THE MINUTE STRUCTURE OF HAIR AND CORRELATIONS WITH MORPHOLOGY, PHYSIOLOGY AND BEHAVIOR[1]

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The hair of mammals varies greatly in its minute structure among individuals of those species that have been studied adequately. Thus, we have short-haired "rex" types with curly vibrissae in the rabbit, rat, mouse, pig and horse. We note almost hairless types in rat, mouse, dog and sheep. We see numerous piebald types in many mammals. Chinchilla forms are found in mouse, cat, and rabbit. Albinos are present in many species. We observe in several mammals: chocolate, blue, yellow, black and pink-eyed buff forms. When individual hairs from the color mutants are examined under a microscope, the colors turn out to be due to variations in quantity, quality and distribution of pigment granules in the hair.

Fig. 1. Adult male black sport of the Norway rat caught at the colony farm.

Gruneberg (1943) suggests that the pigments of mouse hair consist of yellow phaeomelanins which are easily dissolved in alkali, and dark eumelanins which are very resistant to alkali. He suggests that black and brown pigments differ only in particle size. Dunn and

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Einsele (1938), showed that darker forms have larger pigment granules than lighter forms. Daniel (1938), from spectroscopic studies, concluded that albino gene-combinations with black or brown are very similar, if not identical, and hence presumbably of the same chemical constitution. In yellow mice, according to Dry (1928), black pigment is reduced to a few scattered granules, leaving the fur bright yellow or orange. White-bellied agoutis have dorsal hairs showing a darkly pigmented base containing black and brown granules, a subterminal band of yellow, and a black tip. This is like the fur of many wild mammals. Werneke (1916), reported the pigment of pink-eyed dilute mice to be reduced not only in amount, but also that it occurs in granules of less regular shape than normal. Onslow (1915), corroborated by Charles (1938), showed that the white-furred areas of piebald mice and Dutch rabbits are unpigmented because they lack the enzyme (tyrosinase of Onslow, dopa-oxidose of Bloch).

Because many of these microscopic conditions are distinguishable to the human eye, and most of them appear as differences in color, texture or form, it will be simpler for purposes of this paper to speak of them in visual terms. Thus, when we discuss various coat colors in mammals, we must keep in mind that these color terms usually refer to quantity, quality, and distribution of melanin pigment granules within the hair.

The subject of correlations in morphology, physiology and behavior associated with distinct types of melanic pigment development in dermal appendages is not entirely new. It merely has been neglected. For many years white cats or white English bull terriers with blue eyes have been known to tend toward deafness. Darwin (1890) in his chapter on correlated variability, noted such cases and also quoted Professor Wyman to the effect that in Virginia all hogs except black ones suffered from eating the root of *Lachnanthes tinctoria.* Spinola is quoted as stating that *Polygonum fagopyrum* (buckwheat) is injurious to white and spotted pigs in the sunshine, but not to black pigs. Other cases are cited by Darwin. Castle (1941), and his students had found certain coat colors to be associated with size in rats, mice and rabbits.

In 1941 my assistant, Miss Ruth Meeser, pointed out to me certain adult black sports appearing in a strain of wild and savage, gray Norway rats being raised in our laboratory, and upon examination I found them to be tame and docile (Keeler, 1942). Biologists know very well that it is almost impossible to tame adult, Norway rats and the remarkable change in behavior exhibited by our black sports required an explanation. Other coat color variations occurring in this same strain of Norway rats were found to be slightly modified in behavior. Some of these, such as chocolate, piebald and pink eye were in the direction of tameness. The curly rats were extremely wild and savage in their cages but once captured and removed from the cage, they sat quiet and subdued.

A physical basis for these behavior phenomena was sought in Dr. H. H. Donaldson's voluminous records of meticulous dissections carried out mainly by Miss Meeser over a period of many years. (Keeler and King, 1942). We will not review this work in detail here but will merely refer to certain morphological changes in the black sports. The black sports were of less than average body size (Keeler, 1947*a*), and had thyroids, gonads, adrenals, olfactory bulbs and brain, distinctly smaller (Keeler, 1947*b*) than those of their gray Norway controls. The reduced thyroids and gonads caused them to live at a more quiet tempo (Shopbach *et al.*). The reduced olfactory bulbs allowed the mutant blacks to sense fewer of the dangers in the environment, and the reduced adrenals kept them from becoming excited and angry about the little that they did smell. Tests with garlic (Keeler, 1942), which rats hate, showed the blacks to be less affected than are gray rats. They did not react to the presence of strangers until they stood in front of their cages whereas the grays huddled together in the far corners of their cages when strangers entered the door forty feet away. There is evidence that most coat-color mutant rats spin through their life processes at a much more rapid rate than do the gray controls, as measured by the rate of water loss in bones (Keeler, 1946) and other tissues. There is also evidence (unpublished) that the natural length of life is usually reduced in mutants. The reduction of gonads as well as the very slight decrease in body size should affect the voice of the black mutant rat, and certain studies on voice analyzer records indicate that the voice is raised (Keeler, 1945). However, the black sports tend generally to be of a silent, cringing nature, using their voices very little.

