Moving on to Factor Seven -

Using Genetics to Breed Better Racing Pigeons

January 4th 2020
Fort Sutter Racing Pigeon Club
Sacramento, California

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Seminar Objectives

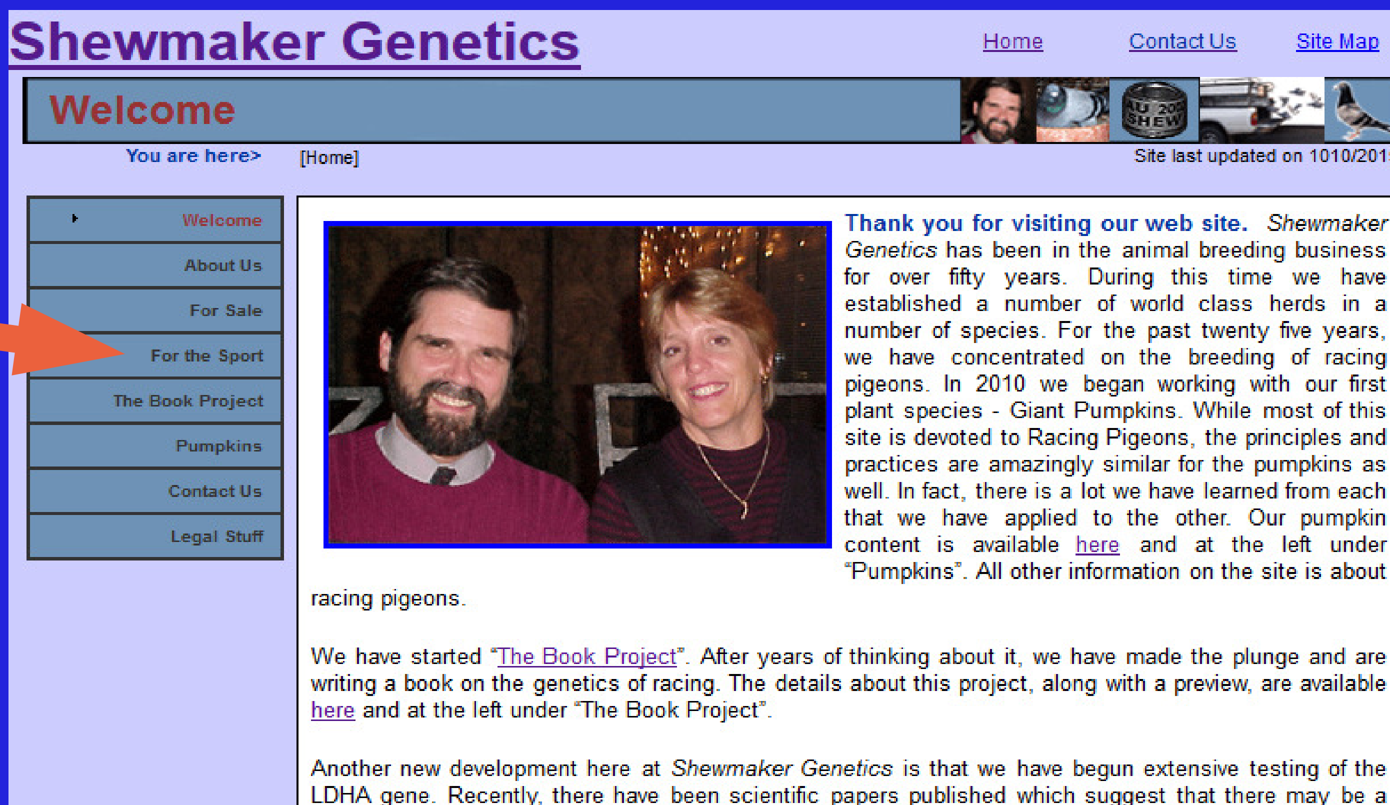
- Genetics is not hard, it just takes a sense of the big picture and some time to absorb the details.
- We have lots of time today and we are not going to rush.
- Ask questions and lets have good discussions.
- There are three objectives for today:
    1) Implore each of you to move on to what I will explain is the “Seventh Factor of Racing Success”, genetics.
    2) Provide you with a high level framework for understanding genetics and a road map for making genetic improvement.
    3) Introduce you to some exciting new developments in DNA testing.

My Biases

- My degree is in genetics.
- I have been an animal breeder and consultant for over 50 years working with dozens of species including swine, cattle, sheep, horses, rabbits and racing pigeons.
- So I have strong opinions based on these two frames of reference.
- Listen to what I have to say, but think for yourself. Some of what I think I know, I am sure is wrong!
- **I am here just to share and not to win converts** - you can and should do it any way you want.
- Pigeon Racing is a hobby – keep it relevant to what ***you*** enjoy.

