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A NOTE ON THE CALCULUS OF THE DISTRIBUTION OF GENETIC CHARACTERS IN CROSSES INVOLVING LINKAGE

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Teachers of genetics will welcome a simplified method for the calculation of the segregation of characters in crosses involving linkage, over the old, laborious method now in use. At the present time, when such crosses of linked characters are made, the usual method employed is to lay out a Punnett Square of the ordinary sort, with the different classes of gametes laid out on the axes, but with the diverse gametes **weighted** with the frequencies of their occurrence. With the purpose of simplifying this process for the use of my students, I have studied the distribution of characters, both as to genotypes and phenotypes, in the diverse sorts of crosses involving any pair of linked factors, A and B. The formulae given below will be found valid for any positive degree of linkage up to 50% of Crossing-over [which is independent segregation.]

In the formulae given below, the terms x and y are used to designate, respectively, the **linkage** and **cross-over** values of any given linked factors. Thus, if the cross-over value ascertained by experiment to exist between two genes on the same chromosome is 20.0%, the value of its linkage is 80%; and in the use of the formulae, 80, or 4; and 20 or 1, are the values to be set for x and y , respectively. The formulae follow:

(A) Crosses in which A and B Enter Together; i. e., when the P₁ involves (AB) (AB) and (ab) (ab), and the F₁ has the genotypic formula (AB) (ab). Distribution formula (*Phenotypic*):

$$\begin{aligned} AB &= 3x^2 + 4xy + 2y^2 \\ Ab &= 2xy + y^2 \\ aB &= 2xy + y^2 \\ ab &= x^2 \text{ totaling, } [2(x+y)]^2 \end{aligned}$$

Distribution formula (*Genotypic*):

$$\begin{array}{ll} (AB) (AB) = x^2 & (Ab) (Ab) = y^2 \\ (AB) (Ab) = 2xy & (Ab) (ab) = 2xy \\ (AB) (aB) = 2xy & (aB) (aB) = y^2 \\ (AB) (ab) = 2x^2 & (aB) (ab) = 2xy \\ (Ab) (aB) = 2y^2 & (ab) (ab) = x^2 \end{array}$$

(B) Crosses in which A and B Enter Separately, i. e., when the P₁ involves (Ab) and (aB), and the F₁ has the genotypic character of (Ab) (aB). Distribution formula (*Phenotypic*):

$$\begin{aligned} (AB) &= 2x^2 + 4xy + 3y^2 \\ (Ab) &= x^2 + 2xy \\ (aB) &= x^2 + 2xy \\ (ab) &= y^2 \quad n = [2(x+y)]^2 \end{aligned}$$

Distribution formula (*Genotypic*):

$$\begin{array}{ll} (AB) (AB) = y^2 & (Ab) (Ab) = x^2 \\ (AB) (Ab) = 2xy & (Ab) (ab) = 2xy \\ (AB) (aB) = 2xy & (aB) (aB) = x^2 \\ (AB) (ab) = 2y^2 & (aB) (ab) = 2xy \\ (Ab) (aB) = 2x^2 & (ab) (ab) = y^2 \end{array}$$

(C) Crosses in Which the Parents Are Diverse as to the Entrance of A and B, i. e., involving (AB) (ab) x (Ab) (aB). Distribution formula (*Phenotypic*):

$$\begin{aligned} (AB) &= 2x^2 + 5xy + 2y^2 \\ (Ab) &= x^2 + xy + y^2 \\ (aB) &= x^2 + xy + y^2 \\ (ab) &= xy \quad n = [2(x+y)]^2 \end{aligned}$$

Distribution formula (*Genotypic*):

$$\begin{array}{ll} (AB) (AB) = xy & (Ab) (Ab) = xy \\ (AB) (Ab) = x^2 + y^2 & (Ab) (ab) = 2y^2 \\ (AB) (aB) = x^2 + y^2 & (aB) (aB) = xy \\ (AB) (ab) = 2xy & (aB) (ab) = 2y^2 \\ (Ab) (aB) = 2xy & (ab) (ab) = xy \end{array}$$

On the following page will be found tables showing the Phenotype distribution in percentages of the three foregoing types of crosses of linked characters: at different cross-over values.

