



CFA BREED AWARENESS AND ORIENTATION SCHOOL 2019-2020



COLORS AND PATTERNS/

**AN INTRODUCTION TO COLOR
GENETICS in the PEDIGREED
CAT**

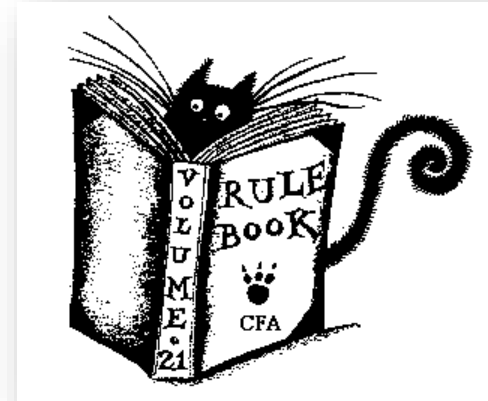


Presentation by
Darrell Newkirk and Pat Jacobberger
CFA Allbreed Judges



INTRODUCTION

- **Purpose of today's presentation**
 - Acquaint you with the **basics** of colors and patterns and the associated genetics
 - Enable you to identify the common patterns/colors found in the pedigreed cat
 - Point out opportunities for further learning
 - **Learn and have fun!!**



CFA BREED STANDARDS

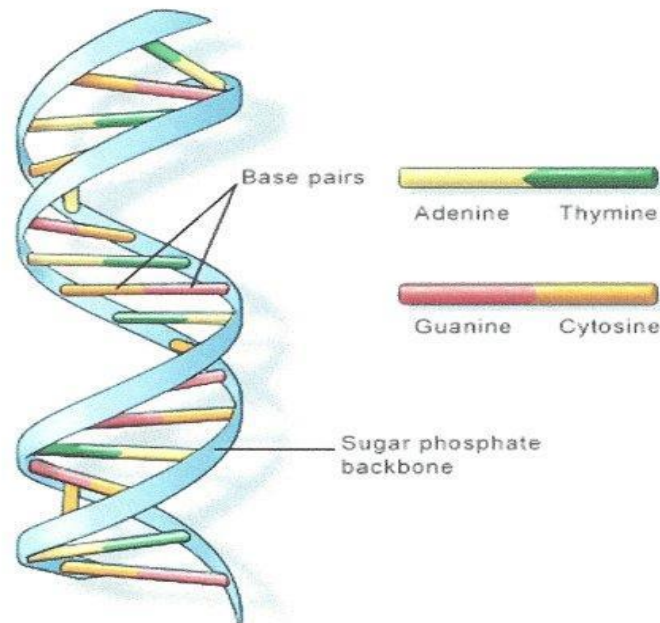
- Basis of all discussions around the descriptions of colors and patterns - the final authority today and during judging.
- Two issues to acknowledge regarding the descriptions of colors and patterns:
 - Many contradictions
 - Many incongruities

GENETIC TERMS

- What is DNA?
- Role of Reproduction
- Genes and Alleles
- Dominant gene vs. recessive gene
- Homozygous vs. Heterozygous
- Phenotype vs. Genotype

DNA

Deoxyribonucleic acid is the hereditary material found in almost all organisms. DNA is stored as a code for building and maintaining an organism. DNA within the nucleus is a long strand. Shortens to a chromosome during reproduction.



U.S. National Library of Medicine

DNA is a double helix formed by base pairs attached to a sugar-phosphate backbone.

GENETIC TERMS

- Role of reproduction
- The Cat Genome has 38 Chromosomes
- During reproduction this number is halved to 19 for each sperm and each ovum (egg).
- A Zygote is created when the sperm and ovum combine and result in a total of 38 chromosomes.
- The genetic material from the sperm and ovum allow for millions of potentially different combinations of the genome for the newly created individual, cat, human, etc.

GENETIC TERMS

- Genes have their special loci on the Chromosome and are the basic elements of heredity
- Chromosomes are only visible during reproduction and carry the genes of the sperm or ovum.
- Alleles are potential variations of a trait. Mutations of the gene.
- The gene for Black color is B. There are two mutant alleles: b and b^l (Chocolate and Cinnamon).

GENETIC TERMS

- Genes of an individual are in pairs, one trait inherited by the sperm and one from the ovum.
- Homozygous: having identical pairs of genes for any pair of a hereditary characteristic.
 - For example: BB for black, AA for Agouti, dd for dilution
- Heterozygous: having dissimilar pairs of genes for any pair of a hereditary characteristic.
 - For example: Bb for black and chocolate, Aa for Agouti and non Agouti

GENETIC TERMS

- **Dominant:** a trait/gene whose effect can be seen in the phenotype of the cat. Only one copy need be present. Capital letters are used to denote dominant genes.
- **Recessive:** a trait/gene that may not be seen in the phenotype. Need the same gene pair for characteristic to be seen. Small letters used to denote recessive genes.
- **Phenotype:** What you see. Only one dominant gene in the gene pair must be present to be seen in the phenotype of a cat.
- **Genotype:** What the cat looks like on the inside, which genes can be inherited. It is the summary of all genetic information which your cat carries and can pass along to its offspring.

WHAT IS A PATTERN?

- Decoration
- Design
- Scheme
- Stencil
- _____
- _____

Template – a Model that can be used over and over again.

THE BASICS

- Our cats have descended from the African Wild Cat – Felis Silvestris Lybica.
- FSL is a Brown McTabby patterned cat.
- Mutations resulted in the variety of colors and patterns that we see in our cats today.
- Mutations result from:
 - Imperfect replication or joining of the components of the DNA molecule
 - Chemical imbalance within the body
 - Mutagens – nicotine and thalidomide
 - Greatest of all mutagen is **radiation**
 - Solar radiation, cosmic rays and Earth's background radiation
- Not all Mutations support survival.

START WITH THE BASICS

Felis Silvestris Lybica and the Seven Ancient Mutations



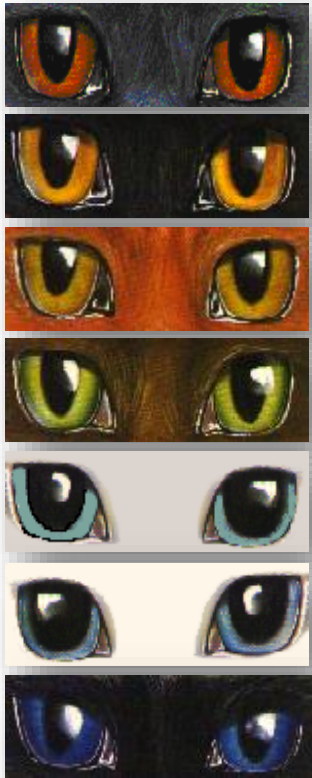
- Long Hair
- Blotched/Classic Tabby
- Solid Color/Non-Agouti
- Dominant/Epistatic White
- White Spotting
- Sex-Linked Orange or Red
- Dilution

WHAT IS A PATTERN?

PATTERN GROUPINGS

- Solid Color
- Shaded
- Tabby
- Parti-color
- Bi-Color
- Albino Series

EYE COLOR



- **Dependent on selective breeding**
- **Exceptions:**
 - Burmese
 - Tonkinese - all patterns
 - Siamese/Pointed/Himalayan Pattern
 - Blue-eyed white Albino

EYE COLOR



Heterochromia of the eye (*heterochromia iridis* or *heterochromia iridum*)

- *Complete heterochromia* - one iris is a different color from the other.
- The “odd-eyed” cat

EYE COLOR



- *Partial heterochromia* or *sectoral heterochromia*, part of one iris is a different color from its remainder.



COLOR

- During development of the embryo, melanoblasts (precursors to melanocytes, the melanin-producing cells) migrate from the neural crest and end up in the skin.
- The migration is controlled by at least two genes: W (Dominant white) and S (Piebald spotting).
- Once at their target location, the melanoblasts differentiate into the melanocytes and start pigment production.

PIGMENT DISTRIBUTION

- The distribution genes control where in the fur pigment will be displayed, they control the migration of melanoblasts.
- W or w: W is called the “Dominant White” gene. It is an epistatic gene. Melanoblasts only make it to the skin in the ww (homozygous recessive) animals. The epistatic white phenotype masks other pigment traits.
- S or s: S is the “piebald-spotting” gene. S and s are incomplete dominant alleles.
 - ss genotype the melanoblasts migrate and the cat is fully colored.
 - Ss animals have less than 50% white fur
 - SS animals have white patches on more than 50% of the body

PIGMENT PRODUCTION GENES

- These genes control the production of melanin.
- Pigment production results in two forms of Melanin:
 - Eumelanin (black pigment) sphere shaped
 - Phaeomelanin (orange/yellow pigment) elongated, football shaped

THE SOLID COLOR GENE

- The dominant, wild color gene is black – B
- Eumelanin pigment
- There are two mutations at the black allele:
 - b – chocolate, and is recessive to B (black)
 - b^l – light brown or cinnamon and is recessive to B and b

THERE ARE EIGHT COLORS IN CATS

- Dense Colors: (DD or Dd)
 - Black
 - Chocolate or Chestnut
 - Cinnamon
 - Red
- Dilute Colors: (dd)
 - Blue
 - Lilac or Lavender
 - Fawn
 - Cream

THERE ARE EIGHT COLORS IN CATS

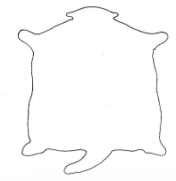
- Hold the phone!!! What about white cats?
- White is not a color, it is the absence of color. There are no melanocytes in the skin so there is no melanin production – and, no color.
- All White cats are not genetically the same:
 - Albino white (c^a and c)
 - Complete Spotting (SS)
 - Dominant White (W-)

SOLID COLOR



Black and White Persian Cats - The Book of the Cat by Frances Simpson; 1903

SOLID COLORS



White



Black



Chocolate



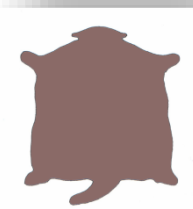
Cinnamon



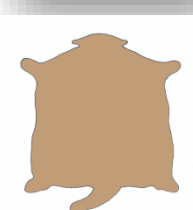
Red



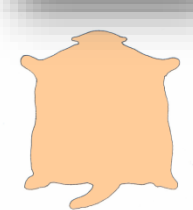
Blue



Lavender/Lilac



Fawn



Cream



SOLID COLOR



Colors specific to the NFC

Amber

Light Amber - dilute of Amber

THE COLOR DENSITY GENE

- The third gene that controls coat color.
- It controls the uniformity and distribution of the pigment throughout the hair.
- “D” is the wild, dominant, and causes the pigment to be evenly distributed.
- “d” is the mutant, recessive gene and causes the pigment to separate so that there are microscopic clumps surrounded by translucent unpigmented areas.

