БИОЛОГИЧЕСКИЕ НАУКИ

STANDARDIZATION OF INDIVIDUAL GROUPS OF GOLD-TIPPED CAT COLORS.

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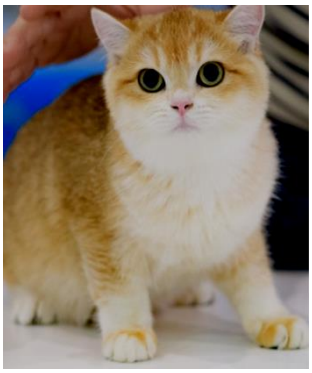
Annotation. The authors conducted a study on the differentiation of golden colors of cats and proposed the author's vision of the genetic rationale for the emergence of new variations of golden colors. As a result of the research, the authors have solved the following tasks: to describe the common features and differences between the "traditional" gold tipped colors and the "new" - Golden light; substantiated the proposed approach to the polymorphism of genes that determine tipped Golden colors of cats; described the phenotype and standard of the Golden Light color, justify the right to its existence as a separate color; substantiated the felinological coding of the Golden Light color.

Key words: color of cats, golden color, differentiation of golden colors of cats.



Formulation of the problem. Typical golden cats are usually distinguished by the degree of coat - the Gaudin Shade and Chinchilla Golden (identical name - Golden Shell). The standards of felinological systems are even consistent with each other. In the last decade, the desire of breeders to achieve "cleaner" and lighter colors has led to new phenotypic features of golden typical cats.

Such a lightening to almost white, more precisely the ivory color, rightly baffled experts who did not have an explanation of the genetics of this color and were afraid to allow animals with an unknown phenotypic deviation from the standard to breed.

Objectives of this article

- describe the common features and differences between “traditional” gold tipped colors and “new” - Golden light; to substantiate the approach proposed in [1] to the polymorphism of genes that determine tipped golden colors of cats;

- describe the phenotype and standard of the Golden Light color, justify the right to its existence as a separate color; substantiate the felinological coding of Golden Light color.

Standardization of the indicated color of cats allows

- to place emphasis on the phenotypic characteristics of such cats;

- to establish the boundaries of the clarified areas, taking into account the juvenile characteristics of the color and in order to avoid admission to breeding of individuals with piebald spotting;

- to substantiate the genotype of the color;

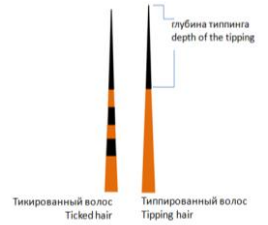
- use the 'Golden Light' color standard in felinological associations to assess the breeding qualities of a significant pool of animals, separating them into a new group among other gold tipped ones;

- to continue research on the genetic characteristics of the color / s of cats, taking into account the diversity of phenotypic characteristics.

Definitions, clauses and general explanations for this article.

A) This article considers only a narrow circle of "work" of color-forming genes and their interactions. Unless otherwise stated, "basic" means a generalized black color. Questions related to red (sex-dependent) colors and their variations, as well as questions of the formation of drawings on the body - tabby are completely excluded.

B) Definitions.



Ticking - zonal hair dyeing, which is formed by alternating granules with pigments - eumelanin (from black to brown) and pheomelanin (from almost red and yellow to almost white).
Tipping - dyeing the upper part of the hair in the main one, one of the eumelinin, with yellow or ticked and tipped hair of the "apricot" root part of the hair (the so-called "Golden tipped").

C) The names of breeds and colors of cats in the article begin with a capital letter to avoid confusion.

Part 1. Materials and methods. To solve the set tasks, we studied and analyzed the following materials.

A) Written, oral and video descriptions of the phenotypes of 179 Golden cats of the British shorthair, British longhair, Scottish fold / straight and Highland fold / straight, Siberian, Burmilla, etc. The descriptions were carried out by experts-felinologists of the international category from Austria, France, the Netherlands, Poland, Russia - in total 12 experts at 17 international cat shows in 3 countries - China, Israel and Russia. Including, with the distribution by age.Четырехколенные родословные 43 кошек.

