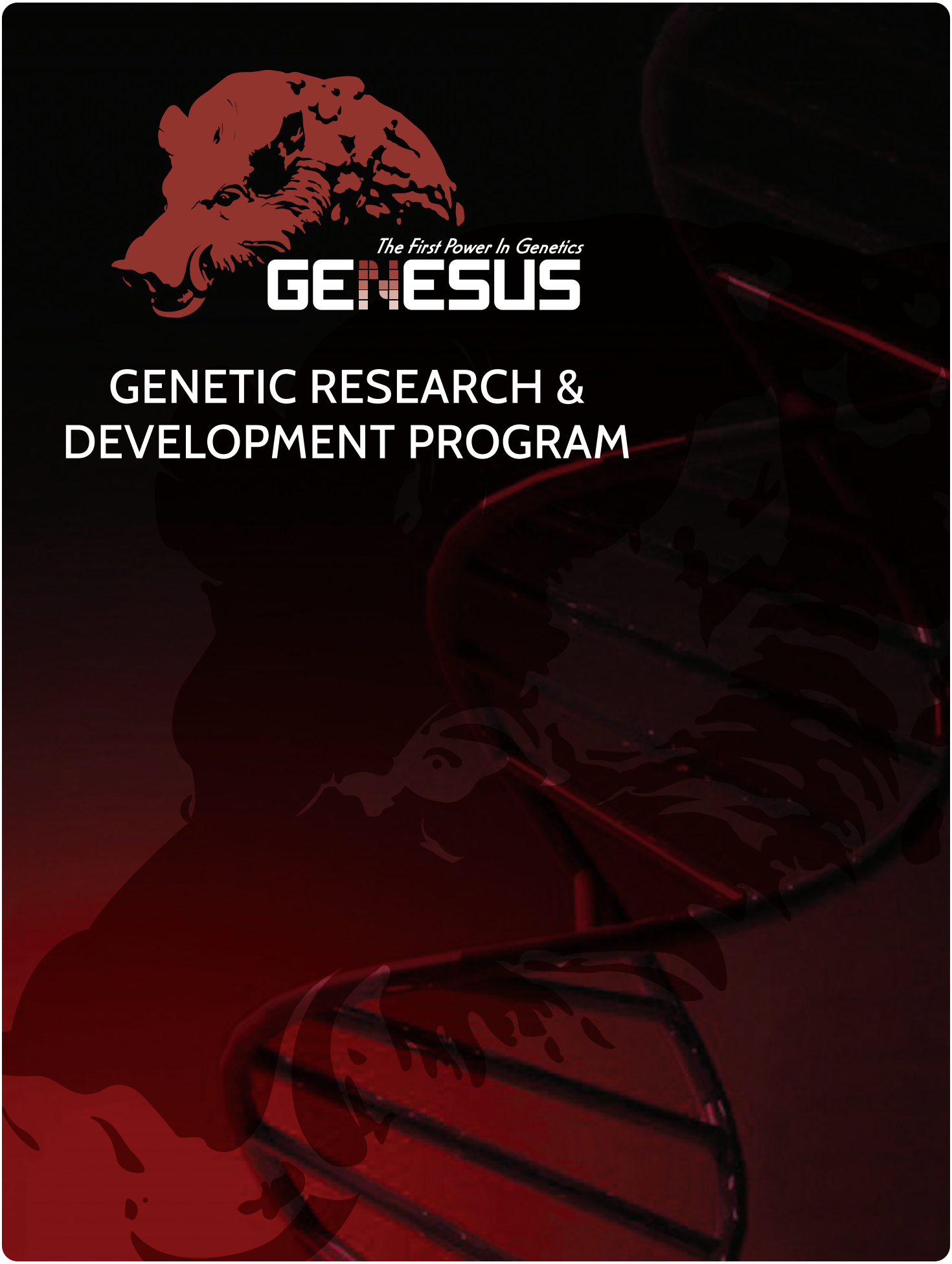


GENETIC RESEARCH & DEVELOPMENT PROGRAM

GENETIC RESEARCH & DEVELOPMENT PROGRAM

THE TOTAL PACKAGE

Genesus Inc. has one focus and passion; developing the best swine genetics. Our goal is simple: **Provide genetic material, programs and services that assist our customers in maximizing profitability.** The success of our customers is our success!

Genesus has an outstanding genetics team with over one hundred fifty years of combined experience and dedication to swine genetics. Our team includes geneticists, technicians, data analysts, information technology and nucleus production specialists. The genetics team works in close coordination with the on-farm team of more than fifty dedicated and experienced staff implementing the Genesus genetic improvement program. Together we deliver consistent genetic improvement driving customer success.

GENETICS TEAM

Bob Kemp, PhD, Vice President – R & D

Nick Boddicker, PhD
Bob McKay, PhD
Chunyan Zhang, PhD
Susan Linto, BSc
Mike Brooks, BS
Lorne Tannas
Mark Jacques
Pius Mwansa, PhD
Dinesh Thekkoot, PhD
Lucie Langlois, Dip Ag
Clint Sigurdson
Vicki Tannas
Pavel Trefilov

NUCLEUS AND MULTIPLICATION STRUCTURE

At the heart of the Genesus genetic program is a global purebred registered nucleus population of more than 19,000 sows genetically linked. This includes over 7,000 sows in nucleus in Canada with F1 multiplication globally in the tens of thousands.

Production locations are North America, Europe, Russia, China and other Asian countries.

Maternal breeds include registered purebred Landrace and Yorkshire. Our registered purebred Duroc is the terminal breed. The nucleus population is strategically located across multiple units. They are geographically isolated and adhere to strict biosecurity standards ensuring high health status for each unit. Each breed is duplicated in at least 2 units and all units are genetically linked. This structure ensures a continual and consistent nucleus population of high-health animals.

Genesus has the largest independent registered purebred swine herd in the world. The Canadian Animal Pedigree Act is implemented and certified by the Canadian Swine Breeders Association. Genesus believes in the value of the registered purebred animal. This commitment results in Genesus accounting for over 79% of all purebred registrations in Canada and assures that Genesus customers receive only certified purebred and true F1 animals.

