Analysis of Quantitative Genetic Variation by Nested Analysis of Variance and Offspring-Parent Regression

A Program Package - NESREG

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CONTENTS

I GENERAL

This package computes a complete analysis of variance (AOV) and covariance (AOCOV) table for a nested classification of up to six levels (the lowest three levels being sires, dams, and progeny) on balanced or unbalanced (see Table 1) data. From this analysis of full- and half-sibs all commonly applied quantitative genetic parameters are estimated. By providing parent data and combining the appropriate sum of squares (products) estimates from the AOV's and AOCOV's of parent and progeny data, offspring on parent regression (O-P) and correlation analyses are possible and are produced on request. Three versions of the package are currently available.

(a) Version 1

Written in FØRTRAN IV for an IBM 7040 computer with 32K store. It is divided into two programs (NESRG1 - with the subroutines FULSIB & READX, & NESRG2 with the subroutines ØPREG & PRØUT) to overcome memory restraints. The restrictions in using Version 1 are

(i) Maximum number of variables (I1) is:

nested problem analysis only - 12;

complete problem analysis - 6 parent and 6 progeny; or 3 sire, 3 dam, 3 male and 3 female progeny

O-P analysis only - as for complete.

(ii) Unbalanced data of Types 1 and 2 may be analysed.

(iii) The number of observations within a single cell of the highest level must be $\leqslant$ 99,999.

(iv) The following must be satisfied

$2*N5*(1+N6) \leqslant 12{,}000$. (see Appendix 1 for N5 and N6).

(v) The user must provide a subroutine (READX) to the first program for reading data into the machine.

(b) Version 2

Written in FØRTRAN Extended language for a CDC6600 computer with 96K store. It consists of a main program (NESREG) and eight subroutines (STEP1, FULSIB, STEP2, MIXTUR, ØPREG, PRØUT, READX, and GETFL). In Version 2 array storage is allocated dynamically at execution time - the maximum capacity is thus data dependent but is considerably greater than Version 1 (see Appendix 2). Unbalanced data of Types 1 and 2 may be analysed and the user must supply subroutine READX.

(c) Version 3

Written in FØRTRAN Extended for a CDC6600. It consists of a main program (NESREG) and ten subroutines (ADDRES, STEPS, STEP1, FULSIB, STEP2, MIXTUR, ØPREG, PRØUT, READX, and GETFL). With Version 3 unbalanced data of Types 1, 2 and 3 may be analysed and there is no limit (with respect to computer store) to the number of variables which may be included. The user must supply subroutine READX.

Table 1. Types of Unbalanced Data and the Appropriate Versions of NESREG to use in their Analysis

Type	Description	Version
1	Unequal class numbers, eg. dams per sire, in one or more levels of nesting	1, 2, 3
2	All observations for one or more relatives are missing, eg. offspring-sire regression only, offspring-dam regression only, paternal half-sib data, etc.	1, 2, 3
3	Varying numbers of observations between variables for some or all relatives	3
4	Varying numbers of variables between relatives, i.e. IS ≠ ID ≠ IM ≠ IF (see Appendix 1 for IS, ID, IM, IF)	Not possible

Operating procedures for Versions 1, 2 and 3 are given in Appendices 1, 2 and 3, respectively. Versions 2 and 3 are readily convertable to a CDC3600 computer, and could be readily adapted to any computer for which fixed and floating point word lengths are equal.

II OUTPUT

The output for Versions 1 and 2 consists of $p(2p + 1)$ analyses where $2p$ is the number of offspring variables per observation set in the problem (see Appendix 3 for layout of the output for Version 3). The following discussion will assume the complete problem analysis is requested; portions of this will not be given if the nested problem analysis only, or the O-P problem only, is requested, or if the data to be analysed contains unequal numbers of parent and/or progeny variables across sexes.

For each analysis the heading shows

Variables i and j

i = j: the table will be an AOV and will include variation due to regression and deviations therefrom. Variable means are given as are variance components for the parent and progeny levels; the phenotypic, genetic and environmental variances; all heritability estimates and their standard errors, for the sib analysis, offspring-parent regression (together with corrections when applied), and offspring-parent correlation; an indication of the influence of natural selection; the common environmental variance and the within-full-sib environmental variance; the k coefficients (for the lower three levels only); and finally some partitioning of the phenotypic variance is performed where possible. The parent-parent correlation is also given (expected to be zero with random mating).

i ≠ j: the table will be an AOCOV for the offspring data only. Covariance components for the parent and progeny levels of the offspring analysis are given as are phenotypic, genetic and environmental covariances; the corrected phenotypic and genetic variances of the differences between i and j and the resultant heritability estimate for the sires level only; the genetic, environmental and phenotypic correlations and standardized correlated responses, and their standard errors for the sib analysis; the genetic correlations, their standard errors and the average coefficient of variation of the denominator covariances of these genetic correlations together with the appropriate standardized correlated responses and their standard errors for the O-P analysis; and the common-environmental and within-full-sib environmental covariances.

III METHODS

(a) Models

The basic nested model is of the form which is applied in the general (balanced or not) case, a complete description of which is given by Gates and Shine (1962). The program is designed basically for full-sib data, that is where the lowest three levels are between sires (within other levels), between dams within sires, and within dams.

(i) Observation sets

Each observation set consists of an array

$$\{x_1^s, x_2^s, \ldots x_p^s, \mid x_1^d, x_2^d, \ldots x_p^d, \mid x_1^m, x_2^m, \ldots x_p^m, \mid x_1^f, x_2^f, \ldots x_p^f\} = x_q^r$$

for q = 1 to p and r = s, d, m, or f, where p is the number of variables per relative, relatives being sires (r=s), dams (r=d), male progeny (r=m), and female progeny (r=f).

In the description which follows, the concept of "pseudo-variable" is used extensively. A pseudo-variable is defined by specifying both the variable and the relative on which it is measured. An observation set thus consists of an array of pseudo-variables, and the observation set previously defined may be rewritten

$$\{x_1, x_2, \ldots x_{4p}\} = X_q \text{ for } q = 1 \text{ to } 4p,$$

ignoring the partitioning into sire, dam, male, and female, for the purposes of AOV and AOCOV.

(ii) Model for nested AOV

The data is an array of observation sets, together with their "identifications", i.e. coding for classes within each level of the hierarchy to which the observations belong. Each parent observation is thus repeated over all its progeny in the data set. Ignoring any higher level than "between sires", the model for AOV of the qth pseudo-variable is

$$X_{qij\ell} = \mu_q + S_{qi} + D_{qij} + E_{qij\ell}$$

where

$X_{qij\ell}$ is the observation for the qth pseudo-variable within the observation set having the "identification" ℓth progeny of jth dam mated to the ith sire;

μ_q is the population mean;

S_{qi} is the effect of the ith sire;

D_{qij} is the effect of the jth dam mated to the ith sire, and

$E_{qij\ell}$ is the uncontrolled environmental and genetic deviations attributable to individuals;

$i = 1,2,\ldots s_q$ is the "identification" for the between sires level;

$j = 1,2,....d_{qi}$ is the "identification" for the between dams level;

$\ell = 1,2,....n_{qij}$ is the "identification" for the lowest level, and

$$\sum_j n_{qij} = n_{qi\cdot}$$

$$\sum_{ij} n_{qij} = \sum_i n_{qi\cdot} = n_{q\cdot\cdot}$$

$$\sum_i d_{qi} = d_{q\cdot}$$

Only Version 3 can carry out analyses where s_q, d_{qi}, and n_{qij} are not the same for all q (unbalanced data of Type 3), except for the special case in which all observations are missing for one or more relatives (unbalanced data of Type 2).

The AOV (q = r) or AOCOV (q ≠ r) is shown in Table 2, for the pair of pseudo-variables q and r.

(iii) SS and SCP matrices from nested AOV

After performing the analyses shown in Table 2 for all pairs of pseudo-variables, matrices ($\underline{A}$, $\underline{B}$, and $\underline{C}$) of sums of squares and cross products (SS and SCP) or ($\underline{U}$, $\underline{V}$, and $\underline{W}$) of mean squares and cross products (MS and MCP), are assembled.

The matrices $\underline{A}$, $\underline{B}$, and $\underline{C}$ can be partitioned as follows:

$$\underline{A} = \begin{bmatrix} \underline{A}^s & \underline{A}^{sd} & \underline{A}^{so} \\ & \underline{A}^d & \underline{A}^{do} \\ & & \underline{A}^o \end{bmatrix}$$

and similarly for $\underline{B}$ and $\underline{C}$, the superscripts s, d, and o referring to observations on sires, dams, and progeny, respectively. The partitions correspond to those in the original notation for an observation set, except that male

Table 2. Analysis of Variance (Covariance) of a Pair of Pseudo-Variables for the Unbalanced Two-fold Nested Classification

SOURCE	D.F.	SS or SCP*	MC or MCP*	E(MS) or E(MCP)*
Sires (S)	s-1=u	$\sum_i \frac{(X_{qi..})(X_{ri..})}{n_{i.}} - \frac{(X_{q...})(X_{r...})}{n..} = A_{qr}$	U_{qr}	$E'_{qr}+k_2D_{qr}+k_3S_{qr}$
Dams (D)/S	d.-s=v	$\sum_{ij} \frac{(X_{qij.})(X_{rij.})}{n_{ij}} - \sum_i \frac{(X_{qi..})(X_{ri..})}{n_{i.}} = B_{qr}$	V_{qr}	$E'_{qr}+k_1D_{qr}$
Offspring/D/S	n..-d.=w	$\sum_{ij\ell} (X_{qij\ell})(X_{rij\ell}) - \sum_{ij} \frac{(X_{qij.})(X_{rij.})}{n_{ij}} = C_{qr}$	W_{qr}	E'_{qr}
Total	n..-1	$\sum_{ij\ell} (X_{qij\ell})(X_{rij\ell}) - \frac{(X_{q...})(X_{r...})}{n..}$		

*q and r denote two variables, and for mean square etc., q = r.

and female offspring are not separated. Where the need arises, male and female offspring will be distinguished by further partitioning. Using the $\underline{A}$ matrix again for example

$$\underline{A}^{so} = \left[\begin{array}{c|c} \underline{A}^{sm} & \underline{A}^{sf} \end{array}\right]$$

$$\underline{A}^{do} = \left[\begin{array}{c|c} \underline{A}^{dm} & \underline{A}^{df} \end{array}\right]$$

$$\underline{A}^{o} = \left[\begin{array}{c|c} \underline{A}^{m} & \underline{A}^{mf} \\ \hline & \underline{A}^{f} \end{array}\right]$$

The matrices $\underline{U}$, $\underline{V}$, and $\underline{W}$ can be similarly partitioned. The interpretation of each partition and its use in subsequent analyses is given in Table 3. The notation for SS and SCP matrices is summarized in Table 4, using the $\underline{A}$ matrix again for example.

(iv) Models for O-P regression

In the offspring-parent analyses, consider pseudo-variables q in the parent and r in the offspring, r being the same variable as q.

The offspring-sire regression coefficient, β_r^s, is defined by the model*

$$X^o_{rij} = \mu_r + \beta^s_r(X^s_{qij} - \bar{x}^s_{q..}) + e_{rij}$$

where

μ_r is the offspring population mean;

X^o_{rij} is the observation of the rth pseudo-variable on the jth offspring of the ith sire;

X^s_{qij} is the observation of the qth pseudo-variable on the ith sire repeated over j;

$\bar{x}^s_{qij}$ is the phenotypic mean of the qth pseudo-variable

and

e_{rij} is random error.

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*See Sokal & Rohlf (1969), Section 14.6, for a description of the method and interpretation of the F tests.

Table 3. Matrices of SS and SCP used for further analyses

Matrix	Interpretation	Use
$\underline{A}^s$	Sire variances (diagonal elements)	offspring-sire regression and correlation
$\underline{A}^{so}$	Sire-offspring covariances	
$\underline{B}^d$	Dam variances (diagonal elements)	intra-sire offspring-dam regression and correlation
$\underline{B}^{do}$	Dam-offspring covariances	
$\underline{A}^{sd}$	Sire x dam covariances for same variable (diagonal elements)	sire-dam correlation
$\underline{A}^o$	sires — Partitioning of offspring variances and covariances by nested AOV & AOCOV	sib analyses
$\underline{B}^o$	dams/sires — Partitioning of offspring variances and covariances by nested AOV & AOCOV	
$\underline{C}^o$	within dams — Partitioning of offspring variances and covariances by nested AOV & AOCOV	
$\underline{A}^d$	Dam variances and covariances among the means for all dams mated to each sire	unused
$\underline{A}^{do}$	Dam-offspring covariances among the means for all dams mated to each sire and all offspring of each sire	unused
$\underline{B}^s, \underline{B}^{sd}, \underline{B}^{so}, \underline{C}^d, \underline{C}^{do}, \underline{C}^{\cdot}, \underline{C}^{\cdot}, \underline{C}$	Null matrices	unused

Table 4. Notation used for SS and SCP Matrices

Symbol	Usage
$\underline{A}$	whole SS and SCP matrix
$\underline{A}^s$	partition of $\underline{A}$ corresponding to SS and SCP's among $\{x_1^s, x_2^s, \ldots x_p^s\}$, the observations on sires
A_{qr}	a particular element of $\underline{A}$ containing the SS or SCP between pseudo-variables q and r
A^s_{qr}	as for A_{qr} but q and r both being observations on sires
A^{do}_{qr}	as for A_{qr} but q being an observation on dams and r being an observation on offspring

The intra-sire offspring-dam regression coefficient β_r^d, is defined by the model

$$X^o_{rij\ell} - S_{ri} = \mu_r + \beta^d_r(X^d_{qij\ell} - \bar{x}^d_q...) + e_{rij\ell}$$

where

μ_r is the offspring population mean;

$X^o_{rij\ell}$ is the observation of the rth pseudo-variable on the ℓth offspring from a mating of the ith sire to the jth dam;

S_{ri} is the effect of the ith sire;

$X^d_{qij\ell}$ is the observation of the qth pseudo-variable on the jth dam mated to the ith sire and repeated over ℓ progeny;

$\bar{x}^d_q...$ is the phenotypic mean of the qth pseudo-variable

and

$e_{rij\ell}$ is random error.