Some Background Information

- My web site (www.shewmaker.com) has some additional information that you may find helpful in sorting out some of the ideas we are going to talk about today (Under the “For the Sport” tab).



The Rule of Seven

- There are seven factors which determine how well you and your birds will perform in pigeon racing.
- **One is beyond your control**.
- **Five are so well perfected within the sport that they have become essentially pass/fail.** You either cover them competently or you are virtually eliminated from the winning positions even before the race starts.
- **One has almost no limit** to its potential and is **largely unrealized** by most fanciers.

The Rule of Seven

1) Beyond our control – **Luck**. Good luck, bad luck, hawks, wires, wind direction, basket position on the truck, bad weather along the course, good weather along the course when we entered a tough weather bird, and on and on and on. It affects us all and so we should just get over it and move on to what we can control.

2) **Condition** (pass/fail)

3) **Training** (pass/fail)

4) **Fuel (aka Nutrition)** (pass/fail)

5) **Motivation** (pass/fail)

The Rule of Seven

6) **Health** (pass/fail though too many flyers are still failing on this one. We could have a week of seminars just on this topic alone.)

7) **Genetics**

When Louis Van Loon was asked “What methods do you use to get those kind of results?” he looked sternly at the gentleman and said, “Remember this, there is only one thing that is important – good pigeons, nothing else.”

Its Time to Move to Factor Seven

- Gregor Mendel's work was published in 1865 (that was 150 years ago!)
- Consider some of the other key discoveries or inventions of that era and their impact on us today:
  - 1861 Louis Pasteur – Germ Theory
  - 1873 James Maxwell – Theory of Electromagnetism
  - 1886 Benz & Daimler – First gasoline automobiles
  - 1898 Marie Curie – Polonium and Radium
  - 1905 Albert Einstein – Theory of Special Relativity

Its Time to Move to Factor Seven

- The science of genetics has made enormous progress since then:
  - 1952 Hershey/Chase - DNA is likely the genetic material
  - 1953 Watson & Crick – Structure of DNA
  - 1978 Genetech – Genetically engineered human insulin
  - 1986 First use of DNA in court proceedings
  - 2003 Complete map of the human genome
  - 2015 FDA approval of genetically modified virus for targeted cancer treatment

Its Time to Move to Factor Seven

- Yet many racing pigeon breeders today still struggle applying even the basic work of Mendel.
  - Some on the forums even question if Mendel's work applies to pigeon racing.

- Yes, it can be complex, but it doesn't have to be.
  - You don't have to know how to build a watch, to be able to use one to tell time.

Does Speed Determine the Winner?

- There is one key detail you have to understand though before we can move on to Factor Seven (improving our genetics):
- What does it actually mean when a pigeon “wins a race”?
    - Yes we all know it is based on speed, since many races involve multiple lofts to which the birds fly. There really is no other way to determine a winner.
    - However, many people make the mistake of correlating the net speed reported on a race sheet with the actual speed the winner flew.
    - There are MANY genes (at least 100) that influence race performance and most go beyond just impacting speed.

Does Speed Determine the Winner?

- Until recently we never really knew exactly what was going on during a race.
- Chic Brooks used to fly his plane behind his trainers to try to get an idea.
- More recently several companies have begun selling GPS systems that can be placed on a bird and (if the bird returns home) the data can be downloaded and analyzed.
- This data includes not only longitude and latitude but also elevation.

