Career Vitae
DR. PAUL M. VANRADEN

Present Position
Research Geneticist (Animal)
Animal Genomics and Improvement Laboratory,
Agricultural Research Service, USDA

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Education
University of Illinois, B.S., dairy science, 1981
Iowa State University, M.S., animal breeding, 1984
Iowa State University, Ph.D., animal breeding, 1986

Employment
Graduate research assistant, Iowa State University, Ames, IA, 1982–86
Postdoctoral research associate, Iowa State University, Ames, IA, 1986
Postdoctoral research associate, University of Wisconsin, Madison, WI, 1987–88
Research geneticist (animal), Animal Genomics and Improvement Laboratory (formerly Animal Improvement Programs Laboratory), ARS, USDA, Beltsville, MD, 1988–present

Honors
American Dairy Science Association
- J. L. Lush Award in Animal Breeding, 2000
- *Journal of Dairy Science* featured article of the month (3 senior authorships, 2 coauthorships), 2013–15
- Most Cited Award, *Journal of Dairy Science*, Genetics and Breeding, 2011–12, 2016
- Northeast ADSA/ASAS Young Scientist Award, 1997
- Richard M. Hoyt Award (best doctoral research), 1986

Clarivate (formerly Thomson-Reuters) Highly Cited Researcher Award, 2014–17
Dairy Shrine Award for Undergraduate Achievement, 1981
Future Farmers of America's State Farmer degree, 1978
Iowa State University
- Holco Research Excellence Award in Animal Science, 1985
- T.A. Bancroft Award (statistics), 1986

National Association of Animal Breeders Research Award, 2002
University of Illinois
- Bronze Tablet Award (top 3% for academic achievement, College of Agriculture), 1981
- Department of Dairy Science's Leo Fryman Leadership Award, 1981

USDA
- Agricultural Research Service Early Career Scientist of the Year, 1995
- Spot award for overseeing development and implementation of all-breed animal model for genetic evaluation of US dairy cattle, 2007

Peer-Reviewed Scientific Publications

VanRaden, P.M., Freeman, A.E., and Rothschild, M.F. Maximizing genetic gain under multiple-stage selection. J. Dairy Sci. 67:1761–1766. 1984.

VanRaden, P.M., and Freeman, A.E. Potential genetic gains from producing bulls with only sires as parents. J. Dairy Sci. 68:1425–1431. 1985.

VanRaden, P.M., and Freeman, A.E. Rapid method to obtain bounds on accuracies and prediction error variances in mixed models. J. Dairy Sci. 68:2123–2133. 1985.

VanRaden, P.M., and Jung, Y.C. A general-purpose approximation to REML: The tilde-hat approach. J. Dairy Sci. 71:187–194. 1988.

VanRaden, P.M., Jensen, E.L., Lawlor, T.J., and Funk, D.A. Prediction of transmitting abilities for Holstein type traits. J. Dairy Sci. 73:191–197. 1990.

Wiggans, G.R., and **VanRaden, P.M.** Animal model evaluation within herd linked to national evaluations. J. Dairy Sci. 73:1956–1963. 1990.

Wiggans, G.R., and **VanRaden, P.M.** Including information from records in later herds in animal model evaluations. J. Dairy Sci. 73:3336–3339. 1990.

Hoeschele, I., and **VanRaden, P.M.** Rapid inversion of dominance relationship matrices for noninbred populations by including sire by dam subclass effects. J. Dairy Sci. 74:557–569. 1991.

VanRaden, P.M., and Hoeschele, I. Rapid inversion of additive by additive relationship matrices by including sire-dam combination effects. J. Dairy Sci. 74:570–579. 1991.

VanRaden, P.M., and Wiggans, G.R. Derivation, calculation, and use of national animal model information. J. Dairy Sci. 74:2737–2746. 1991.

VanRaden, P.M., Wiggans, G.R., and Ernst, C.A. Expansion of projected lactation yield to stabilize genetic variance. J. Dairy Sci. 74:4344–4349. 1991.

Wiggans, G.R., and **VanRaden, P.M.** Method and effect of adjustment for heterogeneous variance. J. Dairy Sci. 74:4350–4357. 1991.

Misztal, I., Lawlor, T.J., Short, T.H., and **VanRaden, P.M.** Multiple-trait estimation of variance components of yield and type traits using an animal model. J. Dairy Sci. 75:544–551. 1992.

