoid having the curl hitting the cheek, or dehorn or disbud lambs (i.e.,fully remove the horns).

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Painter, Ingrid. 1997. ***Jacob Sheep in America.*** © by Ingrid Painter.

And with thanks to all of those who allowed us to use their photographs.

APPENDIX A:

MODERN GENETICS TACKLES THE FOUR-HORNED GENE IN JACOB SHEEP

GARY B. ANDERSON

Reprinted from the 2018 JSBA Newsletter, Vol. 30, Issued 2

Modern genetics has experienced an explosion of new techniques being used to understand inheritance in both plants and animals. Complete genomes have been sequenced for a number of organisms, including humans. Individuals and even embryos can be screened for the presence or absence of specific genetic mutations. In addition, genes can be manipulated with exquisite precision, inserting and/or deleting genes in highly controlled fashion. Applications of modern genetic techniques to livestock are becoming almost commonplace. For example, "gene editing" was used to replace the horned allele in cattle with the hornless allele from a different breed of cattle, producing hornless dairy cattle that differ from the rest of their breed only in that they carry the natural mutation for polled phenotype at the natural horned/hornless locus (Carlson et al., 2016).

Trickle-down of modern genetic techniques for use in sheep has been slow, and even slower for trickle-down to Jacob sheep. Nevertheless, three scientific research reports were published recently with data highly relevant to Jacobs, specifically information regarding the polycerate gene for multiple horns (defined as more than two horns). Authors of one of these papers (Kijas et al., 2016) reported results from research conducted at Utah State University (USU) using genetic material provided by four JSBA members (whose contributions were acknowledged in the scientific report). Blood samples from two- and four-horned Jacobs were provided by Karen Askounis and Terry Lamastus, Three Fates Jacobs in Crete, IL; Ed and Pam Piepergerdes, Belle Ridge Jacobs in Excelsior Springs, MO; Ingrid and Alan Painter, Puddleduck Jacobs in Brownsville, OR; and Gary and Dianne Anderson, Hillside Jacobs in Sparta, MI. The Painters also provided blood samples from polled, two-horned, and four-horned Navajo-Churro sheep. DNA was extracted from the blood and used in a study with the objective to map (i.e., identify the chromosomal location of) the genetic determinant controlling production of four horns in the two breeds. In addition, researchers investigated the relationship between four horns and SUED (split upper eyelid deformity). The researchers used a large array of known chromosomal markers to identify which ones appeared to cluster on a particular chromosome in sheep classified as two- versus four-horned, SUED versus non-SUED, etc. to identify chromosomal location of the gene of interest.

Results from analyses to map the polycerate gene to a particular chromosome showed location on chromosome 2. Analysis of DNA from the polled Navajo-Churros, in concordance with results from other recent scientific reports using other breeds (Wiedemar and Drogemuller, 2015), showed chromosomal location of the polled gene to be on chromosome 10. The authors concluded that the polycerate phenotype (i.e., more than two horns) is not due to a natural allele in series with the gene that controls presence versus absence of horns. Instead, the polycerate gene and the polled gene are located on different chromosomes, even in a breed that expresses both polycerate and polled phenotypes.

Two other laboratories located around the world have corroborated results reported by the USU laboratory. Greyvenstein et al. (2016) used Damara sheep, a fat-tailed breed from southwestern Africa that displays the polycerate phenotype, to map the polycerate gene to chromosome 2. Chinese investigators (He et al., 2016) using three indigenous breeds (Altay, Mongolian and Sishui Fur) also mapped the polycerate gene to chromosome 2.

Location of the polycerate gene, for now, does not appear to be in an area of known active genes (i.e., protein-coding genes). This finding raises the possibility that the polycerate gene has its effect by regulating expression of another gene or other genes located nearby. Comparative studies in sheep have shown that a cluster of genes called HoxD (pronounced hox d) also are located on chromosome 2. HoxD genes have been well-studied and are known to be involved in embryonic limb development. The USU authors speculated that HoxD genes could also be involved in horn ontogenesis (but at this time such suggestion is only speculation).

The USU researchers also conducted an analysis of genetic diversity on Jacob and Navajo-Churro DNA, compared with DNA from Merino, Suffolk, and Polled Dorset breeds, with interesting but not totally unexpected findings. Jacobs were strongly genetically divergent from the other breeds and displayed comparatively low within-breed diversity (the latter result reflecting a relatively narrow genetic base from only a small number of importations of Jacobs into North America).

The USU scientists stated in their publication that their results are consistent with several other observations relevant to Jacob sheep. (Note: Results of their genetic analysis <u>are consistent with</u> but <u>do not prove</u> the anecdotal information to be correct.) Their data are consistent with expression of the polycerate gene as a dominant gene (versus recessive or co-dominant). The authors also suggested the possibility that the polycerate gene could be responsible for expression of SUED, instead of four horns and SUED being controlled by two different genes that segregate independently or are linked to one another; however, the authors cautioned that their analysis of SUED was on only a small number of sheep and was ancillary to their focus to map the polycerate gene.

The full-length publications, as cited in the list below, used to prepare this article may be found online. The studies summarized here were of limited scope but are encouraging in their relevance to Jacob sheep. Interesting questions on which the USU authors speculated, e.g., genetic relationship between the polycerate phenotype and SUED, will require additional, larger-scale, and focused studies to produce conclusions that can be documented scientifically.

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This article was prepared and submitted for publication in the JSBA Newsletter by Gary Anderson, Hillside Jacobs, Sparta, MI