NOTES AND COMMENTS

THE 2×2 GENOTYPE-ENVIRONMENT TABLE

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If two genotypes or groups of genotypes, G_0 and G_1, are raised in each of two environments, E_0 and E_1, the four resulting phenotypes may, in respect

TABLE 1

	G_0	G_1	Mean
E_0	m+d+e+g	m−d+e−g	m+e
E_1	m+d−e−g	m−d−e+g	m−e
Mean . .	m+d	m−d	m

of any quantitative character, be expressed in terms of four parameters. In table 1, m stands for the overall mean, d represents the average genotypic

TABLE 2

	G_0		G_1	
E_0 .	00	d+e+g	01	e
E_1 .	10	d	11	g

effect, e the average environmental effect, and g the genotype-environment interaction. These parameters were recently used by Mather and Morley Jones (1958) in their study of genotype-environment interactions in quantitative inheritance.

In the following we will compare in terms of d, e and g the *relative* magnitudes of the phenotypic values, to be labelled 1, 2, 3 and 4 in descending order. For ease of inspection table 1 may be transformed into table 2 by adding to its elements −m+d+e+g and dividing by 2.

Haldane (1946) compared the relative magnitudes without the use of parameters, and dealt with 3 != 6 situations, left after assigning the largest phenotypic value to 00. This implies (table 2) $e+g>0$, $d+g>0$, and $d+e>0$, *i.e.* not more than one of the parameters is allowed to become negative, and its absolute value must be smaller than the value of the two positive ones. Haldane's six types can be described as follows :—

1a

1	3
2	4

d > e > | g |

3

1	4
2	3

d > g > | e |

4a

1	4
3	2

g > d > | e |

1b

1	2
3	4

e > d > | g |

2

1	2
4	3

e > g > | d |

4b

1	3
4	2

g > e > | d |

Mather and Morley Jones (*loc. cit.*) took all three parameters as positive in that they omitted the modulus sign from the inequalities, and therefore did not cover all possible situations.

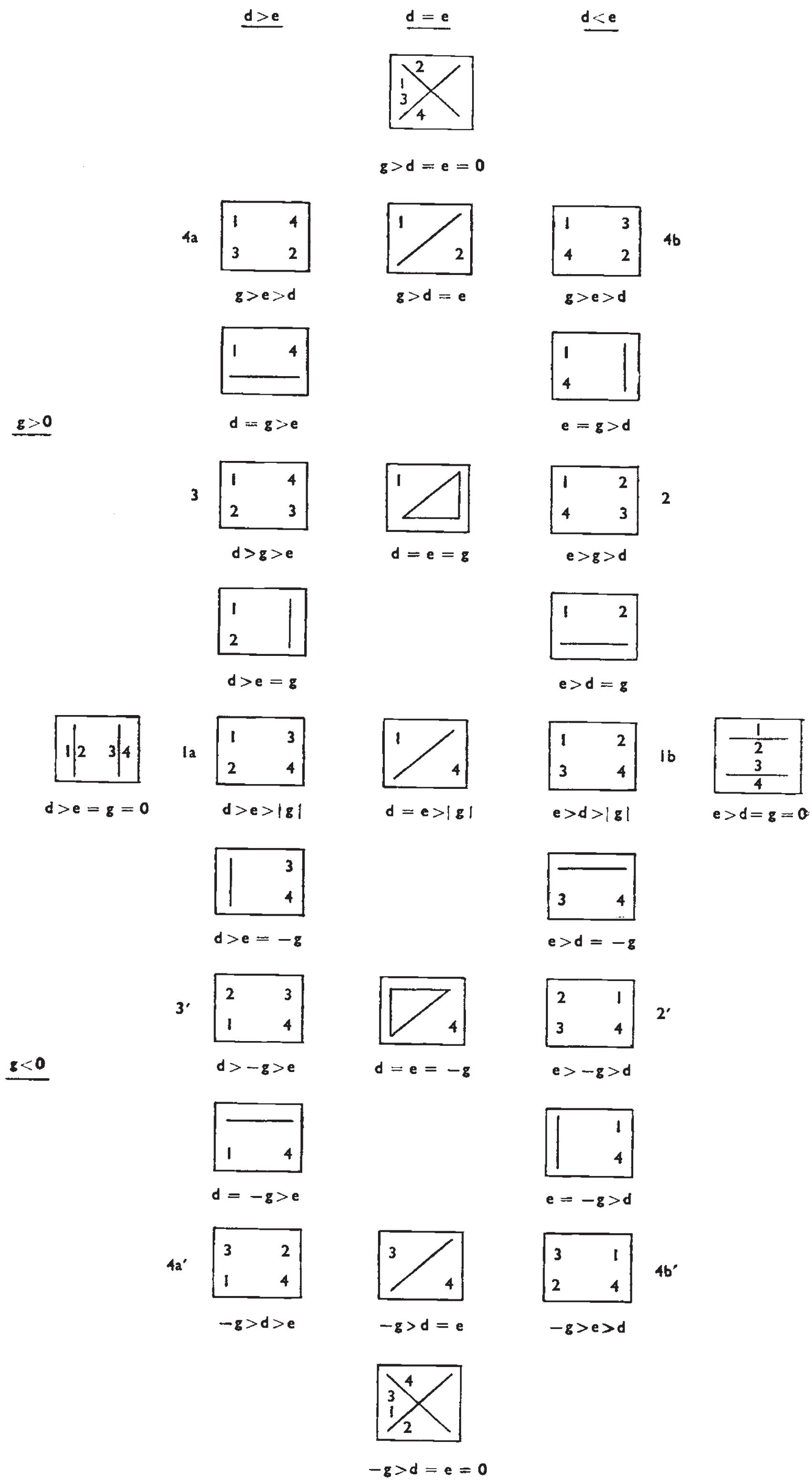
The present author proposes a modified approach as (1) it seems more consistent to take the same two parameters as positive in all cases, and as (2) it is customary in biometrical genetics to define d as non-negative. Let us define d and e as non-negative and consequently allow only g to take sign. This means that the four phenotypic values must be arranged in table 1 so that $00+10 \geqslant 01+11$, as $d \geqslant 0$, and $00+01 \geqslant 10+11$, as $e \geqslant 0$. Then with $g<0$ four new sequences of magnitude arise, *viz.* 3′ ($d>-g>e$) as a counterpart of 3 ($d>g>e$), etc., in which 00 is not the largest phenotype. The $6+4 = 10$ types have been listed in table 3. Inspecting this table with the help of table 2 we see :—