B) Standards of "traditional" tipped Golden colors of cats - Golden Shaded and Chinchilla Golden (in some felinological systems it is also called Golden Shell) [2], [3], [4].

C) Fundamentals of pigmentogenesis in various animals [5], [6], including dogs and cats [7], goats [8], mice [9], etc.

2.1. Color formation, including Golden light. Preface - about the name of the color. To study pigment formation in Golden light cats, it was a great temptation to draw an analogy with the color of the Akita Inu dog (Fig. 3).

Puc.3.
https://zen.yandex.ru/media/gavkusha/chem-otlichaetsia-akitainu-ot-sibainu-5ba88db48f17a800aa4e1390

However, there is one significant circumstance that did not allow us to do this - the black colored nose and lips, in contrast to the cats of the color in question. In contrast, in cats, a pink nasal speculum and its edging is the first mandatory phenotype of cats with active Agouti. It was this significant difference that was the reason for the rejection of the name "Akita" as the official color for Golden Light cats.

Color formation in cats in embryonic development. As in all cats, in embryonic development, the first groups of melanocytes enter the eye and ear in the head region, as well as to the base of the tail on the croup. Dorsal melanocytes then migrate along the dorsolateral pathway. And the melanocytes of the head region move from the poles to the equator: from the ear and eye area to the center of the skull, in the direction of the muzzle, to the back of the head and neck.

The kitten (2 months old) in Fig. 4 demonstrates the location of melanocytes in the skull from the poles to the center, towards the muzzle; as well as the "center of pigmentation" in the area of the base of the tail. This raises questions about the causes of unpainted areas on the chest, face, legs, abdomen, etc. The first impression is that something happened during the migration that destroyed a group of melanoblasts.

Fig. 4. Golden Light kitten, 2 months old.

Development of Golden light color as it matures. However, as can be seen in the collage (Fig. 5), by the age of 11 months, the “white” parts of the chest, paws and muzzles of the same kitten are painted in a color from ivory to cream. This means that the melanoblasts in embryogenesis have successfully reached their goal, and the expression of pheomelanin can change as the animal grows up.

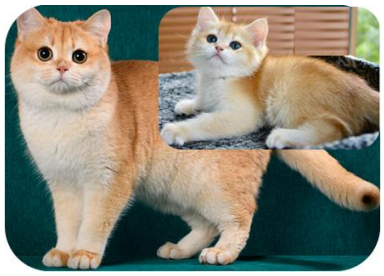


Fig. 5.

Of course, it is impossible to completely exclude the manifestation of piebald spots in the genotype of one of the Golden Light animals, especially taking into account the “successful” camouflage under the bleached areas of the coat. Nevertheless, the manifestation of piebald spotting should be looked for either on the skin epithelium (Fig. 6), or included in the light areas of the coat in adult animals aged 1.5 years.

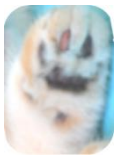


Fig. 6. Spotted spot on the pad of the toe

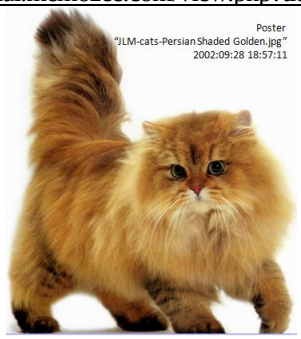
Summing up, we can say that the color of Golden Light cats, in general, is not associated with a violation of pigment formation.

Part 3. Description of phenotypes of colors of Golden tipped cats and correlation with their genotypes.

