

## **Scope for genetic evaluation and selection of beef cattle for growth to weaning when birth dates are not recorded**

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### *Abstract*

Estimates of (co)variance components and genetic parameters were obtained for a pre-weaning weight, recorded between two and five months after birth, and the subsequent gain till weaning for two herds in a selection experiment in Western Australia. Analyses were carried out both accounting for age at weighing and assuming birth dates and thus ages were unknown. Adjusting for the interval between weighings, preweaning gain appeared to be independent of age and equally heritable to weaning weight. Estimates of the direct genetic correlation between preweaning gain and weaning weight (adjusted for age) were 0.9 or higher while both genetic and permanent environmental maternal correlations were close to unity. Implications for the use of preweaning weight as an alternative selection criterion to weaning weight when birth dates are not recorded are discussed.

### **Introduction**

Traits usually considered in the genetic evaluation of beef cattle for growth potential are weights at various ages or gains calculated as differences between such weights. Weights most frequently recorded are birth, weaning, yearling and final weight, and weighings must fit in with other tasks required in the production cycle. In a natural mating situation, calvings generally spread over a period of two to three months or even more. This often leads to considerable differences in age of animals at a particular weighing, for example at weaning, and corresponding differences in size. In order to compare growth of animals accurately, it is thus paramount to know their birth dates and to be able to adjust for differences in age.

In many extensive production situations, however, birth weight is not recorded, in particular for breeds where calving problems are negligible and selection pressure attempting to restrict birth weight while increasing growth potential is not required. In that case, recording of birth dates for the purpose of genetic evaluation can represent a considerable expense, and alternative recording protocols and selection criteria, even if reducing potential selection response to some extent, might be advantageous. The scope for selection on a correlated trait depends on the genetic parameters of the traits in question, in particular the genetic correlation(s).

For illustration, consider the simple case of an animal with record  $Y_A$  for a certain trait A, and assume that there are no maternal effects. The estimate of the animal's breeding value for trait A is then  $BV_A = h_A^2 Y_A$ , where  $h_A^2$  denotes the direct heritability for A. If  $Y_A$  is not measured but a record for a correlated trait B,  $Y_B$ , with heritability  $h_B^2$  is available, the breeding value estimate for A is  $BV_A = r_G h_A h_B s_A / s_B Y_B$  with  $r_G$  the genetic correlation between A and B, and  $s_A$  and  $s_B$  denoting the respective phenotypic standard deviations. The potential response in trait A when selecting on the basis of records for trait B thus depends on the heritabilities of the two traits and the genetic correlation between them. The term  $r_G h_A h_B$  is often

referred to as the co-heritability of traits A and B, and the correlated response to selection is proportional to the co-heritability times the selection intensity (Falconer, 1989).

If birth dates are unknown, the obvious alternative traits to weights at a certain date, which are heavily dependent on the animals' age, are gains between weighings. Some genetic evaluation schemes for beef cattle already use postweaning gain in preference to a postweaning weight, such as yearling or final weight, since it is generally not subject to maternal effects. Correspondingly, weaning weight could be replaced by a preweaning gain. With birth weight and dates not recorded, this would necessitate an additional weight to be taken between birth and weaning. From a management point of view, however, this might be more convenient since all animals in a herd could be weighed at the same time, for instance at marking. While such preweaning gain might be affected by age, this is likely to be much less important than for weaning weight.

This paper examines a preweaning weight taken within two to three months of the end of the calving period and the corresponding gain till weaning. It investigates the scope for selection for weaning weight on the basis of preweaning gain when birth dates and weights are not recorded.

## **Material and Methods**

### *Data*

The data used originated from a selection experiment carried out at the Wokalup research station in the South West of Western Australia. This experiment comprised two herds of about 300 cows each, one being Polled Herefords and the other a multi-breed synthetic formed by mating Charolais × Brahman bulls with Friesian × Angus or Hereford cows. This synthetic breed was named Wokalups. Selection was carried out at weaning for improved growth from birth till weaning. Further details of the experiment, production environment, management and data structure are given by Meyer *et al.* (1993).