The O-P regression coefficients are estimated by

$$b^s_r = A^{so}_{qr}/A^s_{qq}, \quad \text{and} \quad b^d_r = B^{do}_{qr}/B^d_{qq}.$$

The AOV's for the two O-P analyses are given in Table 5. The deviations of individuals from linear regression are not printed but may be obtained by combining the appropriate levels.

The standard errors of O-P regression coefficients are

$$S.E.(b^s_r) = (M^s_{qr}/A^s_{qq})^{\frac{1}{2}},$$

and

$$S.E.(b^d_r) = (M^d_{qr}/B^d_{qq})^{\frac{1}{2}}.$$

Note that these standard errors are computed using the mean squares for deviations of individuals from regression, i.e. the deviations of the means from regression are assumed to be not significant.

(b) Estimates of Genetic Parameters

The following discussion uses, as an example, a problem where 2 variables were measured in each sex of the

Table 5. Analyses of Variance for Offspring-Sire and Intra-Sire Offspring-Dam Regressions

SOURCE	D.F.	SS	MS
Sire-Offspring			
Regression	1	$b^s_r A^{so}_{qr} = R^s_{qr}$	
Deviations (means)	u - 1	$A^o_{rr} - R^s_{qr}$	$\bar{M}^s_{qr}$
Deviations (individuals)	u+v+w-1	$A^o_{rr}+B^o_{rr}+C^o_{rr}-R^s_{qr}$	M^s_{qr}
Dam-Offspring			
Regression	1	$b^d_r B^{do}_{qr} = R^d_{qr}$	
Deviations (means)	v - 1	$B^o_{rr} - R^d_{qr}$	$\bar{M}^d_{qr}$
Deviations (individuals)	v+ w - 1	$B^o_{rr} + C^o_{rr} - R^d_{qr}$	M^d_{qr}

parents and offspring, i.e. pseudo-variables 1 and 2 in sires, 3 and 4 in dams, 5 and 6 in male and 7 and 8 in female offspring.

No allowance has been made for relatedness of parents (see for example, Hinklemann 1971) or for inbreeding of unrelated parents in any estimates. When one is interested in estimates of genetic parameters for the present population then the parents are not inbred although throughout the literature we find a correction being applied in situations where estimates for the present population rather than for past generations of this population, are of concern.

(i) Variance and covariance components

The methods of computing estimates of phenotypic, genetic and environmental variances (covariances) utilizing the progeny mean square in combination with the sire, dam and sire plus dam mean squares (P_{qr}, G^s_{qr}, E^s_{qr}, G^d_{qr}, E^d_{qr}, G^{sd}_{qr} and E^{sd}_{qr} respectively), are given by Hammond and Nicholas (1972). The appropriate values to be substituted for f, ℓ,

a, b and c in the general equation, given by them,

$$\hat{\theta} = f[aU_{qr} + bV_{qr} + cW_{qr}]/\ell,$$

are given in Table 6.

Table 6. Values for the Coefficients used in Computing θ Estimates

$\hat{\theta}_{qr}$	Coefficients				
	f	ℓ	a	b	c
Phenotypic:					
P	1	k_1k_3	k_1	k_3-k_2	$k_2-k_1+k_3(k_1-1)$
Genetic:					
G^s	4	k_3	1	$-k_2/k_1$	$(k_2-k_1)/k_1$
G^d	4	k_1	0	1	-1
G^{sd}	2	k_1k_3	k_1	k_3-k_2	$k_2-k_1-k_3$
Environmental:					
E^s	1	k_3	-2	$2k_2/k_1$	$((k_1-k_2)/k_1)+k_3$
E^d	1	k_1	0	-2	k_1+2
E^{sd}	1	k_1k_3	$-k_1$	k_2-k_3	$k_1-k_2+k_3(k_1+1)$

(ii) Heritabilities

1. Sib estimates: e.g. for q=r=5, from the sire, dam and sire plus dam θ values together with standard errors (approximate method - see Becker (1964)) are

$$H_5^s = G_{55}^s/P_{55}, \quad S.E.(H^s) = 4Var(S)^{\frac{1}{2}}/P_{55},$$
$$H_5^d = G_{55}^d/P_{55}, \quad S.E.(H^d) = 4Var(D)^{\frac{1}{2}}/P_{55},$$
$$H_5^{sd} = G_{55}^{sd}/P_{55}, \quad S.E.(H^{sd}) = 2[Var(S)+Var(D)+2Cov(S,D)]^{\frac{1}{2}}/P_{55},$$

where

$$\text{Var}(S) = 2[U_{55}^2/(u+2)+V_{55}^2/(v+2)]/k_3^2,$$

$$\text{Var}(D) = 2[V_{55}^2/(v+2)+W_{55}^2/(w+2)]/k_1^2, \text{ and}$$

$$\text{Cov}(S,D) = -k_2[\text{Var}(D)-2W_{55}^2/k_1^2(w+2)]/k_3.$$

2. O-P estimates: for the trait represented by variables 1-3-5-7 four separate O-P estimates are possible: (i) Male offspring on sire (51), (ii) female offspring on sire (71), (iii) male offspring on dam (53), and (iv) female offspring on dam (73). Heritability is given by, for example, male-sire

$$HB_{(M-S)} \equiv HB_{51} = 2b_{51}^s, \text{ S.E.}(HB_{51}) = 2[\text{S.E.}(b_{51}^s)].$$

Estimates (ii) and (iii) are corrected for assumed inequality of variances between the sexes so that

$$HB_{71} = 2b_{71}^s(U_{55}/U_{77})^{\frac{1}{2}},$$

and

$$HB_{53} = 2b_{53}^d(V_{77}/V_{55})^{\frac{1}{2}},$$

and these corrections are also applied to the standard errors. N.B. When the data comprises both male and female observations the correction is a ratio of progeny mean squares but when only female progeny are measured it is a ratio of sire and female mean squares. The corrections are printed out alongside the respective corrected estimates.

With random mating one expects a zero correlation between sire and dam measurements and an estimate of the offspring on midparent heritability is given by $b^s + b^d$. When the correlation is not zero this heritability estimate would differ from that derived from the regression of offspring on mid-parent means and its variances would be biassed down.

Heritabilities computed by offspring-parent correlation are also given, for example a female-sire estimate,

$$HR_{71} = 2A_{71}/[A_{11}(A_{77}+B_{77}+C_{77})]^{\frac{1}{2}}.$$

3. The heritability of the difference of two characters: (see Frankham (1968) for discussion on this parameter when the two characters are the same trait in different sexes) is estimated using P_{qr} in combination with G^s_{qr} only. For traits 5 and 7 the sire estimate of this heritability is

$$HD^s_{57} = \frac{G^s_{57}}{P_{57}} = \frac{G^s_{77} + G^s_{55} - 2G^s_{75}}{P_{77} + P_{55} - 2P_{57}},$$

but with heterogeneity of the genetic and phenotypic variances between the traits this estimate is corrected by

$$= \frac{G^s_{57} - (\sqrt{G^s_{55}} - \sqrt{G^s_{77}})^2}{P_{57} - (\sqrt{P_{55}} - \sqrt{P_{77}})^2}$$

$$= \frac{(G^s_{55}G^s_{77})^{\frac{1}{2}} - G^s_{57}}{(P_{55}P_{77})^{\frac{1}{2}} - P_{57}},$$

and only the corrected estimates are printed out.

4. Influence of natural selection: it is possible that some of the difference between heritabilities estimated by sib analysis and those estimated by O-P is due to the differential effect of natural selection on the half-sib covariances (Cov(HS)) and the O-P covariances (Cov(OP)). For an <u>additive situation</u> James (1966) showed that

$$Cov(HS) \simeq \tfrac{1}{2}(1 - \bar{S})\ Cov(OP),$$

where $\bar{S}$ is the coefficient of homeostatic strength. $\bar{S}$ is estimated here from the paternal half-brother and sire-son heritability estimates and will therefore only be printed on a page where an analysis involves one male trait.

(iii) Correlations

1. Sib estimates: of the phenotypic, genetic and environmental correlations ($\hat{r}_\theta$) are computed as the product moment correlation, <u>e.g.</u> those of traits 5 and 7 are given by

$$\hat{f}_{\theta} = \hat{\theta}_{57}/(\hat{\theta}_{55}\hat{\theta}_{77})^{\frac{1}{2}}.$$

The respective standard errors are then

$$S.E.(\hat{f}_{\theta_{57}}) = \left\{2f^2\hat{f}^2_{\theta_{57}}\left[J_{\theta_{57}} + \frac{a^2(U_{55}U_{77}+U^2_{57})/u'+b^2(V_{55}V_{77}+V^2_{57})/v'+c^2(W_{55}W_{77}+W^2_{57})/w'}{2\hat{\theta}^2_{57}} - \frac{a^2U_{55}U_{57}/u'+b^2V_{55}V_{57}/v'+c^2W_{55}W_{57}/w'}{\hat{\theta}_{55}\hat{\theta}_{57}} - \frac{a^2U_{57}U_{77}/u'+b^2V_{57}V_{77}/v'+c^2W_{57}W_{77}/w'}{\hat{\theta}_{57}\hat{\theta}_{77}}\right]/\ell^2\right\}^{\frac{1}{2}}$$

where

$$J_{\theta_{57}} = \frac{a^2U^2_{55}/u'+b^2V^2_{55}/v'+c^2W^2_{55}/w'}{4\hat{\theta}^2_{55}} + \frac{a^2U^2_{77}/u'+b^2V^2_{77}/v'+c^2W^2_{77}/w'}{4\hat{\theta}^2_{77}} + \frac{a^2U^2_{57}/u'+b^2V^2_{57}/v'+c^2W^2_{57}/w'}{2\hat{\theta}_{55}\hat{\theta}_{77}},$$

and where $u' = u+2$, $v' = v+2$ and $w' = w+2$ and f, ℓ, a, b and c are given in Table 6 for the seven $\hat{\theta}$ estimates. When either of the θ variances ($\hat{\theta}_{55}$ and $\hat{\theta}_{77}$ in the above example) are negative or zero the correlation and its standard error are set equal to zero and a statement will be printed out immediately after the listing of the variable names for the problem.

2. The O-P genetic correlation: is computed by the method employing the arithmetic mean of the offspring-parent covariances. No estimate is calculated for variables 5 and 7 as these are the same trait in different sexes. For variables 5 and 6 the sire correlation, for example, is given by

$$\hat{r}^s_{56} = (A_{61} + A_{52})/2(A_{51}A_{62})^{\frac{1}{2}}.$$

The standard error for either the sire or dam estimate of the O-P genetic correlation is given by equation (12) of Hammond and Nicholas (1972) and with their p = 2 this becomes

$$S.E.(\hat{f}_{56}) = \{R[(k_3R/2)+((k_3+k_1-1)(1/D'-\hat{f}_{P_{56}}\hat{f}_{56}/C')/2) + (4(\hat{f}_{56}/D'-\hat{f}_{P_{56}}/C')/R)+2(1-\hat{f}^2_{P_{56}}/C'^2)]/k_3d\}^{\frac{1}{2}},$$

where d = (u-1) for the sire estimate, and d = (v-1) for the dam estimate, the appropriate sire or dam estimates of heritabilities or correlations are substituted and $R=1-\hat{f}^2_{56}$, $1/D = [(1/HB_5)+(1/HB_6)]/2$ and $C' = (HB_5.HB_6)^{\frac{1}{2}}$.

When only the O-P analysis option is utilized then

$$S.E.(\hat{f}_{56}) = R[(SE(HB_5).SE(HB_6))/(HB_5HB_6)]^{\frac{1}{2}}/2^{\frac{1}{2}}.$$

Further explanation of the standard errors of all the above correlations and discussion of their usefulness is given by Hammond and Nicholas (1972).