DENSE – DILUTE CHART

**BLACK-BASED
COLORS**
(eumelanin)

	DENSE (D-)	DILUTE (dd)
BLACK (B-)	Black	Blue
BROWN (bb)	Chocolate	Lilac
LIGHT BROWN (b ^l b ^l)	Cinnamon	Fawn
RED-BASED COLORS (phaeomelanin)	Red	Cream

EPISTATIC GENES

- Another type of gene that is dominant is an **epistatic gene**.
- This is a gene that resides at a different locus of the chromosome or on a completely different chromosome
- It masks the effect of certain other genes

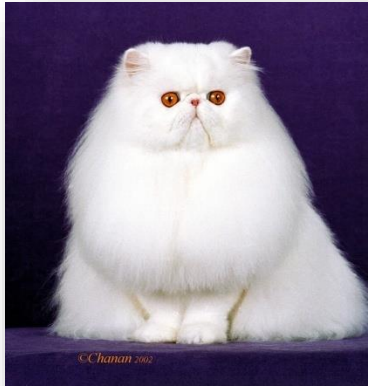
EPISTATIC GENES

- The Dominant White gene, properly called epistatic white, when present masks out all other color genes. It has a phenotype of white, but also has the genes for other colors that it masks.
- The Orange Gene (red) masks the non-agouti gene, making all red cats tabbies. It makes the non-agouti gene inoperative, i.e. unable to express itself.
- Agouti Abyssinian Tabby T^a gene is epistatic to the other tabby patterns. It was originally thought to be an allele of the tabby gene, but was found to be at a different locus.

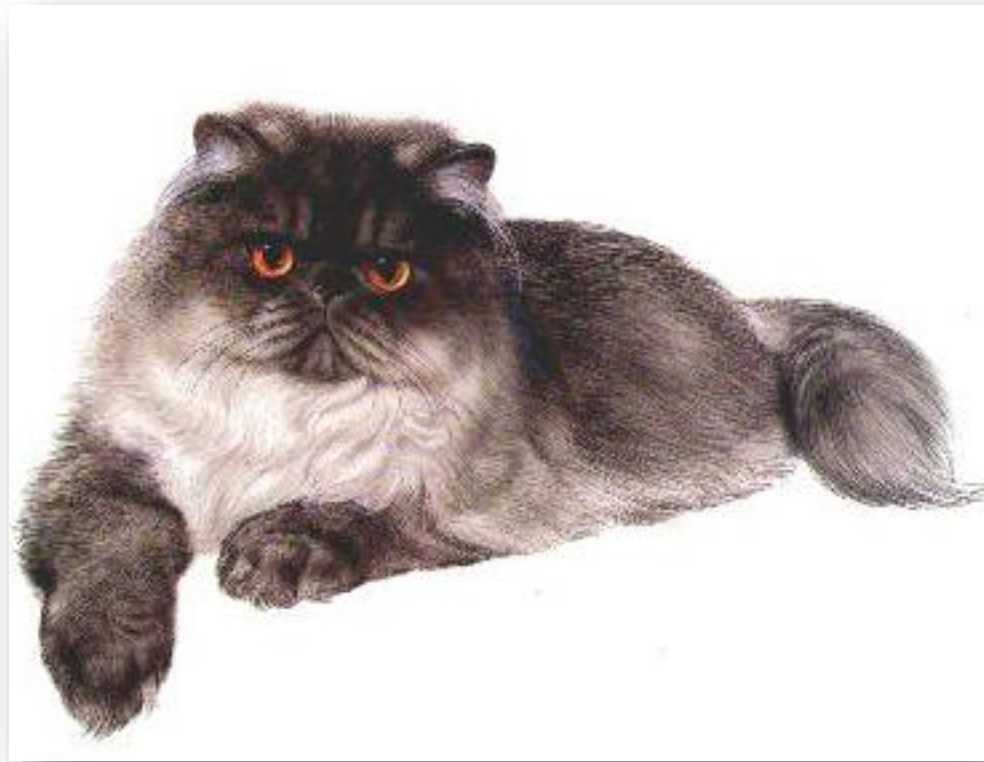
DOMINANT WHITE GENE

- “W” is the white gene, is an epistatic dominant gene.
- “w” is the wild type, is recessive and allow full expression of the coat color.
- Three types of Expression:
 - WW or Ww results in a white cat
 - ww – full color expression
- Also one of the genes that prevents migration of the melanoblast in embryonic development.

SOLID COLOR



SHADED AND SMOKE



Smoke Persian - From Perfect Cats by Peter Warner; 1991



Chinchilla Cat - The Book of the Cat by Frances Simpson; 1903

MELANIN INHIBITOR GENE

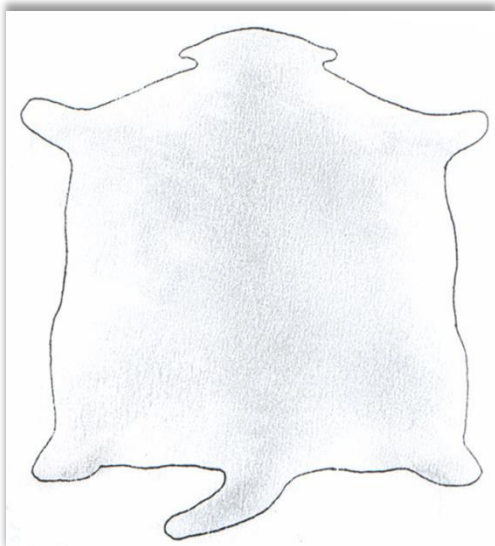
- This gene is also known as the silver gene and controls the degree of “shading”.
- “I” is the mutant and is dominant.
- “i” is recessive and is the wild type.
- Shading causes the agouti band to be lighter in color. It can also cause the agouti band to be wider (Wb), so much so that the agouti band extends all the way to the root. The effect is to produce a hair shaft that has a colored tip in whatever color is determined by the color genes.
- When the light colored hair shaft is near white, it is called Silver. When it is a warm cream color, it is called Golden.

MELANIN INHIBITOR GENE

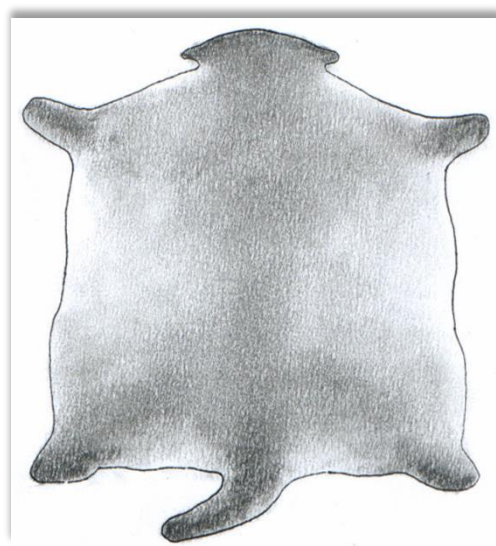
- The Wb (wideband gene) is dominant, produces a wide band $w^b w^b$ is recessive to normal banding.
- Silver Tabby and Silver McTabby:
 - $A-t^{bt^b}I-w^b w^b$ and $A-T-I-w^b w^b$
- Chinchilla and Shaded Silver:
 - $A-T-I- Wb-$
- Chinchilla and Shaded Golden:
 - $A-T-iiWb-$
- Smoke:
 - $aa^{**}I-Wb-$

SHADED AND SMOKE

What's the difference?!