1. Table 3 is symmetrical for $d>e$, *i.e.* $10>01$, and $e>d$, *i.e.* $10<01$.
2. $g>0$ implies that 00 is the largest phenotype, $g<0$ that 11 is the smallest.
3. If $g>0$, then $00-10>|01-11|$ and $00-01>|10-11|$. This means that G_0 is the less stable genotype and at the same time E_0 the most differentiating environment. If $g<0$ this holds for G_1 and E_1 respectively.
4. If $d>|g|$ and $d>e$ (cases 1*a*, 3 and 3′), then G_0 is the highest "yielder" irrespective of environment : G_0 shows *unconditional superiority*. If in additon $|g|>e$ (cases 3 and 3′), then G_0 and G_1 have their highest values in different environments. Thus the superiority of the environment is conditioned by the genotype. This may be described as *conditional superiority of the environment.*

   If $e>|g|$ and $e>d$ (cases 1*b*, 2 and 2′), then E_0 shows *unconditional superiority*. If in addition $|g|>d$ (cases 2 and 2′), then

TABLE 3

The possible comparisons in terms of the parameters d, e and g (cf. *Table* 1), *of four phenotypes obtained by raising two genotypes in each of two environments. The phenotypic values have been labelled 1, 2, 3 and 4 in descending order of magnitude. The parameters d and e have been defined as non-negative. A line indicates equality of phenotypic values. Type numbers have been added to the cases where all four values are different.*


d>e
d = e
d<e
g>d = e = 0
4a
g>e>d
g>d = e
g>e>d
4b
g>0
d = g>e
e = g>d
3
d>g>e
d = e = g
e>g>d
2
d>e = g
e>d = g
d>e = g = 0
1a
d>e>|g|
d = e>|g|
e>d>|g|
1b
e>d = g = 0
d>e = −g
e>d = −g
3′
d>−g>e
d = e = −g
e>−g>d
2′
g<0
d = −g>e
e = −g>d
4a′
−g>d>e
−g>d = e
−g>e>d
4b′
−g>d = e = 0

E_0 and E_1 induce the " better performance " in different genotypes. Thus the superiority of the genotype is conditioned by the environment : *conditional superiority of the genotype.*

If $|g| > d$ and $|g| > e$ (cases 4*a*, 4*a*′, 4*b* and 4*b*′), then there is no unconditional superiority of either kind : *specific adaptation.*

Turning now to the cases of two or more phenotypic values being equal, we find that each of them corresponds uniquely to a parameter equality (*cf.* table 2) :—

$$d = -g \quad \therefore \quad 00 = 01 \qquad e = -g \quad \therefore \quad 00 = 10$$

$$d = g \quad \therefore \quad 10 = 11 \qquad e = g \quad \therefore \quad 01 = 11$$

$$d = g = 0 \quad \therefore \begin{cases} 00 = 01 \\ 10 = 11 \end{cases} \qquad e = g = 0 \quad \therefore \begin{cases} 00 = 10 \\ 01 = 11 \end{cases}$$

$$d = e \quad \therefore \quad 10 = 01 \qquad d = e = -g \quad \therefore \quad 00 = 01 = 10$$

$$d = e = 0 \quad \therefore \begin{cases} 10 = 01 \\ 00 = 11 \end{cases} \qquad \begin{matrix} d = e = g & \therefore & 01 = 10 = 11 \\ d = e = g = 0 & \therefore & 00 = 01 = 10 = 11 \end{matrix}$$

It should be noted that $d = 0$, $e = 0$ or $g = 0$ does not in itself lead to equality of phenotypic values. The different cases, apart from $00 = 01 = 10 = 11$, have been inserted in table 3.

Change in environment or selection in populations of genotypes may cause the different types to pass into each other. When by some selection device g is increased, *e.g.* type 4*a*′, changes into 3′, 1*a*, 3 and 4*a* respectively. Decrease of d leads from, *e.g.* type 1*a* via 1*b* to 2 or 2′, depending on whether $g > 0$ or $g < 0$. When we then allow d to become negative, we obtain $e > -d > |g|$ and finally $-d > e > |g|$. These types derive from 1*b* and 1*a* by interchanging the columns. Having defined d as non-negative, however, the selection result will under the present approach make the particular population change its label G_0 into G_1 or *vice versa.*

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