Van Vleck and Henderson (1961) suggest that both $\hat{f}$ and Var ($\hat{f}$) will be biassed upwards if the average coefficient of variation of the denominator covariances of $\hat{f}$ is > 0.20. The estimate of this coefficient of variation is printed out and is computed as, e.g. for traits 5 and 6

$$CV_{56} = [((4+HB^2_5)/HB^2_5)^{\frac{1}{2}} + ((4+HB^2_6)/HB^2_6)^{\frac{1}{2}}]/2u^{\frac{1}{2}}.$$

(iv) Standardized correlated response (SCR)

1. Sib estimates: of SCR utilising sire, dam, and sire plus dam genetic covariances and phenotypic variances are computed. For example, the sire estimate for variables 5 and 6 is given by

$$SCR^s_{56} = (H^s_5H^s_6)^{\frac{1}{2}}\hat{f}^s_{G_{56}} = G^s_{56}/(P_{55}P_{66})^{\frac{1}{2}},$$

with standard error

$$S.E.(SCR^s_{56}) = \left\{2(SCR^s_{56})^2\left[J_{P_{56}}/\ell^2_P + (f^s_G)^2\left[\frac{(a^s_G)^2(U_{55}U_{66}+U^2_{56})/u'+(b^s_G)^2(V_{55}V_{66}+V^2_{56})/v'+(c^s_G)^2(W_{55}W_{66}+W^2_{56})/w'}{2(G^s_{56})^2(\ell^s_G)^2}\right]\right.\right.$$
$$-f^s_G\left[\frac{a^s_Ga_PU_{55}U_{56}/u'+b^s_Gb_PV_{55}V_{56}/v'+c^s_Gc_PW_{55}W_{56}/w'}{P_{55}G^s_{56}\ell^s_G\ell_P}\right.$$
$$\left.\left.\left.+\frac{a^s_Ga_PU_{56}U_{66}/u'+b^s_Gb_PV_{56}V_{66}/v'+c^s_Gc_PW_{56}W_{66}/w'}{P_{66}G^s_{56}\ell^s_G\ell_P}\right]\right]\right\}^{\frac{1}{2}}.$$

2. The O-P estimate: of SCR^{s}_{56} is

$$SCR^{s}_{56} = (HB_{51}HB_{61})^{\frac{1}{2}}\hat{f}^{s}_{56} = (A_{16}+A_{25})/(A_{11}A_{22})^{\frac{1}{2}}.$$

and its standard error is

$$S.E.(SCR^{s}_{56}) = \{[(S^2+2/k_3)(1+\hat{f}^2_{P_{56}})+((k_3+k_1-2)(C'^2/D'+S\hat{f}_{P_{56}})/2k_3 + (C'^2(1-4\hat{f}_{P_{56}}S/D')-3S^2)/2]/d\}^{\frac{1}{2}},$$

where $S = SCR^{s}_{56}$ and d, C' and 1/D' are as previously defined. This standard error is computed only when a complete analysis is called. The development of the standard errors of the SCR estimates is given by Nicholas (1972).

(c) Partitioning the Phenotypic Variance

Expectations for the heritability estimates have been compiled utilizing Dickerson (1969), Bohidar (1964) and James (1972) and assuming males are the heterogametic sex. These are given in Table 7. Obviously the best estimates of the variance components will be obtained by solving a complete set of simultaneous equations. However, the options available in the program would introduce some difficulties in implementing this procedure, although it is possible to incorporate this for both variance and covariance components. Thus the method used to estimate the relative contributions of each of the components leads to somewhat inefficient estimates, the sum of which is likely to differ from unity. Heritabilities are used in preference to θ's in partitioning the variance as only the heritabilities have been corrected for inequality of male and female variances. The expectations of the partitioned components are given in Table 8. When options other than the complete analysis with IS=ID=IM=IF are selected some of these components will not be given or will be set equal to ± 99.999999.

The common (V_{EC}) and within full-sib (V_{EW}) environmental variance (covariance) components, Falconer (1960), p.174, are computed for all analyses from the variance (covariance) components as

$$V_{EC} = \hat{D}_{qr} - \hat{S}_{qr}$$
$$V_{EW} = \hat{E}'_{qr} - 2\hat{S}_{qr}$$

Table 7. Expectations* for the Heritability Estimates

Estimate	Component (V_C) †														
	A	D	AA	AD	DD	M	EC	AS	AAS	ASAS	DAS	DS	ADS	DDS	DSDS
1.Sire-son	1		.5												
2.Sire-daughter	1		.5					1.41		1					
3.Dam-son	1		.5			1		1.41		1					
4.Dam-daughter	1		.5			1		1	.5	.5					
5.Paternal ½ brother	1		> .25												
6.Paternal ½ sister	1		> .25					2	.5	1					
7.Dams/S-males	1	1	> .75	> .5	> .25	4	4	2	1	1	.5				
8.Dams/S-females	1	1	> .75	> .5	> .25	4	4	1	1	1.25	.75	2	1	.5	1

*Assuming: Males are the heterogametic sex and the variances are equal in the 2 sexes; only 2 -locus interactions are important; no genotype X environment interaction; no genetic covariance between transmitted and direct maternal effects.

†Where subscript C is a combination of:
A - additive
D - dominance
M - maternal
S - sex linkage
EC - common environmental

Table 8. Method of Computing Components and their Expectations

Component	Computed as*	Component (V_C)†														
		A	D	AA	AD	DD	M	EC	AS	AAS	ASAS	DAS	DS	ADS	DDS	DSDS
a.Additive	$\underline{5} - c/4$	1		[.25][2]												
b.Dominance	$\underline{7}-(a+.75c+2di+4ei)$		1	[.5]	.5	.25	(4)[3]	4		.5		.5				
c.Add.xAdd.[1]	$4(\underline{1} - \underline{5})$			1												
di Sex linkage	$(\underline{6} - \underline{5})/2$								1	.25	.5					
ii " "	$\underline{7} - \underline{8}$								1		-.25	-.25	-2	-1	-.5	-1
iii " "	$(\underline{3} - \underline{1} - ei)0.707$						(.71)		1		.71					
ei Maternal[1]	$\underline{3} - \underline{2}$						1									
ii " [1]	$\underline{4} - \underline{2}$						1		-.41	.5	-.5					

* Underlined digits are from first column of Table 7.

† See Table 7 for explanation.

1 = Set equal to 0.0 if negative.

2 = When no O-P analysis performed estimates will include bracketed value.

3 = When no female offspring estimate will include values in parentheses.

(d) Binomially Distributed Data

Allowance is made in the program for the analysis of binomially distributed data although further development of the program to handle this data would be desirable by those using the option. The binomial variance components for the within dams, dams and sires levels are

$$E'B = [(\sum_{ij\ell} C/r_{ij\ell}) + (\sum_{ij} (\sum_{\ell} C/r_{ij\ell})/n_{ij})]/w$$

$$DB = [(\sum_{ij} (\sum_{\ell} C/r_{ij\ell})/n_{ij}) + (\sum_{i} (\sum_{ij} C/r_{ij\ell})/n_{i}.)]/v$$

$$SB = [(\sum_{i} (\sum_{ij} C/r_{ij\ell})/n_{i}.) + ((\sum_{ij\ell} C/r_{ij\ell})/n..)]/u,$$

where $r_{ij\ell}$ is the number of events from which the percentage calculated for cell $ij\ell$ and $C = 0.25$. The variance components are then computed (but not the covariance components) as

$$\hat{E}'_{qr} = W_{qr} - E'B$$

$$\hat{D}_{qr} = (V_{qr} - DB - E'_{qr})/k_1$$

$$\hat{S}_{qr} = (U_{qr} - SB - k_2 D_{qr} - E'_{qr})/k_3.$$

H^s, H^d and H^{sd} are calculated as given previously except 0.25 is added to P_{qr}. See Bogyo & Becker (1965) for derivation of the binomial variance components.

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V APPENDICES

(a) Appendix 1

Operating Procedures and Listing for Version 1

(i) Deck structure

Order of control cards, program, and data decks is:-

```
$ID (or as required by system)
$PAUSE DIAL UNITS 0, 1, 2, 3, 4
$IBJØB (or as required by system)
--
--
Source deck NESRG1
--
--
Data deck
--
--
$IBJØB (or as required by system)
--
--
Source deck NESRG2
--
--
$IBSYS (return to system)
```

(ii) Data Deck

Structure of data deck is:-

```
Parameter card type 1 (number of problems)
Parameter card type 2 for problem No.1 (size
   of problem and type of analysis)
Parameter card type 3 for problem No.1 (title)
Parameter card(s) type 4 for problem No.1
   (variable names)
Data cards for problem No.1
Blank trailer card

Parameter card type 2 for problem No.2
Parameter card type 3 for problem No.2
Parameter card type 4 for problem No.2
Blank trailer card
--
-- etc.
```

(iii) Punching Schedule for Parameter Cards

Columns	Symbol	Information	
Parameter card type 1			
1-4	NPRØB	Number of problems	
Parameter card type 2			
1-6	CHECK(1)	START (sixth column blank)	
7-9	I1	Number of pseudo-variables (limit 12)	
10	I2	Number of fold (=number of levels -1) (maximum is five-fold, minimum is two-fold)	
11	N3	Analysis required 1 = complete problem 2 = nested problem only 3 = O-P problem only	
12	N4	On-line debugging option 1 = first observation set will be printed on line for inspection; if correct the program will proceed if the "start" button is pressed 2 = no debugging pause	
13-16	N5	Maximum number of sires	
17-19	N6	Maximum number of dams per sire	
NB:	$2*N5*(1+N6) \leq 12{,}000$		
20	IS	Number of sire variables	per observation set
21	ID	Number of dam variables	
22	IM	Number of male offspring variables	
23	IF	Number of female offspring variables	
NB:	$IS+ID+IM+IF = I1$		

All information to be punched right adjusted

Parameter card type 3		
1-72	TITLE(I)	Problem title (alphameric)

Operating Procedures and Listing for Version 2

(i) Deck structure

Order of control cards, program, and data decks is:-

```
JØBNAM (CM60000, CL100000, T--, P-)
FTN.
RFL (100000)
REDUCE.
LGØ.
7/8/9
--
--
Source deck
--
--
7/8/9
--
--
Data deck
--
--
7/8/9
6/7/8/9
```

(ii) Data deck

Structure of the data deck is as for Version 1.

(iii) Punching schedule for parameter cards

Columns	Symbol	Information
Parameter card type 1		
1-4	NPRØB	Number of problems
Parameter card type 2		
1-5	ICHEK	START
6	-	Blank column
7-9	I1	Number of pseudo-variables
10	I2	Number of fold (maximum 5-fold, minimum is two-fold)
11	N3	Analysis required 1 = complete problem 2 = nested problem only 3 = O-P problem only

Columns	Symbol	Information
12	N4	Data listing option 1 = listing of all observation sets required 2 = no listing
13-16	N5	Maximum number of sires
17-20	N6	Maximum number of dams per sire
21-23	IS	Number of sire variables)
24-26	ID	Number of dam variables)
27-29	IM	Number of male offspring variables) per observation set
30-32	IF	Number of female offspring variables)

Parameter card type 3

1-72	ITLE	Problem title (alphameric)

Parameter card type 4

1-8	NAMVAR(1)	Alphameric name of first pseudo-variable
9-16	NAMVAR(2)	Alphameric name of second pseudo-variable
17-24	--	--
25-32	etc.	Continue up to column 72 of first card, and as many subsequent cards as required.

(iv) Input of data cards

Subroutine READX is slightly different to that for Version 1. Communication between READX and the calling program is partly via formal parameters in the call statement

```
CALL READX (XID, X)
```

and partly via labelled CØMMØN

```
CØMMØN/CMBLK1/I1, I2, N3, N4, N5, N6, IS, ID,
IM, IF, N1, ITLE(9), Y, KPUT
```

(v) Array storage allocation

In Version 2 all variable-length arrays are equivalenced (by means of formal parameter lists in sub-routine calls) to a single array in the main program, which is in blank CØMMØN. When the program deck is

compiled and loaded into store, only one word of blank CØMMØN is dimensioned. After control is passed to the program and it has read the parameter cards, the number of words of blank CØMMØN required for STEP1 (originally program NESRG1 of Version 1) is calculated, and the amount of central store occupied by the program is increased sufficiently to allow all arrays used by STEP1 to occupy blank CØMMØN. When STEP1 is completed, the number of words of blank CØMMØN required for STEP2 (originally program NESRG2 of Version 1) is calculated, and central store limit is again changed.

Either STEP1 or STEP2 may require the greater amount of store, depending on the data structure. There are thus two restrictions on problem size

$$LPRØG+48+I1(4+I2)+6I2+I1^2(45+3I2)+2(N5+N5*N6) \leq 98304$$

and

$$LPRØG+54+I1+2I2+I1^2(114+3I2) \leq 98304$$

where LPRØG is the field length of the program up to first word of blank CØMMØN. LPRØG will be approximately 16200, but will vary depending on the length of the user-supplied READX subroutine.

