Basic Genetics

Lotz.
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www.felesgrata.dk

Who am I?

- Ole Amstrup
- Cattery name: DK Feles Grata
- Breeding: Oriental shorthair preferably blotched tabby, with silver, in all colours.
- How long: Since 1983
- Home page: www.felesgrata.dk

Who am I?

- What have I been doing.
  - Board member of Danish cat clubs
  - Board member of Felis Danica
  - Chairman of Felis Danica
  - Member of the Danish breeding commission
  - Member of the FIFe B&R (LO) commission
  - Lecturing genetics in Denmark and Norway

Who am I?

- Why colour genetics?
  - Because I once breed budgerigars!
  - Because I love mathematics!

What will happen?

- I will try to give a short explanation of what we think we know right now!
- Give you a basic knowledge about genetics (colours and patterns).

To see a cat

- Some see a cat!
- I see:

a female cat
genetic black
colour not diluted
with white
it's a tortie
mackerel tabby
shorthair

To see a cat

- I see:

A -	agouti
BB	black
D -	not diluted
Mc –	mackerel tabby
LL	shorthair
Ss	bi-colour
x_0x	tortie

To see a cat

- A cat is ”built” of many different elements – a puzzle which can be joint together in many ways.
  - colour
  - sex
  - pattern
  - hair lenght
  - etc.

“Colur - genes”

- **B / b / bl** black / chocolate / cinnamon
- **D / d** dense / dilute
- **W / w** dominant white / coloured
- **X / Y** female / male
- **X_o** sex linked red placed on X

“Pattern - genes”

- **A / a** agouti / non agouti

Old teori:
- **T^a / T / tb** Ticktabby/spotted/mackerel/blotched

New teori:
- **Mc / mc** mackerel / blotched
- **T^a / t^a** Tick tabby / not tick tabby
- **S^p / s^p** Spotted / mackerel

- **S / s** piebald spotted ⇔ no white
- **Wb wb** wideband (tipping) ⇔ normal ticking

“Other genes”

- **C / cb / cs / ca / c** self/burmese pointed/himalaya pointed/ recessiv white/albino
- **I / i** silver / not silver
- **L / l** short hair/ long hair

“Other genes II”

- **Dm/dm dilute modifier?**
- **Bm/bm black modifier**
- **Wb/wb wide band**

Genes

- Colour genes (pattern/hair length ect.)
  - Each gene controls one feature
  - Can be dominant, recessive or partly dominant

Genes

- Poly-genes
  - A lot of ”small” genes works together
  - Works in different ways

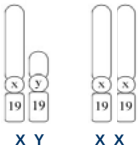
Chromosomes

- Genes are placed on the chromosomes
- There are several thousands genes on every chromosome
- The colour genes we know controls one exact feature.

- There are three different types of genes controlling one feature:
  dominant
  recessive
  partly dominant

Chromosomes

- 18 pairs with two identical.
- 1 pair is not always identical



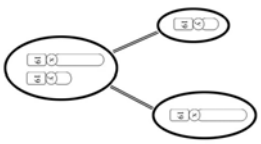
X Y X X

- X carry genes.
- Y carry no genes.

Can only decide that this individual will be a male

Chromosomes

Division in sperm cells - male

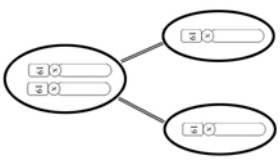


chromosomes at a male [XY]

two different types of sperm cells.

Chromosomes

Division in egg cells - female



chromosomes at a female [XX]

two identical germ cells / eggs.

Distribution of X and Y chromosomes

When performing a mating, we can look at each gene / feature at the time.
In this example we only look at the X & Y genes.
In this table we fill in the possible egg and sperm cells.

♀ \ ♂	X	Y
X		
X		

Distribution of X and Y chromosomes

♀ \ ♂	X	Y
X	XX	XY
X	XX	XY

- Distribution:
  male ofspring [XY] - 50%
  female ofspring [XX] - 50%

Colour genetics

- We will look at one feature at the time.
- They can be combined later on.

B generne - farve

- **B**

B - black

black

F.eks. MCO – NFO – SIB – TUV – RUS – KOR - SOK .

B generne - farve

- **B > b**

B - black
b - chocolate

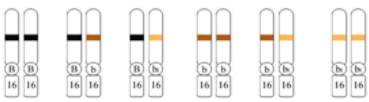
black black choco.

F.eks. BRI – PER/EXO – SBI - BUR

B – genes - colour

- **B > b > bl**

B - black
b - chocolate
bl - cinnamon



black black black choco. choco. cinnamon

Kategori IV – RAG – SNO – ACL – ACS – BRI?

