

## References

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### Erratum

References inadvertently omitted from list:

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- Lindegren, C.C. and Raut, C. 1947. A direct relationship between pantothenate concentration and the time required to induce the production of pantothenate synthesizing "mutants" in yeast. Ann. Mo. Bot. Gard. 34: 85-93.

Table 1A

Symbols used for various mutations

1. Nutritional requirements. The allele for requirement, i.e., lack of synthesis of a substance is "-"; the alternative, independence, is "+".

B	biotin	L	leucine	Pa	phenylalanine
B <sub>1</sub>	thiamin	M	methionine	T	threonine
C	cystine	P	proline		

2. Sugar fermentation. The ability to ferment is "+"; the alternative, inability, is "-".

Lactose Lac

3. Bacteriophage resistance. Resistance is designated by the superscript "r"; sensitivity by "s".

V <sub>1</sub>	reaction to bacteriophage T1
V <sub>6</sub>	reaction to bacteriophage T6.

Table 1B

## A Summary of the Mutants Used

<u>Strain No.</u>	<u>Genotype</u>	<u>Origin</u>	<u>Genotype</u>	<u>Agent</u>
K-12	prototroph.	Original wild strain.		
58	B-	K-12	B+	X-ray
58-161	B-M-	58	B-M+	X-ray
58-278	B-Pa-	58	B-Pa+	X-ray
Y-24	B-Pa-C-	58-278	B-Pa-C+	u.-v.
679	T-	K-12	T+	X-ray
679-680	T-L-	679	T-L+	X-ray
Y-10	T-L-B <sub>1</sub> -	679-680	T-L-B <sub>1</sub> +	X-ray
Y-46	T-L-B <sub>1</sub> -V <sub>1</sub> <sup>r</sup>	Y-10	T-L-B <sub>1</sub> -V <sub>1</sub> <sup>s</sup>	selection
Y-53	T-L-B <sub>1</sub> -Lac-	Y-10	T-L-B <sub>1</sub> -Lac+	u.-v.
Y-64	T-L-B <sub>1</sub> -Lac-V <sub>1</sub> <sup>r</sup>	Y-53	T-L-B <sub>1</sub> -Lac-V <sub>1</sub> <sup>s</sup>	selection
Y-40	B-M-V <sub>1</sub> <sup>r</sup>	58-161	B-M-V <sub>1</sub> <sup>s</sup>	selection
Y-87	B-M-V <sub>1</sub> <sup>r</sup> Lac-	Y-40	B-M-V <sub>1</sub> <sup>r</sup> Lac+	N-mustard
Y-25	B-Pa-C-V <sub>1</sub> <sup>r</sup>	Y-24	B-Pa-C-V <sub>1</sub> <sup>s</sup>	selection
679-183	T-P-	679	T-P+	X-ray
Y-94	T-L-B <sub>1</sub> -Lac-V <sub>6</sub> <sup>r</sup>	Y553	T-L-B <sub>1</sub> -Lac-V <sub>6</sub> <sup>s</sup>	selection

Table 2.

Biochemical recombination types found in a mixed culture  
of Y-24 and Y-46.

B-Pa-C-T+L+B<sub>1</sub>+V<sub>1</sub><sup>S</sup> X B+Pa+C+T-L-B<sub>1</sub>-V<sub>1</sub><sup>R</sup>.

Type:*	No. isolated	No. of prototrophs	Ratio
B Pa C T L B <sub>1</sub>			
- - - + + +	In excess:	parental type	
+ + + - - -	In excess:	parental type	
+ + + + + +	86	--	--
+ + + + + -	36	37	0.97
+ + + - + +	2	31	0.06
+ + + + - +	4	55	0.07
- + + + + +	5	56	0.09
+ - + + + +	1	52	0.02
+ + - + + +	1	19	0.05
- - + + + +	2	41	0.05
+ + + + - -	3	16	0.19
- + + + + -	3	28	0.11
- + + - + +	isolated in a different run.		
- + + + - +	isolated in a different run.		

\* These figures do not include tests of the V<sub>1</sub> character. Of 49 prototrophs tested, 20 (41%) were resistant. Of 20 thiamin-less tested, 7 (35%) were V<sub>1</sub><sup>R</sup>.

Table 3.

Comparisons of  $V_1^r$  segregations with alternative parental couplings.