Subroutine GETFL is used to determine LPRØG and to vary the field length of the program during execution. A

```
CALL GETFL (LPRØG)
```

statement returns to the calling program the field length of the executing program up to the first word of blank CØMMØN. A

```
CALL SETFL (LFIELD)
```

statement (SETFL is a multiple entry point to GETFL) changes the field length of the executing program to LFIELD (in the same way as an RFL control card under SCØPE).

(vi) Compatibility

Users wishing to convert Version 2 of NESREG to other computers should note that subroutine GETFL will not be transferrable. If the proposed computer is time-shared a facility equivalent to GETFL should be available, and should be used, since the user pays for number of store cells occupied as well as time of occupancy, in such a machine. If the proposed computer is not time-shared, array A(1) in blank CØMMØN in the main program should be re-dimensioned to use all the store available, and a dummy subroutine GETFL

which does nothing, should be substituted. In either case Version 2 will only be readily transferrable to a computer in which fixed and floating point word lengths are equal, since both integer and real arrays in the subroutines are equivalenced to a single real array A(1) in the main program.

Listing of Version 2

(c) Appendix 3

Operating Procedures and Listing for Version 3

(i) Deck structure

Order of control cards, program, and data decks is as for Version 2.

(ii) Data deck

Structure of the data deck is as for Versions 1 and 2, except that the data cards and blank trailer card may be either in the data deck, as before, or stored on a separate logical unit such as a magnetic tape.

(iii) Punching schedule for parameter cards

As for Version 2, with the addition of three extra parameters on parameter card type 2:

Columns	Symbol	Information
33-34	ICYC	Single pass or cyclic operation 1 = single pass, all variables and pairs of variables 2 = cyclic, single variables only, i.e. only heritabilities required 3 = cyclic, single variables and pairs 4 = cyclic, pairs of variables only, i.e. only correlations required (see section (vii) of this appendix)
35-36	LUI	Logical unit number for input of data, Punch 05 for card input, or 07 otherwise
37-38	LUS	Logical unit number of scratch unit used to store data during cyclic operation. Unit LUS is rewound every cycle. Punch 04 for cyclic mode, or 00 for single pass mode

(iv) Input of data cards or tape

In cyclic mode Version 3 copies the data cards (LUI=05) or tape (LUI=07) onto scratch unit LUS=04 so that they may be rewound during cyclic operation. Thus, in cyclic mode, subroutine READX must be written to read from unit LUS. In single pass mode, Version 3 reads the data directly from cards (LUI=05) or tape (LUI=07). Thus, in single pass mode, subroutine READX must be written to read from unit LUI. Subroutine READX must supply different observation sets to the main program, depending on which cycle (which trait or pair of traits) is currently being analysed. This information is communicated to READX via a labelled CØMMØN block

```
CØMMØN/CMBLK7/MI1, MIS, MID, MIM, MIF, M1, M2,
ICYC, LUI, LUS
```

where

MI1 = maximum number pseudo-variables (total over all cycles)
MIS = maximum number of sire variables
MID = maximum number of dam variables
MIM = maximum number of male offspring variables
MIF = maximum number of female offspring variables
M1 = variable number for first variable of a pair
M2 = variable number for second variable of a pair

if M1 = M2 supply 4 data items - sire, dam, male and female

if M1 $\neq$ M2 supply 8 data items - 2 sire, 2 dam, 2 male and 2 female

ICYC = cycling option
LUI = unit number for input of data
LUS = unit number for scratch unit

Subroutine READX must also be programmed to check for missing observations, and to supply only complete observation sets, with sire, dam, male, and female observations all present for the pair of traits specified by M1 and M2 of the current cycle. Or, if an analysis is to be performed on Type 2 unbalanced data, READX must supply observation sets which are as complete as the analysis requires.

(v) Array storage allocation

As for Version 2 when in single pass mode. In cyclic mode field length is set once, before cycling starts, to

the greater of the two requirements given for Version 2, taking I1 = 1 if ICYC = 2 and I1 = 2 if ICYC = 3 or 4.

(vi) Compatibility

As for Version 2. A 32K machine should handle any size of problem if cyclic mode is used.

(vii) Single pass or cyclic mode

Single pass mode (ICYC = 1) does exactly the same calculations as Version 2.

Cyclic mode allows large sets of Type 3 unbalanced data to be processed, and the degrees of freedom for any trait or pair of traits may be different to that for every other trait or pair of traits. Therefore, every trait or pair of traits must be analysed by a separate run, the same data set being re-read each run and the appropriate trait or pair of traits extracted. In the notation of section III (iii), this is the case where every element of the $\underline{A}$, $\underline{B}$, and $\underline{C}$ (or $\underline{U}$, $\underline{V}$ and $\underline{W}$) matrices is estimated with different number of degrees of freedom. It is not advisable (Nadler, 1967) to use the elements of such matrices to estimate correlation coefficients. The degrees of freedom for the covariance in the numerator of a correlation coefficient should be the same as those of the variances in the denominator. The only way to achieve this is to re-estimate subsets of the $\underline{A}$, $\underline{B}$ and $\underline{C}$ matrices for each pair of traits, using only those observation sets where the observation for both traits of the pair is present. This is done automatically by the cyclic mode option, if the user supplies an appropriate READX subroutine (see section (iv) of this appendix).

As ICYC = 2 or 4 produces subsets of the output produced by ICYC = 3, only the latter will be described. The output will appear as if a number of single variable problems (I1 = 4, IS = ID = IM = IF = 1) were processed, followed by a number of two variable problems (I1 = 8, IS = ID = IM = IF = 2). Each single variable problem will furnish the appropriate heritability and variance component estimates, for a variable, based on all the observation sets complete for that variable. Each two variable problem will furnish the appropriate correlations and covariance component estimates, for a pair of variables based on all observation sets complete for both variables. Heritability and variance component estimates appearing in the two-variable problems will be based on the same or fewer degrees of freedom as those furnished by the single-variable problems.

Version 3 allows very heterogeneous data to be processed almost automatically. The dangers of misinterpretation should be appreciated. If missing observations are caused by some systematic event (such as death or culling of animals) genetic parameter estimates could be greatly biassed.

Listing of Version 3

Fortran listings omitted

Neville Jackson

20 Oct 2021

1 Note on acces to program code

The listings of fortran program code have been onitted from this document. The code for versions 2 and 3 of nesreg is available at

`https://github.com/nevillejackson`

Go to the *Fortran* repository and look in the *nesreg2* and *nesreg3* subdirectories.

(d) Appendix 4

Listing of Test Data and its Analysis

The test data has been taken from a Drosophila experiment. Three traits, fourth, fifth and total abdominal chaeta number are given for sires, dams, male and female progeny respectively, and the data has been arranged into a five-fold nested problem. Only two traits, the fourth and total abdominal chaeta number, have been used in the test problem. The READX subroutines listed in Appendices 1, 2 and 3 have been written for this test problem.

```
   1
START 006512 101  32222
  ****** TEST DATA OF NESREC ******
 SIRE 4TH     SIRE ABD     DAM 4TH      DAM ABD      MALE 4TH     MALE ABD
 FEML 4TH     FEML ABD
111246737070714111021091019101121                                              TSD10001
111246737070714111021091120121720                                              TSD10002
111246736070714091019070714111021                                              TSD10003
111246736070714091019080816111425                                              TSD10004
111246736070714091019090910071219                                              TSD10005
111247739070714091221060612111122                                              TSD10006
111247739070714091221070613101222                                              TSD10007
111247739070714091221060814091423                                              TSD10008
111247740070714111021050712071118                                              TSD10009
111247740070714111021060612091221                                              TSD10010
111247740070714111021091019071118                                              TSD10011
111247741070714091120070916071219                                              TSD10012
111247741070714091120060713101121                                              TSD10013
111247741070714091120090716081018                                              TSD10014
112248742050611070714070512081119                                              TSD10015
112248742050611070714060511060915                                              TSD10016
112248742050611070714060614111223                                              TSD10017
112248743050611101222060713110920                                              TSD10018
112248743050611101222060612121022                                              TSD10019
112248743050611101222050712111223                                              TSD10020
112248744050611111021080816101121                                              TSD10021
112248744050611111021060612071118                                              TSD10022
112248744050611111021080614131427                                              TSD10023
112249745080614091221060612090918                                              TSD10024
112249745080614091221090716131225                                              TSD10025
112249745080614091221080715101222                                              TSD10026
112249746080614111223090716141024                                              TSD10027
112249746080614111223100919121224                                              TSD10028
112249746080614111223090615141024                                              TSD10029
112249747080614141327060511081321                                              TSD10030
112249747080614141327090716110920                                              TSD10031
112249747080614141327080715111324                                              TSD10032
123250748060713111223060715090918                                              TSD10033
123250748060713111223060614070613                                              TSD10034
123250748060713111223080816111324                                              TSD10035
123250749060713101222060713070815                                              TSD10036
123250749060713101222070411101121                                              TSD10037
123250749060713101222070510111122                                              TSD10038
123250750060713121123060511101121                                              TSD10039
123250750060713121123050611100919                                              TSD10040
123250750060713121123050611091221                                              TSD10041
123251751060612101020080613080816                                              TSD10042
123251751060612101020061016121123                                              TSD10043
123251751060612101020070512111021                                              TSD10044
123251752060612151631070714101121                                              TSD10045
123251752060612151631080715091221                                              TSD10046
123251752060612151631080917101626                                              TSD10047
123251753060612081220050611081018                                              TSD10048
123251753060612081220060612100919                                              TSD10049
123251753060612081220070613101121                                              TSD10050
124252754080816091019110819131225                                              TSD10051
124252754080816091019060814091019                                              TSD10052
124252754080816091019120921100919                                              TSD10053
124252755080816091019090918080917                                              TSD10054
124252755080816091019060713101323                                              TSD10055
124252755080816091019080917091120                                              TSD10056
124252756080816101222080816090817                                              TSD10057
124252756080816101222090918081321                                              TSD10058
124252756080816101222060612071219                                              TSD10059
124253757050712111021070714081220                                              TSD10060
124253757050712111021070512090918                                              TSD10061
124253757050712111021070916110920                                              TSD10062
124253758050712121325070613091120                                              TSD10063
124253758050712121325060713091322                                              TSD10064
124253758050712121325070815081018                                              TSD10065
124253759050712121325060511090817                                              TSD10066
124253759050712121325070815111223                                              TSD10067
                                                                               TSD10068
                                                                               TSD10069
                                                                               TSD10070
                                                                               TSD10071
                                                                               TSD10072
```

```
124253759050712121325090716101323                                      TSD10073
235254760060612131326060612081220                                      TSD10074
235254760060612131326070613091322                                      TSD10075
235254760060612131326080715110819                                      TSD10076
235254761060612081018070815101020                                      TSD10077
235254761060612081018070815091019                                      TSD10078
235254761060612081018070512090918                                      TSD10079
235254762060612101323060713091120                                      TSD10080
235254762060612101323070714070916                                      TSD10081
235254762060612101323070815091322                                      TSD10082
235255763070714121022060511081119                                      TSD10083
235255763070714121022110920080917                                      TSD10084
235255763070714121022060713060915                                      TSD10085
235255764070714121022080715091019                                      TSD10086
235255764070714121022090817110920                                      TSD10087
235255764070714121022080917071219                                      TSD10088
235255765070714161430080715081018                                      TSD10089
235255765070714161430061218121123                                      TSD10090
235255765070714161430100818101222                                      TSD10091
236256766081015111122060612101020                                      TSD10092
236256766081018111122080816101020                                      TSD10093
236256766081018111122070815080917                                      TSD10094
236256767081018121022070613091221                                      TSD10095
236256767081018121022090918091322                                      TSD10096
236256767081018121022070815101222                                      TSD10097
236256768081018101222080816101121                                      TSD10098
236256768081018101222090716111021                                      TSD10099
236256768081018101222110819091019                                      TSD10100
236257769090918091322071118091322                                      TSD10101
236257769090918091322080816131225                                      TSD10102
236257769090918091322070916080816                                      TSD10103
236257770090918091019050611091120                                      TSD10104
236257770090918091019060713091019                                      TSD10105
236257770090918091019070815091120                                      TSD10106
                                                                       TSD10107

  1                                                                    TSD20001
START 008511 101    3  2  2  2  2                                      TSD20002
  ****** TEST DATA OF NESREG ******                                    TSD20003
SIRE.1STSIRE 2ND DAM 1ST DAM 2NDMALE 1STMALE 2NDFEML 1STFEML 2ND       TSD20004
111246737070714111021091019101121                                      TSD20005
111246737070714111021091120121729                                      TSD20006

    DATA AS FOR VERSION 1

236257770090918091019060713091019                                      TSD20104
236257770090918091019070315091120                                      TSD20105
                                                                       TSD20106

  1                                                                    TSD30001
START 012513 101    3  3  3  3  3 3 5 4                                TSD30002
  ****** TEST DATA OF NESREG ******                                    TSD30003
SIRE 1STSIRE 2NDSIRE 3RD DAM 1ST DAM 2ND DAM 3RDMALE 1STMALE 2NDMALE 3RDTSD30004
FEML 1STFEML 2NDFEML 3RD                                               TSD30005
111246737070714111021091019101121                                      TSD30006
111246737070714111021091120121729                                      TSD30007

    DATA AS FOR VERSION 1

236257770090918091019060713091019                                      TSD30105
236257770090918091019070815091120                                      TSD30106
                                                                       TSD30107
```

