

What are the
inbreeding coefficient
and the
ancestor loss coefficient
and how do they affect our breed?

Inbreeding, linebreeding and outcrossing

- **Inbreeding** is the production of offspring (kittens) from the mating of individuals or that are genetically related.
- **Linebreeding** is a form of inbreeding. There is no clear distinction between the two terms.
- **Outcrossing** is where two unrelated individuals are crossed to produce progeny.

Inbreeding, linebreeding and outcrossing



Inbreeding, linebreeding and outcrossing

- Steady decline of heterozygosis
- Steady fixation of all genes
- Increasing genotypic similarity

-> Inbreeding results in homozygosity which can increase the chances of offspring being affected by recessive genes.

A normal breeding:

4 cats (*grand-parents*)

A_1A_2 A_1A_2 A_1A_2 A_1A_2 A_1A_2 A_1A_2 A_1A_2 A_1A_2

2x4 combinations
(*parents*)

A_1A_1 A_1A_2 A_2A_1 A_2A_2 A_1A_1 A_1A_2 A_2A_1 A_2A_2

64 combinations

A_1A_1	A_1A_1	A_1A_1	A_1A_1	A_1A_1	A_1A_1	A_1A_1	A_1A_1	A_1A_1
A_1A_2	A_1A_2	A_1A_2	A_1A_2	A_1A_2	A_1A_2	A_1A_2	A_1A_2	A_1A_2
A_2A_1	A_2A_1	A_2A_1	A_2A_1	A_2A_1	A_2A_1	A_2A_1	A_2A_1	A_2A_1
A_2A_2	A_2A_2	A_2A_2	A_2A_2	A_2A_2	A_2A_2	A_2A_2	A_2A_2	A_2A_2

Inbreeding coefficient = 0 %

A half-brother x half-sister breeding:

3 cats (*grand-parents*)

2x4 combinations
(*parents*)

64 combinations

	A_1A_2	A_1A_2				A_1A_2	A_1A_2		
	A_1A_1	A_1A_2	A_2A_1	A_2A_2		A_1A_1	A_1A_2	A_2A_1	A_2A_2
	A_1A_1	A_1A_1	A_1A_1	A_1A_1	A_1A_2	A_1A_2	A_1A_2	A_1A_2	A_1A_2
	A_1A_1	A_1A_1	A_1A_1	A_1A_1	A_1A_2	A_1A_2	A_1A_1	A_1A_2	A_1A_2
	A_2A_1	A_2A_1	A_2A_1	A_2A_1	A_2A_2	A_2A_2	A_2A_1	A_2A_2	A_2A_2
	A_2A_1	A_2A_1	A_2A_1	A_2A_1	A_2A_2	A_2A_2	A_2A_1	A_2A_2	A_2A_2
	A_2A_1	A_2A_1	A_2A_1	A_2A_1	A_2A_2	A_2A_2	A_2A_1	A_2A_2	A_2A_2
	A_2A_1	A_2A_1	A_2A_1	A_2A_1	A_2A_2	A_2A_2	A_2A_1	A_2A_2	A_2A_2

Inbreeding coefficient = ? %

A half-brother x half-sister breeding:

3 cats (*grand-parents*)

A_1A_2

A_1A_2

A_1A_2

A_1A_2

2x4 combinations
(*parents*)

A_1A_1

A_1A_2

A_2A_1

A_2A_2

A_1A_1

A_1A_2

A_2A_1

A_2A_2

64 combinations

A_1A_1

A_1A_1

A_1A_1

A_1A_2

A_1A_2

A_1A_2

A_1A_2

A_1A_2

A_1A_1

A_1A_1

A_1A_1

A_1A_2

A_1A_2

A_1A_1

A_1A_2

A_1A_2

A_1A_1

A_1A_1

A_1A_1

A_1A_2

A_1A_2

A_1A_1

A_1A_2

A_1A_2

A_2A_1

A_2A_1

A_2A_1

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A_2A_1

A_2A_2

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A_1A_1

A_1A_1

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A_1A_2

A_1A_1

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A_2A_2

A_2A_2

A_2A_1

A_2A_1

A_2A_1

A_2A_2

A_2A_2

A_2A_1

A_2A_2

A_2A_2

Inbreeding coefficient = ? %

A half-brother x half-sister breeding:

3 cats (*grand-parents*)

A_1A_2

A_1A_2

A_1A_2

A_1A_2

2x4 combinations
(*parents*)

A_1A_1

A_1A_2

A_2A_1

A_2A_2

A_1A_1

A_1A_2

A_2A_1

A_2A_2

64 combinations

A_1A_1

A_1A_1

A_1A_1

A_1A_2

A_1A_2

A_1A_2

A_1A_2

A_1A_2

A_1A_1

A_1A_1

A_1A_1

A_1A_2

A_1A_2

A_1A_1

A_1A_2

A_1A_2

A_1A_2

A_1A_2

A_1A_2

A_1A_2

A_1A_2

A_1A_1

A_1A_2

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A_2A_2

A_2A_1

A_2A_2

A_2A_2

A_2A_1

A_2A_1

A_2A_1

A_2A_2

A_2A_2

A_2A_1

A_2A_2

A_2A_2

8 cats (2x4) are homozygotes because their pair of genes come from one gene of their commun ancestor. Inbreeding coefficient = $8 / 64 = 12.5\%$

A brother x sister breeding:

2 cats (*grand-parents*)

A_1A_2

A_1A_2

A_1A_2

A_1A_2

2x4 combinations
(*parents*)

A_1A_1

A_1A_2

A_2A_1

A_2A_2

A_1A_1

A_1A_2

A_2A_1

A_2A_2

64 combinations

A_1A_1

A_1A_1

A_1A_1

A_1A_2

A_1A_2

A_1A_1

A_1A_2

A_1A_2

A_1A_1

A_1A_1

A_1A_1

A_1A_2

A_1A_2

A_1A_1

A_1A_2

A_1A_2

A_1A_1

A_1A_1

A_1A_1

A_1A_2

A_1A_2

A_1A_1

A_1A_2

A_1A_2

A_2A_1

A_2A_1

A_2A_1

A_2A_2

A_2A_2

A_2A_1

A_2A_2

A_2A_2

A_2A_1

A_2A_1

A_2A_1

A_2A_2

A_2A_2

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A_2A_2

A_1A_1

A_1A_1

A_1A_1

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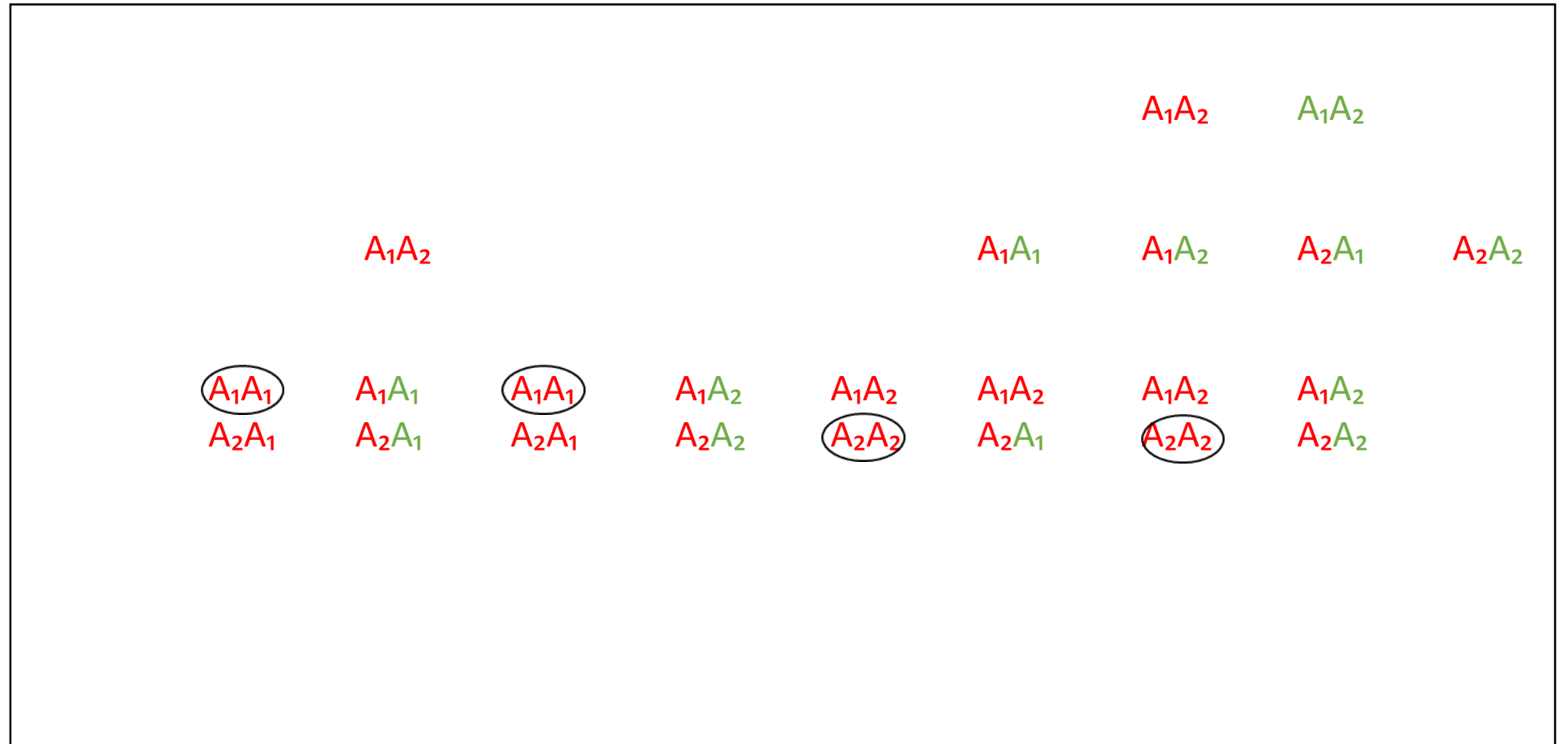
A_2A_1

A_2A_2

A_2A_2

Inbreeding coefficient = $16 / 64 = 25 \%$