Matings occurred between the second half of June and early September each year, resulting in the bulk of calvings in April and May. Calves were generally weaned in November or December. All calves were weighed at birth and subsequently at monthly intervals. From these monthly weighings, a preweaning weight (PWW) was selected and the subsequent gain till weaning (PWG) calculated. Four sampling schemes were considered in order to examine the effect of recording date on the utility of these measures :

*All weights taken in June.* This represented a single weighing at the end of the calving period and included some calves just born.

*All weights recorded in August.* This was similar to the first data set but calves were at least 6 weeks old.

*One weight taken between June and August.* To obtain a wider spread of preweaning weighings, one weight amongst those taken in June, July and August was randomly chosen for each animal in the third analysis. This was chosen to mimic a distribution of ages at preweaning weighing in herds with longer mating and calving periods than in the experimental situation.

*July or September weights.* The fourth alternative, finally, combined a July weight for animals which were more than 14 days old with a September weight for the remainder or animals without a July weight record. This was intended to represent a scheme where PWWs were measured at separate occasions two months apart.

For bivariate analyses of PWG together with birth weight (BW), weaning weight (WW) or PWW, only the latter sampling scheme for PWWs was used. Weaning dates were available for each year and WW records

**Table 1** : Characteristics of the data structure for univariate analyses of preweaning weight (PWW) and preweaning gain (PWG) [kg], considering different weighing dates.

	Herefords				Wokalups				
	June	Aug.	Jun-Aug	Jul/Sep	June	Aug.	Jun-Aug	Jul/Sep	
No. records	2053	1942	2048	2567	2162	1995	2160	2603	
No. animals <sup>A</sup>	2554	2433	2554	2995	2830	2574	2828	3143	
No. sires <sup>B</sup>	151	118	150	156	170	134	170	159	
No. dams <sup>B</sup>	675	603	671	771	740	672	738	843	
PWW	$\bar{x}$	67.9	127.0	88.6	102.3	76.6	145.7	100.1	119.9
	sd	19.4	27.7	32.7	30.3	22.8	29.4	37.7	34.5
PWG	$\bar{x}$	177.7	121.4	157.3	140.9	196.6	131.7	173.2	155.1
	sd	33.7	25.4	36.4	38.6	34.0	26.7	40.5	40.9
Age <sup>C</sup>	$\bar{x}$	45.2	114.8	70.1	88.1	41.3	112.1	65.5	85.7
	sd	20.0	18.8	35.1	26.9	20.6	20.4	36.0	27.3
Interval <sup>D</sup>	$\bar{x}$	178.6	112.6	154.0	137.0	178.7	112.8	154.5	136.9
	sd	16.4	15.9	29.7	30.3	16.0	14.1	29.6	30.1

<sup>A</sup>in the analysis, including parents without records

<sup>B</sup>with progeny in the data

<sup>C</sup>at weighing [days]

<sup>D</sup>between preweaning and weaning weighing dates [days]

selected for all animals were the monthly weights for each animal taken closest to this date, restricting age at weighing as for BREEDPLAN (Schneeberger *et al.*, 1991) to 120 to 300 days. All BW and WW records available were utilised, i.e. including those for animals without a PWG record.

### Analyses

Estimates of variance and covariance components were obtained by Restricted Maximum likelihood (REML) using a derivative-free algorithm and fitting an animal model throughout, incorporating all pedigree information available. Maternal genetic and permanent environmental effects were taken into account by including appropriate random effects into the model of analysis as described by Meyer (1989, 1991a). Previous analyses (Meyer *et al.*, 1993) had shown that direct-maternal genetic covariances for both BW and WW were not significantly different from zero in the data considered here. Hence analyses were carried out assuming no direct-maternal genetic correlation, i.e. fitting Model 5 of previous analyses throughout. All calculations were performed using DFREML (Meyer, 1991b).

Fixed effects fitted were sex, birth type (single *vs.* twin), and year-paddock and year-month of weighing subclasses. Age at weighing, dam age and interval between weighings (PWG only) were taken into account by fitting each of them as a linear and quadratic covariable. For a proportion of animals, age of dam could not be calculated due to unknown birth dates of the dams. For these animals dam age was replaced by the mean age in the respective data set.

Univariate analyses of PWW and PWG were carried out for each breed and each of the four sampling strategies in- and excluding age at weighing as a covariable. Bivariate analyses of PWG together with BW, PWW or WW fitted age at weighing for the weights (i.e PWW or WW) but not PWG. For these, only the July/September preweaning weighing scheme was considered.

