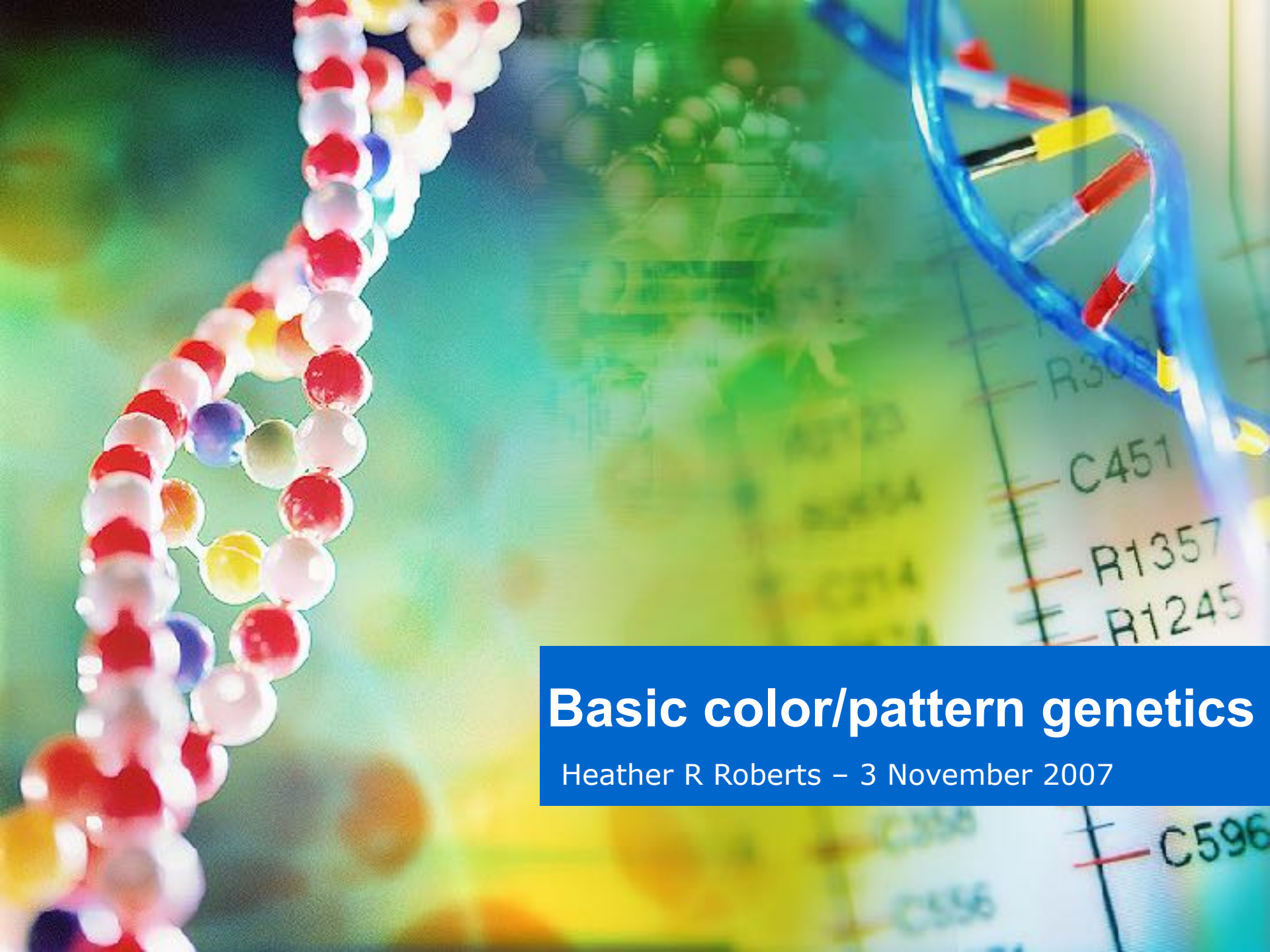
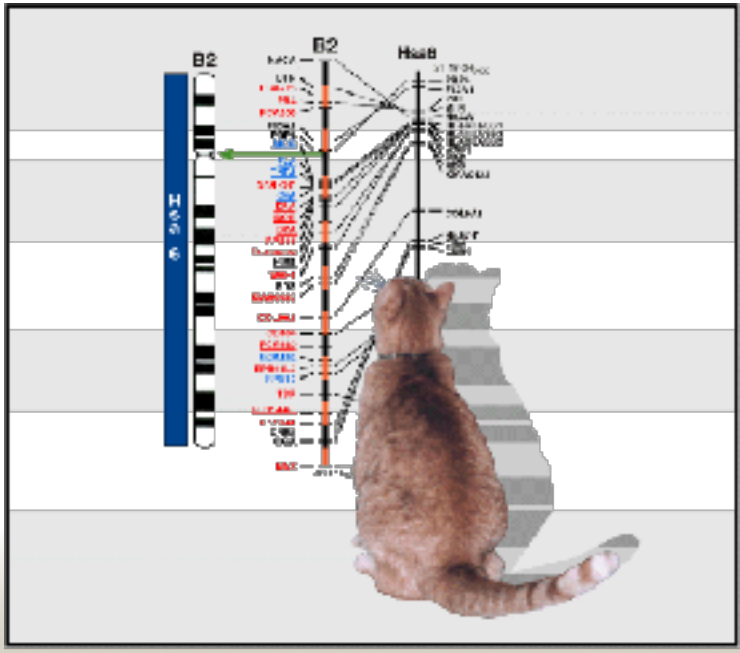