Boettcher, P.J., Hansen, L.B., **VanRaden, P.M.**, and Ernst, C.A. Genetic evaluation of Holstein bulls for somatic cells in milk of daughters. J. Dairy Sci. 75:1127–1137. 1992.

Wiggans, G.R., **VanRaden, P.M.**, and Powell, R.L. A method for combining United States and Canadian bull evaluations. J. Dairy Sci. 75:2834–2839. 1992.

VanRaden, P.M., Lawlor, T.J., Short, T.H., and Hoeschele, I. Use of reproductive technology to estimate variances and predict effects of gene interactions. J. Dairy Sci. 75:2892–2901. 1992.

Peer-Reviewed Scientific Publications *(cont.)*

VanRaden, P.M. Accounting for inbreeding and crossbreeding in genetic evaluation of large populations. J. Dairy Sci. 75:3136–3144. 1992.

Schutz, M.M., **VanRaden, P.M.**, Boettcher, P.J., and Hansen, L.B. Relationship of somatic cell score and linear type trait evaluations of Holstein sires. J. Dairy Sci. 76:658–663. 1993.

Hoeschele, I., and **VanRaden, P.M.** Bayesian analysis of linkage between genetic markers and quantitative trait loci. II. Combining prior knowledge with experimental evidence. Theor. Appl. Genet. 85:946–952. 1993.

Hoeschele, I., and **VanRaden, P.M.** Bayesian analysis of linkage between genetic markers and quantitative trait loci. I. Prior knowledge. Theor. Appl. Genet. 85:953–960. 1993.

VanRaden, P.M., and Klaaskate, E.J.H. Genetic evaluation of length of productive life including predicted longevity of live cows. J. Dairy Sci. 76:2758–2764. 1993.

Schutz, M.M., **VanRaden, P.M.**, and Wiggans, G.R. Genetic variation in lactation means of somatic cell scores for six breeds of dairy cattle. J. Dairy Sci. 77:284–293. 1994.

Powell, R.L., Wiggans, G.R., and **VanRaden, P.M.** Factors affecting calculation and use of conversion equations for genetic merit of dairy bulls. J. Dairy Sci. 77:2679–2686. 1994.

VanRaden, P.M., and Wiggans, G.R. Productive life evaluations: Calculation, accuracy, and economic value. J. Dairy Sci. 78:631–638. 1995.

Wiggans, G.R., **VanRaden, P.M.**, and Zuurbier, J. Calculation and use of inbreeding coefficients for genetic evaluation of United States dairy cattle. J. Dairy Sci. 78:1584–1590. 1995.

Schutz, M.M., **VanRaden, P.M.**, Wiggans, G.R., and Norman, H.D. Standardization of lactation means of somatic cell scores for calculation of genetic evaluations. J. Dairy Sci. 78:1843–1854. 1995.

Weller, J.I., Wiggans, G.R., **VanRaden, P.M.**, and Ron, M. Application of a canonical transformation to detection of quantitative trait loci with the aid of genetic markers in a multi-trait experiment. Theor. Appl. Genet. 92:998–1002. 1996.

Powell, R.L., and **VanRaden, P.M.** Examination of international genetic evaluations of Holstein bulls. J. Dairy Sci. 79:1659–1665. 1996.

Lee, J.K., **VanRaden, P.M.**, Norman, H.D., Wiggans, G.R., and Meinert, T.R. Relationship of yield during early lactation and days open during current lactation with 305-day yield. J. Dairy Sci. 80:771–776. 1997.

Powell, R.L., **VanRaden, P.M.,** and Wiggans, G.R. Relationship between United States and Canadian genetic evaluations of longevity and somatic cell score. J. Dairy Sci. 80:1807–1812. 1997.

Ashwell, M.S., Rexroad Jr., C.E., Miller, R.H., **VanRaden, P.M.**, and Da, Y. Detection of loci affecting milk production and health traits in an elite US Holstein population using microsatellite markers. Anim. Genet. 28:216–222. 1997.

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VanRaden, P.M. Lactation yields and accuracies computed from test day yields and (co)variances by best prediction. J. Dairy Sci. 80:3015–3022. 1997.

Weigel, K.A., Lawlor Jr., T.J., **VanRaden, P.M.**, and Wiggans, G.R. Use of linear type and production data to supplement early predicted transmitting abilities for productive life. J. Dairy Sci. 81:2040–2044. 1998.