PROGRAM NESREG

ANALYSIS OF QUANTITATIVE VARIATION BY NESTED AOV AND/OR O-P REGRESSION

NUMBER OF PROBLEMS = 1

PROBLEM NO 1

ERRORS AND/OR COMMENTS FOR NESRG1

HERIT. OF DIF. FOR CHARS. 5AND 7CANNOT BE CALCULATED

CORRELATION NO 1 FOR CHARACTERS 5AND 7CANNOT BE CALCULATED

CORRELATION NO 2 FOR CHARACTERS 5AND 8CANNOT BE CALCULATED

CORRELATION NO 3 FOR CHARACTERS 5AND 8CANNOT BE CALCULATED

HERIT. OF DIF. FOR CHARS. 6AND 7CANNOT BE CALCULATED

CORRELATION NO 1 FOR CHARACTERS 6AND 7CANNOT BE CALCULATED

CORRELATION NO 2 FOR CHARACTERS 6AND 8CANNOT BE CALCULATED

CORRELATION NO 3 FOR CHARACTERS 6AND 8CANNOT BE CALCULATED

HERIT. OF DIF. FOR CHARS. 7AND 8CANNOT BE CALCULATED

CORRELATION NO 1 FOR CHARACTERS 7AND 8CANNOT BE CALCULATED

CORRELATION NO 2 FOR CHARACTERS 7AND 8CANNOT BE CALCULATED

CORRELATION NO 3 FOR CHARACTERS 7AND 8CANNOT BE CALCULATED

PROBLEM NO 1 ****** TEST DATA OF NESREG ******

NO. OF VARIABLES = 8

NO. OF LEVELS = 5

THE VARIABLES ARE THE FOLLOWING

VARIABLE NO. 1 IS SIRE 4TH

VARIABLE NO. 2 IS SIRE ABD

VARIABLE NO. 3 IS DAM 4TH

VARIABLE NO. 4 IS DAM ABD

VARIABLE NO. 5 IS MALE 4TH

VARIABLE NO. 6 IS MALE ABD

VARIABLE NO. 7 IS FEML 4TH

VARIABLE NO. 8 IS FEML ABD

ERRORS AND/OR COMMENTS FOR NESRG2

PROBLEM NO. 1
VARIABLES 5 AND 5

PARENT MEAN = 0.676238E 01 P-P CORLN. = 0.0104
PROGENY MEAN = 0.735644E 01

ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	1	0.47180176E 00	0.47180176E 00	0.82234042E 00
2	1	0.57373047E 00	0.57373047E 00	0.23988363E 00
3	3	0.71751098E 01	0.23917033E 01	0.36306389E 00
4	6	0.39525330E 02	0.65875550E 01	0.29725178E 01
5	22	0.48755371E 02	0.22161532E 01	0.13178861E 01
6	67	0.11266699E 03	0.16815969E 01	0.
SIRES REGRESSION	1	0.17246244E 02	0.17246244E 02	0.38705007E 01
DEVIATIONS	5	0.22279086E 02	0.44558172E 01	0.20106089E 01
DAMS/S REGRESSION	1	0.12110015E 00	0.12110015E 00	0.52290353E-01
DEVIATIONS	21	0.48634271E 02	0.23159177E 01	0.13772133E 01
TOTAL	100	0.20916833E 03		

VARIANCE (COVARIANCE)

		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.16815969E 01	0.23821120E 01	0.14010302E 01	0.98108176E 00	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.17982017E 00		0.71928067E 00	0.13219565E 01	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.52069494E 00		0.20827798E 01	0.63971584E 00	(SIRE)

HERITABILITIES AND STD. ERRORS

(SIRE)		(DAM)		(S+D)	
OF SIB ANALYSIS					
0.87434167E 00	0.67091212E 00	0.30195082E 00	0.39590464E 00	0.58814623E 00	0.35869111E 00
OF O-P REGRESSION					
0.87991012E 00	0.29619889E 00				

HOMEOSTATIC COEF.(=0.0 IF NO NAT. SEL.) = 0.63284263E-02

O-P CORLN. 0.58591652E 00

0.55284881E-01 0.21508572E 00 CORRECTION APPLD. = 0.12326289E 01
O-P CORLN. 0.54779805E-01

COMMON ENVIR. VAR. (CCVAR.) -0.34087478E 00
W/IN FS ENVIR. VAR. (COVAR.) 0.64020701E 00
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 2.97273 (2) = 2.96544 (3) = 8.39784

PROBLEM NO. 1
VARIABLES 5 AND 6
ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	1	0.24339600E 01	0.24339600E 01	0.18582479E 01
2	1	0.13098145E 01	0.13098145E 01	0.24504803E 00
3	3	0.16035401E 02	0.53451334E 01	0.50857451E 00
4	6	0.63060181E 02	0.10510030E 02	0.32474834E 01
5	22	0.71199951E 02	0.32363614E 01	0.15058032E 01
6	67	0.14400037E 03	0.21492592E 01	0.
TOTAL	100	0.29803967E 03		

		VARIANCE (COVARIANCE)			
		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.21492592E 01	0.33814042E 01	0.24642901E 01	0.91711410E 00	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.36569189E 00		0.14627675E 01	0.14178754E 01	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.86645316E 00		0.34658127E 01	0.41572511E 00	(SIRE)
DIFFERENCE OF VARIABLES 5 AND 6	HERIT. SIRE 0.19009729E 00	0.11955624E 01	0.22727317E 00		

CORRELATIONS AND STD. ERRORS

	(SIRE)		(DAM)		(S+D)	
OF SIB ANALYSIS						
GENETIC	0.96825305E 00	0.56223709E-01	0.11282636E 01	0.24701069E 00	0.10105749E 01	0.53047761E-01
ENVIRONMENTAL	0.43198033E 00	0.81760722E 00	0.67311360E 00	0.16994922E 00	0.59732984E 00	0.24329095E 00
PHENOTYPIC					0.84977297E 00	0.34386782E-01
S.C.R.	0.87098546E 00	0.54019868E 00	0.36760477E 00	0.36661198E 00	0.61929511E 00	0.26360715E 00
OF O-P REGRESSION						
SIRES GENETIC	0.10530582E 01	0.51755604E-01	C.V.(DEN.COVS.) = 0.87774108E 00			
S.C.R.	0.11342653E 01	0.24819926E 00				
DAMS GENETIC			0.13188431E 01	0.10141945E 01	C.V.(DEN.COVS.) = 0.47313591E 01	
S.C.R.			0.13895352E 00	0.15969530E 00		

COMMON ENVIR. VAR. (COVAR.) -0.50076128E 00
W/IN FS ENVIR. VAR. (COVAR.) 0.41635286E 00
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 2.97273 (2) = 2.96544 (3) = 8.39784

PROBLEM NO. 1
VARIABLES 5 AND 7
ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	1	-0.16491699E 01	-0.16491699E 01	-0.90680269E 00
2	1	0.18186646E 01	0.18186646E 01	-0.47657408E 01
3	3	-0.11448364E 01	-0.38161214E 00	-0.13437257E 00
4	6	0.17039734E 02	0.28399557E 01	0.32242871E 01
5	22	0.19377625E 02	0.88080111E 00	0.23924207E 01
6	67	0.24666931E 02	0.36816315E 00	0.
TOTAL	100	0.60108948E 02		

		VARIANCE (COVARIANCE)			
		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.36816315E 00	0.77405256E 00	0.81177883E 00	-0.37726273E-01	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.17244702E 00		0.68978807E 00	0.23269102E-01	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.23344239E 00		0.93376957E 00	-0.98829165E-01	(SIRE)
DIFFERENCE OF VARIABLES 5 AND 7	HERIT. SIRE 0.	0.35576163E 01	0.		

CORRELATIONS AND STD. ERRORS

	(SIRE)		(DAM)		(S+D)	
OF SIB ANALYSIS						
GENETIC	0.	0.	0.74341162E 00	0.79407565E 00	0.95432118E 00	0.51466171E 00
ENVIRONMENTAL	-0.77243971E-01	0.45321832E 00	0.14763554E-01	0.36193477E 00	-0.25566711E-01	0.28988292E 00
PHENOTYPIC					0.30320987E 00	0.97216265E-01
S.C.R.	0.36577380E 00	0.34039980E 00	0.27020200E 00	0.33260791E 00	0.31798791E 00	0.18929285E 00

COMMON ENVIR. VAR. (CCVAR.) -0.60995374E-01
W/IN FS ENVIR. VAR. (COVAR.) -0.98721638E-01
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 2.97273 (2) = 2.96544 (3) = 8.39784

PROBLEM NO. 1
VARIABLES 5 AND 8
ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	1	-0.29721680E 01	-0.29721680E 01	-0.66159447E 00
2	1	0.44924317E 01	0.44924317E 01	0.14381399E 02
3	3	0.93713379E 00	0.31237793E 00	0.78693263E-01
4	6	0.23817383E 02	0.39695638E 01	0.42031059E 01
5	22	0.20777588E 02	0.94443581E 00	0.26003763E 01
6	67	0.24333863E 02	0.36319198E 00	0.
TOTAL	100	0.71386231E 02		

		VARIANCE (COVARIANCE)			
		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.36319198E 00	0.91911410E 00	0.11118442E 01	-0.19273016E 00	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.19552545E 00		0.78210180E 00	-0.27858936E-01	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.36039668E 00		0.14415867E 01	-0.35770746E 00	(SIRE)
DIFFERENCE OF VARIABLES 5 AND 8	HERIT. SIRE -0.10155898E 00	0.64223175E 01	-0.65224403E 00		

CORRELATIONS AND STD. ERRORS

	(SIRE)		(DAM)		(S+D)	
	OF SIB ANALYSIS					
GENETIC	0.12923642E 01	0.16274239E 01	0.	0.	0.	0.
ENVIRONMENTAL	-0.16746683E 00	0.46508071E 00	-0.84233008E-02	0.26902515E 00	-0.70101614E-01	0.259025l4E 00
PHENOTYPIC					0.22253108E 00	0.10127908E 00
S.C.R.	0.34902941E 00	0.31751110E 00	0.18935838E 00	0.28877527E 00	0.26919390E 00	0.17996106E 00

COMMON ENVIR. VAR. (CCVAR.) -0.16487122E 00
W/IN FS ENVIR. VAR. (COVAR.) -0.35760137E 00
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 2.97273 (2) = 2.96544 (3) = 8.39784

PROBLEM NO. 1
VARIABLES 6 AND 6

PARENT MEAN = 0.138812E 02 P-P CORLN. = 0.0386
PROGENY MEAN = 0.145545E 02

ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	1	0.12556885E 02	0.12556885E 02	0.41989550E 01
2	1	0.29904785E 01	0.29904785E 01	0.16180479E 00
3	3	0.55446045E 02	0.18482015E 02	0.96399049E 00
4	6	0.11503442E 03	0.19172404E 02	0.30619033E 01
5	22	0.13775513E 03	0.62615967E 01	0.13838115E 01
6	67	0.30316773E 03	0.45248914E 01	0.
SIRES REGRESSION	1	0.58674073E 02	0.58674073E 02	0.52052616E 01
DEVIATIONS	5	0.56360351E 02	0.11272070E 02	0.18001910E 01
DAMS/S REGRESSION	1	0.10877763E 02	0.10877763E 02	0.18004239E 01
DEVIATIONS	21	0.12687736E 03	0.60417791E 01	0.13352319E 01
TOTAL	100	0.62695068E 03		

VARIANCE (COVARIANCE)

		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.45248914E 01	0.66470076E 01	0.42442324E 01	0.24027751E 01	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.58421279E 00		0.23368512E 01	0.33564657E 01	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.15379034E 01		0.61516137E 01	0.14477629E 01	(SIRE)

HERITABILITIES AND STD. ERRORS

(SIRE)		(DAM)		(S+D)	
OF SIB ANALYSIS					
0.92547114E 00	0.69903561E 00	0.35156439E 00	0.39775492E 00	0.63851776E 00	0.37158510E 00
OF O-P REGRESSION					
0.13185185E 01	0.39591420E 00				
O-P CORLN. 0.64972923E 00					

HOMEOSTATIC COEF.(=0.0 IF NO NAT. SEL.) = 0.29809773E 00

0.24591897E 00 0.16483061E 00 CORRECTION APPLD. = 0.99360376E 00
O-P CORLN. 0.31413657E 00

COMMON ENVIR. VAR. (COVAR.) -0.95369063E 00
W/IN FS ENVIR. VAR. (COVAR.) 0.14490845E 01
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 2.97273 (2) = 2.96544 (3) = 8.39784

PROBLEM NO. 1
VARIABLES 6 AND 7
ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	1	-0.85079346E 01	-0.85079346E 01	-0.20491283E 01
2	1	0.41519776E 01	0.41519776E 01	-0.69046507E 00
3	3	-0.18039917E 02	-0.60133056E 01	-0.12432478E 01
4	6	0.29020630E 02	0.48367716E 01	0.25142770E 01
5	22	0.42321900E 02	0.19237227E 01	0.40701190E 01
6	67	0.31667237E 02	0.47264532E 00	0.
TOTAL	100	0.80613892E 02		

VARIANCE (COVARIANCE)

		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.47264532E 00	0.13080798E 01	0.16708691E 01	-0.36278923E 00	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.48813001E 00		0.19525200E 01	-0.50361470E 00	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.34730453E 00		0.13892181E 01	-0.22210179E 00	(SIRE)
DIFFERENCE OF VARIABLES 6 AND 7	HERIT. SIRE 0.	0.59126636E 01	0.		