GENETIC CROSSES

TABLE I. SEGREGATION OF PHENOTYPES IN THE CROSS
(AB) (ab) x (AB) (ab), at DIVERS CROSS-OVER VALUES

Percentage of Crossing-Over	Percent. of Progeny A,B	of Progeny A,b	Showing a,B	Characters a,b
0	75.00	00.00	00.00	25.00
1	74.50	0.49	0.49	24.50
2	74.01	0.99	0.99	24.01
3	73.69	1.47	1.47	23.69
4	73.04	1.96	1.96	23.04
5	72.56	2.44	2.44	22.56
6	72.09	2.91	2.91	22.09
7	71.62	3.38	3.38	21.62
8	71.16	3.84	3.84	21.16
9	70.70	4.30	4.30	20.70
10	70.25	4.75	4.75	20.25
12.5	69.14	5.86	5.86	19.14
15.0	68.06	6.94	6.94	18.06
17.5	67.01	7.99	7.99	17.01
20.0	66.00	9.00	9.00	16.00
25	64.06	10.94	10.94	14.06
30	62.25	12.75	12.75	12.25
35	60.50	14.50	14.50	10.50
40	59.00	16.00	16.00	9.00
45	57.56	17.44	17.44	7.56
50	56.25	18.75	18.75	6.25

TABLE II. SEGREGATION OF PHENOTYPES IN THE CROSS
(Ab) (aB) x (Ab) (aB) AT DIVERS CROSS-OVER VALUES

0	50.00	25.00	25.00	0.00
1	50.002	24.998	24.998	0.002
2	50.01	24.99	24.99	0.01
3	50.02	24.98	24.98	0.02
4	50.04	24.96	24.96	0.04
5	50.06	24.94	24.94	0.06
6	50.07	24.93	24.93	0.07
7	50.12	24.88	24.88	0.12
8	50.16	24.84	24.84	0.16
9	50.20	24.80	24.80	0.20
10	50.25	24.75	24.75	0.25
12.5	50.39	24.61	24.61	0.39
15.0	50.56	24.44	24.44	0.56
17.5	50.76	24.24	24.24	0.76
20.0	51.00	24.00	24.00	1.00
25	51.56	23.44	23.44	1.56
3	52.25	22.75	22.75	2.25
35	53.06	21.94	21.94	3.06
40	54.00	21.00	21.00	4.00
45	55.06	19.94	19.94	5.06
50	56.25	18.75	18.75	6.25

**TABLE III. SEGREGATION OF PHENOTYPES IN THE CROSS
(AB) (ab) x (Ab) (aB), AT DIVERS CROSS-OVER VALUES**

0	50.00	25.00	25.00	0.00
1	50.25	24.75	24.75	0.25
2	50.49	24.51	24.51	0.49
3	50.73	24.27	24.27	0.73
4	50.95	24.05	24.05	0.95
5	51.18	23.82	23.82	1.18
6	51.41	23.59	23.59	1.41
7	51.63	23.37	23.37	1.63
8	51.84	23.16	23.16	1.84
9	52.05	22.95	22.95	2.05
10	52.25	22.75	22.75	2.25
12.5	52.73	22.27	22.27	2.73
15.0	53.19	21.81	21.81	3.19
17.5	53.61	21.39	21.39	3.61
20.0	54.00	21.00	21.00	4.00
25	54.68	20.32	20.32	4.68
30	55.25	19.75	19.75	5.25
35	55.68	19.32	19.32	5.68
40	56.00	19.00	19.00	6.00
45	56.18	18.82	18.82	6.18
50	56.25	18.75	18.75	6.25