Ashwell, M.S., Da, Y., **VanRaden, P.M.**, Rexroad Jr., C.E., and Miller, R.H. Detection of putative loci affecting conformational type traits in an elite population of United States Holsteins using microsatellite markers. J. Dairy Sci. 81:1120–1125. 1998.

Ashwell, M.S., Da, Y., Van Tassell, **VanRaden, P.M**., Miller, R.H., and Rexroad Jr., C.E. Detection of putative loci affecting milk production and composition, health, and type traits in a United States Holstein population. J. Dairy Sci. 81:3309–3314. 1998.

Da, Y., **VanRaden, P.M.,** Beattie, C.W., Wu, C., and Schook, L.B. Designs of reference families for the construction of genetic linkage maps. Anim. Biotech. 9:205–225. 1998.

Norman, H.D., **VanRaden, P.M.**, Wright, J.R., and Clay, J.S. Comparison of test interval and best prediction methods for estimation of lactation yield from monthly, a.m.-p.m., and trimonthly testing. J. Dairy Sci. 82:438–444. 1999.

Norman, H.D., **VanRaden, P.M.**, Wright, J.R., and L.A. Smith. Mathematical representations of correlations among yield traits and somatic cell score on test day. J. Dairy Sci. 82:2205–2211. 1999.

Da, Y., **VanRaden, P.M.**, Ron, M., Beever, J.E., Paszek, A.A., Song, J., Wiggans, G.R., Ma, R., Weller, J.I., and Lewin, H.A. Standardization and conversion of marker polymorphism measures. Anim. Biotech. 10:25–35. 1999.

Heyen, D.W., Weller, J.I., Ron, M., Band, M., Beever, J.E., Feldmesser, E., Da, Y., Wiggans, G.R., **VanRaden, P.M.**, and Lewin, P.M. A genome scan for QTL influencing milk production and health traits in dairy cattle. Physiol. Genomics 1:165–175. 1999.

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Boettcher, P.J., Jairath, L.K., and **VanRaden, P.M.** Evaluation of sire predicted transmitting abilities for evidence of x-chromosomal inheritance in North American sire families. J. Dairy Sci. 84:256–265. 2001.

VanRaden, P.M. Methods to combine estimated breeding values obtained from separate sources. J. Dairy Sci. (E. Suppl.):E47–E55. 2001.

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VanRaden, P.M., and Sanders, A.H. Economic merit of crossbred and purebred US dairy cattle. J. Dairy Sci. 86:1036–1044. 2003.

Wiggans, G.R., **VanRaden, P.M.**, and Philpot, J.C. Detection and adjustment of abnormal test-day yields. J. Dairy Sci. 86:2721–2724. 2003.

Ashwell, M.S., Heyen, D.W., Sonstegard, T.S., Van Tassell, C.P., Da, Y., **VanRaden, P.M.**, Ron, M., Weller, J.I., and Lewin, H.A. Detection of quantitative trait loci affecting milk production, health, and reproductive traits in Holstein cattle. J. Dairy Sci. 87:468–472. 2004.

Kuhn, M.T., **VanRaden, P.M.**, and Hutchison, J.L. Use of early lactation days open records for genetic evaluation of cow fertility. J. Dairy Sci. 87:2277–2284. 2004.

VanRaden, P.M., Sanders, A.H., Tooker, M.E., Miller, R.H., Norman, H.D., Kuhn, M.T., and Wiggans, G.R. Development of a national genetic evaluation for cow fertility. J. Dairy Sci. 87:2285–2292. 2004.

VanRaden, P.M. Invited review: Selection on net merit to improve lifetime profit. J. Dairy Sci. 87:3125–3131. 2004.

Dechow, C.D., Rogers, G.W., Klei, L., Lawlor, T.J., and **VanRaden, P.M.** Body condition scores and dairy form evaluations as indicators of days open in US Holsteins. J. Dairy Sci. 87:3534–3541. 2004.

Norman, H.D., **VanRaden, P.M.**, Powell, R.L., Wright, J.R., and VerBoort, W.R. Effectiveness of national and regional sire evaluations in predicting future-daughter milk yield. J. Dairy Sci. 88:812–826. 2005.