CORRELATIONS AND STD. ERRORS

	(SIRE)		(DAM)		(S+D)	
			OF SIB ANALYSIS			
GENETIC	0.	0.	0.11674622E 01	0.80747754E 00	0.11285568E 01	0.56406078E 00
ENVIRONMENTAL	-0.11539218E 00	0.54051392E 00	-0.20052899E 00	0.42769231E 00	-0.15710188E 00	0.33641532E 00
PHENOTYPIC					0.30674333E 00	0.97432185E-01
S.C.R.	0.32577017E 00	0.35120924E 00	0.45786387E 00	0.33786502E 00	0.39181702E 00	0.18599657E 00

COMMON ENVIR. VAR. (COVAR.) 0.14082548E 00
W/IN FS ENVIR. VAR. (COVAR.) -0.22196374E 00
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 2.97273 (2) = 2.96544 (3) = 8.39784

PROBLEM NO. 1
VARIABLES 6 AND 8
ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	1	-0.15333496E 02	-0.15333496E 02	-0.14950250E 01
2	1	0.10256348E 02	0.10256348E 02	-0.48679027E 02
3	3	-0.63208008E 00	-0.21069336E 00	-0.27629852E-01
4	6	0.45753418E 02	0.76255696E 01	0.28979956E 01
5	22	0.57889161E 02	0.26313255E 01	0.29712956E 01
6	67	0.59333985E 02	0.88558185E 00	0.
TOTAL	100	0.15726733E 03		

		VARIANCE (COVARIANCE)			
		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.88558185E 00	0.20680507E 01	0.23649377E 01	-0.29688702E 00	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.58725321E 00		0.23490128E 01	-0.28892457E 00	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.59521566E 00		0.23808626E 01	-0.30510814E 00	(SIRE)
DIFFERENCE OF VARIABLES 6 AND 8	HERIT. SIRE -0.96005177E-01	0.96626802E 01	-0.92766732E 00		

CORRELATIONS AND STD. ERRORS

	(SIRE)		(DAM)		(S+D)	
			OF SIB ANALYSIS			
GENETIC	0.12419544E 01	0.14306459E 01	0.	0.	0.	0.
ENVIRONMENTAL	-0.94950974E-01	0.50421508E 00	-0.54823875E-01	0.29310288E 00	-0.69002622E-01	0.28175997E 00
PHENOTYPIC					0.29974396E 00	0.96316405E-01
S.C.R.	0.34508302E 00	0.33396986E 00	0.34046670E 00	0.29921708E 00	0.34277486E 00	0.18123036E 00

COMMON ENVIR. VAR. (COVAR.) -0.79624578E-02
W/IN FS ENVIR. VAR. (COVAR.) -0.30484948E 00
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 2.97273 (2) = 2.96544 (3) = 8.39784

PROBLEM NO. 1
VARIABLES 7 AND 7

PARENT MEAN = 0.106436E 02 P-P CORLN. = 0.0104
PROGENY MEAN = 0.952475E 01

ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	1	0.57644043E 01	0.57644043E 01	0.99995764E 00
2	1	0.57646485E 01	0.57646485E 01	0.88881081E 00
3	3	0.19457398E 02	0.64857991E 01	0.21471678E 01
4	6	0.18123780E 02	0.30206299E 01	0.89708393E 00
5	22	0.74077637E 02	0.33671653E 01	0.13590336E 01
6	67	0.16600037E 03	0.24776174E 01	0.
SIRES REGRESSION	1	0.31676939E 01	0.31676939E 01	0.10589983E 01
DEVIATIONS	5	0.14956085E 02	0.29912171E 01	0.88834874E 00
DAMS/S REGRESSION	1	0.10020263E 01	0.10020263E 01	0.28795589E 00
DEVIATIONS	21	0.73075610E 02	0.34797910E 01	0.14044908E 01
TOTAL	100	0.28918824E 03		

VARIANCE (COVARIANCE)

		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.24776174E 01	0.27358486E 01	0.51646252E 00	0.22193861E 01	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.29923631E 00		0.11969452E 01	0.18791447E 01	(DAM)
VARIANCE COMPONENT 1 (SIRE)	-0.41005038E-01		-0.16402014E 00	0.25589038E 01	(SIRE)

HERITABILITIES AND STD. ERRORS

(SIRE)		(DAM)		(S+D)	
OF SIB ANALYSIS					
-0.59952196E-01	0.31269696E 00	0.43750418E 00	0.52113926E 00	0.18877599E 00	0.22801194E 00

OF O-P REGRESSION

0.55689847E 00
O-P CORLN. 0.22152461E 00

0.51539430E 00 CORRECTION APPLD. = 0.14767717E 01

0.12901531E 00 0.21243611E 00
O-P CORLN. 0.12920918E 00

PRELIMINARY PARTITIONING OF PHEN. VARIANCE

		(2)	(3)
ADDITIVE	0.86877323E 00		
DOMINANCE	-0.58352774E 00		
ADD. * ADD.	0.22273779E-01		
SEX LINK.	0.	-0.13555336E 00	-0.583001004E 00
MAT. EFFECT	0.	0.	

COMMON ENVIR. VAR. (COVAR.) 0.34024134E 00
W/IN FS ENVIR. VAR. (COVAR.) 0.25596275E 01
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 2.97273 (2) = 2.96544 (3) = 8.39784

PROBLEM NO. 1
VARIABLES 7 AND 8
ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	1	0.10388916E 02	0.10388916E 02	0.72954670E 00
2	1	0.14240234E 02	0.14240234E 02	0.42257480E 01
3	3	0.10109619E 02	0.33698731E 01	0.74974199E 00
4	6	0.26968262E 02	0.44947103E 01	0.13049192E 01
5	22	0.75777588E 02	0.34444358E 01	0.10489838E 01
6	67	0.22000073E 03	0.32835930E 01	0.
TOTAL	100	0.35748535E 03		

		VARIANCE (COVARIANCE)			
		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.32835930E 01	0.34628109E 01	0.35843588E 00	0.31043750E 01	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.54106143E-01		0.21642457E 00	0.31753806E 01	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.12511180E 00		0.50044725E 00	0.30324103E 01	(SIRE)
DIFFERENCE OF VARIABLES 7 AND 8	HERIT. SIRE 0.	0.19270361E 01	0.		

CORRELATIONS AND STD. ERRORS

	(SIRE)		(DAM)		(S+D)	
OF SIB ANALYSIS						
GENETIC	0.	0.	0.	0.	0.	0.
ENVIRONMENTAL	0.70983162E 00	0.71359840E-01	0.80527098E 00	0.10927331E 00	0.75073850E 00	0.75988618E-01
PHENOTYPIC					0.78232118E 00	0.38929958E-01
S.C.R.	0.11306147E 00	0.27527367E 00	0.48894823E-01	0.40602148E 00	0.80978138E-01	0.19424157E 00
OF O-P REGRESSION						
SIRES GENETIC	0.12605357E 01	0.48039624E 00	C.V.(DEN.COVS.) = 0.26790984E 01			
S.C.R.	0.28265448E 00	0.35225616E 00				
DAMS GENETIC			0.13424729E 01	0.46729084E 00	C.V.(DEN.COVS.) = 0.20876565E 01	
S.C.R.			0.34423944E 00	0.16711558E 00		

COMMON ENVIR. VAR. (CCVAR.) -0.71005662E-01
W/IN FS ENVIR. VAR. (COVAR.) 0.30333694E 01
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 2.97273 (2) = 2.96544 (3) = 8.39784

PROBLEM NO. 1
VARIABLES 8 AND 8

PARENT MEAN = 0.220099E 02 P-P CORLN. = 0.0386
PROGENY MEAN = 0.204059E 02

ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	1	0.18723145E 02	0.18723145E 02	0.53225896E 00
2	1	0.35176758E 02	0.35176758E 02	0.10745053E 02
3	3	0.98212890E 01	0.32737630E 01	0.44007833E 00
4	6	0.44634277E 02	0.74390462E 01	0.12033881E 01
5	22	0.13599854E 03	0.61817516E 01	0.83167735E 00
6	67	0.49800244E 03	0.74328722E 01	0.
SIRES REGRESSION	1	0.59999999E 00	0.59999999E 00	0.68128744E-01
DEVIATIONS	5	0.44034277E 02	0.88068553E 01	0.14246537E 01
DAMS/S REGRESSION	1	0.46123243E 02	0.46123243E 02	0.10777023E 02
DEVIATIONS	21	0.89875292E 02	0.42797758E 01	0.57579031E 00
TOTAL	100	0.74235644E 03		

VARIANCE (COVARIANCE)

		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.74328722E 01	0.71613570E 01	-0.54303049E 00	0.77043875E 01	(S+D)
VARIANCE COMPONENT 2 (DAM)	-0.42086629E 00		-0.16834651E 01	0.82746045E 01	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.14935105E 00		0.59740423E 00	0.71319992E 01	(SIRE)

HERITABILITIES AND STD. ERRORS

(SIRE)		(DAM)		(S+D)	
OF SIB ANALYSIS					
0.83420534E-01	0.27439024E 00	-0.23507628E 00	0.41104624E 00	-0.75827875E-01	0.20300896E 00
OF O-P REGRESSION					
0.21405156E 00	0.74217270E 00	CORRECTION APPLD. = 0.16053867E 01			
O-P CORLN. 0.59468558E-01					
		0.50964635E 00	0.19395955E 00		
		O-P CORLN. 0.53944224E 00			

PRELIMINARY PARTITIONING OF PHEN. VARIANCE

ADDITIVE	0.53242378E 00		
DOMINANCE	-0.14874711E 01		
ADD. * ADD.	0.15721895E 01	(2)	(3)
SEX LINK.	0.	0.58664066E 00	-0.78085812E 00
MAT. EFFECT	0.31867411E-01	0.29559479E 00	

COMMON ENVIR. VAR. (CCVAR.) -0.57021733E 00
W/IN FS ENVIR. VAR. (COVAR.) 0.71341701E 01
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 2.97273 (2) = 2.96544 (3) = 8.39784

(e) Appendix 5

Some Examples for Type 2 (See Table 1, p.2) Unbalanced Data

There are a number of possible types of type 2 unbalanced data and the program has been checked for only some of these combinations. Five examples from Becker (1964) were tested. NESREG gives correct values for every parameter that can be estimated from these examples, but several misleading values are also printed (a line has been ruled through these in the following listing). The user is urged to gain experience from the Becker examples. A listing of the required parameter cards, data cards, and READX subroutine, together with the output given by NESREG, is included in this Appendix. A brief comment on the method of setting up each example follows.

NB: I2 should never be less than 2.

(i) Paternal half-sib analysis (Becker, p.5)

Data punched with dam and progeny identifications the same. Note that I2 = 2 (3 levels). A dummy dam identification is included to make up 3 levels. Set N3 = 2.

Coding the problem this way, implies that every progeny has a separate dam. This is a basic assumption of "half-sib" analysis. The method of coding for NESREG highlights this assumption, and discourages use of half-sib analysis in inappropriate cases or where the dams are simply not identified.

(ii) Full-sib analysis - one sex of progeny (Becker, p.10)

No difficulties in coding this problem. Set N3 = 2.

Standard errors of heritability estimates given by NESREG for (full or half) sib analyses do not agree with Becker (1964), because Becker's formulae use the degrees of freedom of a mean square, while NESREG adds 2 to the same, to allow for using an estimate in place of a known mean square.

(iii) Regression of offspring mean on sire (Becker, p.27)

Data punched with sire and dam identifications the same. Use can punch progeny means or write READX to read individual progeny data and calculate means. Set N3 =

3 (O-P problem only) - sib analysis is misleading when both dam and progeny degrees of freedom are zero.

(iv) Intra-sire regression of offspring mean on dam (Becker, p.30)

Data punched with dam and progeny identifications the same. Can punch progeny means or write READX to calculate means from individual data. Set N3 = 1 or 3. This problem is coded in a similar way to the half-sib problem.

(v) Intra-sire regression of offspring on repeated dam (Becker, p.33)

This problem is coded in a similar way to the full-sib problem. Set N3 = 1 or 3.

