A Mutation Limiting the Development of Red Pigment in Betta splendens, the Siamese Fighting Fish

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SYNOPSIS: Evidence is provided for an undescribed mutation eliminating red pigment in Bettas. Genetic data suggest a recessive gene, symbolized "nr" (for non-red) is responsible. No evidence of linkage with the few previously described mutations in Bettas was found. Interaction with other color mutations provides an assortment of clearly distinguishable phenotypes.

INDEX DESCRIPTORS: Fish pigment, fish genetics, Siamese Fighting Fish, *Betta splendens*.

The Siamese Fighting Fish (*Betta splendens*) has been a favorite of aquarists for many years. In the Orient it has been cultivated for centuries, mostly for use in the "sport" of fish fighting. It was introduced to the Western world about 75 years ago, and exotic forms were exported to the United States in 1927. From time to time scientific attention has been addressed to the fish because of its interesting pigmentary and morphological variations and unusually specialized behavioral and physiological traits.

Studies of the genetics of Betta pigmentation have been reported by Goodrich and Mercer (1934), Umrath (1939), Eberhardt (1941, 1943a, 1943b) and Wallbrunn (1948, 1951, 1958). These dealt primarily with variations involving melanin (black, brown, grey) and what I think should be best referred to as "iridocyte color" (metallic greens and blues). Red pigment variations, probably pterins or carotenoids, were mentioned by Goodrich (1941). No genes specifically dealing with red and yellow variations have been described, though Wallbrunn reported a gene "b" (bright) which reduced the number of melanophores allowing red phenotypes to appear much brighter than they would otherwise. Red pigment in wild bettas is limited to portions of the caudal, anal and pelvic fins and a patch on the operculum. Domestic forms may have red extended to cover the entire fish.

The range of color phenotypes include several that are uniquely related though they have not been so recognized by breeders. These are the result of the interaction of known pigment modifying genes (the absence of black and variation in the extension of iridocyte color from a fairly limited normal condition) with a general absence of red pigment. Four rather distinct groups of phenotypes are observed: low iridescent light bodied "yellow" or "transparent", high iridescent light bodied types I call "pastel," low iridescent dark bodied types with yellow to clear fins (various names), and high iridescent dark types with yellow to clear fins.

Following examination of progeny from a series of matings I suspected three distinct variations of red pigment development in domestic stocks of Bettas. These are (1) a total absence of red, (2) an extension of red from rather limited distribution in normal stocks (caudal, anal and pelvic fins only) to complete body and fin coverage, and (3) a variegated or pied development of red on fins. This report concerns the absence of red.

A series of matings were made to test for a hypothetical "non-red" gene which does not allow expression of phenotypic red pigment. Domestic stocks of *Betta splendens* were obtained from aquarium shops and betta breeders. These were designated as "red" types (the normal condition) or "non-red," the new type. Comparison of these new types with normal fish reveals only the absence of red as a difference. It appears to leave either nothing or a yellow pigment in its place. Most phenotypes have the yellow. Variations are shown in Figure 1.

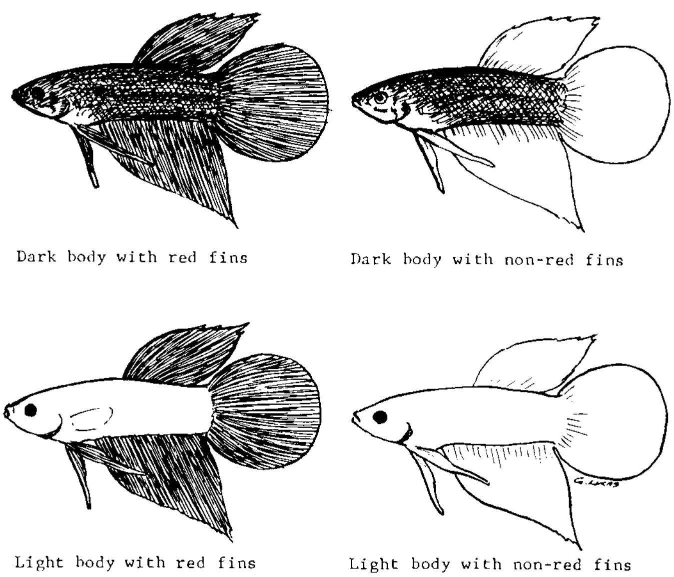

Figure 1. Variations in dark and light bodied red and non-red Bettas.

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Breeding techniques were conventional and are well documented in popular literature. Records were kept of all breeding pairs and progeny. Mating combinations are shown in Figure 2.