Parents		Prototrophs isolated				
		$V_1^r$	$V_1^s$	% $V_1^r$	$X^2(1)$	$X^2(2)$
B-Pa-C-T+P+	B+Pa+C+T+P-	76	6	92	101	7.90
$V_1^r X$	$V_1^s$					
$V_1^s X$	$V_1^r$	30	107	22		
B-Pa-C-T+L+B1+	B+Pa+C+T-L-B1-	80	23	77	65	1.1
$V_1^r X$	$V_1^s$					
$V_1^s X$	$V_1^r$	53	133	28		
B-M-T+P+	B+M+T-P-	49	8	86	32	1.8
$V_1^r X$	$V_1^s$					
$V_1^s X$	$V_1^r$	5	19	21		

$X^2(1)$  refers to a comparison of the classes directly: i. e., to a 2 x 2 table of the data as they stand.

$X^2(2)$  refers to a comparison in which the gametic output of  $V_1^r$  is inverted in the same manner as was done by changing the parental coupling. In both cases,  $n = 1$  for each table. The cumulative  $X^2$  are 198 and 10.8 respectively.

Table 4a.

Data of individual experiments. Lac, V<sub>1</sub> scores on colonies isolated from minimal agar plates in the cross: Y40 x Y53

B-M-T+L+B<sub>1</sub>+Lac+V<sub>1</sub><sup>r</sup> x B+M+T-L-B<sub>1</sub>-Lac-V<sub>1</sub><sup>s</sup>

Class recovered: B+M+T+L+B<sub>1</sub>...

Exp. #	Lac-V <sub>1</sub> <sup>r</sup>	Lac-V <sub>1</sub> <sup>s</sup>	Lac+V <sub>1</sub> <sup>r</sup>	Lac+V <sub>1</sub> <sup>s</sup>
1.	51	11	23	4
2.	28	21	21	0
3.	21	18	11	0
4.	189	44	129	3
5.	52	39	39	2
6.	17	10	9	0
7.	35	30	35	0
8.	20	22	10	3
9.	37	23	16	1
10.	20	13	15	2
11.	26	9	11	3
12.	19	10	11	2
13.	27	12	30	1
14.	27	13	13	1
15.	33	28	14	0
Total	602	303	387	22
%	45.8	23.1	29.4	1.7

Homogeneity:  $\chi^2 = 101.$ ,  $n = 42.$   $p \ll .001$

Table 4 b.

Data of individual experiments. Lac, V<sub>1</sub> scores on colonies isolated from thiamin-supplemented plates in the cross Y 40 x Y53.

B-M-T+L+B<sub>1</sub>+Lac+V<sub>1</sub><sup>r</sup> x B+M+T-L-B<sub>1</sub>-Lac-V<sub>1</sub><sup>s</sup>

Class recovered: B+M+T+L+B<sub>1</sub>- ca. 10% B<sub>1</sub><sup>r</sup>.

Exp.	Lac-V <sub>1</sub> <sup>r</sup>	Lac-V <sub>1</sub> <sup>s</sup>	Lac+V <sub>1</sub> <sup>r</sup>	Lac+V <sub>1</sub> <sup>s</sup>
1.	30	21	17	1
2.	73	46	50	4
3.	27	12	30	1
4.	59	34	31	3
5.	16	12	13	0
6.	21	19	5	0
7.	<u>18</u>	<u>12</u>	<u>13</u>	<u>1</u>
Total	244	156	159	10
%	42.9	27.4	27.9	1.8

Homogeneity:  $X^2 = 16.9$  n = 18, p = .5

Homogeneity of B<sub>1</sub><sup>+</sup> totals with B<sub>1</sub><sup>-</sup> totals (Tables 4a & 4 b)

602	303	387	22	1314
<u>244</u>	<u>156</u>	<u>159</u>	<u>10</u>	<u>569</u>
846	459	546	32	1883

$$x^2_3 = 4.4$$

With a normal distribution of  $X^2$ , p would be 0.2. In view of the heterogeneity of the B<sub>1</sub><sup>+</sup> data however, this result is artificially low.

Table 4 c.

Data of individual experiments. Lac, V scores on colonies isolated from minimal agar in the cross: Y 64 x 58-161.

B-M-T+L+B<sub>1</sub>+Lac+V<sub>1</sub><sup>s</sup> x B-M-T-L-B<sub>1</sub>-Lac-V<sub>1</sub><sup>r</sup>

Class recovered: B-M-T-L-B<sub>1</sub>+.....