Listing of test examples from Becker (1964)

```
      SUBROUTINE READX                                                  RXB10001
C-----VERSION.1                                                         RXB10002
C-----READX FOR BECKER PROBLEMS                                         RXB10003
      COMMON XID(5),X(12),Y,N1,N3,N4,I1,I2,IS,ID,IM,IF                  RXB10004
      GO TO (10,10,10,10,10),N1                                         RXB10005
   10 READ(5,1) (XID(J),J=1,I2),(X(J),J=1,I1)                           RXB10006
    1 FORMAT(2F2.0,2X,2F4.0)                                            RXB10007
      RETURN                                                            RXB10008
      END                                                               RXB10009

   5                                                                    BKD10001
START   1222   5  80010                                                 BKD10002
BECKER P5,NESTED ANALYSIS,SIRE GROUPS ONLY,MALE OFFSPRING ONLY          BKD10003
MALE 1ST                                                                BKD10004
 1 1   687                                                              BKD10005
 1 2   691                                                              BKD10006
 1 3   793                                                              BKD10007
 1 4   675                                                              BKD10008
 1 5   700                                                              BKD10009
 1 6   753                                                              BKD10010
 1 7   704                                                              BKD10011
 1 8   717                                                              BKD10012
 2 1   618                                                              BKD10013
 2 2   680                                                              BKD10014
 2 3   592                                                              BKD10015
 2 4   683                                                              BKD10016
 2 5   631                                                              BKD10017
 2 6   691                                                              BKD10018
 2 7   694                                                              BKD10019
 2 8   732                                                              BKD10020
 3 1   618                                                              BKD10021
 3 2   687                                                              BKD10022
 3 3   763                                                              BKD10023
 3 4   747                                                              BKD10024
 3 5   678                                                              BKD10025
 3 6   737                                                              BKD10026
 3 7   731                                                              BKD10027
 3 8   603                                                              BKD10028
 4 1   690                                                              BKD10029
 4 2   657                                                              BKD10030
 4 3   669                                                              BKD10031
 4 4   606                                                              BKD10032
 4 5   718                                                              BKD10033
 4 6   693                                                              BKD10034
 4 7   669                                                              BKD10035
 4 8   648                                                              BKD10036
 5 1   717                                                              BKD10037
 5 2   658                                                              BKD10038
 5 3   674                                                              BKD10039
 5 4   611                                                              BKD10040
 5 5   678                                                              BKD10041
 5 6   788                                                              BKD10042
 5 7   650                                                              BKD10043
 5 8   690                                                              BKD10044
                                                                        BKD10045
START   1222   5  30010                                                 BKD10046
BECKER P10,NESTED ANALYSIS,S AND D GROUPS,MALE OFFSPRING ONLY           BKD10047
MALE 1ST                                                                BKD10048
 1 1 1 965                                                              BKD10049
 1 1 2 813                                                              BKD10050
 1 1 3 765                                                              BKD10051
 1 2 4 803                                                              BKD10052
 1 2 5 640                                                              BKD10053
 1 2 6 714                                                              BKD10054
 1 3 7 644                                                              BKD10055
 1 3 8 753                                                              BKD10056
 1 3 9 705                                                              BKD10057
 2 410 740                                                              BKD10058
 2 411 798                                                              BKD10059
 2 412 941                                                              BKD10060
 2 513 701                                                              BKD10061
 2 514 847                                                              BKD10062
 2 515 909                                                              BKD10063
```

```
 2 616 905                                                                  BKD10064
 2 617 800                                                                  BKD10065
 2 618 853                                                                  BKD10066
 3 719 696                                                                  BKD10067
 3 720 807                                                                  BKD10068
 3 721 800                                                                  BKD10069
 3 822 752                                                                  BKD10070
 3 823 863                                                                  BKD10071
 3 824 759                                                                  BKD10072
 3 925 686                                                                  BKD10073
 3 926 832                                                                  BKD10074
 3 927 796                                                                  BKD10075
 41028 979                                                                  BKD10076
 41029 798                                                                  BKD10077
 41030 788                                                                  BKD10078
 41131 905                                                                  BKD10079
 41132 880                                                                  BKD10080
 41133 770                                                                  BKD10081
 41234 797                                                                  BKD10082
 41235 721                                                                  BKD10083
 41236 765                                                                  BKD10084
 51337 809                                                                  BKD10085
 51338 756                                                                  BKD10086
 51339 775                                                                  BKD10087
 51440 887                                                                  BKD10088
 51441 935                                                                  BKD10089
 51442 937                                                                  BKD10090
 51543 872                                                                  BKD10091
 51544 811                                                                  BKD10092
 51545 925                                                                  BKD10093
                                                                            BKD10094
START   2232  17  11010                                                     BKD10095
BECKER P27.0-P ANALYSIS.SIRE AND MALE OFFSPRING ONLY                        BKD10096
SIRE 1ST    MALE 1ST                                                        BKD10097
 1 1   601 910                                                              BKD10098
 2 2   733 983                                                              BKD10099
 3 3   793 976                                                              BKD10100
 4 4   7951050                                                              BKD10101
 5 5   8181080                                                              BKD10102
 6 6   8381040                                                              BKD10103
 7 7   85410e0                                                              BKD10104
 8 8   8801025                                                              BKD10105
 9 9   882 994                                                              BKD10106
1010   8951030                                                              BKD10107
1111   9521021                                                              BKD10108
1212   9531078                                                              BKD10109
1313   961 964                                                              BKD10110
1414   979 976                                                              BKD10111
1515   9951110                                                              BKD10112
1616   9971041                                                              BKD10113
1717  10401035                                                              BKD10114
                                                                            BKD10115
START   2232   6  3C1C1                                                     BKD10116
BECKER P3C.0-P ANALYSIS.DAM AND FEML OFFSPR ONLY.OFFSPRING MEAN OBS.        BKD10117
 DAM 1ST    FEML 1ST                                                        BKD10118
 1 1 1 754 808                                                              BKD10119
 1 2 2 648 70C                                                              BKD10120
 1 3 3 861 72C                                                              BKD10121
 2 4 4 740 725                                                              BKD10122
 2 5 5 712 840                                                              BKD10123
 2 6 6 812 8C0                                                              BKD10124
 3 7 7 765 780                                                              BKD10125
 3 8 8 807 84C                                                              BKD10126
 4 9 9 969 850                                                              BKD10127
 41C1C 849 802                                                              BKD10128
 41111 732 830                                                              BKD10129
 51212 740 806                                                              BKD10130
 51313 741 835                                                              BKD10131
 61414 831 630                                                              BKD10132
 61515 639 800                                                              BKD10133
 61616 733 804                                                              BKD10134
                                                                            BKD10135
START   2232   6  3C101                                                     BKD10136
```

```
BECKER P33•0-P ANALYSIS•DAM AND FEML OFFSPR ONLY•REPEATED PARENT OF S•   BKD10137
 DAM IST    FEML 1ST                                                      BKD10138
 1 1 1 754 772                                                            BKD10139
 1 1 2 754 781                                                            BKD10140
 1 1 3 754 871                                                            BKD10141
 1 2 4 648 627                                                            BKD10142
 1 2 5 648 653                                                            BKD10143
 1 2 6 648 694                                                            BKD10144
 1 2 7 648 826                                                            BKD10145
 1 3 8 881 786                                                            BKD10146
 1 3 9 881 653                                                            BKD10147
 1 310 881 851                                                            BKD10148
 1 311 881 588                                                            BKD10149
 2 412 740 782                                                            BKD10150
 2 413 740 668                                                            BKD10151
 2 514 712 665                                                            BKD10152
 2 515 712 977                                                            BKD10153
 2 516 712 878                                                            BKD10154
 2 617 812 936                                                            BKD10155
 2 618 812 779                                                            BKD10156
 2 619 812 685                                                            BKD10157
 3 720 765 666                                                            BKD10158
 3 721 765 871                                                            BKD10159
 3 722 765 817                                                            BKD10160
 3 723 765 766                                                            BKD10161
 3 824 807 916                                                            BKD10162
 3 825 807 657                                                            BKD10163
 3 826 807 962                                                            BKD10164
 3 827 807 825                                                            BKD10165
 4 928 969 962                                                            BKD10166
 4 929 969 738                                                            BKD10167
 41030 849 909                                                            BKD10168
 41031 849 695                                                            BKD10169
 41132 732 747                                                            BKD10170
 41133 732 666                                                            BKD10171
 41134 732 656                                                            BKD10172
 41135 732 878                                                            BKD10173
 41136 7321003                                                            BKD10174
 51237 740 877                                                            BKD10175
 51238 740 807                                                            BKD10176
 51239 740 797                                                            BKD10177
 51240 740 743                                                            BKD10178
 51341 741 895                                                            BKD10179
 51342 741 829                                                            BKD10180
 51343 741 936                                                            BKD10181
 51344 741 856                                                            BKD10182
 51345 741 796                                                            BKD10183
 51346 741 700                                                            BKD10184
 61447 831 822                                                            BKD10185
 61448 831 832                                                            BKD10186
 61449 831 887                                                            BKD10187
 61450 831 696                                                            BKD10188
 61451 831 911                                                            BKD10189
 61552 639 802                                                            BKD10190
 61553 639 790                                                            BKD10191
 61654 733 607                                                            BKD10192
 61655 733 545                                                            BKD10193
 61656 733 477                                                            BKD10194
 61657 733 387                                                            BKD10195
                                                                          BKD10196