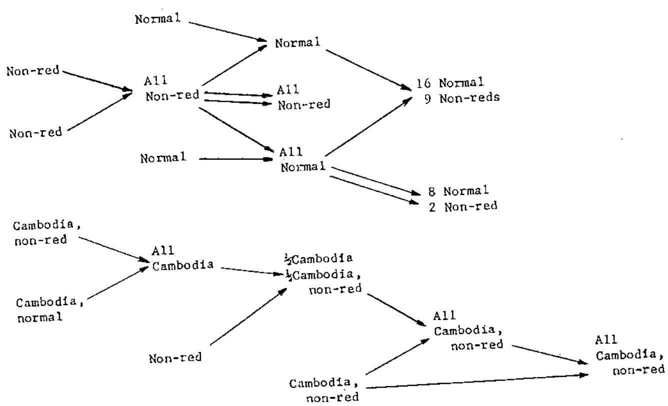

Figure 2. Pedigree chart showing origins and relationships of non-red Bettas.

The term "cambodia" refers to light bodied fish. Others are dark.

Twelve non-red X non-red matings produced only non-red progeny (Table 1), therefore the abnormality breeds true.

TABLE 1. SPAWNS BETWEEN NON-RED MALES AND NON-RED FEMALES.

Spawn Number	Parents Males	Parents Females	Progeny	
	Non-red	Non-red	Normal	Non-red
Dark non-reds				
108	"	"	0	100+
167	"	"	0	40+
Light non-reds	"	"	0	60+
180	"	"	0	5
240	"	"	0	70+
248	"	"	0	100+
306	"	"	0	9
313	"	"	0	13
355	"	"	0	12
364	"	"	0	27
374	"	"	0	3
387	"	"	0	52
12 Matings		Totals	0	491

Twelve matings in various combinations between normal fish having no known non-red ancestry and non-reds produced only normal hybrid progeny (Table 2).

TABLE 2. SPAWNS FROM NORMAL (HAVING NO KNOWN NON-RED ANCESTRY) X NON-RED PARENTS.

Spawn Number	Parents Males	Parents Females	Progeny Normal	Progeny Non-red
	Normal (dark)	Non-red (dark)		
168B	" "	" "	36	0
171	" "	" "	20	0
174	" "	" "	49	0
175	" "	" "	28	0
184	" "	" "	48	0
185	" "	" "	50	0
186A	" "	" "	44	0
189	" "	" "	25	0
	Normal (cambodia)	Non-red (dark)		
100A	" "	" "	33	0
352	" "	" "	25	0
	Normal (cambodia)	Non-red (cambodia)		
77	" "	" "	188	0
A reciprocal cross				
	Non-red (cambodia)	Normal (dark)		
257	" "	" "	13	0
12 Matings		Totals	459	0

Five matings between F_1 individuals produced normal and non-red progeny (Table 3) in a good approximation of the 3:1 ratio.

TABLE 3. F_2, BOTH PARENTS F_1 OF NORMAL X NON-RED MATINGS.

Spawn Number	Parents Male	Parents Female	Progeny Normal	Progeny Non-red
	Normal	Normal		
226	"	"	19	8
232	"	"	8	2
233	"	"	16	9
244	"	"	42	14
274	"	"	3	2
5 Matings		Totals	88	35

Expected: 3:1 (92.25:30.75)
Observed: 88:35
Chi-square = .751 df = 1
p = 0.500>0.250

Two test cross matings (normal F_1 hybrids X non-reds) yielded normals and non-reds (Table 4) in an excellent approximation of the expected 1:1 ratio.

TABLE 4. TEST CROSS SPAWNS FROM NORMAL (F_1 FROM 1 NON-RED PARENT) X NON-RED PARENTS.

Spawn Number	Parents Male	Parents Female	Progeny Normal	Progeny Non-red
	Normal	Non-red		
122	"	"	42	35
A reciprocal cross				
	Non-red	Normal		
366	"	"	10	20
2 Matings		Totals	52	55

Expected: 1:1 (53.5:53.5)
Observed: 55:52
Chi-square = 0.084 df = 1
p = 0.900>0.750

Results clearly show a single factor variation as hypothesized. All mating combinations yielded information suggesting a recessive gene which, in the homozygous state, does not allow the formation of (normal) red pigment. No test data opposed this conclusion nor have such data accumulated since these tests. A new color gene in *Betta splendens* is therefore proposed to be designated "non-red" and symbolized "nr." Though test data are limited, no linkage is suggested with the cambodia (light bodied) factor nor is sex linkage of any kind indicated.

Some specimens develop red flecks in yellow areas as they become aged. No explanation is attempted but this fact coupled with the obvious one that affected fish are usually yellow where they should be red suggests one of the following: (1) The absence of red results from the failure to produce any red pigment revealing yellow that was already present, or (2) Yellow is an intermediary or precursor to red. It is my belief the latter is true. Chemical identification of red and yellow pigment elements is needed to determine precise gene action.

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