Basic color/pattern genetics

Heather R Roberts – 3 November 2007

Today's Outline

1) Review of Mendelian Genetics
2) Review of Extensions
3) Mutation
4) Coloration and pattern

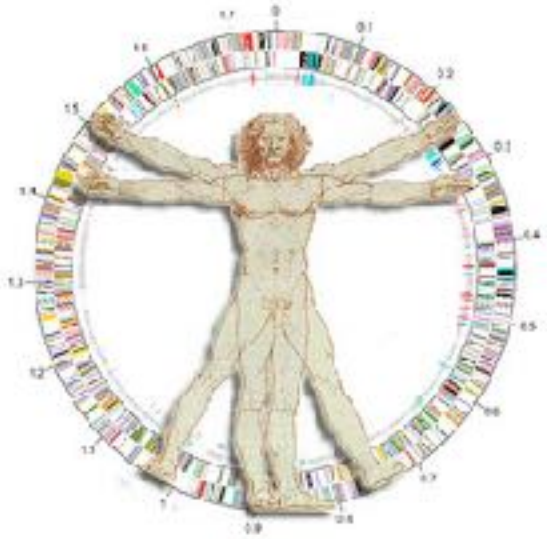


Alleles

- Homozygous – having the same 2 alleles at that gene locus (location). cs/cs
- Heterozygous – having dissimilar alleles at that gene locus. cs/cb

Modes of Inheritance

- Complete dominant – the trait is expressed when present in the homozygous or heterozygous normal state. A/A or A/a
- Complete recessive – the trait is expressed only in the homozygous mutant state. a/a



Multiple alleles

- Sometimes a mutation occurs at a locus which produces a new allele – usually causing a new phenotype (appearance).
- In the cat world, our best example is the albino series….

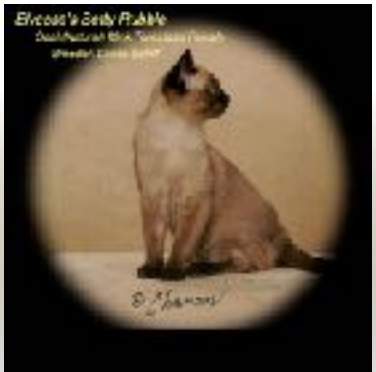
Multiple alleles – albino series

- C = full color
- cb = sepia
- cs = pointed
- ca = blue-eyed albino
- c = pink-eyed albino

- C > cb > cs > ca > c

Multiple alleles – albino series

- The sepia alleles allow little difference between the body color and point color (cb/cb).
- The pointed alleles allow extreme contrast between the body color and the point color (cs/cs).
- The mink condition is a heterozygote – cb/cs. A cat cannot “carry” mink.