      SUBROUTINE READX(XID•X)                                             RXB20001
C-----VERSION 2                                                           RXB20002
C-----READX FOR BECKER PROBLEMS                                           RXB20003
      DIMENSION XID(1)•X(1)                                               RXB20004
      COMMON/CBLK1/ I1•I2•N3•N4•N5•N6•IS•ID•IM•IF•N[•ITLE(9)•Y•KPUT       RXB20005
      READ(5•1)(XID(J)•J=1•I2)•(X(J)•J=1•I1)                              RXB20006
    1 FORMAT(2F2.0•2X•2F4.0)                                              RXB20007
      RETURN                                                              RXB20008
      END                                                                 RXB20009
   5                                                                      BKD20001
START   1221   5   8  0  0  1  0                                         BKD20002
BECKER P5•NESTED ANALYSIS•SIRE GROUPS ONLY•MALE OFFSPRING ONLY           BKD20003
```

```
MALE 1ST                                                                BKD20004
 1 1   687                                                              BKD20005
 1 2   691                                                              BKD20006

    DATA AS FOR VERSION 1

 5 7   650                                                              BKD20043
 5 8   695                                                              BKD20044
                                                                        BKD20045
START   1221   5   3  0  0  1  0                                       BKD20046
BECKER P1C.NESTED ANALYSIS.S AND D GROUPS.MALE OFFSPRING ONLY           BKD20047
                                                                        BKD20048
MALE 1ST                                                                BKD20049
 1 1 1 965                                                              BKD20050
 1 1 2 813

    DATA AS FOR VERSION 1

 51544 811                                                              BKD20092
 51545 925                                                              BKD20093
                                                                        BKD20094
                                                                        BKD20095
START   2211  17   1  1  0  1  0                                       BKD20096
BECKER P27.0-P ANALYSIS.SIRE AND MALE OFFSPRING ONLY                    BKD20097
SIRE 1STMALE 1ST                                                        BKD20098
 1 1   601  910                                                        BKD20099
 2 2   733  983

    DATA AS FOR VERSION 1

1616   9971041                                                          BKD20113
1717  10401035                                                          BKD20114
                                                                        BKD20115
START   2211   6   3  0  1  0  1                                       BKD20116
BECKER P30.0-P ANALYSIS.DAM AND FEML OFFSPR ONLY.OFFSPRING MEAN OBS.    BKD20117
 DAM 1STFEML 1ST                                                        BKD20118
 1 1 1 754 800                                                          BKD20119
 1 2 2 648 700                                                          BKD20120

    DATA AS FOR VERSION 1

 61515 639 800                                                          BKD20133
 61616 733 504                                                          BKD20134
                                                                        BKD20135
START   2211   6   3  0  1  0  1                                       BKD20136
BECKER P33.0-P ANALYSIS.DAM AND FEML OFFSPR ONLY.REPEATED PARENT OBS.   BKD20137
 DAM 1STFEML 1ST                                                        BKD20138
 1 1 1 754 772                                                          BKD20139
 1 1 2 754 781                                                          BKD20140

    DATA AS FOR VERSION 1

 61656 733 477                                                          BKD20194
 61657 733 387                                                          BKD20195
                                                                        BKD20196

      SUBROUTINE READX(XID,X)                                           RXB30001
C-----VERSION 3                                                         RXB30002
C-----READX FOR BECKER PROBLEMS                                         RXB30003
      DIMENSION XID(1),X(1)                                             RXB30004
      COMMON/CMBLK1/ I1,I2,N3,N4,N5,N6,IS,ID,IM,IF,N1,ITLE(9),Y,KPUT    RXB30005
      COMMON/CMBLK7/ M11,MIS,MID,MIM,MIF,M1,M2,ICYC,LUI,LUS             RXB30006
      READ(5,1)(XID(J),J=1,I2),(X(J),J=1,I1)                            RXB30007
    1 FORMAT(2F2.0,2X,2F4.0)                                            RXB30008
      RETURN                                                            RXB30009
      END                                                               RXB3001C

   5                                                                    BKD30001
START   1221   5   8  0  0  1  0 1 9 0                                 BKD30002
BECKER P5.NESTED ANALYSIS.SIRE GROUPS ONLY.MALE OFFSPRING ONLY          BKD30003
MALE 1ST                                                                BKD30004
 1 1   687                                                              BKD30005
 1 2   691                                                              BKD30006

    DATA AS FOR VERSION 1
```

```
 5 7   650                                                                  BKD30043
 5 8   690                                                                  BKD30044
                                                                            BKD30045
START   1221   5   3  0  C  1   0 1 5 0                                    BKD30046
BECKER P1C•NESTED ANALYSIS•S AND D GROUPS•MALE OFFSPRING ONLY              BKD30047
MALE 1ST                                                                   BKD30048
 1 1 1 965                                                                 BKD30049
 1 1 2 813                                                                 BKD30050

    DATA AS FOR VERSION 1

 51544 811                                                                 BKD30092
 51545 925                                                                 BKD30093
                                                                           BKD30094
START   2211  17   1  1  0  1   0 1 5 0                                   BKD30095
BECKER P27•O-P ANALYSIS•SIRE AND MALE OFFSPRING ONLY                       BKD30096
SIRE 1STMALE 1ST                                                           BKD30097
 1 1   601 910                                                             BKD30098
 2 2   733 983                                                             BKD30099

    DATA AS FOR VERSION 1

1616   9971041                                                             BKD30113
1717  10401035                                                             BKD30114
                                                                           BKD30115
START   2211   6   3  C  1  0   1 1 5 0                                   BKD30116
BECKER P30•C-P ANALYSIS•DAM AND FEML OFFSPR ONLY•OFFSPRING MEAN OBS•       BKD30117
 DAM 1STFEML 1ST                                                           BKD30118
 1 1 1 754 808                                                             BKD30119
 1 2 2 646 700                                                             BKD30120

    DATA AS FOR VERSION 1

 61515 639 800                                                             BKD30133
 61616 733 504                                                             BKD30134
                                                                           BKD30135
START   2211   6   3  C  1  0   1 1 5 0                                   BKD30136
BECKER P33•O-P ANALYSIS•DAM AND FEML OFFSPR ONLY•REPEATED PARENT OBS•      BKD30137
 DAM 1STFEML 1ST                                                           BKD30138
 1 1 1 754 772                                                             BKD30139
 1 1 2 754 781                                                             BKD30140

    DATA AS FOR VERSION 1

 61656 733 477                                                             BKD30194
 61657 733 387                                                             BKD30195
                                                                           BKD30196
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PROGRAM NESREG

ANALYSIS OF QUANTITATIVE VARIATION BY NESTED AOV AND/OR O-P REGRESSION

NUMBER OF PROBLEMS = 5

PROBLEM NO 1

ERRORS AND/OR COMMENTS FOR NESRG1

MERIT. OF DIF. FOR CHARS. 1AND 2CANNOT BE CALCULATED

CORRELATION NO 1 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED

CORRELATION NO 2 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED

CORRELATION NO 3 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED

CORRELATION NO 4 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED

CORRELATION NO 5 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED

CORRELATION NO 6 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED

CORRELATION NO 7 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED

PROBLEM NO 1 BECKER P5,NESTED ANALYSIS,SIRE GROUPS ONLY,MALE OFFSPRING ONLY

NO. OF VARIABLES = 1

NO. OF LEVELS = 2

THE VARIABLES ARE THE FOLLOWING

VARIABLE NO. 1 IS MALE 1ST

ERRORS AND/OR COMMENTS FOR NESRG2

PROBLEM NO. 1
VARIABLES 1 AND 1

PROGENY MEAN = 0.683275E 03

ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	4	0.17197500E 05	0.42993750E 04	0.18421419E 01
2	35	0.81686500E 05	0.23339000E 04	0.
3	0	0.	0.	0.
TOTAL	39	0.98884000E 05		

		VARIANCE (COVARIANCE)			
		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.	0.25795844E 04	0.	0.	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.23339000E 04		0.	0.	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.24568439E 03		0.98273758E 03	0.15968468E 04	(SIRE)

HERITABILITIES AND STD. ERRORS

(SIRE)		(DAM)		(S+D)	
0.38096741E 00	0.49249442E 00	0.	~~0.84140798E 00~~	0.	~~0.43975175E 00~~

OF SIB ANALYSIS

PRELIMINARY PARTITIONING OF PHEN. VARIANCE

ADDITIVE	0.99999999E 02		
DOMINANCE	0.99999999E 02		
ADD. * ADD.	0.99999999E 02	(2)	(3)
SEX LINK.	0.99999999E 02	0.99999999E 02	0.99999999E 02
MAT. EFFECT	-0.99999999E 02	-0.99999999E 02	

COMMON ENVIR. VAR. (COVAR.) ~~0.20802136E 04~~
W/IN FS ENVIR. VAR. (COVAR.) 0.

COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 1.00000 (2) = 1.00000 (3) = 8.00000

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 PROBLEM NO   2

ERRORS AND/OR COMMENTS FOR NESRG1
 HERIT. OF DIF. FOR CHARS. 1AND 2CANNOT BE CALCULATED
 CORRELATION NO 1 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED
 CORRELATION NO 2 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED
 CORRELATION NO 3 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED
 CORRELATION NO 4 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED
 CORRELATION NO 5 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED
 CORRELATION NO 6 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED
 CORRELATION NO 7 FOR CHARACTERS 1AND 2CANNOT BE CALCULATED

PROBLEM NO   2  BECKER P10,NESTED ANALYSIS,S AND D GROUPS,MALE OFFSPRING ONLY
 NO. OF VARIABLES =   1
 NO. OF LEVELS = 2
 THE VARIABLES ARE THE FOLLOWING
  VARIABLE NO.   1 IS  MALE 1ST

ERRORS AND/OR COMMENTS FOR NESRG2
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PROBLEM NO. 2
VARIABLES 1 AND 1

PROGENY MEAN = 0.808467E 03

ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	4	0.63208500E 05	0.15802125E 05	0.17934084E 01
2	10	0.88112250E 05	0.88112250E 04	0.15949578E 01
3	30	0.16573275E 06	0.55244250E 04	0.
TOTAL	44	0.31705350E 06		

		VARIANCE (COVARIANCE)			
		PHENOTYPIC	GENETIC	ENVIRONMENTAL	
VARIANCE COMPONENT 3 (ERROR)	0.55244250E 04	0.73967916E 04	0.37447334E 04	0.36520583E 04	(S+D)
VARIANCE COMPONENT 2 (DAM)	0.10956000E 04		0.43824000E 04	0.33332249E 04	(DAM)
VARIANCE COMPONENT 1 (SIRE)	0.77676669E 03		0.31070668E 04	0.39708915E 04	(SIRE)

HERITABILITIES AND STD. ERRORS

(SIRE)		(DAM)		(S+D)	
OF SIB ANALYSIS					
0.42005601E 00	0.58925862E 00	0.59247309E 00	0.69456949E 00	0.50626455E 00	0.37059210E 00

PRELIMINARY PARTITIONING OF PHEN. VARIANCE

ADDITIVE	0.42005601E 00		
DOMINANCE	0.99999999E 02		
ADD. * ADD.	0.99999999E 02	(2)	(3)
SEX LINK.	0.99999999E 02	0.99999999E 02	0.99999999E 02
MAT. EFFECT	-0.99999999E 02	-0.99999999E 02	

COMMON ENVIR. VAR. (CCVAR.) 0.31883331E 03
W/IN FS ENVIR. VAR. (COVAR.) 0.39708916E 04
COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 3.00000 (2) = 3.00000 (3) = 9.00000

PROBLEM NO 3

ERRORS AND/OR COMMENTS FOR NESRG1

HERIT. OF DIF. FOR CHARS. 2AND 3CANNOT BE CALCULATED

CORRELATION NO 1 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 2 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 3 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 4 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 5 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 6 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 7 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

PROBLEM NO 3 BECKER P27,O-P ANALYSIS,SIRE AND MALE OFFSPRING ONLY

NO. OF VARIABLES = 2

NO. OF LEVELS = 2

THE VARIABLES ARE THE FOLLOWING

VARIABLE NO. 1 IS SIRE 1ST

VARIABLE NO. 2 IS MALE 1ST

ERRORS AND/OR COMMENTS FOR NESRG2

PROBLEM NO. 3
VARIABLES 2 AND 2

PARENT MEAN = 0.880353E 03 P-P CORLN. = ~~0.0000~~
PROGENY MEAN = 0.102076E 04

ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	16	0.38699250E 05	0.24187032E 04	0.
2	0	0.	0.	0.
3	0	0.	0.	0.
SIRES REGRESSION	1	0.92561891E 04	0.92561891E 04	0.47156386E 01
DEVIATIONS	15	0.29443061E 05	0.19628707E 04	0.
TOTAL	16	0.38699250E 05		

HERITABILITIES AND STD. ERRORS

(SIRE)	(DAM) OF O-P REGRESSION	(S+D)
0.43010532E 00	0.19806355E 00	

O-P CORLN. 0.97812606E 00 HOMEOSTATIC COEF.(=0.0 IF NO NAT. SEL.) = ~~0.99999999E-02~~

COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 0.00000 (2) = 1.00000 (3) = 1.00000

PROBLEM NO 4

ERRORS AND/OR COMMENTS FOR NESRG1

HERIT. OF DIF. FOR CHARS. 2AND 3CANNOT BE CALCULATED

CORRELATION NO 1 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 2 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 3 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 4 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 5 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 6 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 7 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

PROBLEM NO 4 BECKER P30,O-P ANALYSIS,DAM AND FEML OFFSPR ONLY,OFFSPRING MEAN OBS.

NO. OF VARIABLES = 2

NO. OF LEVELS = 2

THE VARIABLES ARE THE FOLLOWING

VARIABLE NO. 1 IS DAM 1ST

VARIABLE NO. 2 IS FEML 1ST

ERRORS AND/OR COMMENTS FOR NESRG2

PROBLEM NO. 4
VARIABLES 2 AND 2

PARENT MEAN = 0.772063E 03 P-P CORLN. = 0.0000
PROGENY MEAN = 0.779375E 03

ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	5	0.30330500E 05	0.60661000E 04	0.74218265E 00
2	10	0.81733250E 05	0.81733250E 04	0.
3	0	0.	0.	0.
DAMS/S REGRESSION	1	0.80349137E 03	0.80349137E 03	0.89354305E-01
DEVIATIONS	9	0.80929758E 05	0.89921953E 04	0.
TOTAL	15	0.11206375E 06		

HERITABILITIES AND STD. ERRORS

(SIRE)	(DAM)	(S+D)
	OF O-P REGRESSION	
	0.20050629E 00	0.67076480E 00
O-P CORLN.	0.19829932E 00	

COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 1.00000 (2) = 1.00000 (3) = 2.65000

PROBLEM NO 5

ERRORS AND/OR COMMENTS FOR NESRG1

HERIT. OF DIF. FOR CHARS. 2AND 3CANNOT BE CALCULATED

CORRELATION NO 1 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 2 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 3 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 4 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 5 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 6 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

CORRELATION NO 7 FOR CHARACTERS 2AND 3CANNOT BE CALCULATED

PROBLEM NO 5 BECKER P33,O-P ANALYSIS,DAM AND FEML OFFSPR ONLY,REPEATED PARENT OBS.

NO. OF VARIABLES = 2

NO. OF LEVELS = 2

THE VARIABLES ARE THE FOLLOWING

VARIABLE NO. 1 IS DAM 1ST

VARIABLE NO. 2 IS FEML 1ST

ERRORS AND/OR COMMENTS FOR NESRG2

PROBLEM NO. 5
VARIABLES 2 AND 2

PARENT MEAN = 0.768158E 03 P-P CORLN. = 0.0000
PROGENY MEAN = 0.779088E 03

ANALYSIS OF VARIANCE (COVARIANCE)

LEVEL NO. (SOURCE)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	COMPUTED F-VALUES
1	5	0.12986300E 06	0.25972600E 05	0.84596343E 00
2	10	0.30701800E 06	0.30701800E 05	0.27892298E 01
3	41	0.45129800E 06	0.11007268E 05	0.
DAMS/S REGRESSION	1	0.11884916E 05	0.11884916E 05	0.36242717E 00
DEVIATIONS	9	0.29513308E 06	0.32792564E 05	0.29791738E 01
TOTAL	56	0.88817900E 06		

HERITABILITIES AND STD. ERRORS

(SIRE)	(DAM) OF O-P REGRESSION	(S+D)
	0.42000252E 00	0.47072113E 00
O-P CORLN.	0.25038191E 00	

COEFFICIENTS OF VARIANCE (COVARIANCE) COMPONENTS (1) = 3.35652 (2) = 3.89750 (3) = 9.46667