3.1. Phenotypes of Golden tipped cats. The three types of Golden tipped cats phenotypically (in color) differ in the proportions of colored hair tips, that is, eumelanin granules (more in Golden Shaded) and pheomelanin deposited at the ends. These proportions are noticeable not only in the depth of the colored hair tips (especially on the metatarsal parts of the hind legs), but also in the degree of coloration of the epithelium.

Table 1

Description of the phenotypes of Golden Tipped cats

<table>
<tr><td>Golden Shaded</td><td>Shell (Chinchilla golden)</td><td>Golden Light</td></tr>
<tr><td colspan="3">All three animals (fig. 7-9) are representatives of gold tipped colors. The shade of the "golden" color depends on the expression of pheomelanin (ivory / yellow to red), on the amount of eumelanin granules mixed with it and on the "depth" of the ends of the hair painted in the base color.</td></tr>
<tr><td>Fig.7.http://animal.memozee.com/view.php?tid=3&did=14785
 
</td><td>Fig. 8. Pi SAZo K&S *RU (F). Ow. Konstantin Kargaltsev – Ryazan, RUS
  </td><td>Fig.9. Ronigaldo the PERFECT ONE (M) Ow. Leonid Ruder - Israel
  </td></tr>
<tr><td colspan="2">n individuals with Golden Shaded (Fig. 7) and Shell (Fig. 8), black pigment (eumelanin) is deposited on the skin epithelium, including on the paw pads, eyelids, and the edging of the nose;
in the coat - more brightly along the spine, on the metatarsals of the hind limbs, at the tip of the tail, open single rings on the forelimbs are possible; dark interdigital hair tufts, vertical stripes on the forehead and some other places.</td><td>Black pigment is deposited on all paw pads (metatarsal, toes,
 
metacarpals, etc.), visible at the tip of the tail; slight "plaque" along the spine is possible.</td></tr>
<tr><td colspan="3">IMPORTANT HEATING IN FENO TYPE FOR CURRENT GENO TYPE</td></tr>
<tr><td colspan="2">Closed edging of the mirror of the nose, brightly colored eyelids, lips and epithelium on the anal and genitals. Painted hind limbs; dark hair on the lower limbs (in Golden shaded up to the hock), especially between the toes.</td><td>The edging of the nose is not closed or absent, the eyelids, lips and other epithelium are poorly colored; bleached hair on the legs, especially on the toes, on the cheekbones, on the lower part of the tail, chest and abdomen.</td></tr>
</table>

3.2. Abstracts for the substantiation of genotypes for the color of Golden tipped cats, including the Golden Light color.

Determination of the probable genotype by phenotypic traits allows you to draw a line between all three Gold tipped colors, as well as to separate them from ticked colors of Gold and non-Gold colors.

The whole variety of colors of mammals is determined by the combination of two pigments: eumelanin - from black to brown and pheomelanin from red to yellow. Eumelanin is produced if MC1R is activated by its α-melanocyte hormone (α-MSH) stimulating ligand, whereas pheomelanin is produced if α-MSH is absent and / or displaced by binding of a competitive antagonist ASIP to MC1R [9]. Both genes - MC1R at locus E (Extension) and ASIP at locus A (Agouti) - are widely known as genes with a large number of alleles in many animals [10], for example,

for dogs [11], minipigs [12], macaques [13], mice and many others.

For cats, these two genes have long been regarded as genes with a simple type of dominance. The multiplicity of their allelism was first proved in works on mutations in the ASIP gene (for the Asian leopard, Bengal, and others [14], [15] cats). This was followed by work on mutations in the MC1R - ec gene (in the Copal [16] or Carnelian [17] colors of Kurilean Bobtail). A little later, hypotheses were put forward about the polymorphism of both genes for cats of golden colors [1]. The order of dominance of genes at the E locus: E> ey> ec> e and genes at the locus A: Ay>A>Apb>a.