Sex-linked traits

- …and of course, there are those genes which are found only on the X chromosome and are therefore considered to be sex-linked.
- Red is X-linked in cats, but we will talk more about that later on.

Mutations

- Mutations happen all the time. They are simply a change in the code of the DNA.
- Most mutations are “silent” – i.e. they do not cause any effect. Some are bad, and some are good.
- There are numerous ways you get mutations in DNA strands, but there are only 3 underlying factors as to WHY mutation happens…..

GENETICS

ENVIRONMENT

CHANCE

MUTATION

ONLY SOURCE OF NEW VARIATION

Color and Pattern Genetics

- Color and pattern are extremely important in some breeds (BG and OC for example). In other breeds, they are fairly irrelevant (0 points in the PD).

Color and Pattern Genetics

- There are many genes which contribute heavily to the appearance of every cat.
- **Every cat is black.
- **Every cat is tabby.
- We simply make changes to the genotype to make a cat look non-black and non-tabby. We will primarily talk about 11 genes.

1. Agouti gene – chromosome B1

- Agouti (tabby) cats = A/- (= A/A or A/a)
- Non-agouti (solid) cats = a/a

A/A or A/a

a/a only

2. Black, chocolate, cinnamon – D4

** Here is another example of multiple alleles.

- Black = B/-
- Chocolate = b/b or b/b1
- Cinnamon = b1/b1

- **Black** > **chocolate** > **cinnamon**

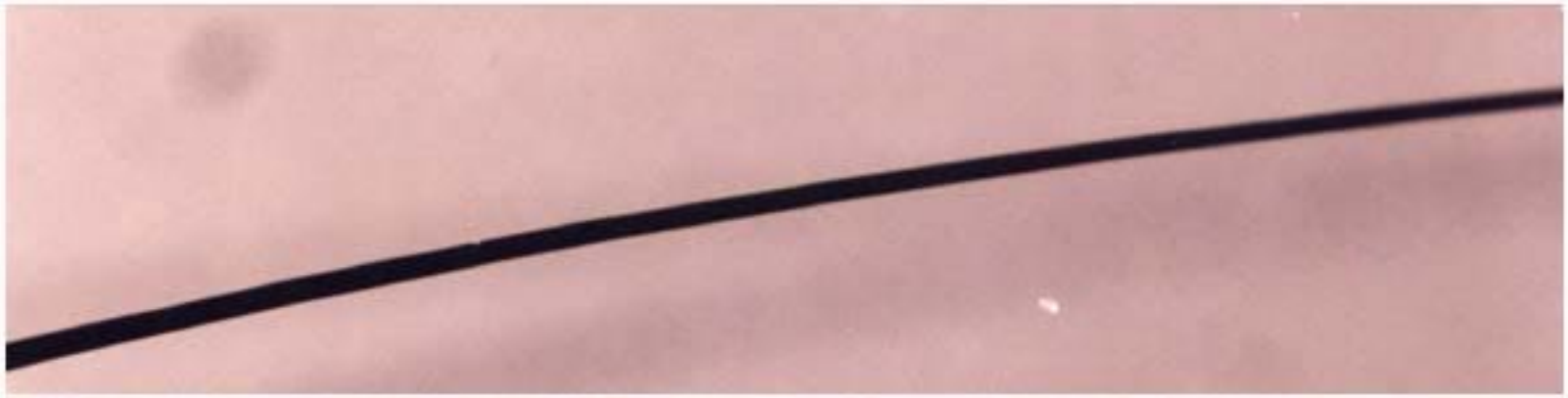
3. Dilute – C1

- Dense pigmentation = D/-
- Dilute pigmentation = d/d

- **Black** > **chocolate** > **cinnamon** becomes
- **Blue** > **lilac** > **fawn**

*These are the eumelanistic colors

Black



Blue

Photos courtesy of Heather Lorimer

Chocolate

Lilac

Photos courtesy of Heather Lorimer

Cinnamon

Fawn

Photos courtesy of Heather Lorimer

4. Dilute Modifier

- Dm = modifies the dilute colors
- dm = has no effect on dilutes

Dm will make blue/lilac/fawn cats look like: blue-caramel/lilac-caramel/fawn-caramel.