The purity of the Canadian Government authorized registered swine breeding stock guarantees a pedigree that ensures a breeding animal that has become a world barometer for quality.

LARGEST REGISTER OF PUREBREDS IN CANADA

BREED	GENESUS	CANADA	% OF TOTAL
Duroc	24,663	31,911	77.3
Landrace	23,452	30,879	76.0
Yorkshire	56,565	69,058	81.9
Total	104,680	131,848	79.4

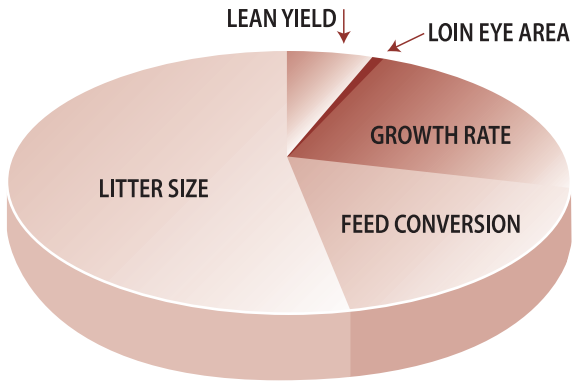
Source: Canadian Swine Breeders Annual Report

GENETIC INDEXES

Selection and mating in all breeds utilizes specialized indices. These indices combine the economically important traits and maximize the genetic contribution to customer profitability.

MATERNAL INDEX

The maternal index has the highest emphasis on litter size, followed by growth rate, feed conversion, lean yield, and loin eye area.

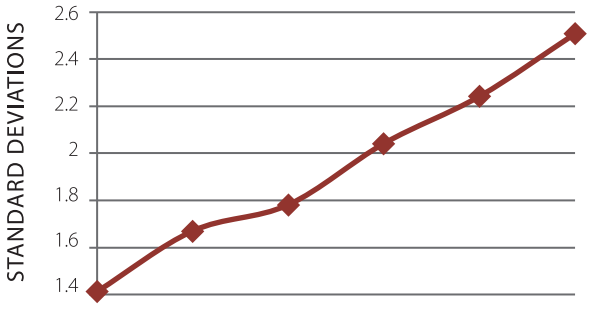


This index has yielded substantial genetic gains in both maternal breeds

LANDRACE

Genesus Landrace have large, long frames and their offspring, deliver larger carcasses. They have unrivaled milking capacity, combined with excellent litter size and growth.

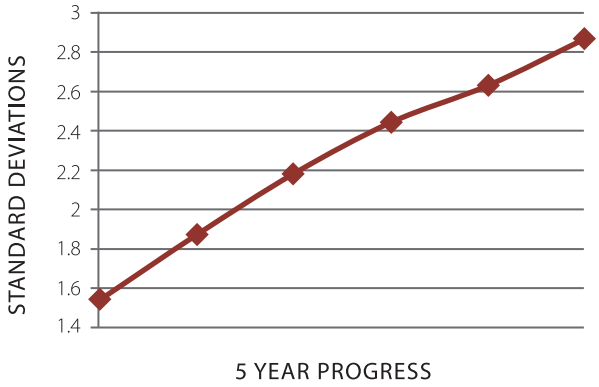
LANDRACE MATERNAL INDEX TREND



YORKSHIRE

Genesus Yorkshires have tremendous ability to have large litters, milk well and grow quickly. Their structural capacity, with strong feet and legs, allows them to stay in production for multiple litters.

YORKSHIRE MATERNAL INDEX TREND



STRUCTURE AND CONFORMATION

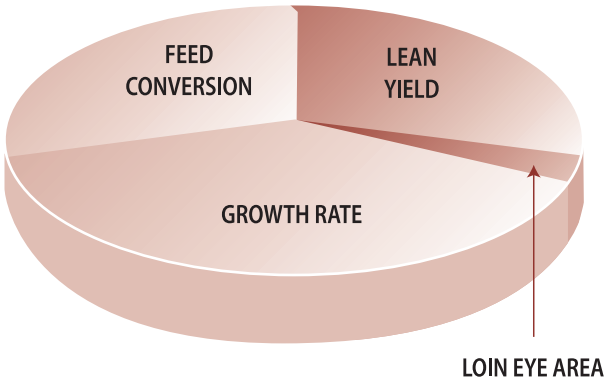
All replacement gilts and boars selected back into the nucleus herd have a minimum of 14 functional teats to support large litter size. Consistent selection for structure and conformation has been achieved by utilizing rigid criteria overseen by an experienced head selector.

MATERNAL BREEDS

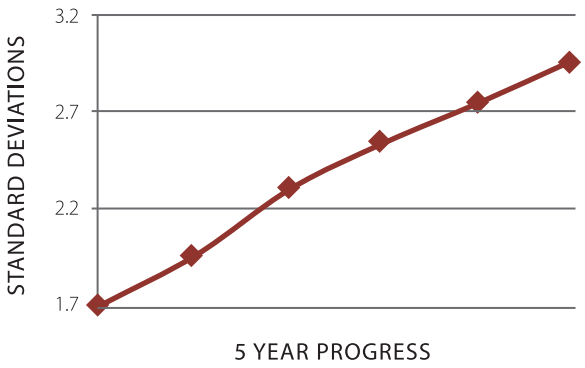
As a result of strict implementation of the genetic program Genesus Landrace and Yorkshire sows are very prolific with excellent mothering ability, fast, efficient growth and superior carcass characteristics. They are easy to manage, have high feed intake during lactation supporting the growth of large litters, and remain in the herd to later parities.

DUROC

Genesus Durocs are the premium global purebred terminal sire. They grow well, have excellent carcass and meat quality traits, and sire pigs that are easy to manage and withstand health challenges. The Duroc index has the largest weight on growth rate, followed by feed conversion, lean yield, and loin eye area.