Exp.	Lac-V <sub>1</sub> <sup>r</sup>	Lac-V <sub>1</sub> <sup>s</sup>	Lac+V <sub>1</sub> <sup>r</sup>	Lac+V <sub>1</sub> <sup>s</sup>	Sum
1.	37	55	5	19	116
2.	42	53	1	23	119
3.	8	9	1	2	20
4.	13	16	1	9	39
5.	8	12	1	8	29
Total	108	145	9	61	323
%	33.4	45.0	2.8	18.9	

Homogeneity:  $\chi^2 = 5.6$  n = 12. p = .95.

Table 4d.

As above, scores on colonies isolated from thiamin-supplemented agar

Class recovered: B+M+T+L+B<sub>1</sub>- + ca. 10% B<sub>1</sub>+

1.	109	125	8	70	312
2.	20	21	1	9	51
3.	4	5	0	1	10
Total	133	151	9	80	373
%	35.6	40.5	2.4	21.4	

Homogeneity:  $\chi^2 = .65$  n = 3, p = .85 (expts. 1 & 2 only)

Comparison of 4c and 4d totals (B<sub>1</sub>+ with B<sub>1</sub>-)

4d	133	151	9	80	373
4c	108	145	9	61	323
	241	196	18	141	696

$\chi^2 = 1.7$  n = 0.6

Table 4e

Lac,  $V_1$  scores on colonies isolated from minimal agar in the cross: Y87 X Y10. B.

$B-M-T+L+B_1+Lac-V_1^R$  x  $B+M+T-L-B_1-Lac+V_1^S$

Class recovered:  $B+M+T+L+B_1+...$

Single Experiment.

Lac- $V_1^R$	Lac- $V_1^S$	Lac+ $V_1^R$	Lac+ $V_1^S$	Total
28	6	46	57	117
% 23.9	5.1	39.3	31.6	

Table 4f

As above. Isolates from thiamin agar.

Class recovered:  $B+M+T+L+B_1^-$  + 10%  $B_1^+$

102	7	201	91	401
% 25.4	1.7	50.1	22.7	

Comparison of 4e and 4f ( $B_1^+$  with  $B_1^-$ )

28	6	46	37	117
102	7	201	91	401
130	13	247	128	518

$$\chi^2 = 8.2, n = 3, p = .04.$$

Table 4g

Tests of allelism of mutations at Lac and V loci.

1. Test of allelism of Lac<sup>-</sup> in stocks Y53 and Y87.

B<sup>+</sup>M<sup>+</sup>T<sup>-</sup>L-B<sub>1</sub>-Lac<sup>-</sup> x B<sup>-</sup>M<sup>-</sup>T<sup>+</sup>L<sup>+</sup>B<sub>1</sub>-Lac<sub>2</sub><sup>-</sup>. 134 prototrophs isolated: all Lac<sup>-</sup>.

2. Test of allelism of V<sub>1</sub><sup>r</sup> in stocks Y40 and Y-46

B<sup>-</sup>M<sup>-</sup>T<sup>+</sup>L<sup>+</sup>B<sub>1</sub><sup>+</sup>Lac<sup>+</sup>V<sub>1</sub><sup>r</sup> X B<sup>+</sup>M<sup>+</sup>T<sup>-</sup>L-B<sub>1</sub>-Lac-V<sub>1</sub><sup>r</sup>  
161 prototrophs isolated: all V<sub>1</sub><sup>r</sup>

128 Lac<sup>-</sup> ; 33 Lac<sup>+</sup>.

Table 5  
 Summary of Tables 4.

The segregation of Lac and V into "prototrophs" derived from various crosses. Scores of B<sub>1</sub><sup>+</sup> and B<sub>1</sub><sup>-</sup> classes have been pooled in view of their homogeneity.

