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Review Article

## The Power of Genomic Selection in Animal Breeding

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### Abstract

Genomic selection has emerged as a groundbreaking approach in animal breeding, leveraging genomic information to revolutionize selection strategies and drive genetic progress across livestock species. This abstract provides a succinct overview of genomic selection, highlighting its principles, applications, benefits, challenges, and future directions. By integrating genomic data with phenotypic information, genomic selection enables accurate prediction of an individual's genetic merit for desired traits, facilitating early selection decisions and enhancing breeding efficiency. Despite challenges such as cost and data quality, genomic selection offers unparalleled advantages, including increased prediction accuracy and the ability to target complex traits. Looking forward, ongoing research aims to expand the scope of genomic selection, encompassing multi-trait selection, niche species, and precision breeding techniques, thereby paving the way for sustainable genetic improvement in animal agriculture.

### Introduction

Animal breeding has long been a cornerstone of agriculture, driving improvements in livestock productivity, health, and adaptability. Animal breeding involves the selection of domestic animals with the goal to improve quantitative or qualitative traits in the next generation. A number of breeding methods have been used to improve animals, but the main aim has always been to improve the production of superior animals of desired traits. Historically, breeders relied on observable traits and pedigree information to make breeding decisions. However, the advent of genomic selection has transformed the breeding landscape, offering unprecedented insights into the genetic makeup of animals and revolutionizing



breeding practices.

### **What is Genomic Selection?**

Genomic selection represents a paradigm shift in animal breeding, leveraging advances in genomics, bioinformatics, and statistical genetics to enhance breeding strategies. At its core, genomic selection harnesses information from the entire genome, comprising DNA sequences and genetic markers, to predict an individual's genetic merit for specific traits of interest. Unlike traditional breeding methods, which rely solely on pedigree and phenotypic data, genomic selection integrates genomic information to provide more accurate estimates of breeding values and accelerate genetic progress.

### **Principles of Genomic Selection in Animal**

1. **Genotyping:** Animals are genotyped using high-throughput sequencing or genotyping technologies to identify genetic markers distributed across the genome. These markers serve as indicators of genetic variation and are crucial for constructing genomic profiles of individuals.
2. **Phenotyping:** Animals are phenotyped for traits of interest, such as milk yield, meat quality, disease resistance, and fertility. Phenotypic data provide essential information on the expression of traits and serve as the basis for evaluating genetic performance.
3. **Training Population:** A training population is assembled, comprising animals with both genotype and phenotype data. This population serves as the foundation for developing prediction models that relate genetic markers to phenotypic traits.
4. **Statistical Models:** Sophisticated statistical models, including genomic prediction models and Bayesian methods, are employed to analyze the training population data and estimate the effects of genetic markers on phenotypic variation. These models account for genetic relatedness, population structure, and the polygenic nature of traits.
5. **Prediction:** Once the models are trained, they can be applied to individuals in a validation population to predict their genetic merit based on genomic information alone. These predictions yield estimates of breeding values, enabling breeders to identify superior animals for selection.

### **Applications of Genomic Selection**

- 1) **Milk Production:** In dairy cattle breeding, genomic selection enables the identification of superior bulls and cows with high milk yield, milk components (e.g., fat and protein content), and udder health. By selecting animals with favorable genomic profiles, breeders can enhance milk production efficiency and quality.
- 2) **Meat Quality:** In beef and pork production, genomic selection facilitates the improvement of meat quality traits, including tenderness, marbling, flavor, and juiciness. By selecting



animals with desirable genetic markers associated with meat quality, breeders can meet consumer preferences and enhance market competitiveness.

- 3) **Disease Resistance:** Genomic selection plays a crucial role in enhancing disease resistance and resilience in livestock populations. By identifying genetic markers linked to disease resistance traits, breeders can selectively breed animals with enhanced immunity and reduced susceptibility to infectious diseases, thereby improving animal welfare and reducing reliance on antimicrobial treatments.
- 4) **Reproductive Performance:** In livestock breeding programs, reproductive performance is a key determinant of productivity and profitability. Genomic selection allows breeders to target traits related to fertility, reproductive efficiency, and reproductive lifespan, leading to more prolific and efficient breeding programs.
- 5) **Environmental Adaptation:** With the growing challenges of climate change and environmental stressors, genomic selection offers opportunities to breed animals with enhanced adaptability and resilience to changing environmental conditions. By identifying genomic markers associated with heat tolerance, drought resistance, and feed efficiency, breeders can develop livestock populations better suited to diverse environmental contexts.

#### **Advantages of Genomic Selection**

1. **Early Selection:** Genomic selection enables breeders to assess an individual's genetic potential at a young age, even before phenotypic traits are fully expressed. This early selection accelerates genetic progress by reducing generation intervals and shortening the time required to achieve breeding objectives.
2. **Increased Accuracy:** By leveraging information from the entire genome, genomic selection provides more accurate predictions of breeding values compared to pedigree-based methods. These precise estimates enhance selection decisions, resulting in greater genetic gain and more efficient breeding programs.
3. **Selection for Complex Traits:** Genomic selection facilitates the improvement of complex traits controlled by multiple genes and influenced by environmental factors. Traditional selection methods may struggle to make progress in such traits, but genomic selection offers a robust framework for targeting polygenic traits and achieving significant improvements.
4. **Genetic Diversity Preservation:** Genomic selection allows breeders to maintain and manage genetic diversity within livestock populations. By considering genomic relationships and diversity metrics, breeders can design breeding strategies that preserve rare alleles and mitigate the risk of inbreeding depression, thereby safeguarding the long-term sustainability of breeding programs.



## Challenges and Considerations of Genomic Selection

- **Cost:** Genomic selection requires substantial investment in genotyping technologies, phenotyping infrastructure, computational resources, and expertise in statistical genetics.
- **Data Quality and Quantity:** Inadequate sample sizes, incomplete phenotypic records, genotyping errors, and population structure can compromise the validity of prediction models and undermine the effectiveness of genomic selection.
- **Trait Complexity and Plasticity:** Some traits of interest exhibit high complexity and phenotypic plasticity, making them challenging to predict accurately using genomic information alone.
- **Ethical and Societal Considerations:** The widespread adoption of genomic selection raises ethical and societal concerns related to animal welfare, biodiversity, and the equitable distribution of breeding benefits.

## Conclusion

Genomic selection represents a paradigm shift in animal breeding, offering unprecedented opportunities to accelerate genetic progress and achieve breeding objectives more efficiently. By harnessing genomic information, breeders can make more informed selection decisions, leading to enhanced productivity, disease resistance, and environmental adaptability in livestock populations. While challenges such as cost, data quality, and ethical considerations remain, ongoing advancements in genomics and computational biology continue to drive innovation in genomic selection methodologies. Looking ahead, the integration of genomic selection with emerging technologies such as genome editing and precision breeding holds immense potential for further enhancing the resilience, sustainability, and profitability of animal agriculture. As genomic selection continues to evolve, collaboration among researchers, breeders, and stakeholders will be crucial for realizing its full impact and ensuring its responsible and ethical application in shaping the future of animal breeding.

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