B – generne - farver

- **B > bl**

B - black
bl - cinnamon

vildt-farvet

vildt-farvet

Sorrel

ABY - SOM

B genes - colourdistribution

Distribution of B genes / B black – b chocolate

	B	B
B	BB	BB
B	BB	BB

black X black
100% black

	B	b
B	BB	Bb
b	Bb	bb

black (choco.) X black (choco.)
75% black (25/50), 25% choco.

B generne - farvedistribution

Distribution of B genes / B black – b chocolate

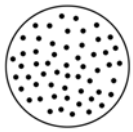
	B	b
b	Bb	bb
b	Bb	bb

black (choco.(X choco.
50% black / 50% choco.

	b	b
b	bb	bb
b	bb	bb

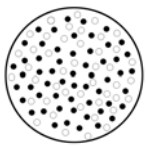
choco. X choco.
100% choco.

D - genes - dilution



- cross section of a normal coloured hair (dense).
- colour pighment evenly distributed in the hair
- colour is black, choco., cinnamon

D - genes - dilution



- Hair with dilution.
- Colur pigment is mixed with air bubbles
- The hair looks paler

- black → blue
- choco. → lilac
- cinnamon → fawn

D - generne – fortynding / $BB - Bb - Bb_l$

black — full colur intensity/dense | black | blue — diluted

- [DD] and [Dd] do not change the colour of the hair.
- [dd] spread out the pigment and the hair will look paler.

D - generne – fortynding / $bb - bb_l$

choco. choco. lilac
full colur intensity/dense diluted

- [DD] and [Dd] do not change the colour of the hair.
- [dd] spread out the pigment and the hair will look paler.

D - generne – fortynding / b_lb_l

cinnamon cinnamon fawn
full colur intensity/dense diluted

- [DD] and [Dd] do not change the colour of the hair.
- [dd] spread out the pigment and the hair will look paler.

”Mating”
black [Bb Dd] X lilac [bb dd]

Distribution of B genes and D genes

	B	b
b	Bb	bb
b	Bb	bb

50% black / 50% choco.

	D	d
d	Dd	dd
d	Dd	dd

50% dense/ 50 diluted

”Mating”
black [Bb Dd] X lilac [bb dd]

- distribution

Tabby paterns

- All cats have a tabby pattern!!

But you cannot always se it!!

There are various theories about which genes which decides the tabby patterns.

When it can be seen it is a a colured pattern on an agouti background

Tabby patterns

- Old teori:

Three different genes decide the tabby patterns

T_a - tick tabby
T - mackerel/spotted
t_b - blotched

This theory is more or less outdated, but it works on a daily base.

Problem – sometimes ticked, blotched and spotted kittens are born in the same litter - after a mating between a tick tabby and a blotched!

Tabby patterns

- New theory:

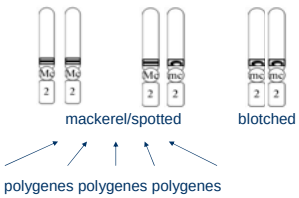
Mc/mc	A gene controls if it is mackerel or blotched
Sp/sp	A gene controls if the patterns should break up in spots (this is questionable – it might just be polygenetic)
T_a/t_a	A gene which cause the tick tabby pattern – this is partly dominant.

I doubt that there is a spotted gene – so I will not talk about this.

I do believe that the breaking up in spots is polygenetic and has to be managed via selection.

Mc genes

- Mc / mc controls the basic tabby pattern



Mc gener

- Mc / mc controls the basic tabby pattern

The difference in appearance is polygenetic (in my opinion)

Mc gener

- mc mc

A generne – agouti / non agouti

AA (Aa) is the originally pattern for cats and the tabby pattern can be seen.

A causes band in different colours in the single hairs

The hairs will be ticked – gives an agout ground

The coloured pattern stands on an agouti ground.

A genes – agouti / non agouti

- aa is a mutation.

  there is only single coloured hairs – no ticked hair / agouti ground.

A generne – agouti / non agouti

- Ticket hair.
  Bands of various colours on every hair. The true colour is to be found in the tip of every hair.

A generne – agouti / non agouti

- Non-agouti hair
  One colour
  (the tabby pattern should have the same type of hair)

A genes – agouti / non agouti

AA The tabby pattern can be seen (agouti)
Aa The tabby pattern can be seen (agouti)

aa The tabby pattern can not be seen.
The cat is self (non-agouti)

Two agouti cats can have self kittens, but two self cat cannot have tabby/agouti kittens!!

The red colour

- The red colour.
  The red colour is sex linked.
  The gene is placed on the X chromosome.