Chinchilla



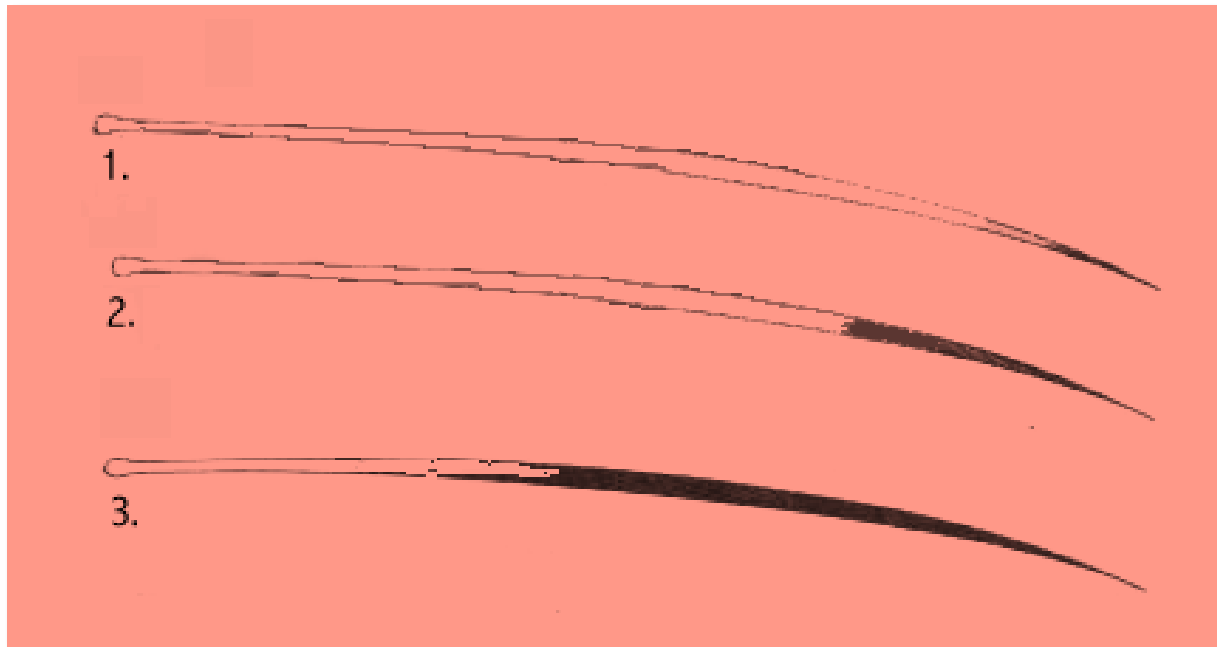
Shaded



Smoke

SHADED AND SMOKE

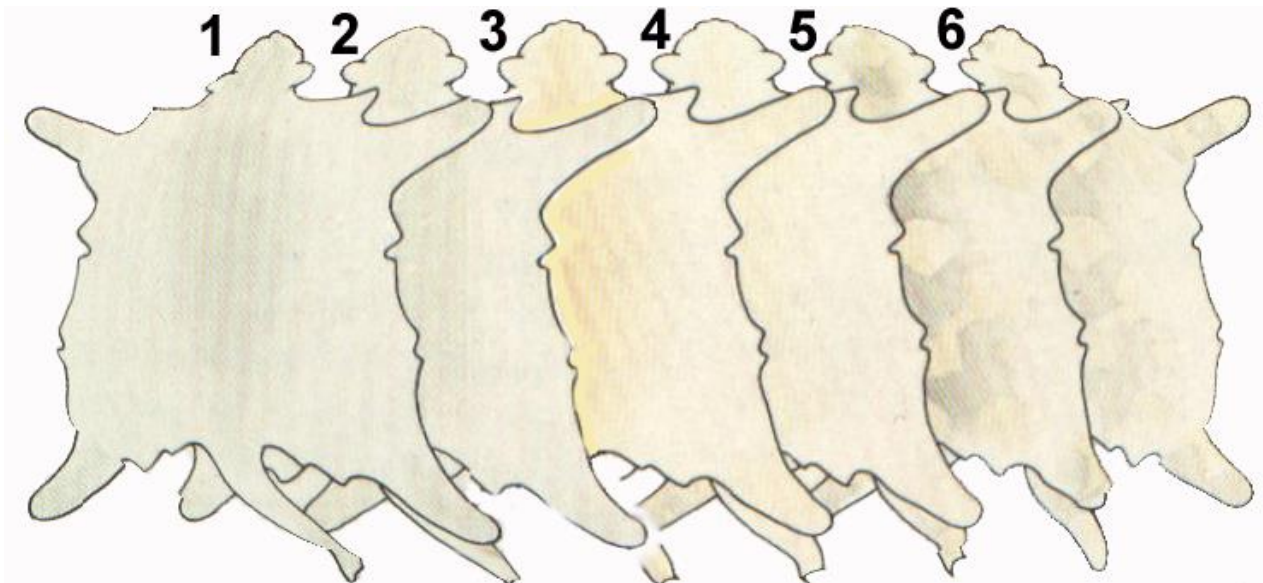
What's the difference?!



Adapted from The Book of the Cat by Michael Wright and Sally Walters, 1980

SHADED AND SMOKE

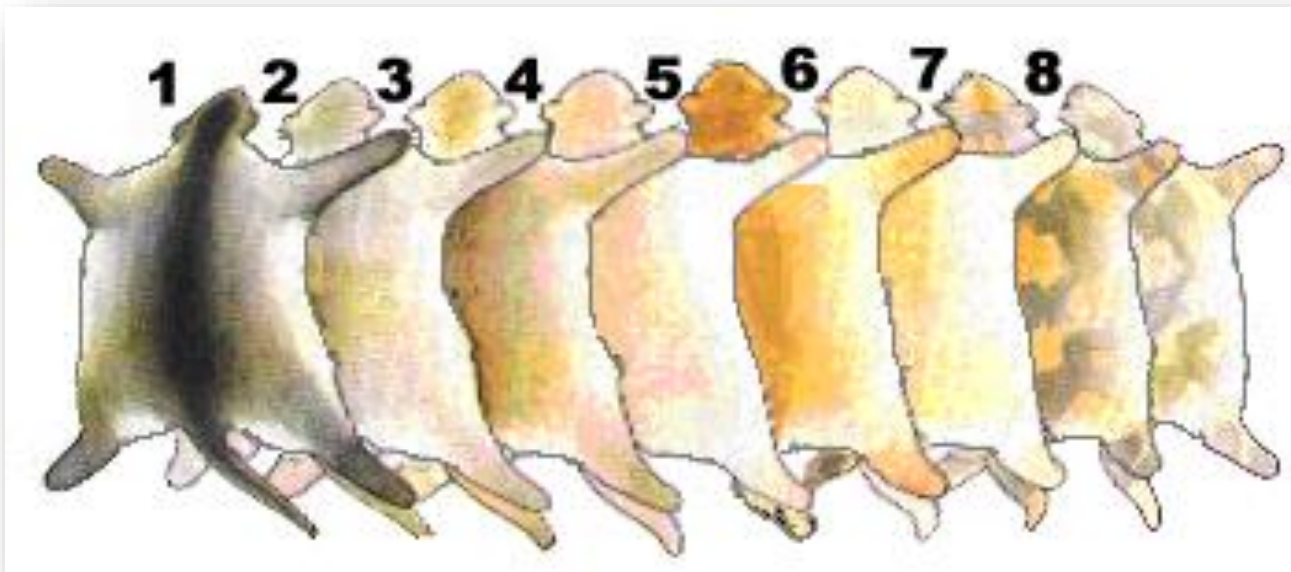
Chinchilla/Shell



Shaded Colors - Adapted from The Book of the Cat by Michael Wright and Sally Walters, 1980

SHADED AND SMOKE

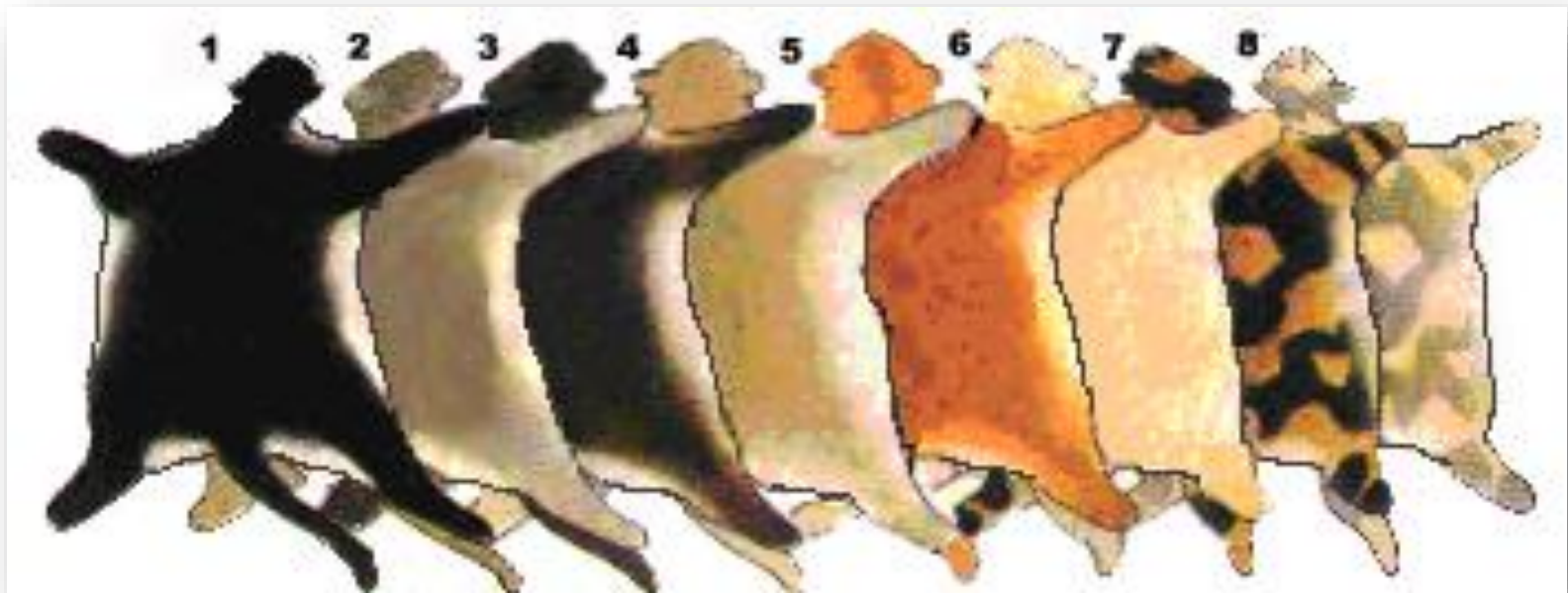
Shaded



Shaded Colors - Adapted from The Book of the Cat by Michael Wright and Sally Walters, 1980

SHADED AND SMOKE

Smoke



Shaded Colors - Adapted from The Book of the Cat by Michael Wright and Sally Walters, 1980

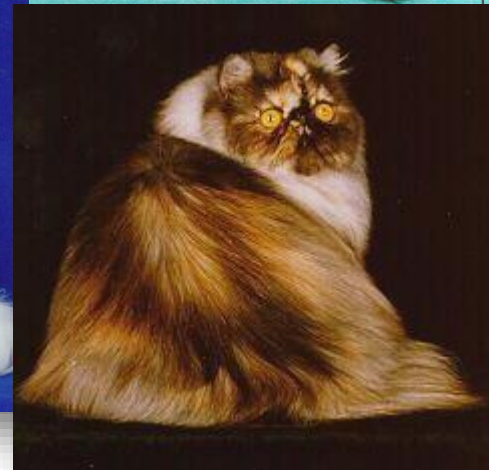
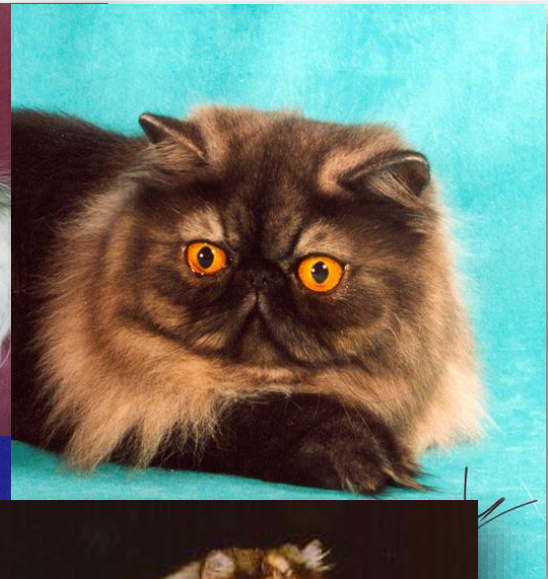
SHADED AND SMOKE

Goldens



Shaded Colors - Adapted from The Book of the Cat by Michael Wright and Sally Walters, 1980

SHADED AND SMOKE



TABBY PATTERNS



Brown Tabby and Orange Tabby SH Cats- The Book of the Cat by Frances Simpson; 1903

THE AGOUTI GENE

- This is the gene that controls pattern.
- There are two alleles:
 - “A” which is the wild type, is dominant and has a banded or ticked (agouti) hair which produces a tabby coat.
 - “a” which is non-agouti, is a mutation, is recessive and suppresses ticking and in turn produces a solid-colored coat.
- This gene operates on the color gene (black, chocolate and cinnamon) in conjunction with the non-orange allele.
- The orange gene masks the non-agouti gene making red cats tabbies.