Genotype of Gold-tipped colors

Initially, the melanocyte cell is tuned to synthesize black pigment. That is why the hair tips of Agouti cats are dyed in the base color. Agouti signaling proteins (ASIPs) are then activated, whose job is to [7.1 and illustration], [11, pp. 44-46]:

2.3-a) "intercept" the signals coming from the pituitary gland - molecules of melanostimulating hormone (MSH);

2.3-b) disable the MC1R receptor;

2.3-c) start the process of pheomelaninogenesis.

The result of the dominant, "strongest" allele (Ay) of the Agouti gene is the shortening of the blackened hair ends. Moreover, in order for the animal to remain with the Golden color, along with the "strong" Aguti, the MC1R gene must remain sufficiently "weak" (ec or ey). The genotypes of the colors of the cats shown in Table 1 can presumably be written as follows: Golden shaded (рис.7) – Ay/A ey/ey, Chinchilla Golden (рис.8) – Ay/Ay ey/ey.

All the above reasoning regarding mutations in the MC1R and ASIP genes is also valid for the Golden light genotype (Fig. 9). However, it is obvious that there are additional factors that should answer questions about the features in the phenotype of these particular cats:

- why does the cell, which is initially tuned to the synthesis of black pigment, leave the border of the nose without staining, the eyelids, epithelium on the genitals and anal organs are poorly colored?

- Why does a cat of this color have a strong bleached coat on the chest, throat, cheekbones, fingers, etc.?

The answer, most likely, lies in the rate of switching synthesis from eu- to pheomelanin, prolonged at the micro-level. The enzyme tyrosinase (Tyr), a transmembrane protein, whose intramelanosomal domain catalyzes the initial and rate limiting synthesis of both eumelanin and pheomelanin, is responsible for this rate. This enzyme is encoded by the C (Color) gene. Allelic variations in the C gene result in several characteristic phenotypes. These include the well-known Siamese (or Himalayan) allele cs / cs, Sepia allele cb / cb, Mink (or Tonkin) allele cb / cs, which are associated with acromelanism (limitation of pigment to the limbs of the body).

This multiple allelism is known in cats, mice, rabbits and many others. At the same time, in most of the listed animals, other alleles of the C gene are well studied, for example, ch (chinchilla). It is this mutation that looks the most logical for the role of a candidate responsible for the phenotype in color Golden light.

We studied the pedigrees of 79 animals, which, according to experts, corresponded to the description of the Golden light color. The results of the studied pedigrees of Golden light cats can be seen in Table 2. The left column of the table shows the alleles of the C locus (from the father's side / from the mother's side) found in the ancestral lines, which can be traced by the pedigrees.

Table 2

Analysis of the pedigrees of Golden light cats (by alleles of gene C).

Breed genome by (C)	British shorthair	British longhair	Burmilla	Munchkin	Highland fold & straight	Scottish fold & straight	Siberian cats	Всего
Number of pedigrees with ancestors having a mutant gene at the locus (C)								
cs/cs	12	14			6	1	6	39
C/cs	11	4		1	3	7	3	29
cb/cb			2					2
C/cb				3				3
C/C	3				1	2		6
Всего	26	18	2	4	10	10	9	79

From table 2 it follows that more than 92.4% of animals of Golden light color are carriers of mutant alleles of the Color gene. In our opinion, a closer further study of the mutations of this locus in cats is necessary. Perhaps, taking into account the "mouse" mutation ch, which could simultaneously explain the "weak speed" of the tyrosinase enzyme - accordingly, it will explain the absence of a fringing of the nose, and the expression of bleached areas, with their gradual staining as they grow older.

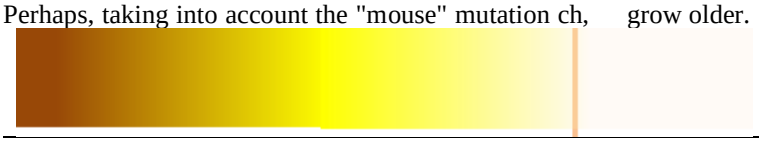


Fig. 10. The range of pheomelanin colors.