DUROC INDEX TREND



Genesus Duroc is known for its superior carcass and meat eating quality traits. Commercial animals sired by Genesus Duroc boars have dominated in independent studies of carcass and meat quality. Furthermore, Genesus Duroc boars bred to Genesus F1's easily qualify for the strict Japanese market, attesting to the excellent carcass and meat quality traits of commercial Genesus market pigs.

THE POWER OF HETEROSIS

Heterosis is fundamental to the swine industry and is free to any producer utilizing crossbreeding.

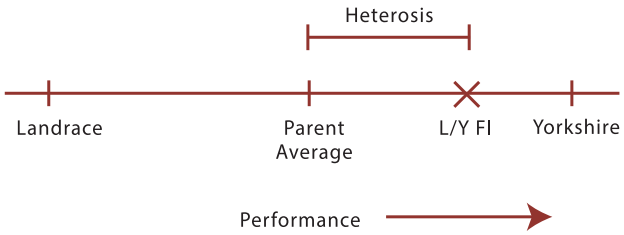
Heterosis results in a bump up in production and reproduction that brings the producer increased profits. Genesus has built its breeding program on this simple concept. Genesus has all registered purebred Duroc, Landrace, and Yorkshire nucleus stock. All aspects of our breeding program maximize heterosis, through maternal and terminal lines and to the commercial animal. The purebred registry guarantees the Genesus system of an F1 female (York x Landrace) and a Duroc sire delivers 100 % heterosis. Heterosis is not passed on from parent to progeny. Heterosis must be maximized through the breeding program. Another benefit to this breeding scheme is uniformity of the commercial stock. Al commercial animals from a full Genesus program have the same breed composition (25% L, 25% Y, and 50% Duroc). Below is a table showing the actual percentage increase in performance of crossbred animals due to heterosis compared to the average of the parent breeds.

TRAIT	INDIVIDUAL (%)	MATERNAL (%)
Number Born	2	8
Number Weaned	9	11
21-d Litter Weight	12	18
Days to 120kg	-7	-1
Feed Conversion	-2	-
Back Fat Depth	1.5	4

Understanding Animal Breeding. Richard M. Bourdon, 2000.

Offspring from a Landrace x Yorkshire F1 female mated to a Duroc boar will reach 120kg faster compared to purebred parent. This is attributed to individual heterosis. Because the dam of these offspring is crossbred herself, she will contribute maternal heterosis to the growing offspring. F1 females produce larger, faster growing litters compared to purebred females.

BELOW IS A PICTORIAL EXAMPLE OF THE DEFINITION OF HETEROSIS.



IMPACT ON GENESUS COMMERCIAL PIG

The genetic improvement resulting from the Genesus genetic program also benefits the Genesus commercial pig. Below is a table of the cumulative response to selection on the commercial pig.

TRAIT	5 YEAR CUMULATIVE RESPONSE	
Growth Rate	-7.7	days to 120kg
FCR	-0.26	
Loin Depth at 120kg	0.91	mm
Fat Depth at 120kg	0.83	mm
Number Born	1.2	per F1 litter

Todays Genesus commercial pig is faster growing, more efficient, and more prolific than commercial pigs from 2009. All of these traits have an impact on profitability. The estimated economic impact per sow for the 5-year period is over $400, translating into almost $1million in value for a 2400 sow farm. Clearly the economic value of genetic improvement is large and is a key to enhanced profitability for commercial pork producers.

BOTTOMLINE

The final product, a Genesus Duroc Sire bred to a Genesus Yorkshire/Landrace (F-1) is a powerful combination.

It maximizes heterosis, enhancing litter size, growth uniformity, livability and feed conversion.

And most importantly, it maximizes profitability.

RESEARCH AND DEVELOPMENT

Genesus Genetics is dedicated to enhancing our customer's profitability and our competitiveness by directly investing over $5 million dollars annually in research and development. Our R&D strategy combines in-house and collaborative projects engaging leading researchers at world-class universities, government institutes and private industry. This approach has resulted in several opportunities to leverage our investment into significantly larger and more comprehensive projects. Leveraging opportunities are made available through industry and government funding programs aimed at enhancing the pork industry.

COLLABORATIONS

- University of Alberta
- University of Guelph
- Iowa State University
- Kansas State University
- University of Nebraska
- Genome Canada
- Genome Alberta
- United States Department of Agriculture
- East 40 Packing Ltd.
- McKay Genstat Ltd.

Our research projects are focused by our desire to use genetics to increase profitability for our customers. Strategic R&D investment with this clear over-riding objective driving specific projects results in a win-win proposition for our customers and Genesus. Research topics are balanced across all key components of the pork industry and include:

- sow efficiency and longevity
- feed intake and growth
- carcass and meat quality
- population health
- genomic evaluation and selection

Research projects involve key industry segments including nucleus, multiplier, collaborator commercial herds and packers. This allows Genesus to ensure the applicability of our R&D to our customers. All research projects include the use of our dedicated R&D herds, extensive on-farm data collection, large pedigreed databases, and genomic approaches.

Through Genesus' extensive research and development, the commercial pig is productive, robust, and easy to manage with the highest meat and eating quality.

PROJECT LIST

1. Genomics of carcass and meat quality
2. Growth, feed intake, and feed efficiency
3. Sow efficiency and longevity
4. Population health
    a. Porcine Reproductive and Respiratory Syndrome
    b. Sow Robustness
    c. Disease Resilience
5. Genomics and Selection

A synopsis of specific projects follows.

GENOMICS OF CARCASS AND MEAT QUALITY

Although most producers do not get paid directly for meat quality, it is a key building block to the success of the swine industry. Without excellent meat and eating quality, many export markets would not be available to producers, consumers would not continually buy pork, and the industry would be dramatically changed. Consumers are demanding juicy and flavorful pork. People want to have a great eating experience when they consume pork. Carcass and meat quality is an area that sets Genesus apart from the competition.