THE TABBY GENE

- The other gene that affects coat pattern.
- “T” represents Mackerel or striped tabby.
- “t^b” represents classic or blotched tabby, it is a recessive allele.
- “T^a” represents the ticked tabby allele or the all-agouti tabby pattern.
- “T^a” is now considered an epistatic gene and is not located at the same locus as “T” and “t^b”.
- The spotted tabby in domestic cats, usually, is due to polygene influence on the Mackerel tabby pattern.

TABBY PATTERNS

**Mackerel
Tabby**



TABBY PATTERNS

Classic Tabby



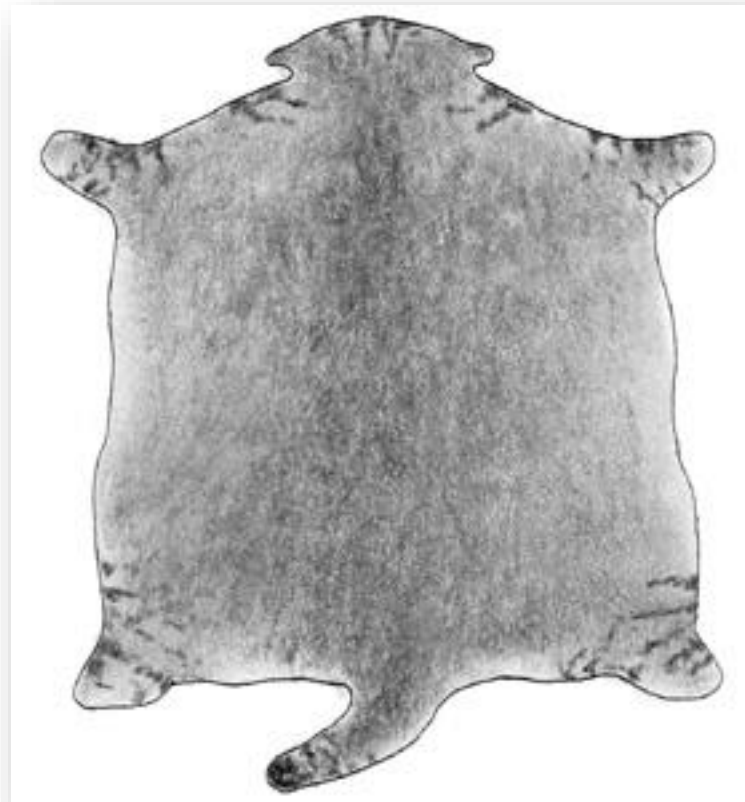
TABBY PATTERNS

**Spotted
Tabby**



TABBY PATTERNS

**Ticked
Tabby**



TABBY PATTERNS

**Marbled
Tabby**



TABBY PATTERNS

Rosetted/Spotted Tabby



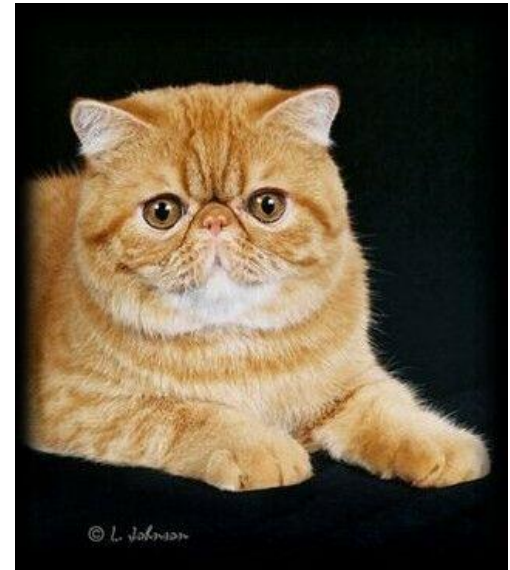
TABBY PATTERNS

Patched

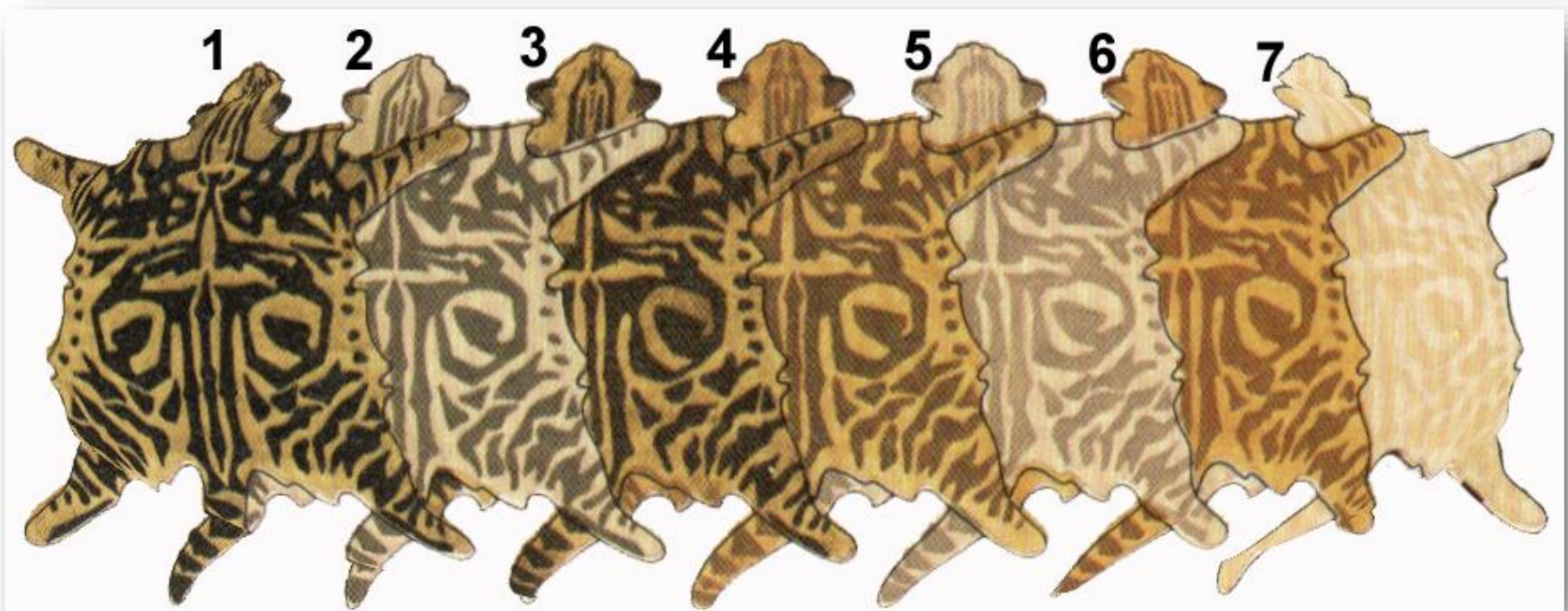


TABBY PATTERNS

Agouti Cats . . . Not bi-colors

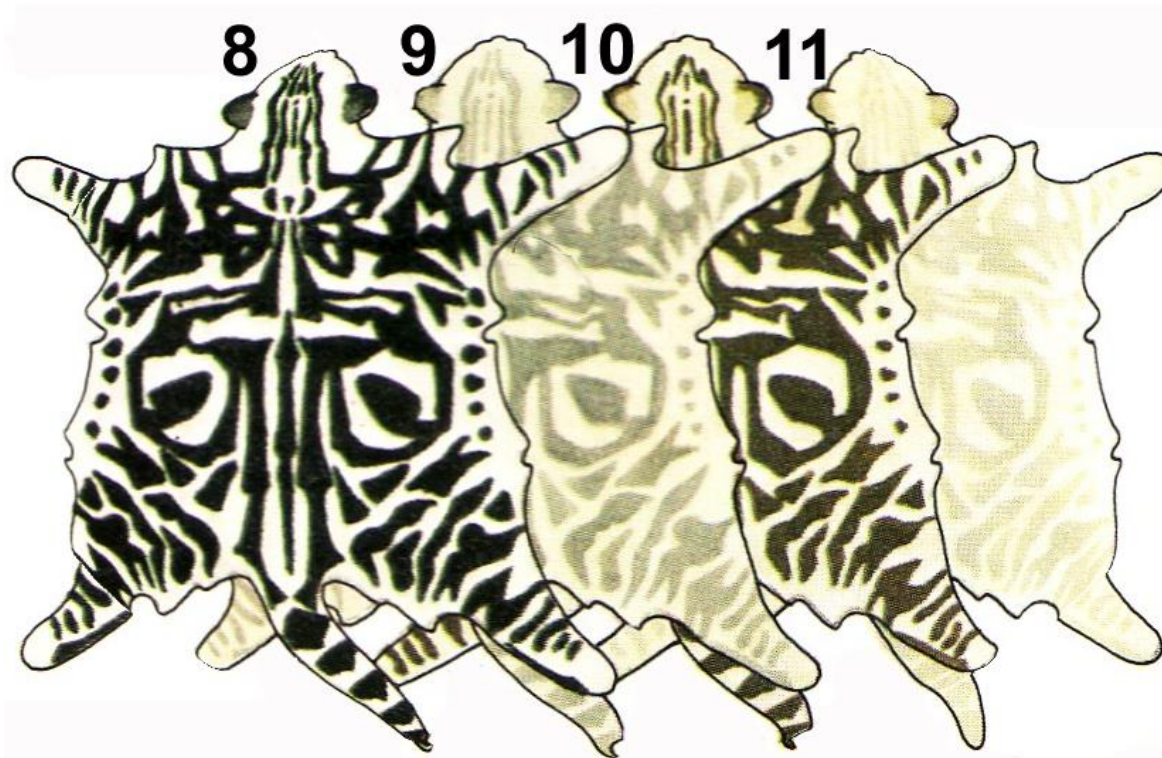


TABBY PATTERNS



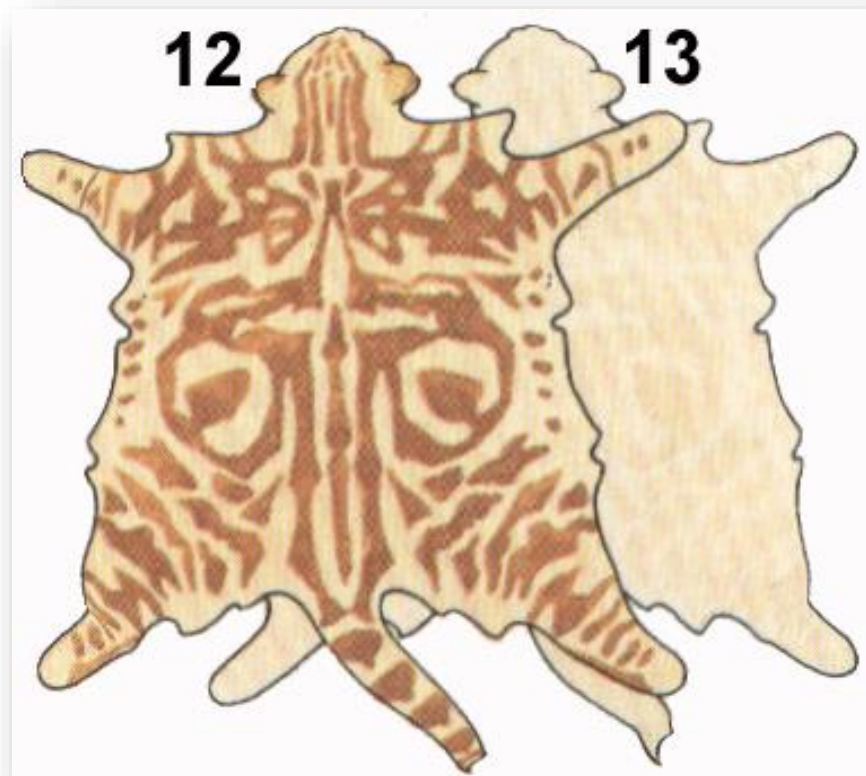
Tabby Colors - Adapted from The Book of the Cat by Michael Wright and Sally Walters, 1980

TABBY PATTERNS



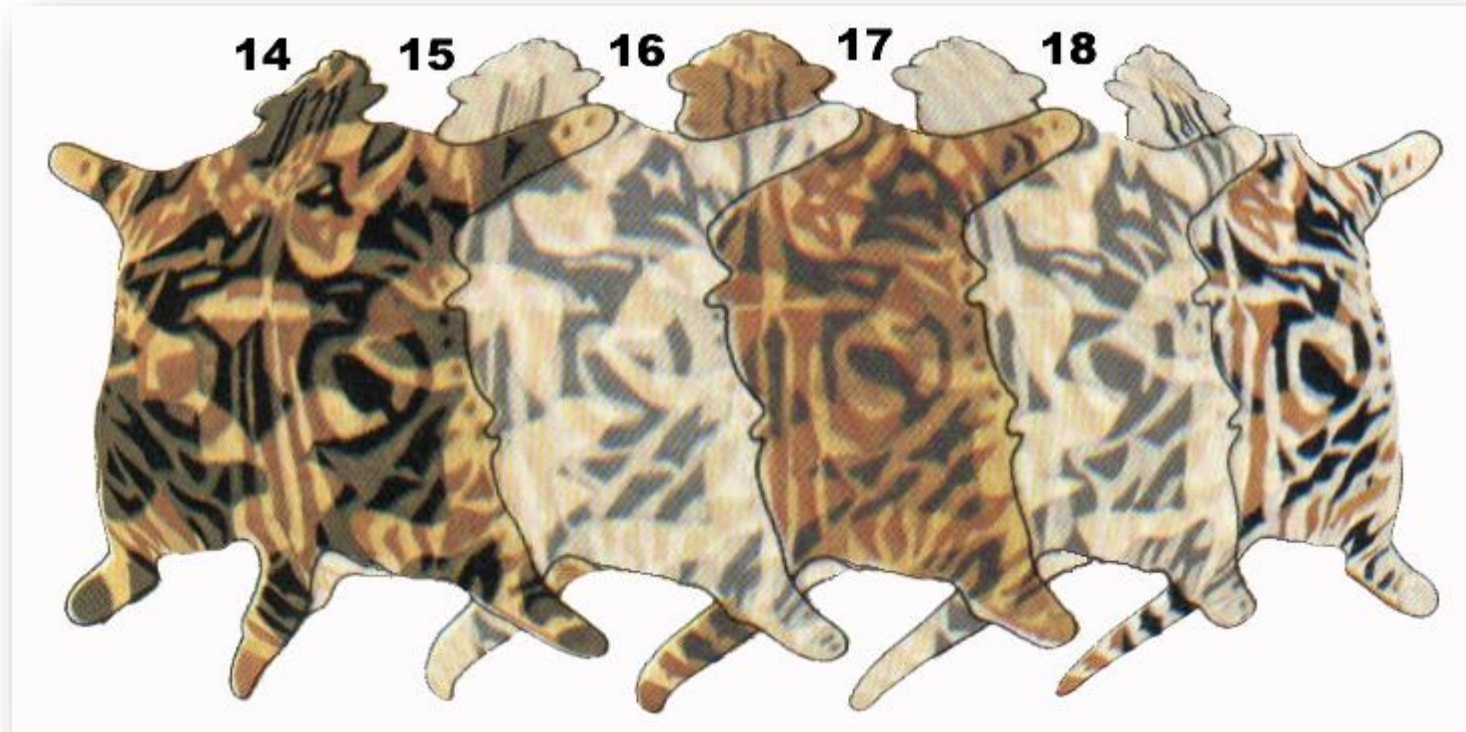
Tabby Colors - Adapted from The Book of the Cat by Michael Wright and Sally Walters, 1980

TABBY PATTERNS



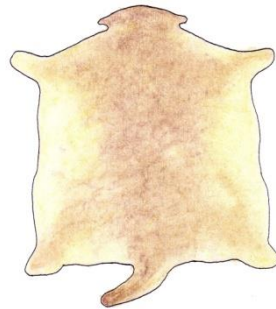
Tabby Colors - Adapted from The Book of the Cat by Michael Wright and Sally Walters, 1980