Addition.

The study of mutation ch, possibly new for cats, is all the more interesting because some individuals of Golden light color have more contrasting color schemes. Representatives of such colors live in China, South Korea, in various regions of the Russian Federation (Vladivostok, Novosibirsk, Rostov-on-Don, etc.), Ukraine, the USA and a number of other regions of the world that are very distant from each other.

Representatives of this contrasting Urajiro effect are registered by breeders and presented in competitions in various felinological systems in the Chinchilla color.

In our opinion, these are cats with the Golden light genotype, but not tipped, but ticked with 1-2 bands at the ends of their hair.

Fig.11. From MariBessa Ow. Marina Bessergeneva, Rostov-na-Donu - RF

Part 4. Color standard Golden Light.

General description of the standard. The base color is tipped or ticked by 1-2 bands of the base color - Black, Chocolate, Blue, Lilac. The general shade is "gold". It is much more intense on the face and back, with an urajiro effect - pads, cheeks, possibly part of the cheekbones, chin, neck, chest, thighs, inner legs, fingers, belly and underside of the tail are much lighter, and from sandy straw color to almost white or ivory. The tip of the tail is colored in the base color (tipping / ticking color).

Base color tipping / ticking, takes from 1/8 to 1/4 hair; some cats have some gold or bronze / copper pigment. Sometimes different hairs have different colorings of the tip of the hair - one of them can be with a basic tipping / ticking color, another is golden and without tipping, and the third one with a bronze / copper color tipping.

The color of the bleached areas ranges from sandy-straw color to almost white or ivory. The color around the eyes and the triangular area on the muzzle may be significantly lighter; bright, with blurred edges marks on the eyebrows in the form of a flame; there may be blurry whitish spots on the vertex; the lower part of the forearm from the outside can also be highlighted, but has smooth transitions from basic to almost white or ivory. For ticked Golds, the contrast of the lightened part is much more pronounced compared to tipped ones. White patches of any shape on the forehead are not permissible, except as described on the brows.

Undercoat color - from sandy-straw, apricot-peach to almost white / ivory.

Eye rims match the color of the tipping, lightened but not colorless.

Eye color - all shades of green. A deep green color is preferred.

The edging of the mirror (lobe) of the nose can only be outlined, absent or significantly lightened. The color of the nose is pink or brick-colored.

The color of the paw pads corresponds to the base color - black, chocolate and their lightened variations.

Features: around paws and fingers, on each of the fingers around the claws - the effect of a "light glove", the coat is almost white / ivory. The inner part of the hind legs is strongly bleached.

Note: The color appears in newborn kittens. As they grow older, the color of the tipping becomes more intense, especially on the apical parts. Defects in color (PENALIZE) affecting the assessment. Minor residual tabby (picture) along the hull. Defects in color (DISQUALIFY) leading to disqualification. Brown in color, stripes on the legs, white piebald on the pads, not green eyes in adults. Spotted spot on the forehead.

Rationale for color coding. Most felinological associations with a “European” style of judging [18] use the letter “n” for the short designation of Black color, and the letter “y” for Golden colors. After the color lettering, the numerical designation of agouti and / or tabby is used. For example, ny 11- Golden shaded, ny 12- Golden shell (Golden chinchilla).

Following the generally accepted tradition, with the gratitude of FIFe, it is logical to propose a new coding for the color Golden Light – ny 13.