5. Albino series – D1

- C = full pigmentation/color
- cb/cb = sepia
- cb/cs = mink
- cs/cs = pointed

So what color is..a/a B/- d/d dm/dm cb/cb ?
Answer – blue sepia

6. Inhibitor

- The inhibitor gene inhibits the deposition of yellow pigmentation in the coat. The color band will not be present at the bottom half of the hair, and the undercoat will appear silvery-white.
- Sometimes the inhibitor gene cannot fully suppress the production of yellow, and tarnishing occurs.

6. Inhibitor

- Silver cats are I/-.
- Non-silver cats are i/i.

- In reality, it is probably more complex than this, to include mild and strong forms.

7. Wide band gene

- The wide band gene (Wb) is responsible for the tip of color in the top ½ of the hair.

7. Wide band gene

- Regular silver tabbies are the result of being wb/wb.
  A/- I/- wb/wb

- Chinchilla (tip of hair) and shaded silvers (up to ½ the hair) are Wb/-. They are tabby cats AND silver AND wide band.
  A/- I/- Wb/-

7. Wide band gene

- In non-inhibitor cats, chinchilla and shaded goldens are Wb/-.

  A/- i/i Wb/-

7. Wide band gene

- Smokes are non-agouti, but still silvered. So they are:
  a/a I/- wb/wb or Wb/-

In other words, the Wb gene does not affect smokes because they are not genetically agouti.

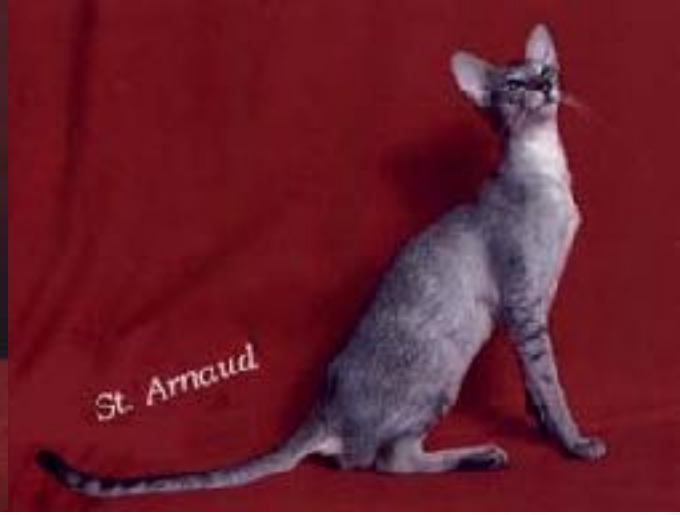
8. Tabby pattern

- The genotype must first be A/-. If so, then we can add:
- Ta = ticked, perhaps a different locus….
- T = mackerel/spotted
- tb = classic (marbled)
- Ta > T > tb
  - **This is the traditional thinking….**

8. Tabby pattern

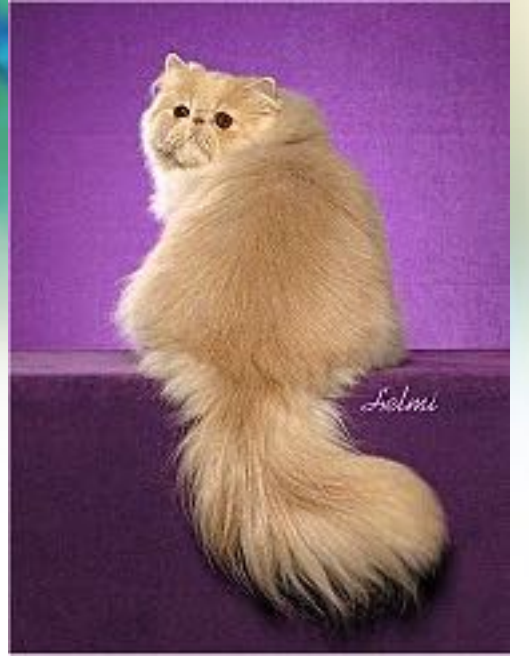
- However, some litters have revealed all 3 patterns in a single litter, when they should not have. This could suggest that at least 2 different loci are at work – depending on what the parents were.
- The Ta allele is most likely at a new locus and partially epistatic to mackerel and classic at the old tabby locus.