TABBY PATTERNS



Tabby Colors - Adapted from The Book of the Cat by Michael Wright and Sally Walters, 1980

TABBY PATTERNS



Singapura

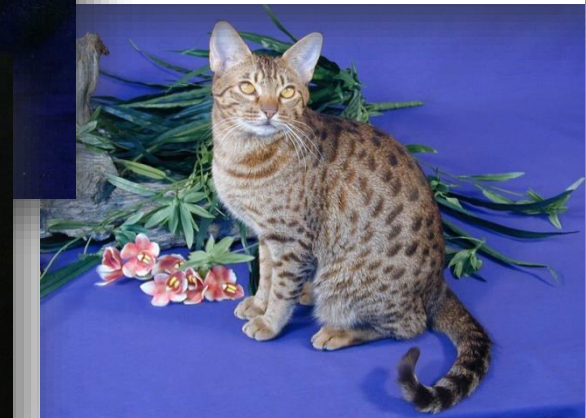
Abyssinian Colors

TABBY PATTERNS



Amber and Light Amber Tabby

TABBY PATTERNS



TABBY PATTERNS



PARTI COLORS



ORANGE MAKING GENE

- Second gene controlling coat color.
- Converts the coat color into orange and masks the non-agouti gene.
- “o” is the wild type and allows full expression of the black, brown and light brown/cinnamon colors.
- “O” is a mutation and converts black and brown to orange and mask the non-agouti gene. i.e. all orange cats are tabbies.
- It is a sex linked gene.

ORANGE MAKING GENE

- The orange gene (O and o) is located on the X chromosome.
- XO converts eumelanin (black) to phaeomelanin (red/orange/yellow).
- Xo results in no melanin conversion.
- Possible combinations of the sex linked gene:
 - XOXO – red female
 - XOXo – tortoiseshell female
 - XoXo – black female
 - XOY – Red male
 - XoY – Black male
- The orange gene masks the non-agouti gene.

PARTI COLORS

Tortoiseshell Pattern



PARTI COLORS

1



2



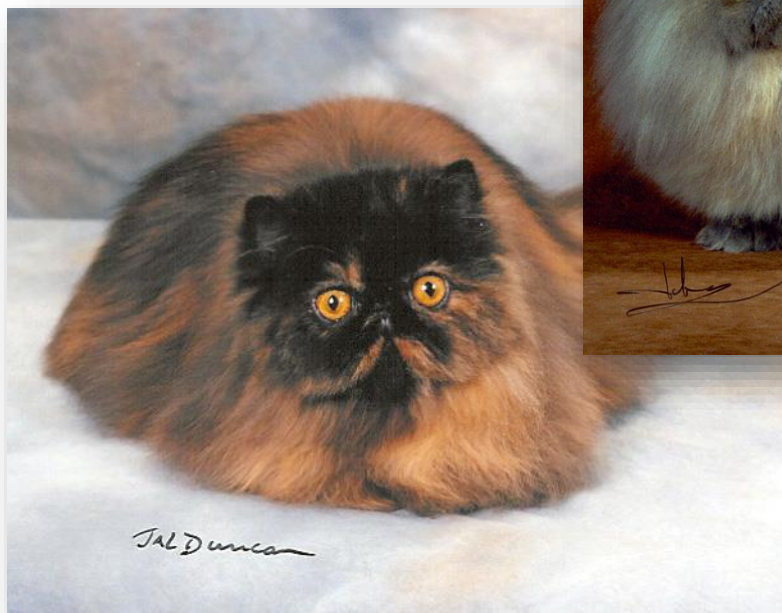
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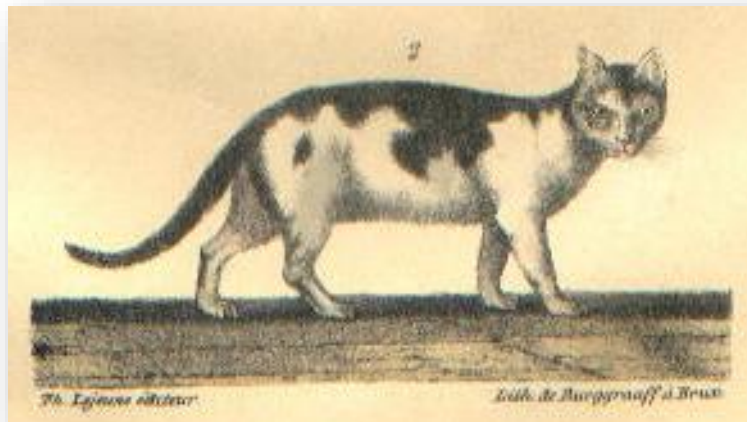
PARTI COLORS