Parents		Recombinants: B+M+T+L+B <sub>1</sub> <sup>±</sup>				Total
	B+M+T-L-B <sub>1</sub> <sup>-</sup>	Lac-V <sub>1</sub> <sup>r</sup>	Lac-V <sub>1</sub> <sup>s</sup>	Lac+V <sub>1</sub> <sup>r</sup>	Lac+V <sub>1</sub> <sup>s</sup>	
B-M-T+L+B <sub>1</sub> <sup>+</sup>	B+M+T-L-B <sub>1</sub> <sup>-</sup>	846	459	546	32	1883
A. Lac-V <sub>1</sub> <sup>r</sup>	Lac-V <sub>1</sub> <sup>s</sup>	% 44.9	24.4	29.0	1.7	
B. Lac-V <sub>1</sub> <sup>s</sup>	Lac-V <sub>1</sub> <sup>r</sup>	241	296	18	141	696
		% 34.6	42.5	2.6	20.3	
C. Lac-V <sub>1</sub> <sup>r</sup>	Lac-V <sub>1</sub> <sup>s</sup>	130	13	247	128	<u>518</u>
		% 25.1	2.5	47.7	24.7	3097.

The 3x4 contingency tables of Table 5 gives the following X<sup>2</sup>

Value (for 6 degrees of freedom.)

$$X^2 = 777.3$$

Table 6.

The data of Table 5. are rearranged so as to bring corresponding interchange classes in the same column.

B-M-T+L+B<sub>1</sub>+Lac  $\underline{x}$  V<sub>1</sub> $\underline{y}$  X B+M+T+L-B<sub>1</sub>-Lac  $\underline{x'}$  V<sub>1</sub> $\underline{y'}$

Parents

Class recovered: B+M+T+L+...

	x	y	x'	y'	x'y'	xy'	xy	x'y	Total
ab	+	r	-	s	546 (29.)	846 (44)	459 (24)	32 (2)	1883
cd	+	s	-	r	141 (20)	296 (42)	241 (35)	18 (3)	696
ef	-	r	+	s	130 (25)	247 (48)	128 (25)	13 (2)	518
Totals					817	1389	828	63	3097
%					26.4	44.8	26.8	2.0	
s					.270 a	: .458 b	: .273 c	---	

$\chi^2 = 40.7$ ,  $n = 6$ . No true value of  $p$  can be calculated because of the inconsistent variance of the different populations. Compare, however, with the value of  $\chi^2 = 777$  of Table 5.

The figures in parentheses are the percent contribution of each class to the row total. "s" are the proportions of the single interchanges according to the map:

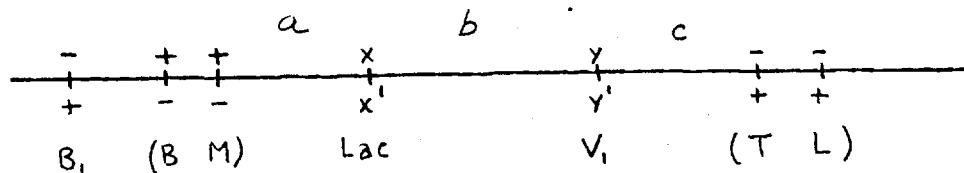


Table 7

RELATIVE FREQUENCY OF VARIOUS BIOCHEMICAL RECOMBINATION CLASSES  
IN THE CROSSB-M-T+L+B<sub>1</sub>+ x B+M+T-L-B<sub>1</sub>- \*

From plates supplemented with	Number of colonies tested	Recombination classes found				Ratio	$\chi^2$
		Type	Number	Type	Number		
Biotin	70	B-	10	B+	60	0.17	36
Threonine	46	T-	9	T+	37	0.24	17
Leucine	56	L-	5	L+	51	0.096	38
Thiamin	87	B <sub>1</sub> -	79	B <sub>1</sub> +	8	9.88	56

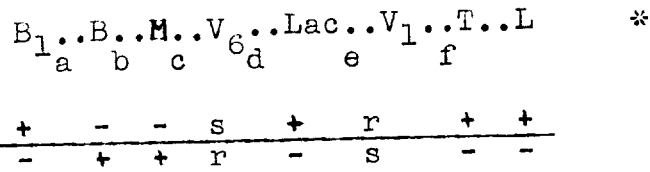
\* Cells of the parental types were mixed and plated into agar supplemented with the growth factor indicated. On this medium, the two recombination classes indicated on each line of the table could form colonies. Contrasting alleles only are specified; other loci, unless otherwise specified, have the "+" configuration. The  $\chi^2$  for the ratio of single biochemical deficient types, types to prototrophs is calculated for a comparison with the 1:1 expectation of a random segregation. As can be seen from the  $\chi^2$  values, the probability that the deviations are due solely to chance is, in each case, less than .001.