List of references

1. GOLDEN COLOR CATS – HYPOTHESES, RESEARCHES AND EVIDENCE [Электронный ресурс] Режим доступа: https://ppublishing.org/upload/iblock/194/Biomed_1_2020.pdf

2. CFA, Breed standard. Persian. [Электронный ресурс] Режим доступа: https://cfa.org/wp-content/uploads/2019/06/persian-standard.pdf

3. FIFe, Breed standards. Colour varieties: Silver. Golden. [Электронный ресурс] Режим доступа: http://www1.fifeweb.org/dnld/std/GEN-SGA.pdf

4. TICA Uniform Color Descriptions, Page 18, Version B 03/27/20. [Электронный ресурс] Режим доступа: https://tica.org/phocadownload/UCD.pdf

5. Le Pape E, Wakamatsu K, Ito S, Wolber R, Hearing VJ. Regulation of eumelanin/pheomelanin synthesis and visible pigmentation in melanocytes by ligands of the melanocortin 1 receptor. Pigment Cell Melanoma Res. 2008;21: 477–486. pmid:18627531 [Электронный ресурс] Режим доступа: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1755-148X.2008.00479.x

6. Graham A, Wakamatsu K, Hunt G, Ito S, Thody AJ. Agouti protein inhibits the production of eumelanin and pheomelanin in the presence and absence of alpha-melanocyte stimulating hormone. Pigment Cell Res.

1997; 10: 298–303. pmid:9359625 [Электронный ресурс] Режим доступа: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1600-0749.1997.tb00689.x

7. Genetics of Pigmentation in Dogs and Cats [Электронный ресурс] Режим доступа: https://www.annualreviews.org/doi/abs/10.1146/annurev-animal-031412-103659

8. The European Society for Pigment Cell Research (ESPCR) [Электронный ресурс] Режим доступа: http://www.espcr.org/micemut/

9. Selection signatures in goats reveal copy number variants underlying breed-defining coat color phenotypes. [Электронный ресурс] Режим доступа:

https://doi.org/10.1371/journal.pgen.1008536 Published: December 16, 2019.

10. Suzuki H. Evolutionary and phylogeographic views on Mc1r and Asip variation in mammals. [Электронный ресурс] Режим доступа: https://pubmed.ncbi.nlm.nih.gov/24025244/

11. Пасечник Л.А. Окрасы собак. Генетические, биохимические и молекулярно-биологические аспекты / Научно-популярные записки. –X: Team Publish Group, 2012 – 252 с.

12. Variation of the Melanocortin 1 Receptor Gene in the Macaques Kazuhiro Nakayama, Takayoshi Shotake, Osamu Takeneka, Takafumi IshidaFirst published:02 May 2008. [Электронный ресурс] Режим доступа: https://pubmed.ncbi.nlm.nih.gov/18454455/

13. Nikitin S.V., Shatokhin K.S., Knyazev S.P., Goncharenko G.M., Zaporozhets V.I., Ermolayev V.I. Polymorphic loci of coat color in mini-pigs. Vavilovskii Zhurnal Genetiki i Selektsii =Vavilov Journal of Genetics and Breeding.

14. Schneider A, David VA, Johnson WE, O'Brien SJ, Barsh GS, Menotti-Raymond M, et al. (2012) How the Leopard Hides Its Spots: ASIP Mutations and Melanism in Wild Cats. PLoS ONE 7(12). [Электронный ресурс] Режим доступа: https://doi.org/10.1371/journal.pone.0050386

15. Who's behind that mask and cape? The Asian leopard cat's Agouti (ASIP) allele likely affects coat colour phenotype in the Bengal cat breed

L. C. Gershony, M. C. T. Penedo, B. W. Davis, W. J. Murphy, C. R. Helps, L. A. Lyons First published:20 August 2014

16. Copal, a new MC1R allele in the domestic cat. [Электронный ресурс] Режим доступа: https://www.researchgate.net/publication/334779687_Copal_a_new_MC1R_allele_in_the_domestic_cat

17. Результаты исследований на ген «Амбер» (Carnelian). Код исследования [Электронный ресурс] Режим доступа:

http://zoogen.org/rus/index.php/cats/okrasy-koshek/item/cornelian-color-kurilian-bobtail?category_id=54

18. The FIFe Easy Mind System (EMS) [Электронный ресурс] Режим доступа: http://fifeweb.org/wp/breeds/breeds_ems.php

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