COLLECTION OF PH VALUES

Since September of 1998, Genesus has been dedicated to improving carcass and meat quality traits in the Duroc terminal line. Each week, two littermates from each Duroc litter born are sent to a packing plant where a detailed cutout is performed and measurements collected on over 50 traits per animals. Over 16,000 animals have been phenotyped for key traits including hot carcass weight, loin eye area, loin depth, fat depth, Minolta L (color score), loin pH, marbling score and primal yield. The Genesus Duroc continues to excel in carcass, meat and eating quality traits.

PHENOTYPIC MEANS OF DUROC GILTS

TRAIT	AVERAGE
Hot Carcass Weight (kg)	94.3
Loin Eye Area (cm2)	50.1
Loin Depth (mm)	64.3
Fat Depth (mm)	15.0
Minolta L	47.2
pH	5.8
Marbling Score[1]	3.0

Marbling score 0 = devoid, 1 = practically devoid,
2 = traces, 3 = slight, 4 = small, 5 = modest, 6 = abundant

EVALUATION OF LOIN MARBLING AND COLOR

WEIGHTS OF PRIMALS AND CUTOUTS

The end product for the producer and consumer is the commercial crossbred animal. It is important that the end product possess the desirable carcass and meat quality traits. Information about genetic control of carcass and meat quality of commercial animals can be implemented into selection at the nucleus level thru genomic selection. Genomics can contribute to the genetic progress of carcass and meat quality since the information used for selection is directly from the individual in addition to full- and half-sib performance.

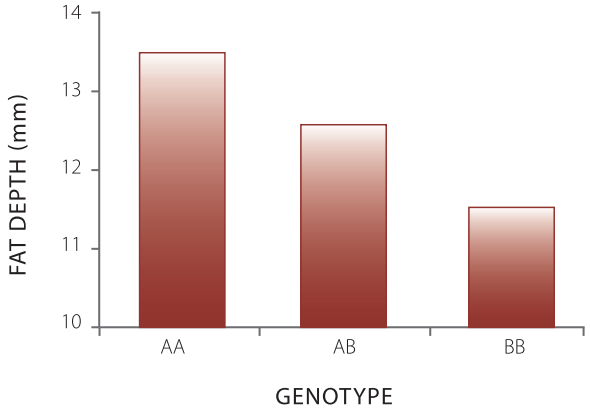
A large project involving Genesus commercial animals was used investigate the genomic effects on carcass and meat quality traits. One thousand animals were genotyped and more than 2,000 animals were phenotyped in this project. Genome-wide association analyses of crossbred animals have yielded genomic regions associated with key carcass and meat quality traits, including carcass fat depth, loin marbling, and peak shear force, which is an indicator of tenderness.

NUMBER OF CROSSBRED PIGS GENOTYPED AND PHENOTYPED FOR CARCASS AND MEAT QUALITY

	NUMBER OF ANIMALS	
BREED	PHENOTYPED	GENOTYPED
Duroc x Landrace/ Yorkshire F1	2,258	1,000

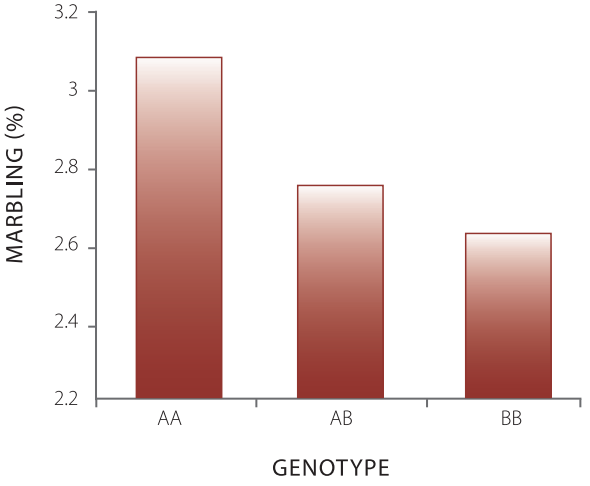
One region associated with carcass fat depth had a 2mm difference between the AA and BB genotyped animals, with BB animals having the favorable phenotype.

CARCASS FAT DEPTH

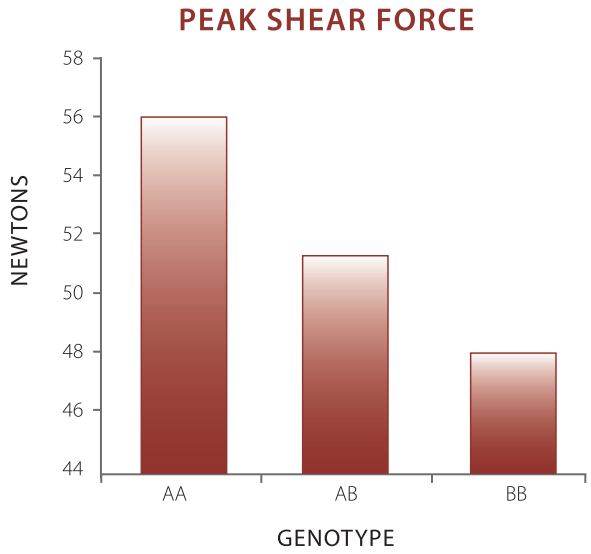


Marbling is a key trait associated with tenderness, juiciness, and flavor. All of these attributes contribute to a good eating experience for the consumer. A region in the genome was identified that has a significant association with marbling. Animals with an AA genotype had a 0.5 percentage point higher marbling than animals with BB genotype.

MARBLING



Peak shear force is an indicator trait for tenderness, another contributing factor to a good eating experience. A region with a large effect was identified for peak shear force. The lower the shear force value, the more tender the meat.