The result is that only Phaeomelanin (the yellow/red colour) There is not produced eumelanin which gives the black, chocolate and cinnamon colours.

The red colour

- I have chosen to place the gene as a variation of the normal X gene, as the placing of the red gene is here at the X chromosome.

  X the normal coloured cat
  X_o red
  Y carry no genes

- This way I think it is more clear that the colour is sex linked and the explanation about the outcome as a result of mating red/torti cat is more clear.

This I my way of seeing it – and not all shares my opinion on this matter.

The red colour

- X_o blocks the normal colours. Only red will be produced.
- In order to work fully there must be two X_o at a female .
- At the male, who only has one X chromosome, one X_o gives a red male

The red colour - females

- Possible combination of the female sex chromosomes.

Normal Tortie red

The red colour - hanner

- Possible combination of the male sex chromosomes.

Normal red

The red colour

- The red gene blocks the result of [aa]
- There is no difference between a red with a genetic f black, chocolate or cinnamon background
- The tabby pattern is always visible in red cats!!!
- A red self is genetically impossible

Red mating

Male: red Females: normal - tortie - red

females: tortie
males: normal

	x_o	y
x	$x_o x$	xy
x	$x_o x$	xy

red og tortie
normal og red

	x_o	y
x_o	$x_o x_o$	$x_o y$
x	$x_o x$	xy

red
red

	x_o	y
x_o	$x_o x_o$	$x_o y$
x_o	$x_o x_o$	$x_o y$

Red mating

Male: Normal Hunner: normal - tortie - red

females: normale
male: normale

	x	y
x	xx	xy
x	xx	xy

normale and tortie
normale and red

	x	y
x_o	$x_o x$	$x_o y$
x	xx	xy

tortie
red

	x	y
x_o	$x_o x$	$x_o y$
x_o	$x_o x$	$x_o y$

C genes – albino serie

- C gene is in 5 levels.
- C normal colour
- c_b burmese point
- c_s himalayan point (siameser, colour point, sc. birma, rag doll)
- c_a recessiv white (blueeyed albino)
- c redeyed albino

C genes – albino serie

- Strength between the 5 different genes are:
  $C > c_b > c_s > c_a > c$
- C dominates all others
- c_b dominate only partly c_s (tonkanese)

I will only talk about C og c_s.

C genes – albino serie

[c_sc_s] causes the pigmentation to be dependet of the temperature.
The coldest areas will have colour.
Colour on legs, tail, ears and face.
The warmer areas will be ligter.
Eyes will be deep blue.
de deep blue.

A pointed cat is genetically a cat in whatever colour, which is lighter in the warmest parts of the cat.

At birth all kittens are white (no pigmentation)

I generne – Silver (inhibitor)

[II] & [Ii] causes a suppression of the yellow pigment in the individual hairs.

and that leaves the lowest part of the hair without pigmentation (but can wary a lot!!)

[ii] is the normal coloured cat. (non-silver)

I genes – Silver (inhibitor)

- The I gen ”push” the colour up by non agouti hairs. The lower part of the hair is completly white Non agouti and silver = smoke.

non-agouti hair

smoke hair.

I genes – Silver (inhibitor)

- At agouti cats the I gene surpresses the phaomelanin (the yellow/red colour) and the ticked hairs vil be black and white without coloured bands.

agouti hair

silver agouti har

I genes – Silver (inhibitor)

- At agouti cats the I gene inhibit the phaomelanin (the yellow/red colour) and the ticked hairs will be black and white without coloured bands.

non silver OSH n 22

silver OSH ns 22

I genes – Silver (inhibitor)

- Rufism/tanning?
  - Unwanted colouring - mostly on legs, neck and sides….
  - Selection will reduce the problem
  - Is it connected to the warmth in colour??

  - I think I have observed that a deep, warm, intense colour at a non-silver cat leads to a cold, clear, non-rufistic silver ofspring!

S - genes Piebald spottet

- S genes are only partly dominant towards s
  That means that there is a difference between [SS] og [Ss]
- S gene causes a smalle or larger distribution of white in the normal colour.

S - genes Piebald spottet

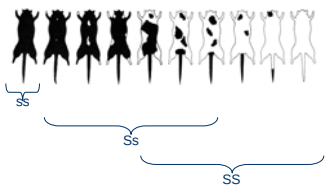
- The variation is very big and it is impossible to predict any outcome of the white patern!!!

S - genes Piebald spottet

The amount of white is controlled on a cellur basesis / polygenetic, and it is ossible to find cats with the genetic [SS] og [Ss] which have the same amount of white.