PARTI COLORS



BI-COLORS AND CATS WITH WHITE



Bi-Color and Calico Cats - By George Louis LeClerc Buffon

from Oeuvres Completes de Buffon, Volume III, 1833

PIEBALD – WHITE SPOTTING

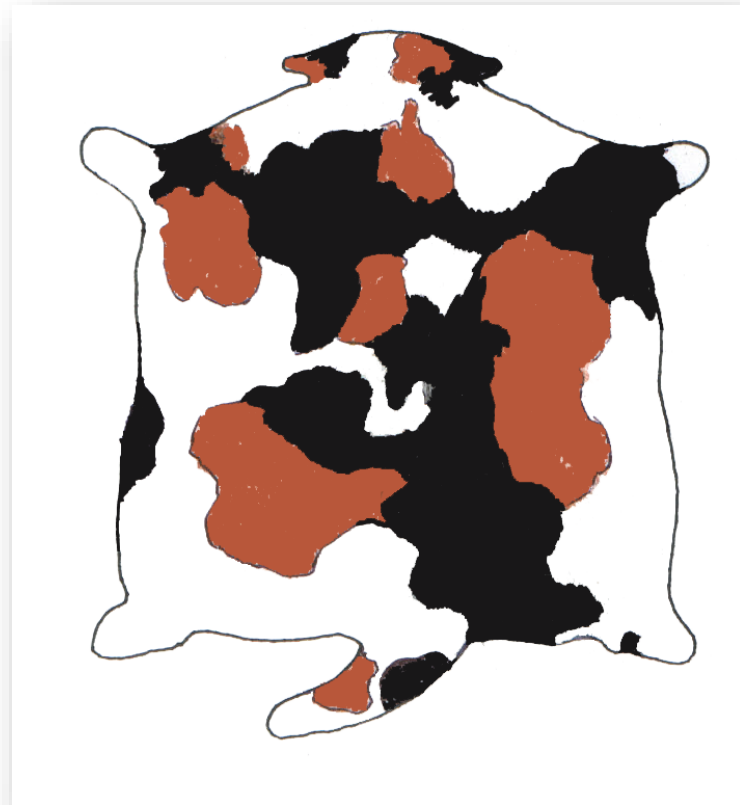
- Wide range of expression from only white toes to a completely white coat.
- One of the genes that prevents migration of the melanoblasts during embryonic development.
- Is an example of incomplete dominance > Variable expression.
- Three possible expressions – “S” is dominant:
 - “SS” – greater than 50% white
 - “Ss” – less than 50% white
 - “ss” - no white

BI-COLORS AND CATS WITH WHITE



BI-COLORS AND CATS WITH WHITE

Calico

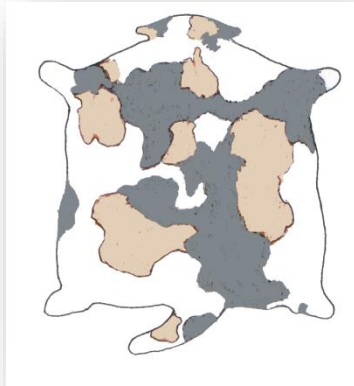


BI-COLORS AND CATS WITH WHITE

1



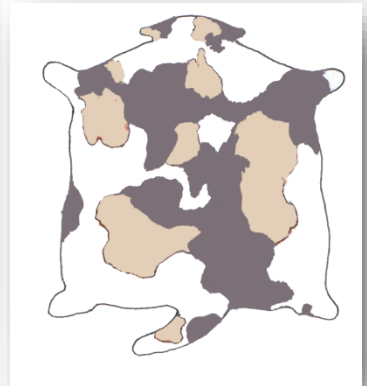
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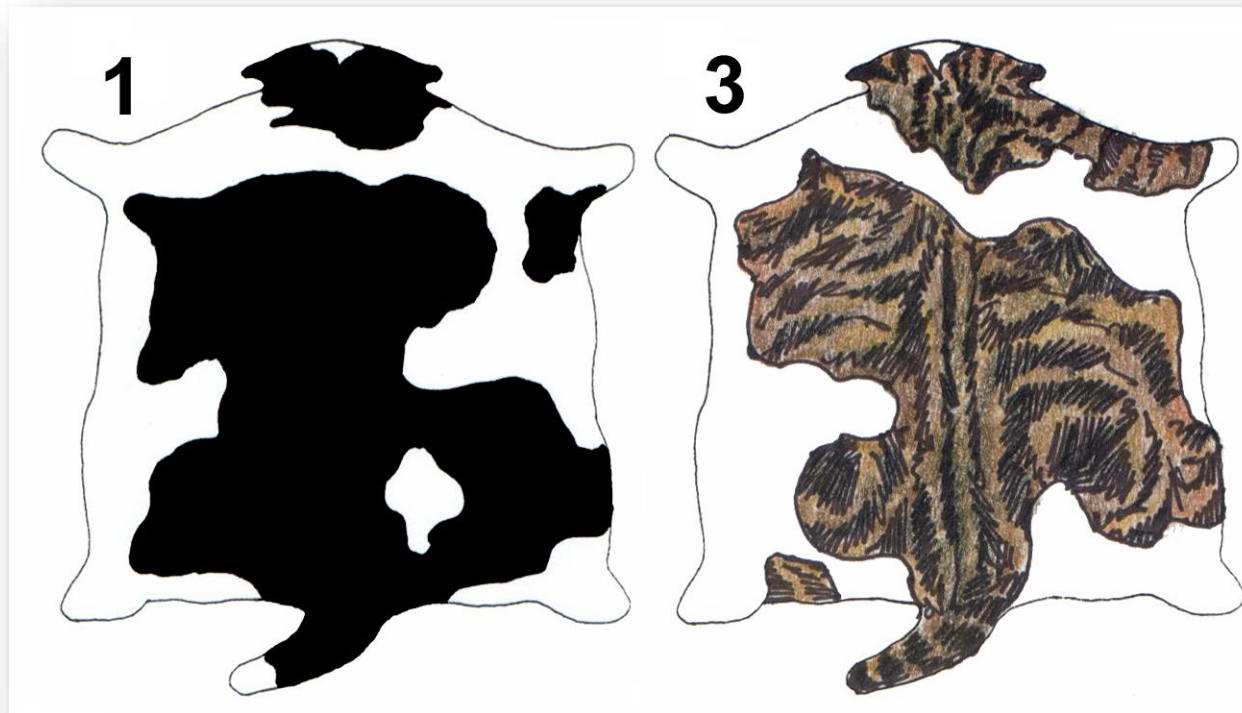
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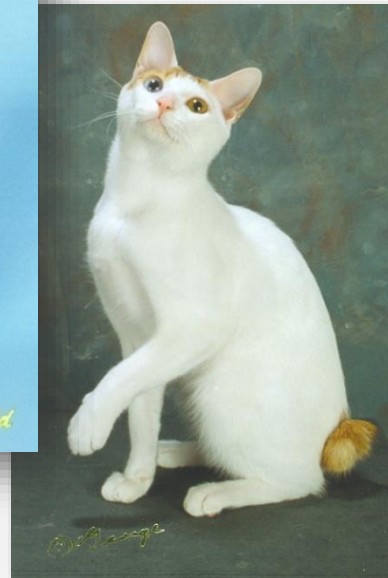
4



BI-COLORS AND CATS WITH WHITE



BI-COLORS AND CATS WITH WHITE



BI-COLORS AND CATS WITH WHITE



Bi-Colors are FUN!



BI-COLORS AND CATS WITH WHITE



From The Messy Beast
www.messybeast.com

PATTERNS OF THE ALBINO SERIES



From the Tamra Maew as shown in The Legend of the Siamese Cats by Martin R. Clutterbuck, 1998



BLACK MANX AND ROYAL SIAMESE CATS.

(From a Painting by W. Laker, Jun.)

THE ALBINISM GENE

- There are 5 alleles for this gene.
 - “C” results in full color, dominant gene
 - “c^b” Burmese gene
 - “c^s” Siamese gene
 - “c^a” blue-eyed albino
 - “c” true albino
- Dominance: $C > c^b = c^s > c^a > c$
- c^bc^s mink pattern of the Tonkinese
- Temperature sensitive genes

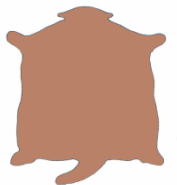
ALBINO SERIES CHART

Full Color (C-)	→ Sepia (c ^b c ^b)	→ Mink (c ^b c ^s)	→ Pointed (c ^s c ^s)
Black (B-D-)	Sable Seal Sepia	Seal Mink Natural Mink	Seal Point
Blue (B-dd)	Blue Sepia	Blue Mink	Blue Point
Chocolate (bbD-)	Chocolate Sepia Champagne	Chocolate Mink Champagne Mink	Chocolate Point
Lilac (bbdd)	Lilac Sepia Platinum	Lilac Mink Platinum Mink	Lilac Point Platinum Point
Cinnamon (b ^l b ^l D-)	Cinnamon Sepia	Cinnamon Mink Honey Mink	Cinnamon Point
Fawn (b ^l b ^l dd)	Fawn Sepia	Fawn Mink	Fawn Point
Red (D-O(O))	Red Sepia	Red Mink	Red Point
Cream (dd O(O))	Cream Sepia	Cream Mink	Cream Point