### Results

**Table 2** : Characteristics of the data structure and estimates of phenotypic variances ( $\sigma_P^2$ ) and genetic parameters<sup>A</sup> for birth weight (BW) and weaning weight (WW)<sup>B</sup>, together with numbers of animals in bivariate analyses of BW or WW with preweaning gain.

	Herefords		Wokalups	
	BW	WW	BW	WW
No. records	3414	3088	3769	3190
Mean [kg]	31.5	227.6	36.0	257.7
sd	5.3	51.5	6.3	52.9
$\sigma_P^2$	18.6	752.5	28.4	764.3
$h^2$	0.43	0.19	0.52	0.27
$m^2$	0.11	0.14	0.05	0.07
$c^2$	0.09	0.20	0.04	0.11
No. animals in bivariate analyses				
records for both traits	2566	2567	2602	2603
records for BW/WW only	848	521	1167	587
in the analysis <sup>C</sup>	3783	3426	4524	3856

<sup>A</sup> $h^2$ : direct heritability,  $m^2$ : maternal heritability, and  $c^2$ : permanent environmental maternal effects.

<sup>B</sup>From Meyer *et al.* (1993).

<sup>C</sup>including parents without records

Characteristics of the data structure for each of the four weighing schemes are summarised in Table 1. Accounting for differences in size, PWW and PWG were about equally variable in the two breeds. Considering preweaning weights taken in different months (June-August and July/September) roughly doubled the standard deviation in interval from preweaning to weaning weighings compared to single date weighings (June, August) and, correspondingly, increased the variation in age at weighing considerably. Numbers of records, means and standard deviations for BW and WW are given in Table 2 together with estimates of genetic parameters from previous, univariate analyses of BW and WW and numbers of animals in bivariate analyses with PWG.

### Univariate Analyses

Results from univariate analyses of PWW and PWG are summarised in Table 3. For all four sampling schemes, ignoring age increased estimates of the phenotypic variance ( $\sigma_P^2$ ) for PWW dramatically in both breeds. This was most pronounced for June weights which included a proportion of newly born or very young calves, emphasizing the major effect age has on weight and that age differences are most important in the earlier periods of growth. Adjusting for age, estimates of  $\sigma_P^2$  were, except for July/September weighings, similar for both breeds. Ignoring age,  $\hat{\sigma}_P^2$  were considerably larger for Wokalups than Herefords though variation in age was similar for the two breeds (the superscript  $\hat{\phantom{x}}$  denoting a parameter estimate).

For Herefords, estimates of genetic parameters for PWW differed markedly between analyses allowing for and ignoring differences in age at weighing. Not fitting age, estimates of the direct heritability ( $h^2$ ) were consistently higher than those obtained adjusting for age. Correspondingly, estimates of the maternal heritability ( $m^2$ ) and the proportion of  $\sigma_P^2$  explained by permanent environmental maternal effects ( $c^2$ ) were considerably lower ignoring age than allowing for it. In other words, analyses not fitting age attributed differences between animals largely to (direct) additive genetic differences between animals in growth potential and thus identified less maternal effects. Accounting for age, values for  $\hat{m}^2$  and  $\hat{c}^2$  were similar to corresponding estimates for WW of 0.14 and 0.20 (Meyer *et al.*, 1993), especially for weighing schemes

**Table 3** : Estimates of phenotypic variances ( $\sigma_P^2$ ) and genetic parameters<sup>A</sup> from univariate analyses of preweaning weight and preweaning gain, accounting for and ignoring age at weighing and considering various weighing schemes.

