A Mother's Contribution

Maternal inheritance may play a role in backfat and percent retail product.

by ***Corinne Patterson***

As an Angus producer, you may have a favorite cow family that always seems to have the top-producing females with the best calves each year. Cow families are even a popular selling point from the auction block when a pedigreed heifer steps into the ring.

Dan Moser, a geneticist at Kansas State University (K-State), and recent graduate student Larry Keenan found that there might be more to the sale manager's spin on promoting cow families. Not all of an animal's genetic code is derived from chromosomes (nuclear DNA); some traits are determined by mitochondrial DNA (mtDNA), which is maternally inherited.

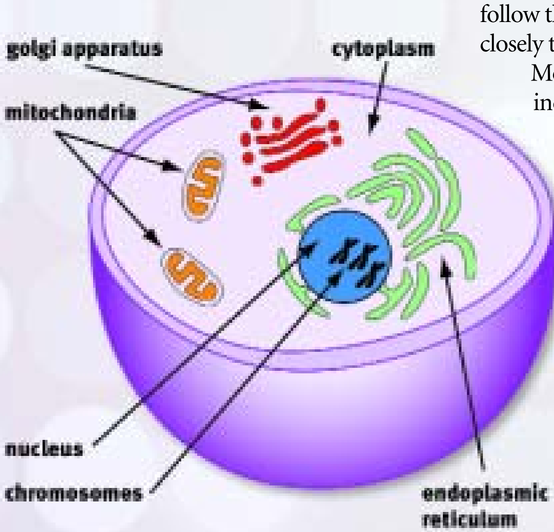
"I tell producers and my students that, by far, a majority of the genetic improvement you'll make is through sire selection because you have the power of AI (artificial insemination)," Moser says. "You are pretty limited in what female genetics you can access unless you've got an endless pocketbook. You can't necessarily get the genetics of any cow in the breed, but you can get the genetics of almost any bull in the breed."

With embryo transfer (ET) some females have been able to make their marks on the Angus industry. However, the majority of females produce up to 10 calves during their productive lifetime, not really allowing breeders to gain the high accuracies on their expected progeny differences (EPDs) like those that can be achieved on AI sires.

Still, some traits seem to follow the cow line more closely than the bull line.

Moser and Keenan knew the dairy industry had significant data that showed a cow's cytoplasmic DNA — including mtDNA — contributed to her milk fat and milk yield. The studies also proved that cytoplasmic DNA is only inherited through the dam's side of the pedigree.

Fig. 1: Animal cell



What dairy taught us

Don Beitz, animal science and biochemistry researcher at Iowa State University (ISU), studied mtDNA in dairy cattle for five or six years. With research partner A.E. Freeman, ISU emeritus professor of animal science, Beitz explains how these tiny organelles work.

> **"Mitochondria allow for a possible genetic basis for maternal inheritance and a possible genetic basis of why some cow families are better milk producers than are other families."**
>
> ***— Don Beitz***

Mitochondria are the powerhouses of cells and are essential in the events that generate more than 92% of the energy, or adenosine triphosphate (ATP), production in mammals, Beitz says. While mitochondria are only about 1-2 microns (μm) long and about ½ μm wide, they are essential for life and the productivity of livestock.

Mitochondria use volatile fatty acids from ruminal fermentation and long-chain fatty acids, amino acids and glucose from digestion of fats, protein and starch as energy sources, Beitz adds.

So, what does that have to do with a calf's mother?

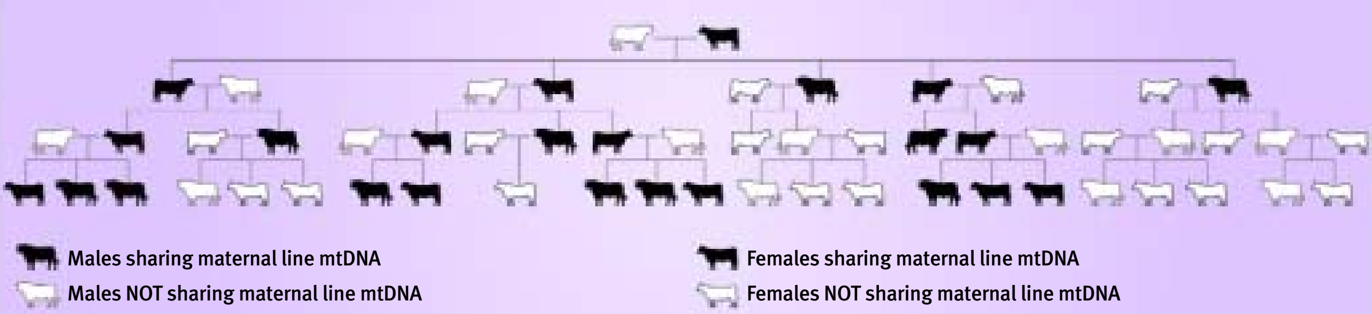
"Mitochondria are maternally inherited," Beitz says, "that is, mitochondria are transmitted from females to both male and female offspring."

Males do not transmit mitochondria to their offspring because of the makeup of the sperm, Beitz explains. The mitochondria are located near the sperm's tail, which never penetrates into the egg, allowing the female to code for the mtDNA of progeny.

CONTINUED ON PAGE **196**

Fig. 2: The path of mitochondrial DNA transfer through four generations

The following graphic illustrates the concept of maternal inheritance through mitochondrial DNA (mtDNA).