Cole, J.B., Goodling Jr., R.C., Wiggans, G.R., and **VanRaden, P.M.** Genetic evaluation of calving ease for Brown Swiss, Jersey, and Holstein bulls from purebred and crossbred calvings. J. Dairy Sci. 88:1529–1539. 2005.

Norman, H.D., Wright, J.R., Powell, R.L., and **VanRaden, P.M.** Impact of maturity rate of daughters on genetic ranking of Holstein bulls. J. Dairy Sci. 88:3337–3345. 2005.

VanRaden, P.M., and Miller, R.H. Effects of nonadditive genetic interactions, inbreeding, and recessive defects on embryo and fetal loss by seventy days. J. Dairy Sci. 89:2716–2721. 2006.

Cole, J.B., and **VanRaden, P.M.** Genetic evaluation and best prediction of lactation persistency. J. Dairy Sci. 89:2722–2728. 2006.

VanRaden, P.M., Dematawewa, C.M.B., Pearson, R.E., and Tooker, M.E. Productive life including all lactations and longer lactations with diminishing credits. J. Dairy Sci. 89:3123–3220. 2006.

VanRaden, P.M., Tooker, M.E., Cole, J.B., Wiggans, G.R., and Megonigal Jr., J.H. Genetic evaluations for mixed-breed populations. J. Dairy Sci. 90:2434–2441. 2007.

Cole, J.B., Wiggans, G.R., and **VanRaden, P.M.** Genetic evaluation of stillbirth in United States Holsteins using a sire-maternal grandsire threshold model. J. Dairy Sci. 90:2480–2488. 2007.

Cole, J.B., Wiggans, G.R., **VanRaden, P.M.**, and Miller, R.H. Stillbirth (co)variance components for a sire-maternal grandsire threshold model and development of a calving ability index for sire selection. J. Dairy Sci. 90:2489–2496. 2007.

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Dematawewa, C.M.B., Pearson, R.E., and **VanRaden, P.M.** Modeling extended lactations of Holsteins. J. Dairy Sci. 90:3924–3936. 2007.

Norman, H.D., Wright, J.R., Powell, R.L., **VanRaden, P.M.**, Miglio, F., and de Jong, G. Consistency of maturity rate for milk yield across countries. J. Dairy Sci. 90:3937–3944. 2007.

Mark, T., Fikse, W.F., Sullivan, P.G., and **VanRaden, P.M.** Prediction of genetic correlations and international breeding values for missing traits. J. Dairy Sci. 90:4805–4813. 2007.

VanRaden, P.M. Efficient methods to compute genomic predictions. J. Dairy Sci. 91:4414–4423. 2008.

VanRaden, P.M., Van Tassell, C.P., Wiggans, G.R., Sonstegard, T.S., Schnabel, R.D., Taylor, J.F., and Schenkel, F.S. Invited review: Reliability of genomic predictions for North American Holstein bulls. J. Dairy Sci. 92:16–24. 2009.

Cole, J.B., Null, D.J., and **VanRaden, P.M.** Best prediction of yields for long lactations. J. Dairy Sci. 92:1796–1810. 2009.

Norman, H.D. Wright, J.R., Kuhn, M.T., Hubbard, S.M., Cole, J.B., and **VanRaden, P.M.** Genetic and environmental factors that affect gestation length in dairy cattle. J. Dairy Sci. 92:2259–2269. 2009.

Cole, J.B., **VanRaden, P.M.**, O'Connell, J.R., Van Tassell, C.P., Sonstegard, T.S., Schnabel, R.D., Taylor, J.F., and Wiggans, G.R. Distribution and location of genetic effects for dairy traits. J. Dairy Sci. 92:2931–2946. 2009.

Wiggans, G.R., Sonstegard, T.S., **VanRaden, P.M.**, Matukumalli, L.K., Schnabel, R.D., Taylor, J.F., Schenkel, F.S., and Van Tassell, C.P. Selection of single-nucleotide polymorphisms and quality of genotypes used in genomic evaluation of dairy cattle in the United States and Canada . J. Dairy Sci. 92:3431–3436. 2009.

VanRaden, P.M., and Sullivan, P. International genomic evaluation methods for dairy cattle. Genet. Sel. Evol. 42:7. 2010.