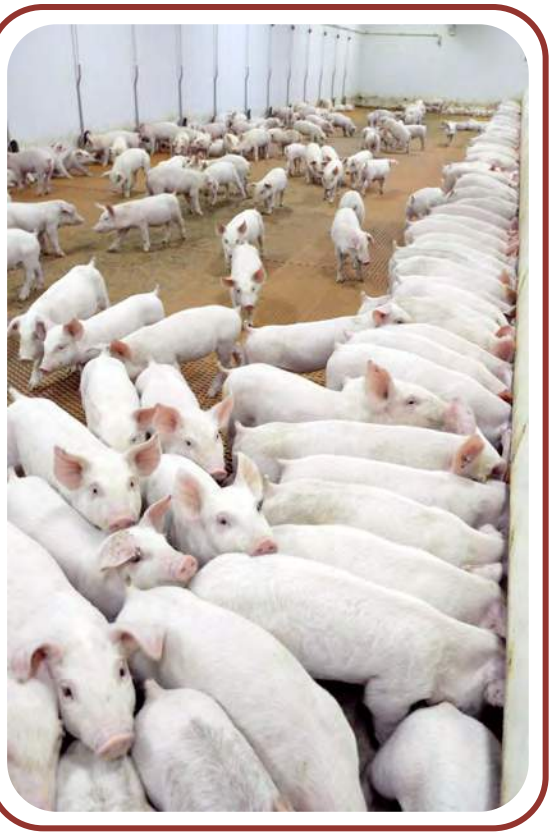
The following table demonstrates that many regions on several of the pig's chromosomes have influence on the pig's genetic merit for carcass and meat quality traits.

DETECTED GENOMIC REGIONS

TRAIT	CHROMOSOME
Hot carcass weight	1, 13
Carcass length	2, 7, 12, 13, 17
Loin muscle area	2, 18
Carcass Fat depth	1
Carcass Loin depth	2
Ultrasound IMF	4, 12
Marbling score	1, 2, 17
Loin pH	15
Loin colour L*	8, 17
Loin drip loss	3, 15
Shear force (tenderness)	2

By including these results and others into the Genesus genetic improvement program the rate of improvement in carcass, meat and eating quality will increase and produce a more satisfying product for the consumer.

GENESUS CARCASSES

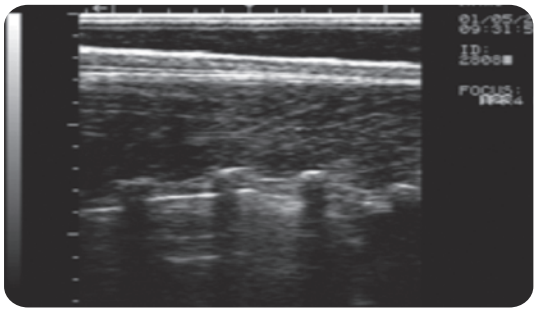


GROWTH, FEED INTAKE AND EFFICIENCY

The Genesus Duroc is a superior terminal sire that is known for its fast and efficient growth. Feed intake is the largest variable cost in swine production and growth rate is one of the most economically important traits affecting profitability. Therefore, Genesus has invested in sophisticated technology to collect accurate data associated growth and efficiency. This includes electronic feed intake and ultrasound equipment.

ELECTRONIC FEED INTAKE EQUIPMENT

Genesus has been collecting individual feed intake on Duroc boars since 2004 using electronic feed intake equipment. Animals are on test for seven weeks from 75 to 120 kg. Once the animals are off-test, they are scanned for backfat depth, loin depth, and intramuscular fat. This information, with growth and feed intake, allows for accurate selection of fast growing and efficient pigs.



LONGITUDINAL IMAGE OF THE LONGISSIMUS DORSI OF A DUROC DURING OFF-TESTING

Genesus continues to invest and improve our already superior Duroc. Recently, Duroc boars were genotyped with 80K or 650K SNP chips or whole-sequenced in order to incorporate genomic information into the genetic evaluation.

GENOTYPE INFORMATION

# Markers per boar	Number of boars genotyped
80,000	1,467
650,000	171
Sequence (~3 Billion)	29

The goal of this project is to increase the rate of improvement in feed efficiency, growth, feed intake, and composition of gain. Through enhanced genomic breeding values using pedigree, phenotypic performance, and genomic information these advancements will be realized. A unique aspect of this project is genomic sequence, which allows for the identification of novel markers within the Genesus Duroc population that can be used to enhance genomic breeding values above that of commercially available SNP panels.

Below is a table listing the chromosomes that contain regions within the genome that significantly contribute to the economically important traits of interest.

Trait	Chromosomes
Average daily feed intake	1,2,3,4,5,7,10,14
Average daily gain	7,8,11,13
Back fat depth	1,6,18
Loin depth	1,2,3,4,5,17,18

These traits are controlled by many genes with small effects. Genomic selection can greatly enhance the genetic improvement of these traits by increasing the accuracy of the estimated breeding values.

BENEFITS OF GENOMIC SELECTION

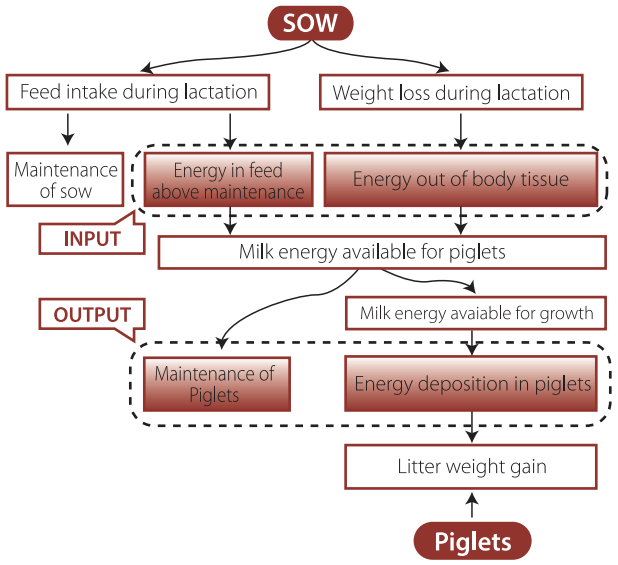
Trait	%Increase in Accuracy
Average daily feed intake	55
Back fat depth	39

Using genomic selection, including the novel markers from the sequence information in addition to the 80K genotypes, increased accuracies of the GEBV's by 55% for average daily feed intake and 39% for back fat depth. The improvement in accuracy directly translates into genetic improvement.