PATTERNS OF THE ALBINO SERIES



Sable/Brown/
Natural



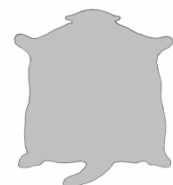
Champagne/
Chocolate



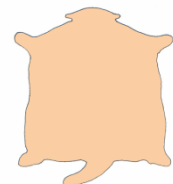
Red



Blue



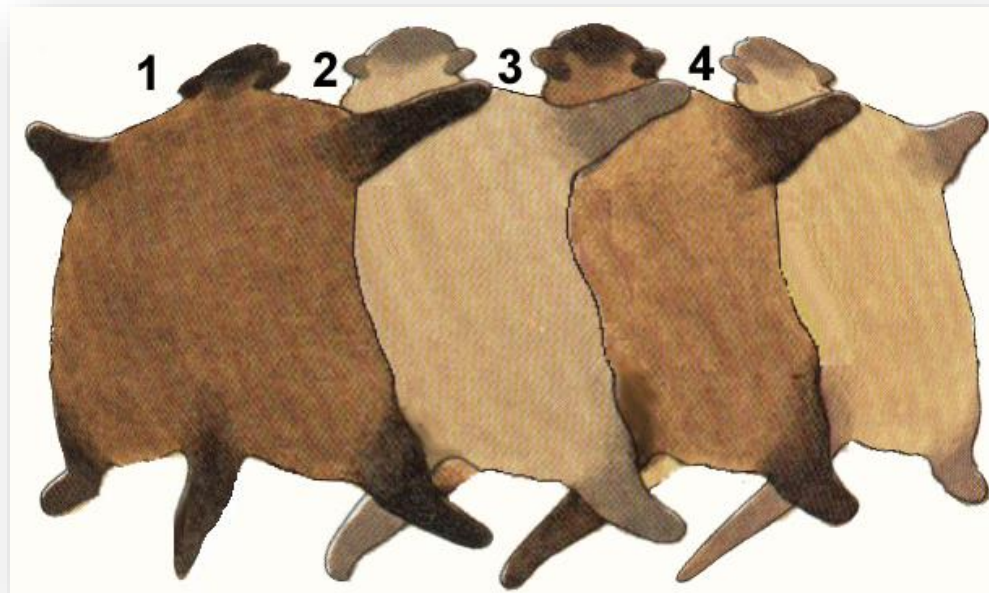
Platinum/Lilac



Cream

Burmese/Sepia Pattern

PATTERNS OF THE ALBINO SERIES

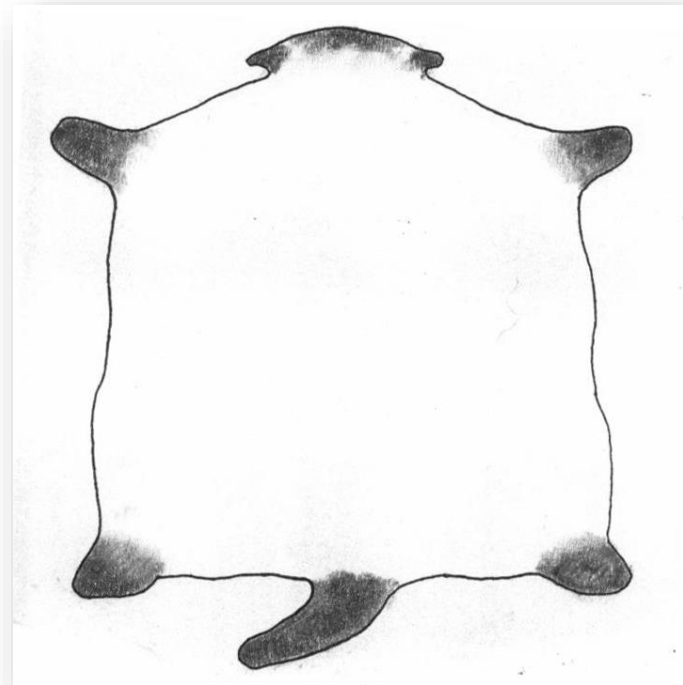


Mink Pattern

Adapted from The Book of the Cat by Michael Wright and Sally Walters, 1980

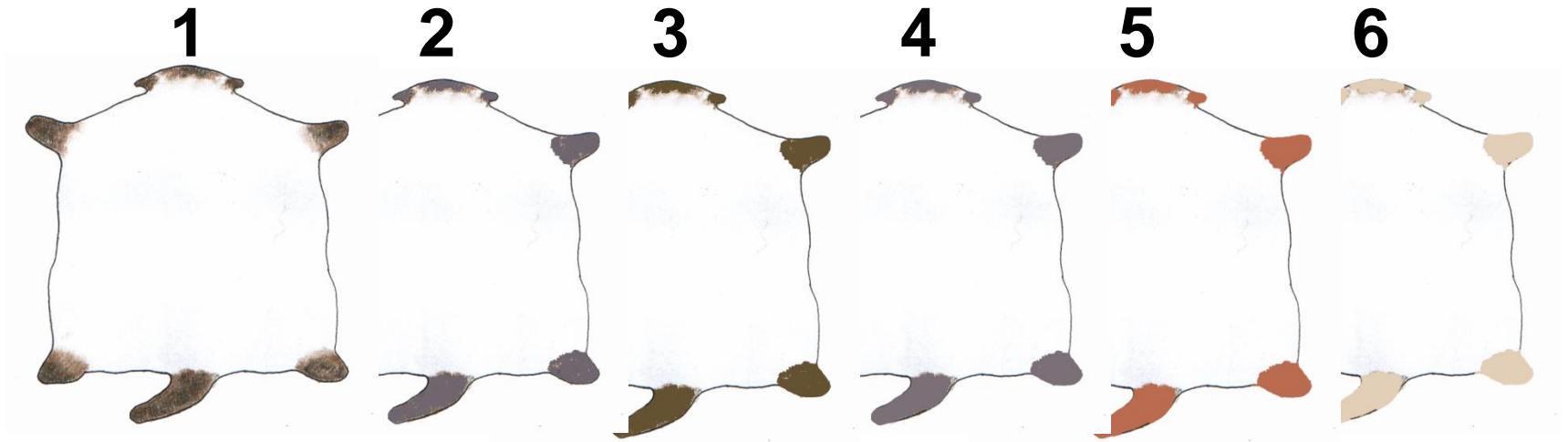
PATTERNS OF THE ALBINO SERIES

Colorpoint
Pointed
Himalayan
Siamese



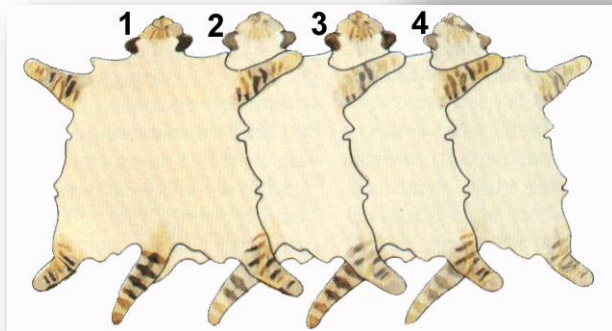
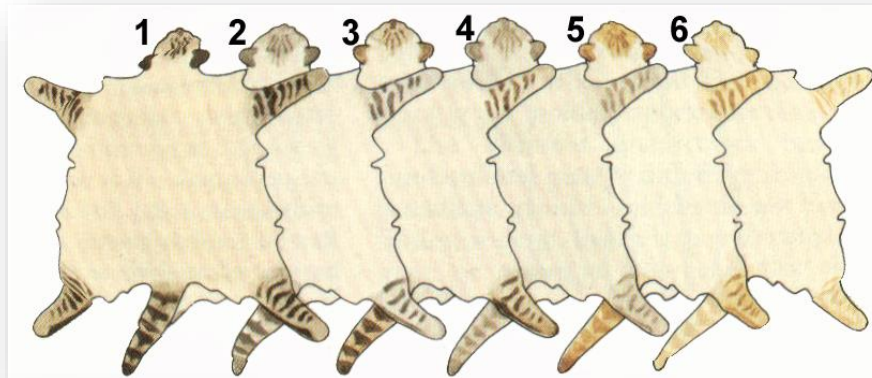
PATTERNS OF THE ALBINO SERIES

Solid



PATTERNS OF THE ALBINO SERIES

Lynx

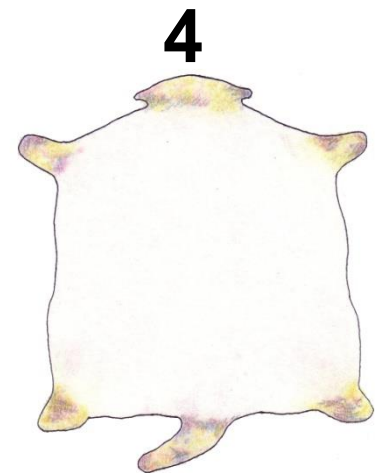
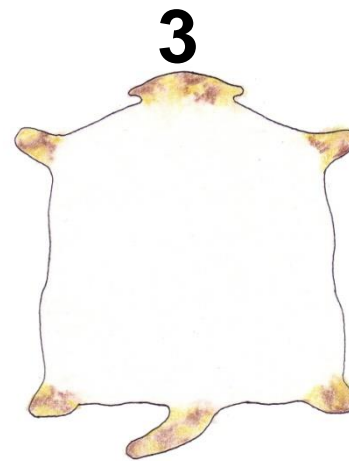
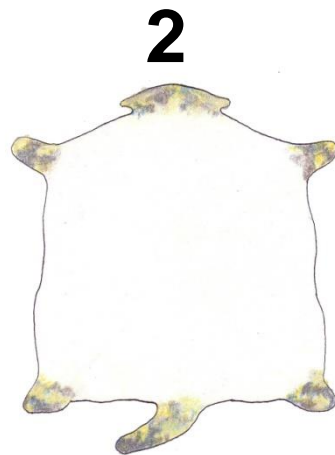
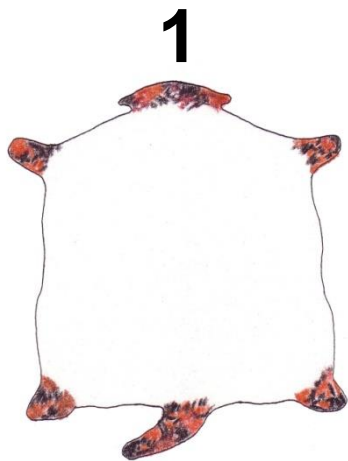