A father x daughter breeding:



Inbreeding coefficient = $\frac{4}{16} = 25\%$

Inbreeding coefficient (F):

- Father x daughter, mother x son, brother x sister	25 %
- Grandfather x granddaughter, grandmother x grandson	12,5 %
- Half-brother x half-sister	12,5 %
- Uncle x niece, aunt x nephew	12,5 %
- Great-grandfather x great-granddaughter, great-grandmother x great-grandson	6,25 %
- First cousins	6,25 %
- First cousins once removed or half-first cousins	3,125 %
- Second cousins or first cousins twice removed	1,5625 %
- Second cousins once removed or half-second cousins	0,78125 %

A half-brother x half-sister breeding - the common ancestor carries for an unwanted recessive gene:

3 cats (*grand-parents*)

a_1A_2 A_1A_2 a_1A_2 A_1A_2

2x4 combinations
(*parents*)

a_1A_1 a_1A_2 A_2A_1 A_2A_2 a_1A_1 a_1A_2 A_2A_1 A_2A_2

64 combinations

a_1a_1	a_1A_1	a_1a_1	a_1A_2	a_1A_2	a_1A_2	a_1A_2	a_1A_2
A_1a_1	A_1A_1	A_1a_1	A_1A_2	A_1A_2	A_1A_1	A_1A_2	A_1A_2
a_1a_1	a_1A_1	a_1a_1	a_1A_2	a_1A_2	a_1A_1	a_1A_2	a_1A_2
A_2a_1	A_2A_1	A_2a_1	A_2A_2	A_2A_2	A_2A_1	A_2A_2	A_2A_2
A_2a_1	A_2A_1	A_2a_1	A_2A_2	A_2A_2	A_2A_1	A_2A_2	A_2A_2
A_1a_1	A_1A_1	A_1a_1	A_1A_2	A_1A_2	A_1A_1	A_1A_2	A_1A_2
A_2a_1	A_2A_1	A_2a_1	A_2A_2	A_2A_2	A_2A_1	A_2A_2	A_2A_2
A_2a_1	A_2A_1	A_2a_1	A_2A_2	A_2A_2	A_2A_1	A_2A_2	A_2A_2

At least 4 cats out of 64 (6,25 %) will be homzygotes for the disease.

