Linkage of the Analbuminemia Locus (*alb*) and the Hooded Locus in the Rat, *Rattus Norvegicus*

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A linkage study of the analbuminemia (*alb*) with some coat color loci (*a, b, c, h*) has been carried out by crossing the analbuminemic random-bred mutant NAR strain with the *abh* tester strain of rats, the Agouti-Irish inbred ACI strain and the Agouti-Nonhooded inbred IS strain. The analbuminemia (*alb*) locus is not linked to *a*, *b*, and *c* loci but linked to hooded locus from F2 and backcross progeny of the F1 hybrids of *abh*×NAR, ACI×NAR and IS×NAR to NAR. Recombination value between *alb* and *h* was 16.4 ± 2.3 per cent from the data of F2 and backcross progeny of (ACI×NAR) F1 and (IS×NAR) F1 to NAR. This is the third locus on the sixth linkage group of the rat.

In 1977, we established an analbuminemic rat mutant strain (NAR) from Sprague-Dawley rats [4, 5]. The analbuminemia was inherited as an autosomal recessive trait. We designated the analbuminemia trait as '*alb*' [6]. Biochemically, the mutant was characterized by extraordinarily low albumin and hyperlipidemia. Total protein level of the serum in the mutant rat was similar to that of control Sprague-Dawley rats and globulin increased compensatorily.

The present paper deals with the linkage relation of the *alb* with some coat color genes (*a, b, c, h*).

Four rat strains have been used in test crosses: the *abh* tester strain of rats (genotype: *C/C, a/a, b/b, h/h, +^{alb}/+^{alb}*) [9] for testing coat color genes, the analbuminemic random-bred mutant NAR strain [4, 5], the Agouti-Irish inbred ACI strain (genotype: *C/C, A/A, B/B, hⁱ/hⁱ, +^{alb}/+^{alb}*) and the Agouti-Nonhooded inbred IS strain

(genotype: *C/C, A/A, B/B, H/H, +^{alb}/+^{alb}*) [7], all maintained at the Sasaki Institute.

Blood samples were obtained by cutting the tip of the tail. After coagulation at room temperature, serum was separated by centrifugation at 3,000 rpm for 10 minutes. Cellulose acetate membrane electrophoresis of 0.3 μ l of serum was carried out on a Titan III strip (Helena Laboratories) with a constant voltage of 220 V for 30 minutes at 10°C in 0.15 M Tris/Veronal buffer (PH 8.8). After electrophoresis, the membrane was stained with Ponceau S, destained in 5% acetic acid, and dehydrated in methanol.

First, (*abh*×NAR) F1 hybrids were obtained to test coat color genes of NAR. F1 hybrids of 142 rats (male: 72, female: 70) were all Black-Hooded and showed normal albumin concentrations in serum. Therefore, it was strongly suggested that the genotypes of NAR were fixed as *c/c, a/a, B/B, h/h, alb/alb*.

Second, we carried out progeny tests

Table 1 Coat color and albumin phenotypes in (aN×aN) F2 and (aN×N) BC progeny of rats.

cross	Black Hooded		Brown Hooded		Albino		Total
	Normal	Analbuminemia	Normal	Analbuminemia	Normal	Analbuminemia	
F2 aN×aN	32	11	10	3	10	1	67
BC aN×N	13	14	0	0	18	17	62

a : abh (C/C, a/a, b/b, h/h, +^{alb}/+^{alb}), N : NAR (c/c, a/a, B/B, h/h, alb/alb)

Table 2 Coat color and albumin phenotypes in (AN×AN) F2, (IN×IN) F2, (AN×N) BC and (IN×N) BC progeny of rats.

Cross	Agouti Non-hooded or Irish		Agouti Hooded		Black Non-hooded or Irish		Black Hooded		Albino		Total	
	Normal	Analbu- minemia	Normal	Analbu- minemia	Normal	Analbu- minemia	Normal	Analbu- minemia	Normal	Analbu- minemia		
F ₂	AN×AN	52	7	9	12	22	2	1	3	28	10	146
	IN×IN	61	4	5	12	17	1	1	9	29	7	146
	Total	113	11	14	24	39	3	2	12	57	17	292
BC	AN×N	13	3	2	13	12	0	2	8	33	38	124
	IN×N	15	2	4	15	17	4	7	18	39	25	146
	Total	28	5	6	28	29	4	9	26	72	63	270

A : ACI (C/C, A/A, B/B, hⁱ/hⁱ, +^{alb}/+^{alb}), I : IS (C/C, A/A, B/B, H/H, +^{alb}/+^{alb}), N : NAR (c/c, a/a, B/B, h/h, alb/alb)

Table 3 Linkage analysis of alb locus with some coat color loci in the F2 progeny.