SOW LACTATION EFFICIENCY

Profitable sows show strong heats, produce and raise large litters, achieve efficient and high litter weight gains, return to estrus quickly after weaning, conceive on first mating after weaning and repeat this consistently for 6 or more parities. As gilts, they cycle early and conceive on their first mating. Sows nursing large litters, require a substantial amount of energy to support growth of her piglets. Lactation is the most energy demanding phase of the reproductive cycle. Understanding the genetic and physiological components of lactation efficiency is critical in understanding sow efficiency and will lead to increased profitability.

FLOW DIAGRAM OF ENERGY INPUT AND OUTPUT OF THE SOW TO GROW HER LITTER



Sow lactation efficiency is defined as energy output adjusted for energy input. Energy input to produce milk is sourced from the feed that is consumed by the sow along with body resources. Losses of body weight, back fat, and loin depth indicate that the feed intake portion of the equation is not inadequate to support her lactation needs. Larger litter size, as a result of genetic and management improvements has demanded greater output from sows than in the past. Due to these litter size increases, today's sow must deal with increased milk production, increased lean growth rate, higher mature body weight, and decreased backfat. These challenges have generally lead to sows being in a negative energy balance during lactation.

Genesus has invested heavily, in efforts to understand sow efficiency by collecting significant amounts of data using electronic individual lactation feed intake equipment, sow weight and body composition changes, piglet weights, survival and growth to weaning plus genotyping thousands of females.

ELECTRONIC FEED INTAKE EQUIPMENT

Traits associated with reproduction are typically lowly heritable, which means most of the phenotype that we see is due to the environment rather than genetic effects. Heritability is defined as the proportion of phenotypic variation that is due to genetics. However, these traits still show sufficient genetic variation that including them in a genetic improvement is beneficial. Below are heritability estimates for some important traits relating to sow efficiency in the two Genesus maternal breeds.

TRAIT	LANDRACE	YORKSHIRE
Age at First Farrowing	0.20	0.20
Wean to Service Interval	0.07	0.07
Feed Intake	0.37	0.28
Body Weight Loss	0.32	0.25
Back Fat Loss	0.16	0.09
Litter Weight Gain	0.18	0.16

Many of the traits affecting sow efficiency are difficult to measure accurately, are only expressed in the female and can be expensive to measure. Thus, there are significant benefits to enhance genetic improvement using genomic tools. Through genomics, regions in the genome associated with these traits have been identified. In the following table are examples of some major regions on the pig's chromosomes that affect some of the component traits of sow efficiency.

MAJOR REGIONS IDENTIFIED FOR SOW LACTATION PERFORMANCE

TRAIT	CHROMOSOME
Litter weight gain	2, 16
Back fat loss	7
Sow feed intake	5
Loin depth loss	4

Using genomic information in the genetic evaluation will increase the accuracy of the EBV's, which will increase the rate of genetic gain, especially in low to moderately inherited traits. This will assist in producing sows that will be able to consistently and efficiently produce large litters with heavy weaning weights.

While sow efficiency is a key economic driver of profitability another important driver is sow longevity or length of productive life of the sow. There are associations between sow longevity and key component traits of sow efficiency and thus sow longevity must be evaluated with these associations taken into consideration. Sow longevity is usually thought about as the parity at removal from the herd and there are economic advantages to have as many sows as possible reach the high producing parities, usually parities 4 to 5. Sows in the nucleus are usually culled after 2 parities because of the direct effect on the rate of genetic improvement. Therefore, genetic improvement of sow longevity requires information from multiplication and commercial herds in which sows are not removed at early parities. Additionally, selection at the nucleus level can be directly aided by genomic tools focused on sow longevity.

SOW WITH LITTER

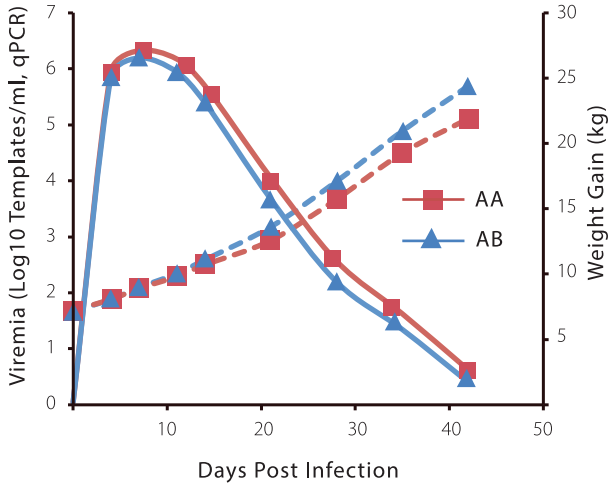
POPULATION HEALTH

Population health is one of the most important factors in swine production and overall profitability. No matter how superior the genetics, a dead or diseased animal is a financial loss to the producer. Even with strict biosecurity, swine producers face disease challenges daily. Animals that are tolerant or resistant to disease challenges can reduce the cost of vaccines and limit the reduced production performance during a disease challenge.

Genesus has participated in large-scale collaborative research projects revolving around disease challenges. Collaborators include Canadian Swine Health Board, Genome Canada, Genome Alberta, United States Department of Agriculture, Canadian, US, European universities, and other swine genetics companies.

One component of the project is large-scale disease challenges, in which pigs are infected with economically important diseases including Porcine Reproductive and Respiratory Syndrome Virus (PRRS) and Porcine Circovirus Type 2 (PCV2).

EFFECT OF GENOTYPE ON VIREMIA AND WEIGHT GAIN IN PIGS INFECTED WITH PRRS



Boddicker et al. 2012. Evidence for a Major QTL Associated with Host Response to Porcine Reproductive and Respiratory Syndrome Virus Challenge. Journal of Animal Science, 90:1733-1746.