Weigel, K.A., Van Tassell, C.P., O'Connell, J.R., **VanRaden, P.M.**, and Wiggans, G.R. Prediction of unobserved single nucleotide polymorphism genotypes of Jersey cattle using reference panels and population-based imputation algorithms. J. Dairy Sci. 93:2229–2238. 2010.

Wiggans, G.R., **VanRaden, P.M.**, Bacheller, L.R., Tooker, M.E., Hutchison, J.L., Cooper, T.A., and Sonstegard, T.S. Selection and management of DNA markers for use in genomic evaluation. J. Dairy Sci. 93:2287–2292. 2010.

Cole, J.B., and **VanRaden, P.M.** Visualization of results from genomic evaluations. J. Dairy Sci. 93:2727–2740. 2010.

Cole, J.B., and **VanRaden, P.M.** Use of haplotypes to estimate Mendelian sampling effects and selection limits. J. Anim. Breed. Genet. 128:448–445. 2011.

Olson, K.M., **VanRaden, P.M.**, Tooker, M.E., and Cooper, T.A. Differences among methods to validate genomic evaluations for dairy cattle. J. Dairy Sci. 94:2613–2620. 2011.

Wiggans, G.R., **VanRaden, P.M.**, and Cooper, T.A. The genomic evaluation system in the United States: Past, present, future. J. Dairy Sci. 94:3202–3211. 2011.

Peer-Reviewed Scientific Publications *(cont.)*

VanRaden, P.M., Olson, K.M., Wiggans, G.R., Cole, J.B., and Tooker, M.E. Genomic inbreeding and relationships among Holsteins, Jerseys, and Brown Swiss. J. Dairy Sci. 94:5673–5682. 2011.

Norman, H.D., Hutchison, J.L., and **VanRaden, P.M.** Evaluations for service-sire conception rate for heifer and cow inseminations with conventional and sexed semen. J. Dairy Sci. 94:6135–6142. 2011.

VanRaden, P.M., Olson, K.M., Null, D.J., and Hutchison, J.L. Harmful recessive effects on fertility detected by absence of homozygous haplotypes. J. Dairy Sci. 94:6153–6161. 2011.

Wiggans, G.R., Cooper, T.A., **VanRaden, P.M.**, and Cole, J.B. Technical note: Adjustment of traditional cow evaluations to improve accuracy of genomic predictions. J. Dairy Sci. 94:6188–6193. 2011.

VanRaden, P.M., O'Connell, J.R., Wiggans, G.R., and Weigel, K.A. Genomic evaluations with many more genotypes. Genet. Sel. Evol. 43:10. 2011.

Wiggans, G.R., Cooper, T.A., **VanRaden, P.M.**, Olson, K.M., and Tooker, M.E. Use of Illumina Bovine3K Beadchip in dairy genomic evaluation. J. Dairy Sci. 95:1552–1558. 2012.

Boichard, D., Chung, H., Dassonneville, R., David, X., Eggen, A., Fritz, S., Gietzen, K.J., Hayes, B.J., Lawley, C.T., Sonstegard, T.S., Van Tassell, C.P., **VanRaden, P.M.**, Viaud-Martinez, K.A., and Wiggans, G.R. Design of a bovine low-density SNP array optimized for imputation. PLoS One 7:e34130. 2012.

Wiggans, G.R., **VanRaden, P.M.**, and Cooper, T.A. Technical note: Adjustment of all cow evaluations for yield traits to be comparable with bull evaluations. J. Dairy Sci. 95:3444–3447. 2012.

Olson, K.M., **VanRaden, P.M.**, and Tooker, M.E. Multibreed genomic evaluations using purebred Holsteins, Jerseys, and Brown Swiss . J. Dairy Sci. 95:5378–5383. 2012.

Hou, Y., Liu, G.E., Bickhart, D.M., Cardone, M., Wang, K., Kim, E.-S., Matukumalli, L.K., Ventura, M., Song, J., **VanRaden, P.M.**, Sonstegard, T.S., and Van Tassell, C.P. Genomic characteristics of cattle copy number variations. BMC Genomics 12:127. 2012.

Misztal, I., Tsuruta, S., Aguilar, I., Legarra, A., **VanRaden, P.M.**, and Lawlor, T.J. Methods to approximate reliabilities in single-step genomic evaluation. J. Dairy Sci. 96:647–654. 2013.