Breed <sup>B</sup>		June		Aug.		June-Aug.		July/Sept.	
		w/out <sup>C</sup>	with <sup>D</sup>	w/out	with	w/out	with	w/out	with
<i>Prewaning weight</i>									
Hef	$\sigma_P^2$	208.2	94.9	429.0	279.3	286.4	165.4	346.4	230.3
	$h^2$	0.31	0.20	0.26	0.11	0.23	0.13	0.25	0.14
	$m^2$	0.01	0.13	0.11	0.23	0.03	0.14	0.06	0.15
	$c^2$	0.07	0.23	0.11	0.23	0.08	0.16	0.11	0.22
Wok	$\sigma_P^2$	311.2	93.9	485.9	271.6	354.8	159.7	418.3	213.6
	$h^2$	0.24	0.24	0.25	0.26	0.20	0.20	0.29	0.26
	$m^2$	0.02	0.04	0.01	0.03	0.00	0.01	0.01	0.05
	$c^2$	0.06	0.08	0.14	0.19	0.09	0.12	0.10	0.15
<i>Prewaning gain</i>									
Hef	$\sigma_P^2$	467.3	461.3	266.2	264.8	393.0	388.1	327.4	324.1
	$h^2$	0.23	0.23	0.18	0.19	0.22	0.22	0.16	0.16
	$m^2$	0.16	0.18	0.11	0.11	0.16	0.17	0.10	0.10
	$c^2$	0.07	0.08	0.14	0.19	0.09	0.12	0.10	0.15
Wok	$\sigma_P^2$	523.5	522.2	288.0	289.0	447.6	445.1	381.2	380.3
	$h^2$	0.37	0.37	0.37	0.37	0.36	0.35	0.43	0.43
	$m^2$	0.07	0.07	0.00	0.01	0.08	0.08	0.00	0.01
	$c^2$	0.10	0.10	0.07	0.07	0.07	0.07	0.05	0.05

<sup>A</sup> $h^2$ : direct heritability,  $m^2$ : maternal heritability, and  $c^2$ : permanent environmental maternal effects.

<sup>B</sup>Hef: Herefords, Wok : Wokalups.

<sup>C</sup>analysis assuming age at weighing is unknown.

<sup>D</sup>analysis fitting age at weighing as a covariable.

not including newborn or very young calves.

For Wokalups, however, there were little differences in  $\hat{h}^2$  and  $\hat{m}^2$  for PWW between analyses with and without age, and only a small but consistent increase in  $\hat{c}^2$  when allowing for age. As for WW (*cf* Meyer *et al.*, 1993), estimates of direct heritabilities for PWW were considerably higher and estimates of maternal heritabilities were lower in Wokalups than in Herefords, especially for the later sampling schemes (August and July/September). For WW, this pattern has been attributed to differences in milk production between the breeds, milk available in Herefords often limiting growth of calves. Estimates indicate that this holds to a similar extent for PWW.

In contrast to PWW, estimates of  $\sigma_P^2$  and genetic parameters for PWG were very similar whether or not age at weighing was taken into account. To some extent, this could be explained by age effects on both PWW and WW being similar and thus being canceled out when the difference between WW and PWG is considered. Furthermore, fitting the length of interval between PWW and WW weighings as a covariable might have removed variation in PWG due to differences in age as well due to differences in time between weighings as longer intervals were generally associated with younger ages at weighing.

Direct heritability estimates for PWG were higher than for PWW, adjusting for age, especially for Wokalups. Correspondingly, estimates of maternal effects for PWG were lower than for PWW. In particular,  $\hat{c}^2$  was considerably lower for PWG than PWW for both breeds, except for June weighings in Wokalups. This re-

flects the fact, in part at least, that maternal effects on preweaning and weaning weights are highly correlated and thus quite similar, so that in considering PWG only the difference between maternal effects on PWW and WW is found to affect PWG. Shi *et al.* (1993) found lower estimates of  $m^2$  and  $c^2$  for gain from 120 to 210 days than for gain from birth to 120 days in French Limousins and attributed this to calves being able to eat supplemental feed in the later parts of lactation and maternal effects (milk production) thus becoming less important.

Estimates for PWG were comparable overall to previous estimates for preweaning gain considering growth from birth till weaning (PWGB). Baker (1980) gave average literature values of  $\hat{h}^2$  and  $\hat{m}^2$  for PWGB of 0.26 and 0.24, respectively, with a corresponding direct-maternal genetic correlation ( $r_{AM}$ ) estimate of -0.45. Trus and Wilton (1988) reported estimates of  $h^2$ ,  $m^2$  and  $r_{AM}$  for PWGB in Canadian Herefords of 0.30, 0.27 and -0.42, while Mackinnon *et al.* (1991) found values of 0.16, 0.31 and 0.00, respectively, in Australian Zebu Crosses. None of these studies, however, fitted maternal permanent environmental effects, i.e. estimates of  $m^2$  were likely to reflect both genetic and environmental maternal effects and should be compared to the sums of  $\hat{m}^2$  and  $\hat{c}^2$  from our analyses.