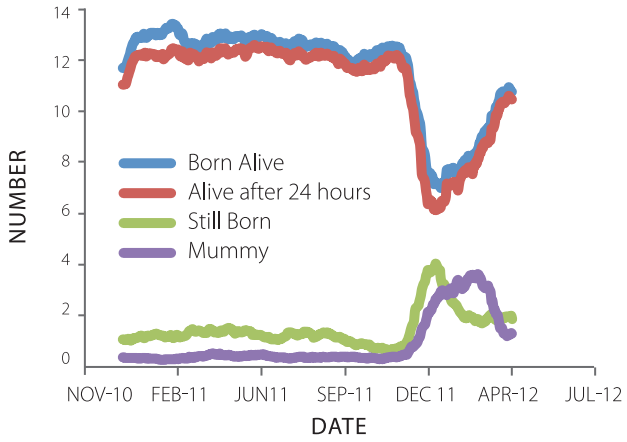
For PRRS, all aspects of production are studied. Projects include infection of nursery pigs and the effects on growth and viremia. As seen in the above figure, nursery pigs with the AB genotype had higher weight gain and lower viremia levels. A similar study using PCV2 has been completed and regions of the genome have been identified that reduce viremia and increase weight gain while nursery pigs undergo a PCV2 challenge.

CHROMOSOME	EFFECT OF CHROMOSOMAL REGION
6	Increased growth, reduced virus load
12	Increased growth, reduced virus load
12	Increased growth, reduced virus load
11	Reduced virus load

A.M McKnite et al. 2014. Animal Genetics.

Genesus is currently evaluating these regions in other populations and also their effect on other traits in the genetic improvement program.

Herds that break with PRRS possess a wealth of data on disease challenges in the field. Genesus has collected and analyzed genomic and phenotypic litter size information from an outbreak herd to identify important genomic markers or genes to incorporate into the genetic improvement program in order to produce pigs that can withstand disease challenges.



Serao et al. 2014. Genetic Analysis of Reproductive Traits and Antibody Response in a PRRS Outbreak Herd. Journal of Animal Science, 92:2905-2921.

Above is a figure demonstrating the effects of reproductive performance during an outbreak of PRRS. After the outbreak, sows were genotyped and blood samples were collected. This projected yielded promising results, including genomic regions that accounted for a substantial proportion of the genetic variance.

Another important aspect with respect to genetic improvement for disease is a pig's ability to perform in a lower level herd environment. Some herds have stable levels of a disease (e.g. PRRS) in their herds. It is important to understand differences in sow performance in lower level herd environments and what portion of the performance difference is due to genetics. Genesus is involved in a project in which high health F1 replacement gilts are introduced into a lower health herd. The gilts performance during the acclimation phase and her subsequent production thru 4 parities is monitored. The genomic information and performance data is being used to determine genetic effects on gilt acclimation and sow performance. Some of the same regions identified from the analysis of the outbreak herd data also have an effect on the gilt acclimation phase of this project. Further information can be found in Serao et al., 20141.

A new project has been funded which will focus on disease resilience in grow-finish pigs. This project will follow grow-finish pigs in a health challenged environment to determine if there are any differences in performance or immune response between individual pigs and if any of this difference has a genetic basis. In addition to standard growth and carcass composition traits, several health traits and immune response measures will be collected on each pig. A unique aspect of this study is that individual feed intake will be collected on each pig allowing for an examination of the effect of disease status and immune response on grow-finish feed intake and efficiency.

These health projects will be important in the development of genetic improvement programs for disease resilience in both growing pigs and producing sows. The potential contribution to increased profitability of Genesus customers is large. This is the reason Genesus has made such a significant investment in the population health area.

Serão, NVL, RA Kemp, B. Mote, JCS Harding, P. Willson, SC Bishop, GS Plastow, JCM Dekkers. 2014b. Whole-genome scan and validation of regions previously associated with PRRS antibody reposne and growth rate using gilts under health challenge in commercial settings. Proceedings 10th World Congress of Genetics Applied to Livestock production, Vancouver, BC.

GENOMICS AND SELECTION

Genesus is dedicated to using cutting-edge technology, such as genomics. Genomics is the study of the genome, or the DNA that makes a pig a pig. Some regions within the genome are functional, or have an effect on traits of interest. Genomics is beneficial for increasing the rate of genetic gain, particularly in the following trait categories:

Traits measured on one sex

- Sow efficiency
- Reproductive traits

Expensive/Hard to measure traits

- Feed efficiency
- Carcass and meat quality
- Traits associated with disease

Traits measured later in life

- Longevity
- Crossbred performance

There are two primary applications for genomics, each with their own role. Genome wide association analyses (GWAS) are used to identify regions in the genome that have a significant effect on the trait of interest. The goal is to identify a region(s) that explains a substantial amount of the genetic variation in a trait so that the genomic information can be incorporated into the breeding program. This type of analysis has been particularly beneficial in the analysis of disease challenge studies.

The second application of genomics is called genomic selection (GS). In this analysis, all genomic information is used in the genetic evaluation, along with performance data to improve the accuracy of EBV. GS is especially beneficial for traits that are polygenic (controlled by many genes). This typically includes feed intake, feed efficiency, carcass and meat quality, and reproductive performance.

The principle of genomic selection is quite simple:

First, a large group of animals (reference population) are phenotyped and genotyped. The large group of animals typically includes the most recent one to three generations.

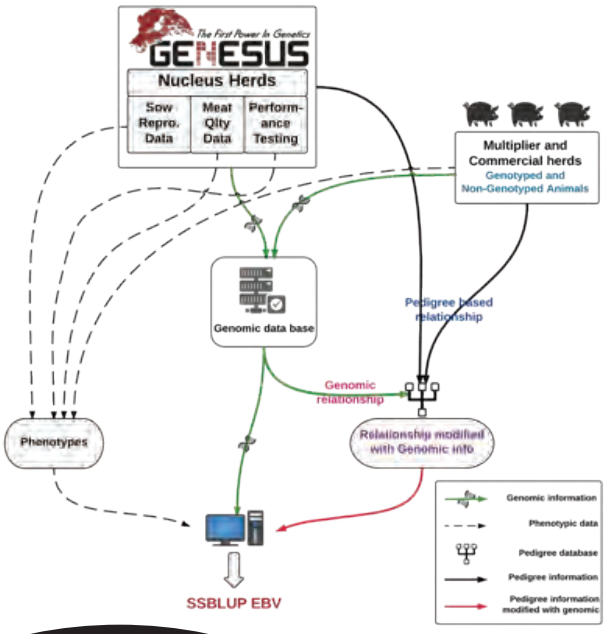
The information from the reference population is analyzed to estimate the effects of the single nucleotide polymorphisms (SNPS). Later these SNP effects are used to predict the breeding values commonly called a genomic estimated breeding value (GEBV) of young animals that do not have their own phenotypic records. Research conducted by Genesus has shown that the genomic selection methods can improve accuracies of EBVs significantly.