8. Tabby pattern

- There are variations in Ta cats right? So….
- Homozygotes (Ta/Ta) totally mask mk or cl.
- Heterozygotes (Ta/ta) partially mask mk or cl. So,
  - **Ta/- T/- = ticked pattern, totally or partially masking mackerel/spotted**
  - **ta/ta T/- = mackerel/spotted**
  - **Ta/- tb/tb = ticked pattern, masking classic**
  - **ta/ta tb/tb = classic**

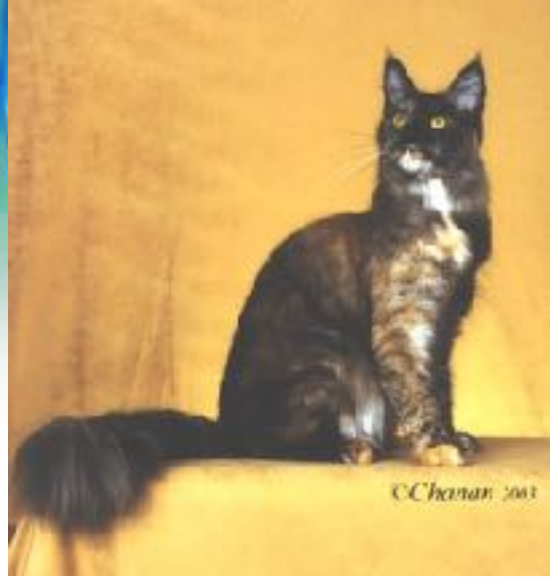


9. Orange gene (red)

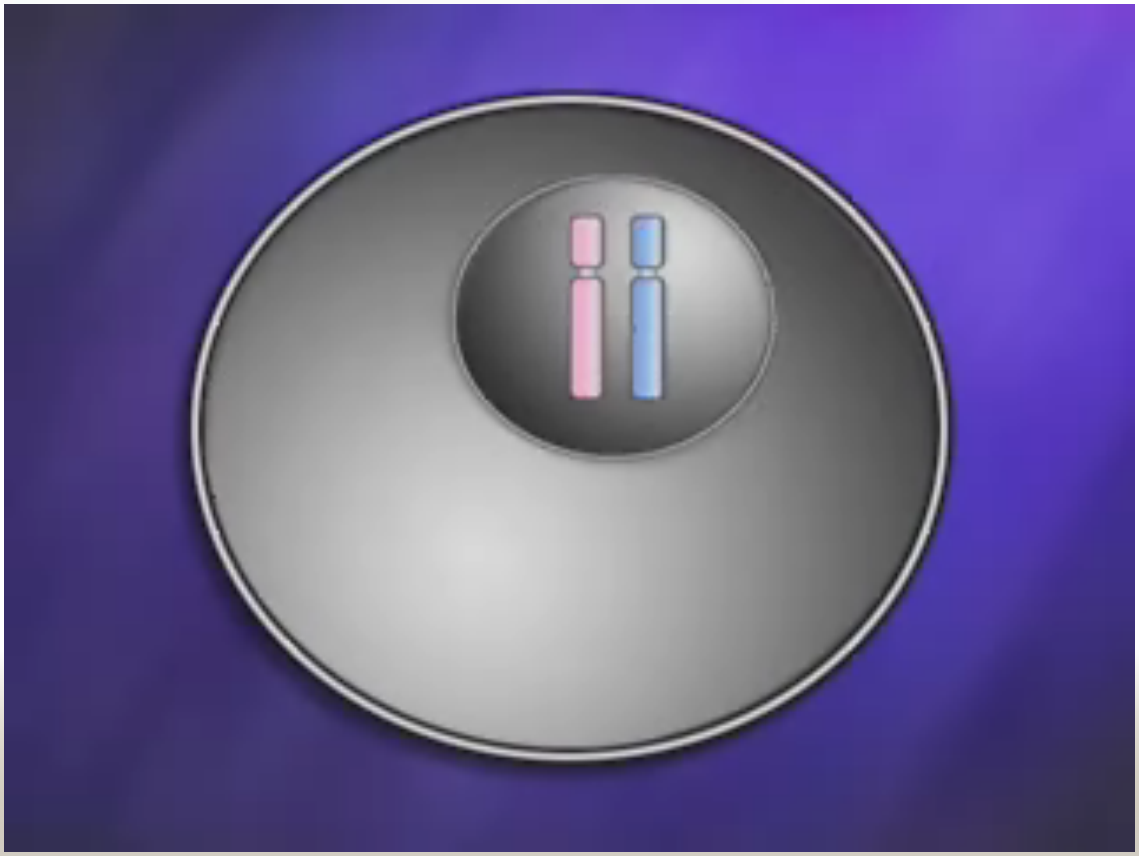
- Red coloration is a result of the orange gene, which is X chromosome linked.
- O = red
- o = non-red
- If we combine this with dilute (d/d), we will get **cream**.
- If we combine our **cream** with Dm, we get **apricot**.