At least 24 cats out of 64 (37,5 %) will carry for the disease.

Wright's equation for calculating the Inbreeding Coefficient (F) is:

$$F_X = \sum \left[\left(\frac{1}{2} \right)^{n_1 + n_2 + 1} (1 + F_A) \right]$$

A second problem: the loss of ancestors

	Parents	Grand-Parents	Great-Grand-Parents
		3	7
	1		8
		4	9
our cat			10
		5	11
	2		12
		6	13
			14

The loss of ancestors: a half-brother x half-sister breeding

	Parents	Grand-Parents	Great-Grand-Parents	
our cat	1	3	6	
				7
				8
			4	9
				6
	2		3	7
				10
			5	11

The cat in our example has only 11 instead of the normal 14 ancestors. He has lost **21,4%** of his ancestors. (He has **78.6 %** of his ancestors).

Inbreeding depression and hybrid vigor

- Decline in birth weight (small, thin and lethargic kittens)
- Development problems (below standard individuals)
- Smaller average litter size
- Increase of the number of stillborn or abnormal kittens in litters.
- Problems in reproductive performance (in both sexes)
- Weaker immune system (more illness at any stage of development)
- Physical indications (asymmetry, crooked noses, uneven eye size etc.)

-> It is impossible to predict what form inbreeding depression may take.

(Robinson's Genetic for Cat Breeders & Veterinarians)

Inbreeding depression and hybrid vigor

«We must be careful not to 'fix' immunodeficiency when we are trying to 'fix' type.

Heather Lorimer, Oriental Shorthair breeder, 1988

How much inbreeding should we accept?

There are very few recommendations for cat breeders:

- According to population geneticists the average coefficient, of all the matings we do in a breed, should increase by less than 0,25-0,5 percentage point per generation. If the increase is higher, the population will be at risk of health problems due to inbreeding.

(pawpeds.com)

- Übersteigt der Inzuchtfaktor 15%, sollte man nicht weiter Inzucht betreiben.

(katzenzeitung 3/2007)

How much inbreeding do dog breeders accept?

According to the experts is also recommended that an individual's COI should not exceed 6% counted from the 5 generation pedigree, (...) and 9% counted from the 10 generations pedigree.

FCI (Fédération Cynologique Internationale) recommendation for rare breeds is that IC should not exceed 10%.

(<http://www.czerwonytrop.com>)

Inbreeding: the Kennel Club (GB)



Chihuahua (Smooth Coat)
5.8%



Border Collie
4.0%



German Shepherd Dog
3.2%



French Bulldog
3.5%



Dachshund (Wire-Haired)
6.1%



Retriever (Golden)
9.4%

Inbreeding: the Kannel Club (GB)



Poodle (Standard)

3.6%

A study of Standard Poodles discovered that dogs with a COI of less than 6.25% lived on average four years longer than those with COIs over 25%.

(<http://www.dogbreedhealth.com>)

Inbreeding: Agricultural Research

There is no defined limit as to what is an acceptable level of inbreeding in domestic animal populations. However, inbreeding depression is likely to be more apparent once inbreeding levels get to above 10%. As a very rough guide, there is often a 2-20% decrease in performance of the trait per 10% of inbreeding coefficient.

Agricultural Business Research Institute, University of New England in Armindale, Australia

A goal for our breed:



We should try to keep the COI under **15** %.