On the whole, estimates for the four preweaning weighing strategies were remarkably consistent, considering the fact that they comprised records taken over a wide range of ages, in particular for the June-August and July/September schemes. This suggests that PWG is quite robust and that genetic parameters for this trait are similar across a wide range of ages at preweaning weighing. Hence only one weighing scheme, the July/September regime, was considered in bivariate analyses of PWG together with PWW or WW.

### *Bivariate Analyses*

Results from joint analyses of PWG together with BW, PWW and WW, respectively are given in Table 4. Overall estimates of genetic parameters for each trait agreed reasonably well with their univariate counterparts, see Table 2 for BW and WW and Table 3 for PWG and PWW. Only  $\hat{h}^2$  for PWG in Wokalups from an analysis together with WW was considerably lower than the univariate estimate or corresponding values from bivariate analyses of PWG with BW or PWW. This could only be attributed to sampling variation.

Estimates of all correlations between PWG and WW were consistently high and very similar for the two breeds. All maternal correlation estimates, both genetic and permanent environmental, were close to unity, indicating, not surprisingly, that maternal effects on WW were virtually identical to those on PWG. Analogously, all estimates of maternal correlations between PWG and PWW were similarly high, ranging from 0.9 to unity. Direct genetic correlations ( $r_A$ ) of PWG with PWW were moderate, and low for PWG and BW. Corresponding phenotypic correlations ( $r_P$ ) of PWG with both BW and PWW were low, ranging from 0.36 to 0.44. Mackinnon *et al.* (1991) reported somewhat lower estimates of  $r_A$  and  $r_P$  for Australian Zebu Crosses between PWGB and BW of 0.36 and 0.24, while a value of 0.94 for both  $\hat{r}_A$  and  $\hat{r}_P$  between PWGB and WW was comparable to our results. For all three weights, estimates of  $r_A$  with PWG were higher for Wokalups than Herefords, emphasizing the fact that maternal milk production is less limiting in Wokalups than in Herefords and that direct growth potential of a Wokalup calf is thus more important in determining its growth rate.

Estimates of genetic parameters in Table 4 give co-heritabilities for direct genetic effects of 0.12 and 0.25 between BW and PWG, and 0.13 and 0.23 between WW and PWG for the Hereford and Wokalup data sets, respectively. For BW, these were considerably smaller than the respective heritability estimates of 0.43 (Herefords) and 0.51 (Wokalups). For WW, however, the co-heritabilities with PWG were only slightly smaller than the corresponding heritability estimates of 0.14 and 0.25 for Herefords and Wokalups, respectively. Similar results hold for the maternal co-heritabilities of WW and PWG. This implies that, with the same number of animals recorded and selected, about 90% of the response to selection in WW through direct selection on WW could be achieved through indirect selection on the basis of PWG. Alternatively,

**Table 4** : Estimates of (co)variance components<sup>A</sup> and genetic parameters<sup>B</sup> from bivariate analyses of preweaning gain (PWG) (trait 1) together with birth weight (BW), preweaning weight (PWW) and weaning weight (WW) (trait 2).

Trait 2	<i>i</i>	<i>j</i>	$\sigma_{Aij}$	$\sigma_{Mij}$	$\sigma_{Cij}$	$\sigma_{Eij}$	$\sigma_{Pij}$	$h^{2C}$	$m^{2C}$	$c^{2C}$	$r_P$
								$r_A$	$r_M$	$r_C$	
<i>Herefords</i>											
BW	1	1	56.2	34.1	19.5	224.1	334.0	0.17	0.10	0.06	0.36
	1	2	9.5	3.2	4.7	10.6	28.0	0.44	0.39	0.80	
	2	2	8.2	1.9	1.8	6.8	18.6	0.44	0.10	0.09	
PWW	1	1	55.7	38.9	18.3	225.5	338.4	0.17	0.12	0.05	
	1	2	22.4	34.4	30.7	21.1	108.6	0.56	0.93	1.00	
	2	2	29.3	35.1	51.5	113.4	229.3	0.13	0.15	0.23	
WW	1	1	48.4	35.7	23.6	237.3	345.0	0.14	0.10	0.07	
	1	2	66.5	68.5	61.1	262.6	458.7	0.90	0.99	1.00	0.87
	2	2	114.2	135.4	158.2	396.4	804.3	0.14	0.17	0.20	
<i>Wokalups</i>											
BW	1	1	160.0	5.1	18.4	216.7	400.2	0.40	0.01	0.05	0.41
	1	2	26.5	2.7	0.7	14.1	44.0	0.55	0.95	0.15	
	2	2	14.5	1.6	1.2	11.2	28.5	0.51	0.06	0.04	
PWW	1	1	167.8	10.3	20.8	208.2	407.0	0.41	0.03	0.05	
	1	2	73.0	11.6	22.8	24.9	132.3	0.72	1.00	0.90	
	2	2	60.8	13.0	31.1	115.5	220.5	0.28	0.06	0.14	
WW	1	1	96.8	5.1	25.3	251.3	378.5	0.26	0.01	0.07	
	1	2	128.6	11.3	50.3	399.9	490.1	0.93	1.00	0.97	0.89
	2	2	197.7	25.4	107.0	475.9	806.0	0.25	0.03	0.13	