Patched Lynx



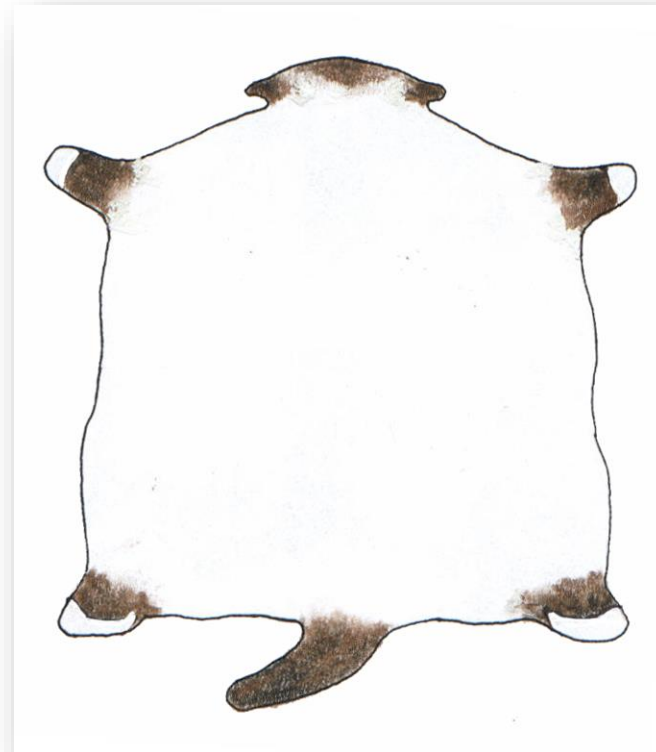
PATTERNS OF THE ALBINO SERIES

Partis

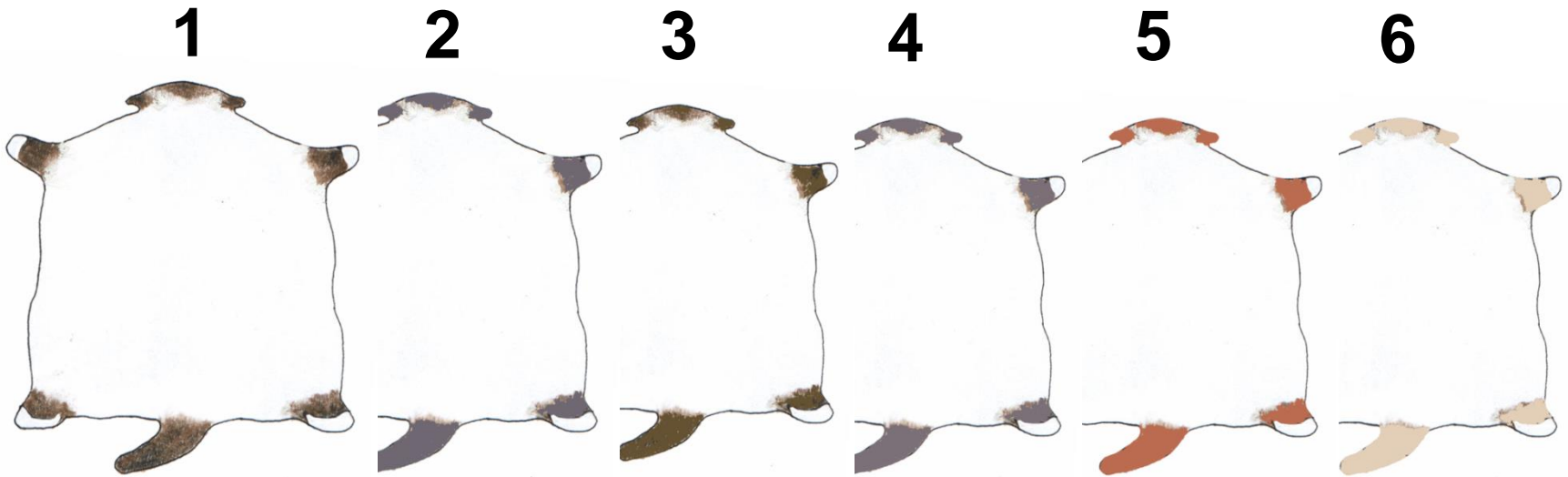


PATTERNS OF THE ALBINO SERIES

**Birman
Pattern**



PATTERNS OF THE ALBINO SERIES



TABBY PATTERNING ON COLORPOINTS

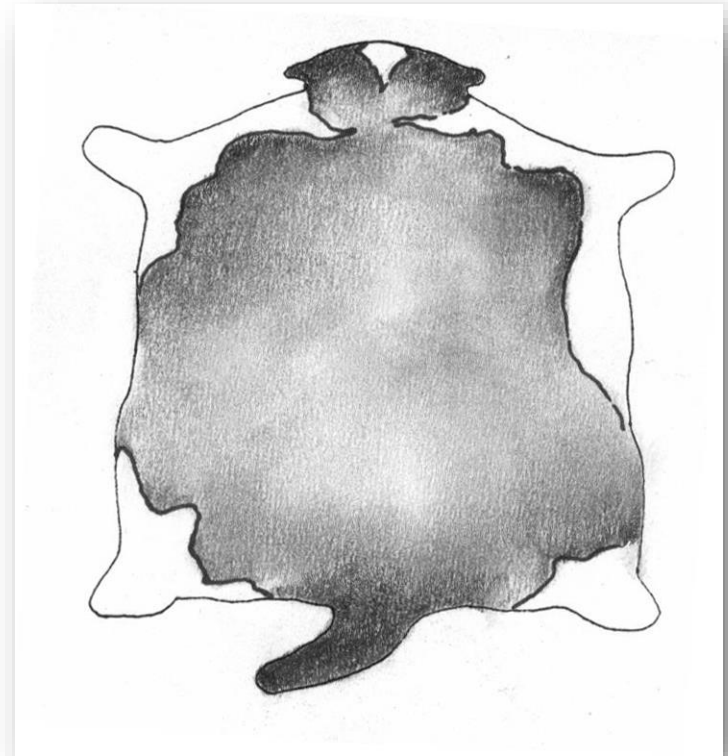


TABBY PATTERNING ON COLORPOINTS

- Patterning is seen in the pointed examples of many breeds—American Bobtail, American Curl, Siberian to name a few. There are several reasons for this:
 - Underneath it all, all cats are tabbies and it is hard to camouflage that pattern genetically.
 - Breeders of those breeds where it is allowed are generally not breeding for the pointed pattern per se so they do not develop breeding programs to "improve" the patterning to eventually breed it out of the gene pool.
- In fact, some breeds standards that state this is preferred because the patterning on the pointed cats gives a feral appearance for example, American Bobtail
- Breeds standards like the Siamese, Balinese, CPSH, etc., have a significant number of points on pattern. So much so that, the pattern is explicitly spelled out in their standards and it is integral to every breeder's program.

PATTERNS OF THE ALBINO SERIES

**The Ragdoll/
Pointed Bi-Color
Pattern**



PATTERNS OF THE ALBINO SERIES

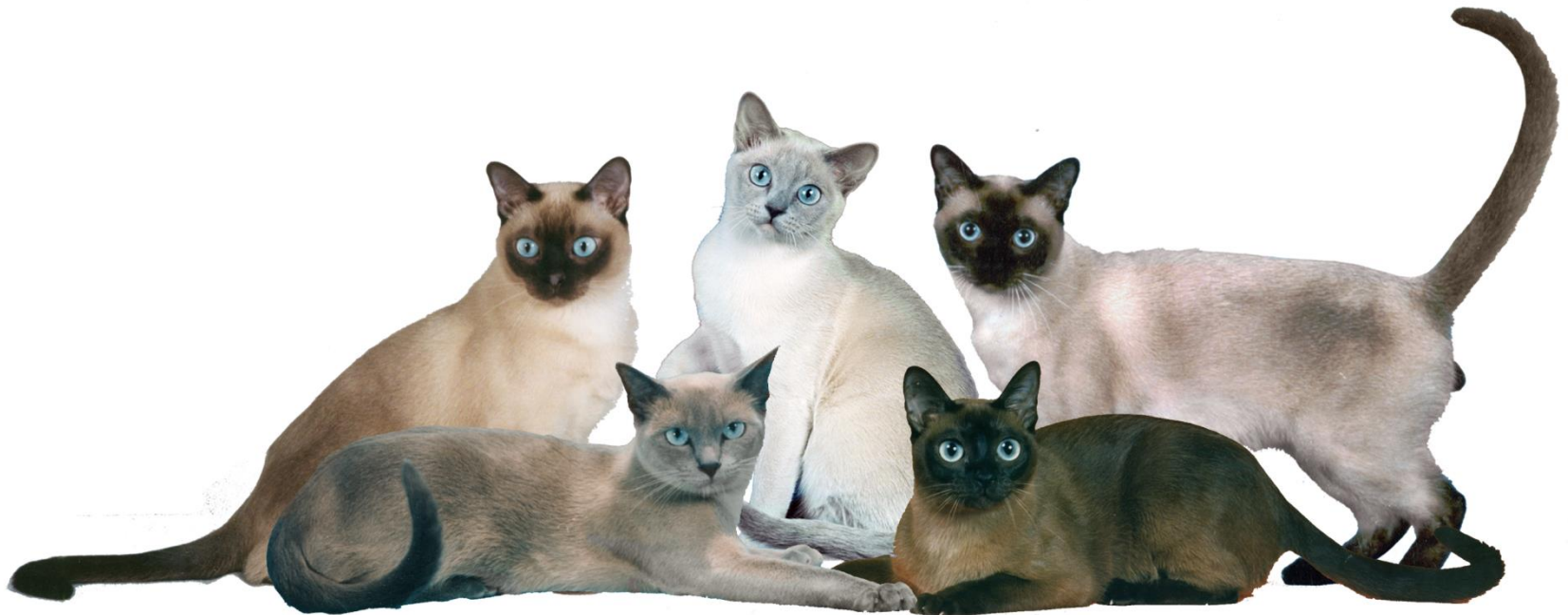


PATTERNS OF THE ALBINO SERIES

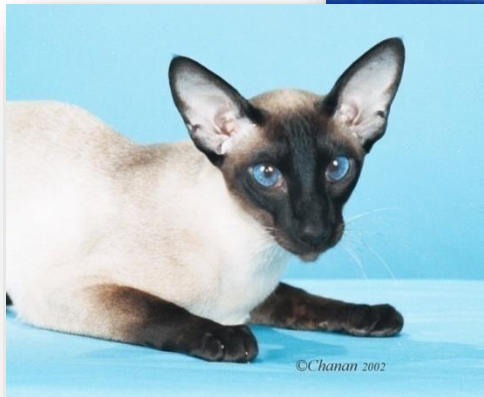
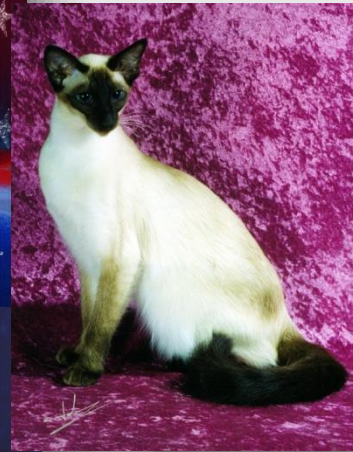
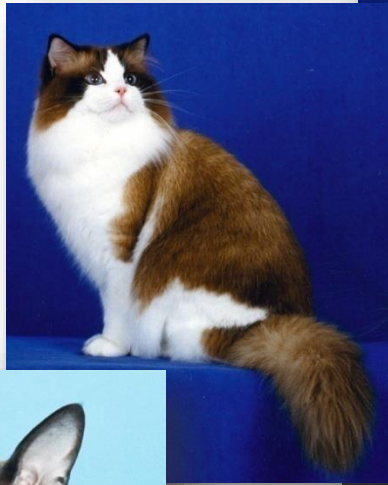


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PATTERNS OF THE ALBINO SERIES



PATTERNS OF THE ALBINO SERIES



OH MY! WHAT NEXT?!