Coefficient of Inbreeding (COI) in Bengals

	5 gen.	8 gen.	10 gen.	Total
1. Bridlewood A Licence To Thrill, (OS IW SGC), M, 2003-05-20	>0,586%	>10,0%	>16,9%	>16,9%
2. Calcatta's Custom Made, (RW SGC), M, 2002-06-30	1,76%	>7,10%	>19,6%	>19,8%
3. DiCaprio of Starbengal, (RW QGC), M, 1999-08-15	0,0%	>24,0%	>25,3%	>25,4%
4. Drinkwater London, (RW SGC), M, 2007-02-27	7,03%	>9,26%	>15,8%	>26,2%
5. Exoticrose De Niro, (IW, SGC), M, 2001-09-06	>4,30%	>9,69%	>16,1%	>16,2%
6. Exoticrose Poppy Seed of Spice, (IW RW SGC), M, 2001-10-06	14,5%	>33,0%	>36,7%	>37,1%
7. Gogees Heaven Made, F, 2006-06-07	4,88%	>9,18%	>24,0%	>25,0%
8. Heritage Shiloh of Legacie, (CH), M, 1994-05-10	14,5%	>30,2%	>30,5%	>30,5%
9. Joykatz Ace Inda Hole of Eraser, (RW SGC), M, 1996-07-15	9,28%	>31,3%	>31,3%	>31,4%
10. Joykatz Bandido Rosatta, M, 1994-07-18	23,6%	>23,6%	>23,6%	>23,6%
11. Joykatz Momentum of Spice, (RW SGC), M, 1999-06-08	2,83%	>26,8%	>27,5%	>27,5%
12. Joykatz Tierra of Jumanji, F, 1998-11-08	2,83%	>26,8%	>27,5%	>27,5%
13. Jumanji Mercury Rising of Wildlove, (IW), M, 2001-07-23	0,0%	>17,6%	>23,3%	>23,4%
14. Junglebook Cubby Coo the Rajahs Cat, M, 2004-05-03	>1,76%	> 7,85%	>21,8%	>22,3%
15. Junglebook Virtual Reality, (IW SGC), F, 1997-03-12	2,54%	>22,9%	>23,1%	>23,1%
16. Kalanikats Chanel of Spice, (RW, SGC), F, 2007-03-02	0,195%	>2,47%	>21,0%	>22,8%
17. Kalanikats Rockstar, (RW SGC), M, 2008-05-15	>0,0%	>1,61%	>7,34%	>10,3%
18. Katznjamr Hercules of Jumanji, M, 2000-03-15	>0,391%	>18,9%	>21,1%	>21,2%
19. Katznjamr Inkosi of ABCbengals, (IW SGC), M, 2000-10-16	>0,391%	>18,9%	>21,1%	>21,2%
20. Koppiekatz Kool Kat of Fakirbengal, (CH), M, 2005-01-01	16,0%	>17,2%	>31,6%	>33,2%
21. Legacie Catanga of Drinkwater, F, 2005-11-09	7,81%	>8,95%	>20,7%	>25,7%
22. Llandar Canelle of Spice, (TGC), F, 2000-03-13	0,879%	>16,8%	>18,2%	>18,2%
23. Millwood Bakari of Katznjamr, M, 1998-09-06	0,391%	>24,0%	>24,3%	>24,3%