The responses of scientists to our correlation studies on black sports have ranged from recognition (Cook, 1941), to scientific doubt. Critics have objected to the fact that our black sports appeared in a stock of wild gray Norway rats being maintained in laboratory cages. Anything could happen in a laboratory, they maintained. Adhering to the "one gene—one function" idea, they denied that the physical modifications of glands, sense organs and brain could possibly be pleiotropic manifestations of the black pigment-producing gene itself, but contended that these alterations must be due to a second mutant gene closely linked on the same chromosome with the black-producing gene. They did concede, however, that if one caught an adult, black sport among wild Gray Norway rats, and if that sport was found to be tame, then this was a case of pleiotropy, as I maintained, rather than one of close linkage, because the simultaneous mutation of the same two linked genes is a highly improbable event.

On January 3, 1950, Harvey Clark, a professional exterminator, brought me the adult, male, black sport of the Norway rat shown in figure 1. The photograph was taken three weeks after capture.

This animal is silent, slow, and cringing. It has never offered to bite. The black sport was caught on the large Colony Farm of the Milledgeville State Hospital seven-and-a-half miles south of town.

A month after its capture the exterminator and I went back to this farm and smoked out two more adult, black mutants, a male and a female—both tame. (A total of 2085 wild and savage Norway rats have been caught at this farm in four years.) If these mutants reproduce, their offspring should constitute a "predomesticated" stock of tame laboratory rats directly out of the wild. The physical modifications of these black sports of the Norway rat must determine quietness and docility within the normal range of behavior as was the case with the mutant blacks of the laboratory.

If we look at other species of mammals, we find a number of cases that appear to be similar. For example, a group of raccoon fanciers reported the black raccoon sport to be docile as compared with the gray (Keeler, 1947*c*). Clarke recorded the pink-eyed Peromyscus to bear tame tendencies, and Barto believes that ivory and silver Peromyscus are tamer and more lethargic than those bearing the wild-type coat color (Keeler, 1947*c*). The Silverblu platinum mutation has occurred twice in mink and both times it was accompanied by tamer behavior than that of the average dark mink (Keeler, 1947*c*). The Snowball mutation of the Cotton rat of Danforth and Schwentker (1949), shows tame tendencies (personal communication). Recently the white-faced mutation of the hamster described by Foote (1949) has been found to be accompanied by increased nervousness (personal communication). In these cases it may be said that the modifications associated with the simply inherited color variations are within the *normal* range of behavior.

In contrast to the above, many cases are known of coat color mutants in which morphology, physiology and behavior are *abnormally* modified. For example, we may mention the varitint-waddler mouse of Cloudman and Bunker (1942), in which a peculiar spotting is always accompanied by palsy. Completely white Vienna White rabbits with blue eyes tend to epileptoid fits when frightened, as Castle and I observed (unpublished) many years ago, and as had been thoroughly studied before World War II by Nachtsheim (1939). It appears, according to Larry Moore and others, that the Aleutian sport, used in the production of Sapphire mink, tends to spontaneous bleeding. Numerous individuals raising Pastel mink have noted the jerky head movements manifested by some individuals. These head movements (screw neck) follow the Pastel gene and appear in any combination of coat colors containing Pastel. A study of this characteristic has been made by Shackleford and Cole (1947). We might mention the case of the dominant white mouse derived from the Manhattan Project and published by Grobman and Charles (1947). One dose of this gene changes a black coat to blue. Two doses makes the animal completely white and usually prevents the

development of its eyeballs. Many blue-eyed white cats and white English bull terriers are deaf. The deaf, white cats were recorded by Darwin (1890) and studied thoroughly by Przibram (1907). The eye and ear abnormalities of surviving purebred Blue Merle Collies and Dunkerhunde might also be mentioned (Hagedoorn, 1946). Many dominant *lethals* are known in mammals associated with coat colors: as yellow and dominant spotting in the mouse (Cuenot, 1908; Ibsen *et al.,* 1917), Blufrost in mink (Moore and Keeler, 1947), and Snowball in the Cotton rat (Danforth *et al.,* 1949). When a single gene for these characteristics is present, the animal is viable, but two genes for these variations will kill every individual that receives them.