VanRaden, P.M., Null, D.J., Sargolzaei, M., Wiggans, G.R., Tooker, M.E., Cole, J.B., Sonstegard, T.S., Connor, E.E., Winters, M., van Kaam, J.B.C.H.M., Valenti, A., Van Doormaal, B.J., Faust, M.A., and Doak, G.A. Genomic imputation and evaluation using high density Holstein genotypes. J. Dairy Sci. 96:668–678. 2013.

Sonstegard T.S., Cole J.B., **VanRaden P.M.**, Van Tassell C.P., Null D.J., Schroeder, S.G., Bickhart, D.M., and McClure, M.C. Identification of a nonsense mutation in CWC15 associated with decreased reproductive efficiency in Jersey cattle. PLoS ONE 8:e54872. 2013.

Hutchison, J.L., **VanRaden, P.M.**, Norman, H.D., and Cole, J.B. Technical note: Change to herd cutoff date in conception rate evaluations. J. Dairy Sci. 96:1264–1268. 2013.

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Cooper, T.A., Wiggans, G.R., and **VanRaden, P.M.** Short communication: Relationship of call rate and accuracy of single nucleotide polymorphism genotypes in dairy cattle. J. Dairy Sci. 96:3336–3339. 2013.

Weller, J.I., **VanRaden, P.M.**, and Wiggans, G.R. Application of a posteriori granddaughter and modified granddaughter designs to determine Holstein haplotype effects. J. Dairy Sci. 96:5376–5387. 2013.

Sun, C., **VanRaden P.M.**, O'Connell J.R., Weigel, K.A., and Gianola, D. Mating programs including genomic relationships and dominance effects. J. Dairy Sci. 96:8014–8023. 2013.

Sun, C., and **VanRaden P.M.** Increasing long-term response by selecting for favorable minor alleles. PloS ONE 9:e8850. 2014.

McClure, M.C., Bickhart, D., Null, D., **VanRaden, P.**, Xu, L., Wiggans, G., Liu, G., Schroeder, S., Glasscock, J., Armstrong, J., Cole, J.B., Van Tassell, C.P., and Sonstegard, T.S. Bovine exome sequence analysis and targeted SNP genotyping of recessive fertility defects BH1, HH2, and HH3 reveal a putative causative mutation in *SMC2* for HH3. PLoS ONE 9:e92769. 2014.

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Xu, L., Cole, J.B., Bickhart, D.M., Hou, Y., Song, J., **VanRaden, P.M.**, Sonstegard, T.S., Van Tassell, C.P., and Liu, G.E. Genome wide CNV analysis reveals additional variants associated with milk production traits in Holsteins. BMC Genomics 15:683. 2014.

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Cooper, T.A., Wiggans, G.R., and **VanRaden, P.M.** Short communication: Analysis of genomic predictor population for Holstein dairy cattle in the United States—Effects of sex and age. J. Dairy Sci. 98:2785–2788. 2015.

Wiggans, G.R., Su, G., Cooper, T.A., Nielsen, U.S., Aamand, G.P., Guldbrandtsen, B., Lund, M.S., and **VanRaden, P.M.** *Short communication:* Improving accuracy of Jersey genomic evaluations in the United States and Denmark by sharing reference population bulls. J. Dairy Sci. 98:3508–3513. 2015.

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Ma, L., O'Connell, J.R., **VanRaden, P.M.**, Shen, B., Padhi, A. Sun, C., Bickhart, D.M., Cole, J.B., Null, D.J., Liu, G.E., Da, Y., and Wiggans, G.R. Cattle sex-specific recombination and genetic control from large pedigree analysis. PLoS Genet. 11:e1005387. 2015.

VanRaden, P.M. Practical implications for genetic modeling in the genomics era. J. Dairy Sci. 99:2405–2412. 2016.

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Bickhart, D.M., Hutchison, J.L., Null, D.J., **VanRaden, P.M.**, and Cole, J.B. Reducing animal sequencing redundancy by preferentially selecting animals with low-frequency haplotypes. J. Dairy Sci. 99:5526–5534. 2016.

García-Ruiz, A., Cole, J.B, **VanRaden, P.M.**, Wiggans, G.R., Ruiz-López, F.J., and Van Tassell, C.P. Changes in genetic selection differentials and generation intervals in US Holstein dairy cattle as a result of genomic selection. Proc. Natl. Acad. Sci. 113:E3995–4004. 2016.

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