Coefficient of Inbreeding (COI) in Bengals

1. Millwood Epitimiss of Mainstreet, F, 2000-06-28	15,2%	>34,8%	>35,9%	>35,9%
2. Millwood French Lace, (GRC), F, 1996-04-24:	2,25%	>26,5%	>26,5%	>26,5%
3. Millwood Inner Circle, (GRC), F, 1993-02-22	>24,7%	>26,0%	>26,0%	>26,0%
4. Millwood Italian Filigree, (OS CH), M, 1998-04-19	8,01%	>28,8%	>29,5%	>29,5%
5. Millwood Midas Touch, (CH), M, 1994-03-15	>11,8%	>22,8%	>22,8%	>22,8%
6. Millwood Rajin Cajun, M, 1987-04-15	>31,2%	>31,2%	>31,2%	>31,2%
7. Nairobi's Jungle Jaguar, M, 2001-01-23	> 1,56%	> 9,75%	>13,3%	>13,3%
8. Nola Lamborghini of Joykatz, (GC), M, 1991-07-27	28,8%	>34,1%	>34,1%	>34,1%
9. Nola Voodoo Magic of Junglebook (GRC), M, 1995-01-17	13,6%	>30,5%	>30,5%	>30,5%
10. Oceanwoods Rococo of Millwood, M, 1998-03-06	2,44%	>27,0%	>30,0%	>30,1%
11. Silvergene's Splendor of Starbengal, M, 2001-02-11	>0,586%	>7,05%	>16,1%	>16,2%
12. Spice Basil, (IW, SGC), M, 2010-02-26	0,586%	>1,56%	>9,69%	>22,9%
13. Spice Estragon, (RW CH), M, 2007-08-31	0,0%	>1,20%	>18,4%	>22,2%
14. Spice Red Hot Chili Pepper, (IW, SGC), M, 2010-08-25	0,586%	>1,56%	>9,69%	>22,9%
15. Spice Pimienta, F, 2009-03-16	0,586%	>1,56%	>9,69%	>22,9%
16. Spice Sedano, (SGC), M, 2009-03-16	0,586%	>1,56%	>9,69%	>22,9%
17. Starbengal Sahara of Kalanikats, (RW, SGC), F, 2002-03-24	0,391%	>11,3%	>21,8%	>21,9%
18. Stonehenge Wurththawate of Snopride, (OS RW SGC), M, 2002-07-03	1,17%	6,72%	>25,0%	>25,1%
19. Wildlove Santana, M, 2004-03-08	>18,8%	>19,7%	>30,2%	>33,6%

**The Bengals do have an average
Inbreeding Coefficient (COI)
of about 25 – 35% !!!!**

Sooner or later this will become a BIG problem for our breed.

Coefficient of Inbreeding (COI) in Bengals

Two questions:

1. Why is the Coefficient of Inbreeding (COI) so high in our breed?
2. What can we do to get a lower Coefficient of Inbreeding (COI) ?

Why is the Coefficient of Inbreeding (COI) so high?

Inbreeding can arise at two levels:

1. In a breed as a whole (long term Inbreeding).

It is now impossible to find two cats unrelated to each other because every pedigree is based on a few early founding cats.

2. In the hands of individual breeders.

For example: if the same stud is used over and over again.

1. In a breed as a whole (long term Inbreeding).

First pedigrees (1982-83):

Millwood Destiny (F3) (M)

Millwood Polyspot (F3)

Millwood Trademark (F3) (M)

Millwood Rosetta Stone (F3)

Tory of Millwood

Millwood Praline (F2)

Millwood Pennybank (F2)

unknown

unknown

Millwood Finally Found

Rorschach of Millwood (F1)

1986

Millwood Destiny x Millwood Polyspot

(1986-04-10) (3 F4 kittens - 25%)

Millwood Destiny x Millwood Rosetta Stone

(1986-03-15) (4 F4 kittens - 25%)

Millwood Destiny x Millwood Praline

(1986-05-18) (4 F3 kittens - 25%)

Millwood Trademark x Millwood Pennybank (F2)

(1986-09-16) (3 F3 kittens – 12,5%)

1987

Millwood Trademark x Millwood Pennybank (F2)

(1987-05-09) (3 F3 kittens – 12,5%)

Millwood Trademark x Millwood Pennybank (F2)

(1987-10-12) (1 F3 kitten – 12,5%)

2. In the hands of individual breeders.

- **Is there a cat here in the show who is not related to Worthy?**
- Di Caprio used to breed 40 queens every year.
- The same happened with Thriller.....
- Look at the pedigree of Santana.

**The Bengals do have an average
Inbreeding Coefficient (COI)
of about 25 – 35% !!!!**

**If we really care about the health of our Breed
we have to change the way we breed!**

What can we do to get a lower Coefficient of Inbreeding (COI) ?

- 1. We should avoid close linebreeding.**
- 2. We have to share more our lines**
- 3. One study should never breed too many queens.**
- 4. We should continue to work with ALCs because it is one way to introduce new (unrelated) blood.**
- 5. We should start thinking about using non pedigreed cats in our breeding programs.**