<sup>A</sup> $\sigma_{Aij}$  : direct additive genetic covariance,  $\sigma_{Rij}$  : permanent environmental covariance due to the animal,  $\sigma_{Eij}$  : residual covariance, and  $\sigma_{Pij}$  : phenotypic covariance.

<sup>B</sup> $h^2$  : direct heritability,  $m^2$  : maternal heritability,  $c^2$  : permanent environmental maternal effects,  $r_A$  : direct genetic correlation,  $r_M$  : maternal genetic correlation,  $r_C$  : permanent environmental maternal correlation, and  $r_E$  : residual correlation, and  $r_P$  : phenotypic correlation.

<sup>C</sup>First line parameter for  $i = j$ , second line parameter for  $i \neq j$

additional animals could be recorded for PWG and this could be included in a multi-trait mixed model as a correlated trait, increasing the accuracy of estimation of breeding values for WW and to a much smaller extend BW.

## Discussion

Management practices in commercial herds and many Northern Australian stud herds do not normally include recording of individual birth dates of calves, which is a prerequisite for recording on Australia's National Beef Recording Scheme. However, many of these herds have the ability to weigh the calves at marking early in life, and calves could be weighed again at weaning to allow the calculation of a preweaning gain which could be used *in lieu* of a WW in a genetic evaluation scheme for growth when birth date and thus age at weaning is unknown. Results from this study indicate that this would be worthwhile : preweaning gain appears to be almost independent from age of calf at preweaning weighing or marking when adjusted for the interval between weighings. Furthermore, it has a very high genetic correlation with WW and a heritability of similar magnitude than WW itself.

However, it has to be emphasized that the calculations above are based on the assumption that the accuracy of parental identification is unchanged. If birth dates are not recorded, a very good and reliable mothering up system is required, as otherwise the pedigree information might be wrong for a large proportion of animals. As this is utilised in genetic evaluation, it would render the breeding value estimation unreliable, thus negating any beneficial effects of obtaining additional information through the inclusion of PWG. In breeds or herds for which mothering up is not a reliable method to identify parents, an animal model evaluation for PWG is unsuitable, as heritabilities will be underestimated, resulting in increased relative weights being given to the wrong parents. For such groups of animals, birth date and dam identification should be recorded.

Results for the different sampling schemes indicate that actual age of the calf at first weighing is of secondary importance. Hence a single weighing of all calves shortly after the end of the calving season is recommended. It has to be stressed, however, that this study used data from an experimental herd with a somewhat unusual management scheme (groups of 25 cows were kept in separate 20 hectare paddocks year round; see Meyer *et al.* (1993)) which resulted in an almost linear growth of calves. Results need to be confirmed for commercial production conditions. While it appears reasonable to expect results to be transferable to other herds with *bos taurus* cattle and temperate environments, relationships between PWG and WW need to be re-examined for herds in Northern Australia where cattle (*bos indicus*), management and seasonal growth patterns are very different.

If results from this study can be verified in field data, the additional information which could be collected in commercial herds to improve the accuracy of estimated breeding values of registered stud animals in a national evaluation could be quite substantial. In particular, it would allow weight information to be recorded on animals for which carcass information from abattoirs becomes available at a later stage.

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