Locus	LG	Progenitor's genotype		Genotype	<i>alb</i>		Total	χ^2 (P)
		A/I/a	N		+ ^{<i>alb</i>} —	<i>alb alb</i>		
<i>a</i>	IV	(AN×AN/IN×IN)						
		<i>AA</i>		<i>A—</i>	127	35	218	1.140
		<i>aa</i>		<i>aa</i>	41	15		(0.80–0.70)
<i>b</i>	II	(aN×aN)						
		<i>bb</i>		<i>B—</i>	32	11	56	0.127
		<i>BB</i>		<i>bb</i>	10	3		(0.99–0.98)
<i>c</i>	I	(aN×aN/AN×AN/IN×IN)						
		<i>CC</i>		<i>C—</i>	210	64	359	1.364
		<i>cc</i>		<i>cc</i>	67	18		(0.80–0.70)
<i>h</i>	VI	(AN×AN/IN×IN)						
		<i>HH/h^th^t</i>		<i>H—/h^t—</i>	152	14	218	76.589
		<i>hh</i>		<i>hh</i>	16	36		(<0.01)

Table 4 Linkage analysis of *alb* locus with some coat color loci in the backcross progeny.

Locus	LG	Progenitor's genotype A/I/a	N	Genotype	<i>alb</i>		Total	χ^2 (P)
					+ <i>alb</i> - <i>alb</i>	<i>alb alb</i>		
<i>a</i>	IV	(AN×N/IN×N)						
		<i>AA</i>		<i>Aa</i>	34	33	135	0.970
		<i>aa</i>		<i>aa</i>	38	30		(0.90–0.80)
<i>c</i>	I	(aN×N/AN×N/IN×N)						
		<i>CC</i>		<i>Cc</i>	85	77	332	1.181
		<i>cc</i>		<i>cc</i>	90	80		(0.80–0.70)
<i>h</i>	VI	(AN×N/IN×N)						
		<i>HH/h'h'</i>		<i>Hh/h'h</i>	57	9	135	56.733
		<i>hh</i>		<i>hh</i>	15	54		(<0.01)

for testing of the linkage of *alb* and coat color gene loci using the abh, ACI, IS and NAR strains (Table 1 and 2).

From these results, we rearranged the data for linkage analyses of *alb* with each color gene locus. Results are shown in Table 3 and 4. The frequency of analbuminemia gene *alb* and coat color gene *a*, *b*, *c* locus among the F2 and backcross progeny were in close agreement with independent Mendelian inheritance. From these results, it appears the *alb* locus is not linked to the *a*, *b* or *c* locus. However, the frequency of *alb* and *h* locus among the F2 and backcross progeny did not agree with independent Mendelian inheritance (χ^2 was 76.589 and 56.733). Thus, it is suggested the *alb* locus is linked to Hooded locus *h*. Therefore, we calculated the recombination value between *alb* and *h* loci from the data of F2 and backcross progeny according to Green [1]. The recombination Value from the backcross and F2 progeny were 17.8±3.4 and 15.3±3.1 per cent respectively ; the combined value was 16.4±2.3 per cent. There was no significant heterogeneity among the mating.

Moutier *et al.* [2] reported the linkage of plasma protein (*Gl-1*) and Hooded (*h*) loci. This is the sixth linkage group of the rat [8], but any other loci had not been assigned to this linkage group. The *alb* is the third locus of the sixth linkage group

of the rat. Moutier *et al.* [3] reported that the August, LEW and WAG strains always expressed the type A pattern of plasma protein *Gl-1*, while the Long Evans strain always exhibited the type B pattern.

Further studies are required to analyze for measurement of recombination value among *alb*, *Gl-1* and *h* loci.

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ラットにおける無アルブミン遺伝子座 (*alb*) と hooded 遺伝子座の連鎖

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無アルブミンラット NAR と毛色遺伝子テスト用ラット abh, 近交系ラット ACI (Agouti-Irish) および IS (Agouti-Nonhooded) の交配により, 無アルブミン遺伝子座 *alb* と毛色遺伝子座 *a, b, c, h* の間の連鎖試験を行なった。(abh×NAR) F1, (ACI×NAR) F1 および (IS×NAR) F1 の F2 と NAR へのもどし交配の結果, 無アルブミン遺伝子座 *alb* は毛色遺伝子座

a, b, c とは独立であり, hooded 遺伝子座 *h* と連鎖していることが判明した。(ACI×NAR) F1 および (IS×NAR) F1 の F2 と NAR へのもどし交配の成績より, *alb* と *h* の間の組換え価は $16.4 \pm 2.3\%$ であった。無アルブミン遺伝子座 *alb* はラットにおける第6連鎖群に属する第3番目の遺伝子座であることが判明した。