S - genes Piebald spottet

- Grades of white



L - genes

- The L - genes works on the hair length.

  [LL] and [Ll] is short hair.
  [ll] is long hair.

  A short haired cat can carry gene for longhair

L - genes

- Long hair cats




L - genes

- The difference between long hair and semi long hair is not genetic – it is not a result of the L genes. The difference is a result of selection and is polygenetic.

T_a genes

- The T_a gene cover the ”normal” tabby patern.
- Is only partly dominant.

T_a genes

$T_a T_a$

Abyssinan ticket – no stripes

$T_a t_a$
$t_a t_a$

Tick tabby – striber on legs and tail an head
Normal tabby tabby patern

T_a gener

- Homozygot tick tabby
- A - McMc T_aT_a

T_a genes

- Heterozygot tick tabby
- A - McMc T_at_a

W – genes – dominant white

Dominant white.

- Removes all pigment from the the fur.
- Cover up ALL other colours/paterns!
- Eyecolour can be blue, orange/green or one of each (odd eyed).

W – genes – dominant white

- Can cause defness in white cats.
- The Gene for defness is placed on the same chromosome and will ”follow” the W gene.

W – generne

- Genkode:

-- -- -- -- -- -- -- --

-- -- -- W-

Dilute modifier

- Not recognized by FIFe!
- Does it acturally excist??
- Modifies diluted colours (can only be seen when the cat i homozygot [d d])
- The EMS codes is only for registration purposes when importing cars from other organisations.

Dilute modifier

- 2 x ”caramel” og 1 x lilac?

Dilute modifier

- 2 x ”caramel” og 1 x lilac?
- lilac silver ticket

Dilute modifier

B - dd Dm -	bluebaseret caramel
b - dd Dm -	lilacbaseret caramel
$b_l b_l$ dd Dm -	fawnbaseret caramel
- - dd Dm - $x_o y / x_o x_o$	apricot (+ all tortier)

Black modifier

- Amber / light amber
- A resessicive gene
  - Dm for normal colour
  - dm for amber
- Do not work with red (epistatic)
- Cancels the blocks the work of [a a]

Black modifier

- BB Dd Mc- bmbm

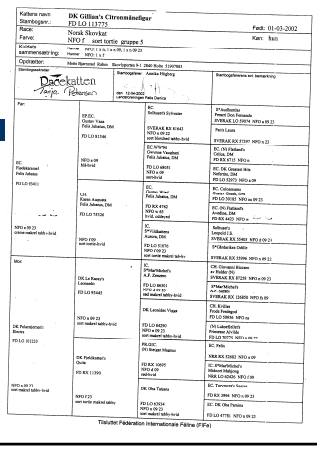
Pedigrees

- What do you need to decide the genetic code?
  - Colour of the cat
  - Parents colour
  - Colour of of spring

All the rest can only give you an idea! – no precise knowledge.

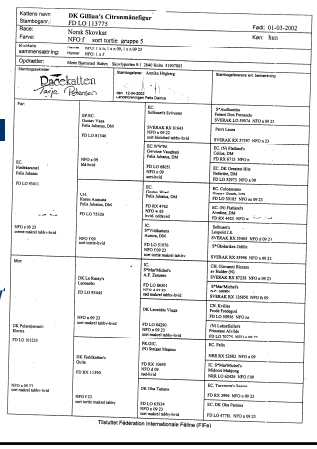
Pedigrees

- What can we see?
  - non-agouti
  - black
  - tortie
  - non silver



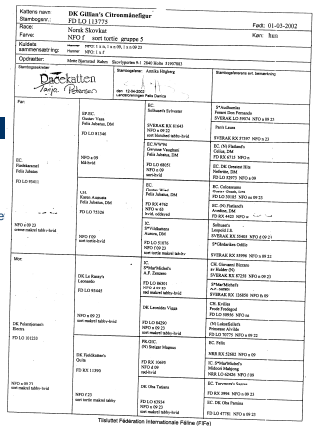
Pedigrees

- What can we see?
  - non-agouti
  - black
  - tortie
  - non silver
- What can we know
  - Carry dilution
  - Is probably Mc –
  - is [ss] [ww] / [ii]



Pedigrees

- What can we see?
  - non-agouti
  - black
  - tortie
  - Non silver, ikke white/whitespotte
- What do we know?
  - Carry dilution
  - Is probably Mc –
  - is [ss]/ [ww] / [ii]
- Gentic code?
  [aa BB Dd ii Mc- ss ww x,x]



Pedigrees

- What can we see?

Pedigrees

- What can we see?
  - A-
  - bb
  - Cc
  - Dd
  - Ii
  - mcmc