- Males get only one copy of the X chromosome. If they get a red X (O) from mom, you can have red males (they are OY). If they get a non-red X (o) from mom, they will be non-red males (they are oY).

- Females get two copies of the X chromosome (one from mom and one from dad). So you can have non-red females (oo), tortie females (Oo), or red females (OO). Red females tend to be a bit rare because you would have to breed a red male (OY) to a female with red (OO or Oo).



- Tortie females (Oo) are the result of “X inactivation.” Early in embryogenesis, one X chromosome in each cell will become inactive. If the “O” becomes inactive, then that cell will want to be black. If the “o” becomes inactive, then that cell will want to be red….

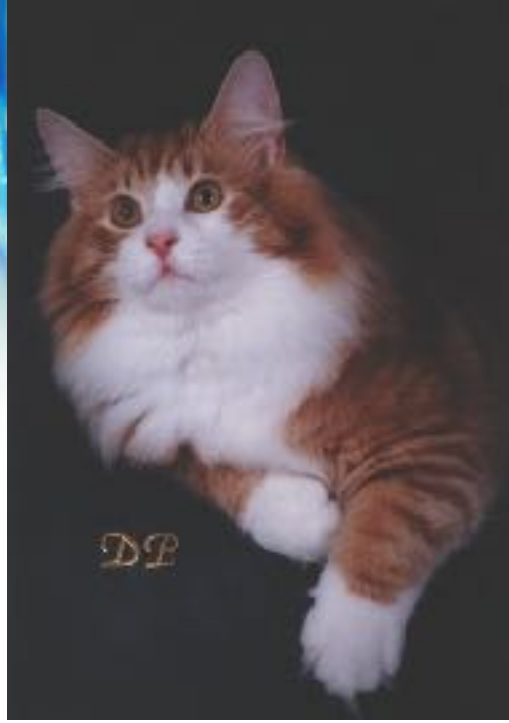


Red solids and red tabbies

- So why do all red cats have tabby markings?
  - **Phaeomelanistic colors (red and cream) are insensitive to the agouti protein (A/-) and the mutant form (a/a). So the phenotypes will be similar.**

Red tabby

Red solid



10. White spotting factor – B1

- Good luck with this one!!
- S/- = white spotting
- s/s = no white spotting
- It is thought that S/S produces the most white, S/s a bit less white, and s/s produces no white.

11. Dominant white

- Phenotypically overrides every color gene in the genotype (it is epistatic)!
- W/- = the cat is all white
- w/w = the cat is not all white.