Table 8

SEGREGATION OF Lac, V<sub>1</sub> and V<sub>6</sub>

B-M-T+L+B<sub>1</sub>+Lac+V<sub>1</sub><sup>r</sup>V<sub>6</sub><sup>s</sup> x B+M+T-L-B<sub>1</sub>-Lac-V<sub>1</sub><sup>s</sup>V<sub>6</sub><sup>r</sup>

B-M-T-L-	Lac:	-	-	-	-	+	+	+	+	To-
	V <sub>1</sub> :	r	s	r	s	r	s	r	s	tal
	V <sub>6</sub> :	r	r	s	s	r	r	s	s	
...B <sub>1</sub> +		24	16	1	0	2	1	10	2	56
...B <sub>1</sub> -		52	42	2	0	6	1	16	1	120
Total		76	58	3	0	8	2	26	3	176
%		43	33	1.7	0	4.6	1.1	15	1.7	
Crossover region		e	f	cde	cdf	d	def	c	ced	

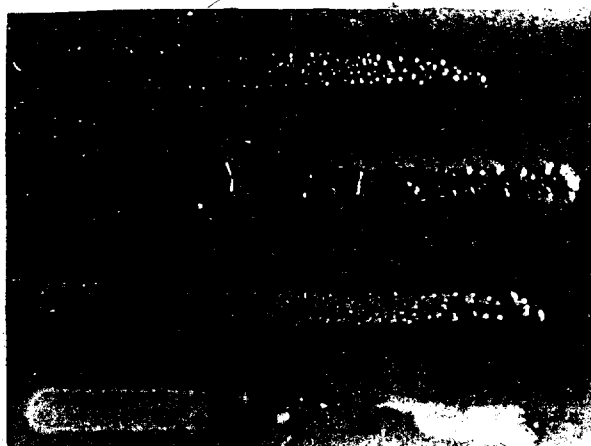


\*This map is not intended to represent the map distances, merely the linear order.

Table 9

Pairwise Occurrence of Recombination in Mixtures of Three Components

Parental Types		Recombinant Prototrophs				
B-N-T+L+B <sub>1</sub> <sup>+</sup>	B+M+T-L-B <sub>1</sub> <sup>-</sup>	B+M+T+L+B <sub>1</sub> <sup>-</sup> or B <sub>1</sub> <sup>+</sup>				
		Lac-V <sub>1</sub> <sup>r</sup>	Lac-V <sub>1</sub> <sup>s</sup>	Lac-V <sub>1</sub> <sup>r</sup>	Lac+V <sub>1</sub> <sup>s</sup>	Tot
Lac-V <sub>1</sub> <sup>r</sup>	Lac+V <sub>1</sub> <sup>r</sup> Lac-V <sub>1</sub> <sup>s</sup>	173	49	4	0	226
Lac+V <sub>1</sub> <sup>s</sup>	Lac+V <sub>1</sub> <sup>r</sup> Lac-V <sub>1</sub> <sup>s</sup>	0	136	37	40	213
Lac+V <sub>1</sub> <sup>s</sup> Lac-V <sub>1</sub> <sup>r</sup>	Lac-V <sub>1</sub> <sup>s</sup>	65	48	0	25	138
Lac+V <sub>1</sub> <sup>r</sup>	Lac-V <sub>1</sub> <sup>r</sup> Lac+V <sub>1</sub> <sup>s</sup>	16	0	7	28	51
Total.....						628



Caption for Fig. 1.

Fig. 1. The phenotypes of the four combinations of Lac and V are illustrated. In order they are:  $\text{Lac}+\text{V}_1^{\text{R}}$  ;  $\text{Lac}+\text{V}_1^{\text{S}}$  ;  $\text{Lac}-\text{V}_1^{\text{R}}$  ;  $\text{Lac}-\text{V}_1^{\text{S}}$ . An EMB-lactose agar plated was first streaked vertically with the virus T1. Subsequently, each of the bacteria was streaked, from left to right, perpendicularly across the virus streak. After 16 hours incubation, both the Lac and  $\text{V}_1$  phenotypes are well developed. Development in the zone where  $\text{Lac}-\text{V}_1^{\text{S}}$  has been lysed can be seen two colonies of resistant mutants:  $\text{Lac}-\text{V}_1^{\text{R}}$ .