GEBV calculation described above does not utilize phenotypic or pedigree information from the relatives of selection candidates that are not genotyped. But studies have shown that accuracies of genomic selection methodologies can further be increased by combining pedigree and performance information from non-genotyped relatives with genotyped animals. This method is commonly referred as the **Single Step genomic BLUP (SSBLUP)**.

The conventional selection methodologies utilize pedigree based relationships and phenotypes for estimating EBVs. In SSBLUP method the pedigree-based relationship information is modified with relationship information from genotyped animals. These modified pedigree relationships provide a better estimation of relationship between animals and combined with the SNP information provide more accurate EBVs.

The figure shows a schematic representation of single step method of estimating genomic EBVs, that is being implemented at Genesus.

- The dashed and solid back lines indicate the flow of phenotypic and pedigree based information in the Genesus breeding program.
- The solid green line indicates the flow of new genomic information collected as a part of implementation of genomic selection.
- In the nucleus herds, all selection candidates along with their sires and dams are genotyped



Before the SNPs are implemented in a genetic evaluation, the predictive ability of the SNPs must be determined using a sub-population that has both phenotypic and genotypic information but is not included in the reference population. The SNP estimates from the reference population are used to calculate genomic EBV, which are then correlated to the pedigree based EBV. If the genomic EBV is sufficiently high enough to accurately predict the performance of the animal, it is incorporated into the genetic evaluation. Studies conducted at Genesus have shown that SSBLUP EBV accuracies were around 30-50% higher than BLUP based EBVs. A higher accuracy of prediction means a greater genetic change per year.

GENESUS MARKET HOGS

HETEROSIS

Crossbreeding is incorporated into most commercial breeding programs in the swine industry, unlike other animal production industries (e.g. dairy and beef to a certain extent). One of the greatest benefits to crossbreeding is the phenomenon of heterosis, or hybrid vigor. Heterosis is the counterpart to inbreeding depression, which occurs when related animals are bred together. Different breeds tend to have different allele frequencies across the genome. When these 2 breeds are bred together, the allele frequencies become intermediate in the offspring. In genetic terms, this is called an increase in heterozygosity and contributes to heterosis. Heterosis is defined as the increase in performance of the offspring compared to the average of the parents. It is quantifiable and typically expressed as a percentage. As an example, let's assume two purebred maternal populations and the trait of interest is litter size. The Landrace (L) population has an average litter size of 13 and Yorkshire (Y) has an average of 14. The average of the two parent breeds is 13.5. The LxY F1's have an average litter size of 14.5. Therefore, the percent increase from the parent average (heterosis) is (14.5-13.5)/13.5*100 = 7.4% heterosis. The above example calculated the exact percentage of heterosis. However, it is most common to compare the heterosis for different mating schemes using a common standard, which is typically the heterosis in an F1 and is considered 100%. The mating of any 2 different breeds yields 100% heterosis on the standardized scale. On the standardized scale, it is essential to know the percent breed composition of the animals in the breeding program. Building onto our previous example, what is the expected heterosis when a third breed (e.g. Duroc) is mated to the LxY F1? Again, this is 100% heterosis because the F1 female is York and Landrace and does not contain any Duroc in the breed composition. There are three additional types of breeding schemes commonly used in the swine industry and they are backcrosses (mating the F1 to one of the parent breeds), mating of F1's together and results in F2s, and composite lines (e.g. 3-breed composite). All of these breeding schemes result in less heterosis than that achieved by an F1. Simply stated, when the same breed is present in the sire and dam, heterosis will not be 100%. Heterosis can be broken down into individual and maternal heterosis. Everything discussed above is referring to individual heterosis. Maternal heterosis is heterosis of maternal traits such as litter size or milking ability. F1 females will have larger litters compared to their purebred parents. If the dam is an F1, then maternal heterosis is 100%. Below is a table summarizing the standardized heterosis for different breeding schemes. Maximizing heterosis, both individual and maternal, is only achieved through structured breeding schemes.

Breeding Scheme	Scheme Name	% Heterosis(Individual)	% Heterosis(Maternal)
L x Y	F1	100	0
(LxY) x Duroc	3-way cross	100	100
(LxY) x Y	Backcross	50	100
(LxY) x (LxY)	F2	50	100
((LxY) x D) x ((LxY) x D)	3-breed comp.*	62.5	62.5

* Assuming breed composition is 25% Landrace, 25% Yorkshire, and 50% Duroc In the era of genomics and highly sophisticated genetic techniques, we must not forget about the basics. Heterosis is a simple concept and is free to the producer that utilizes crossbreeding. It results in a bump up in production and reproduction that in turn brings the producer increased profits. Genesus has built its breeding program on this simple concept. Genesus has all registered purebred Duroc, Landrace, and Yorkshire nucleus stock. Therefore, all aspects of our breeding program maximizes (100%) heterosis, both individual and maternal all the way to the commercial animal. Because all of the purebred animals are registered, it is guaranteed that the Genesus system of an F1 female (York x Landrace) and a Duroc sire maximizes heterosis. Heterosis is not passed on from parent to progeny and therefore must be maximized through the breeding program. Another benefit to this breeding scheme is uniformity of the commercial stock because all commercial animals from a full Genesus program have the same breed composition (25% L, 25% Y, and 50% Duroc).

NOTES