• Could be “hiding” other colors underneath the white (masking).

Grizzled

- This is a new color seen onl in the Chausie thus far. It is a dominant trait and is most likely a mutation at either the agouti or extension locus. All patterns have been achieved with the coloration.

“Merle”

- Only known from a few cats thus far (and only red silvers).
- Similar to the merle coloration of dogs and mice – but nothing is known of its inheritance or influence on other genes.

Amber Norwegian Forest Cats

- May be due to the Extension gene (E).
- In other mammals, this gene will produce black (E/-) or red (e/e) and therefore used to be called the x-factor gene.
- In cats, it influences the development of color from kitten to adult.

3 weeks

6 weeks

4 months

11 months

4 weeks

6 weeks

4 months

8 months

Test-breedings for amber

- Amber to chocolate-point Birmans:
  - **Produced brown tabbies and blue tabbies**
    - So not related to the B locus
- Solid ambers to solid non-ambers:
  - **Produced no tabbies**
    - So not related to the A locus

What's my genotype???

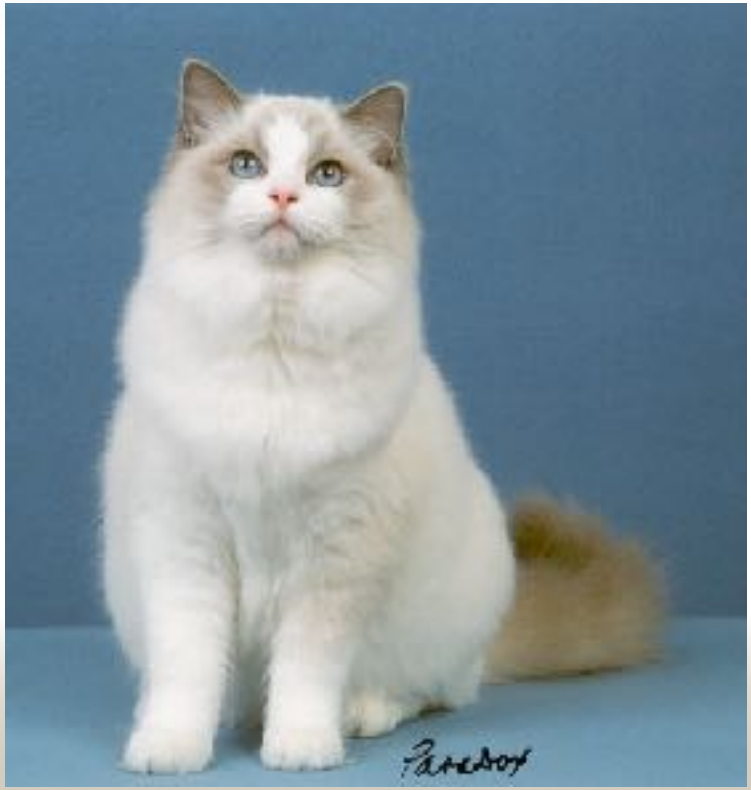
- A or a? a/a
- B, b, or b1? B/-
- C, cs, cb? C/-
- D or d? D/-
- Dm or dm? -/-
- I or i? i/i
- S or s? s/s
- Ta, T, tb? -/-
- W or w? w/w
- Wb or wb? wb/wb

Black British Shorthair

What's my genotype???

oY

- A or a? a/a
- B, b, or b1? B/-
- C, cs, cb? cs/cs
- D or d? d/d
- Dm or dm? dm/dm
- I or i? i/i
- S or s? S/-
- Ta, T, tb? -/-
- W or w? w/w
- Wb or wb? wb/wb



Blue point bicolor Ragdoll male

What color am I???

A/a	tabby
B/B	black
C/-	full color
D/d	dense
dm/dm	not modified
i/i	not silver
S/s	particolor
ta/ta tb/tb	classic
w/w	not all white
OY	red male

Red classic tabby and white NFC male

Any Questions?

OOH OOH, ME ME ME!!