My co-workers and I (1949) have been able to prove that morphology, physiology and behavior differences are associated with a variation of the broadbreasted bronze turkey known as "faded feather." Faded feather mutants are smaller and weaker than normal turkey poults at hatching. Their eyes are defective. They are reduced in energy. They remain of smaller size. Their bones are weak and apparently deficient in calcium. They break their wings more frequently than do the normals, and may show green-stick fractures. Their feathers are weak and break readily in all parts, including the barbules. A high percentage of faded toms do not gobble. The mortality of faded feather mutants is 50 percent compared with 10 percent for normal broadbreasted bronze turkeys.

I have extended my observations to the albino mutant of the ring-neck dove *(Streptopelia roseogrisea)* and find the albinos reduced in activity, lacking in energy, and softer in voice than the controls. The albino form is much more easily tamed than the bisque colored birds. In two weeks I had a pair of albinos sitting on my finger, but in four months I have not been able to get a pair of bisque birds to sit on a stick held in my hand. From the literature it is apparent that albinism reduces voluntary activity and softens the voice in mocking birds (McIlhenny, 1940). Darwin (1890) states that the albino Pea-fowl of England and France are smaller than the normal in body size. The albino rice bird of the Japanese fancier is smaller of body, softer of voice and less active than the normal color variety. Mr. Carnochan and Dr. Myron Gordon tell me that the albino form of the Paradise Fish is probably more quiet, and that the males fight less, than is the case with the normally pigmented variety. Thus, the correlations that we have been considering, are not confined to mammals alone, but are characteristic of birds and possibly of fish as well.

At present, I have under observation in my laboratory, the Vienna white rabbit, the Snowball Cotton rat, the white-faced hamster, the black mutant rat, the albino ringneck dove, the Manhattan Project dominant white mouse, and the varitint-waddler mouse, as well as other more widely known mouse variations. If this association of

alterations in morphology, physiology and behavior with color of dermal appendages is true for mammals and birds and possibly for fish, then this is a vertebrate phenomenon and likely to apply to man. But human behavior is so complex that it is difficult to collect incontrovertable data. At present, I am searching for such correlations among human beings. I am confining my studies to albinos and redheads (Keeler, 1947*c*).

There appears to be some reason to suspect that human albinos may be low in basal metabolism and often deficient in energy, as is the case with certain albino birds and mammals. They may possibly be low in blood calcium. They may be deficient in the production of antibodies against various disease germs, thus shortening their average length of life. Red heads are hypersensitive to ether and narcotics and are profuse bleeders at operations. They have a sensitive sympathetic system control of the skin capillaries. They may possibly be more responsive than others to niacin in that they blush more readily after the administration of this vitamin. Some think that they may be more susceptible than the average to pulmonary tuberculosis. It appears that other variations in physiology and behavior may be associated with the exaggerated capillary reactions.

Curiously enough, these probable associations of capillary phenomena with physiology and behavior are in line with the age-old, popular conception of red heads, which may turn out to have some basis in fact. It is desirable that observations be made in this direction, but they must be made on a strictly scientific basis, and this is a rather difficult thing to do. However, such scientific researches are not impossible, and I believe that in the near future they will reveal true associations of morphology, physiology, and behavior associated with natural hair colors in man, as has been demonstrated so abundantly in mammals and also in birds.

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NEWS OF TENNESSEE SCIENCE

(Continued from page 104)

The Tennessee Valley Authority is serving as the contracting agency for a program of biological survey work in the Oak Ridge area. The technical personnel engaged in this survey are newcomers to Tennessee and are Dr. Louis Krumholz, Indiana University, Mr. Felton Nease, Duke University, and Mr. Robert D. Ross, Cornell University. C. S. Shoup, Biologist to the U. S. AEC, is acting as biological consultant to the group, and the fisheries work is in operation with the advisory association of Dr. A. H. Wiebe, Chief, Biology Division, Tennessee Valley Authority, Norris.

(Continued on page 116)