"There has been only one reported exception where mitochondrial DNA from the sire got into an embryo, but this occurred after 26 generations of backcrossing in mice," he points out. "Thus, mitochondria allow for a possible genetic basis for maternal inheritance and a possible genetic basis of why some cow families are better milk producers than are other families."

While most of an animal's DNA, or the storehouse of genetic information, is located in the nucleus, enough DNA to code for 13 proteins is found in the mtDNA, Beitz says. The nuclear DNA is packaged as chromosomes and is linear in nature, and the mtDNA is circular.

The mitochondria have a separate set of DNA than nuclear DNA, and it is much smaller, being about 16,300 bases (nucleotides) compared to an estimated 3 billion bases per nucleus in humans.

Beitz explains, "mtDNA contains a displacement loop (D-loop) of 910 base pairs (steps on the spiral staircase) that is a control region for replication of the mtDNA and is known to be more variable in nucleotide order than the remainder of the mtDNA. Mitochondria do not have enough DNA to code for all of their own proteins. Nuclear genes code at least 48 proteins that are part of the respiratory chain that produces ATP, which, upon degradation to ADP (adenosine diphosphate), releases energy to drive chemical reactions that support life and that result in growth, milk production, and reproduction. The coding of some mitochondrial enzymes (proteins) by both mtDNA and nuclear DNA allows for possible maternal line-by-sire interactions. These interactions may explain why some producers think that some dairy sires 'work better' on some cow families than on others."

Fig. 3: Nuclear DNA

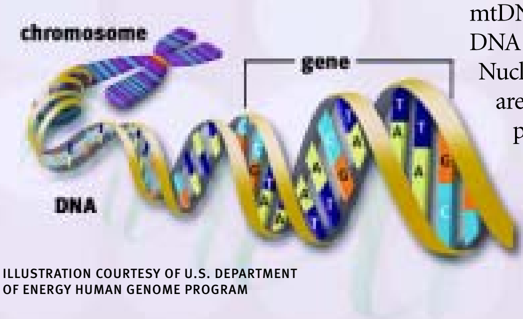


ILLUSTRATION COURTESY OF U.S. DEPARTMENT OF ENERGY HUMAN GENOME PROGRAM

While Beitz is not currently studying mtDNA due to lack of funding, he and Freeman found "maternal lineages show associations with production traits in dairy cattle." The ranges of significant differences in Beitz and Freeman's D-loop study were: 3,121 pounds (lb.) milk, 28.6 lb. milk fat, 321 lb. solids not fat, 978 megacalorie (Mcal) lactation energy and 0.60% milk fat. While these are significant results and could mean real profits or losses in a dairy herd, before mtDNA variation will be widely used in breeding programs, they believe more research is needed.

Opportunity in beef cattle

What does the beef industry know about mitochondrial inheritance? Studies in the past looked at the relation of mtDNA and

CONTINUED ON PAGE 198

A Mother's Contribution CONTINUED FROM PAGE 196

growth traits. Researchers theorized that if ATP is the result of mitochondria, then muscle growth — which requires a lot of energy — may be influenced by the mtDNA contributed from the mother. The conclusions of only a few studies in beef cattle determined cytoplasmic variance failed to be significant for growth performance of beef calves.

Instead of evaluating growth traits, Moser says he and Keenan looked at ultrasound data from the American Hereford Association (AHA).

"We thought if the dairy research indicated fat effects [in milk], then maybe we'd see something with marbling, or maybe we'd see something with backfat [in beef cattle]," Moser says. They began by tracing nearly 9,000 yearling bulls and heifers to their original founder dams and found 321 foundation cows represented with an average of 30 cows per family.

"There were some foundation lines in that Hereford data set that had more than 100 animals that all traced back to the same original foundation cow," Moser says. "They may look unrelated on their pedigree, because that foundation cow might be 12 generations back, but there seemed to be some significant effects."

What they found while looking at several traits was, on an age-constant basis, cytoplasmic line effects were expressed in backfat and percent retail product. Cytoplasmic line effects on backfat ranged from -0.11 inches (in.) to +0.07 in., Moser reports.

"It did not have an effect on ribeye area, which we would expect because we believe that the cytoplasmic effects are with fat synthesis," Moser says. "It was not significant in intramuscular fat." The latter finding, Moser says, was most interesting, and could be a result of ultrasound data being more accurate in determining backfat than marbling.

Moser and Keenan may be the first to look at cytoplasmic effects in fat deposition in beef cattle. More research will continue to explore this topic before it will actually be widely used, Moser points out.

"I don't see [the industry] to the point where we can really manipulate this, and I think anything transgenic in beef cattle is still a long ways away," Moser continues, but he admits there may be more to the sale manager's spin on cow families if more research confirms cytoplasmic effects.

"The only way to really take advantage of it would be to have some foundation females that have the cytoplasmic DNA combination a producer wants (i.e., identifying foundation lines with more or less backfat), and then replicate those females and keep more females out of them. That's about the only way to access [the traits] if there are cows out there that have superior cytoplasmic DNA."

Beitz and Moser agree that both the dairy and beef industries could someday use mtDNA as an adjustment factor to improve accuracy of EPD calculations, but it probably won't be a means on which to solely base selection. Moser says, "It's a whole different way of thinking about genetic evaluation and genetic improvement."

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