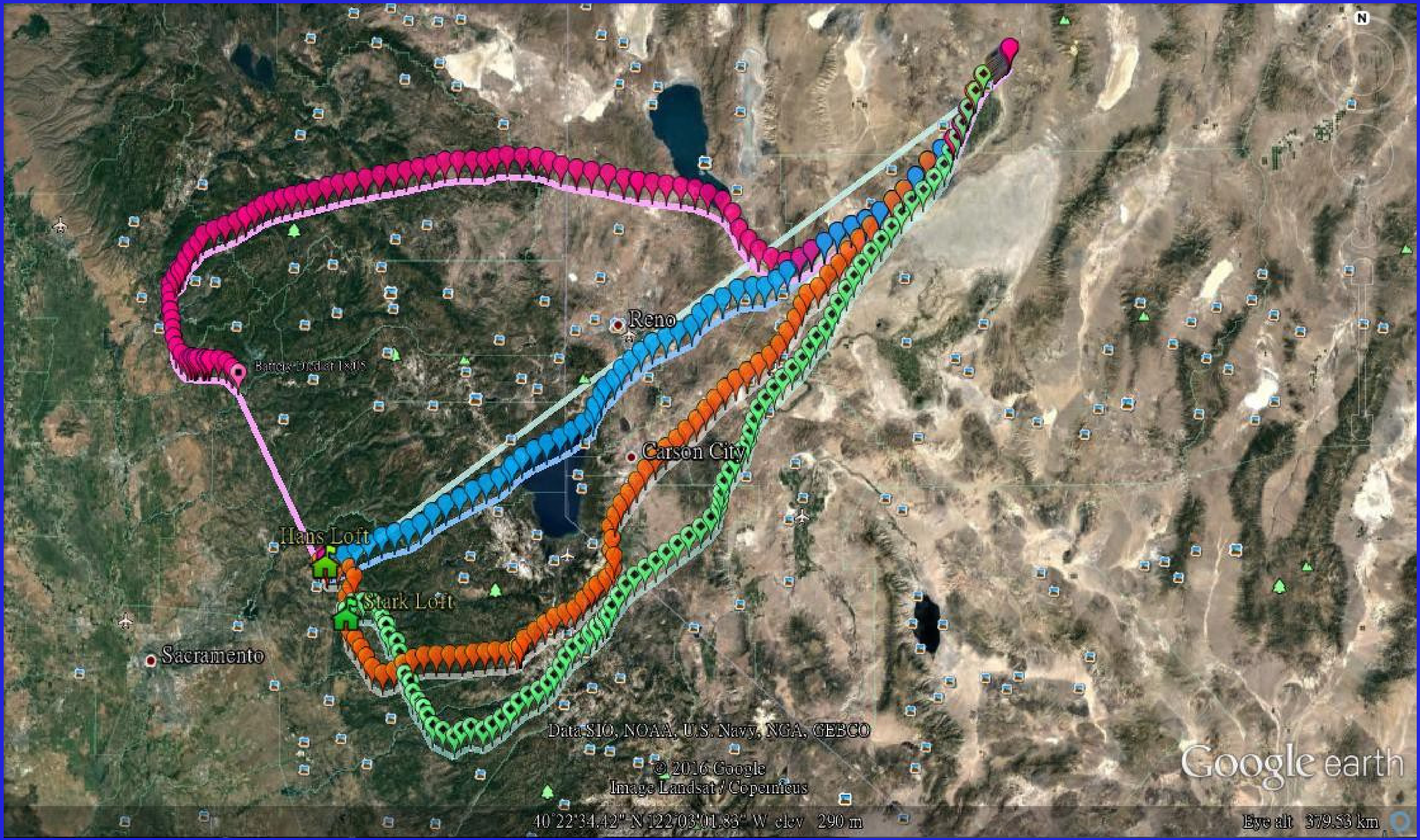
Does Speed Determine the Winner?

- Two years ago, I got very excited when a combine member placed 4 of these devices on birds in a race and one of the birds turned out to be the race winner!
- For the first time we could know exactly what the winning bird did over the course of several hours in order to win the race!
  - Did it fly a straight line of flight even if it meant flying over water?
  - Did it fly a slightly longer path in order to avoid flying over the top of a mountain range?
  - Did it follow a road or river or railroad track?

Does Speed Determine the Winner?

- Matt Hans used the SkyLeader GPS Pigeon Tracking System and he put the GPS bands on four of his birds in the first race of the 2017 Old Bird Season.
  - Lovelock, NV to Placerville, CA
  - 164.785 miles, 638 birds, 39 lofts
  - The course started out in the high desert (3980 feet). The birds traveled west and eventually encountered a large lake (Lake Tahoe) (6237 feet) and then a high mountain range (The Sierras) (10,891 ft at Freel Peak).
  - The winner clocked 1584 ypm

Does Speed Determine the Winner?



Does Speed Determine the Winner?

- The =1st bird flew an almost straight path (the blue path).
- When he came to Lake Tahoe, he went directly across the lake and did not veer to the north and follow highway 80 or veer to the south and follow highway 50.
- When he came to the Sierras he did not search out a pass with a lower elevation, but instead went right over the mountains along the most direct path.
- This doesn't tell us how all birds win races, but it does tell us that when motivated to do so, at least some birds will fly a direct path even if that direct path is difficult.
- The data also shows the paths taken by the three other birds who did not win the race.
  - Several different routes were taken with a spread of about 100 miles
  - None of the routes were direct

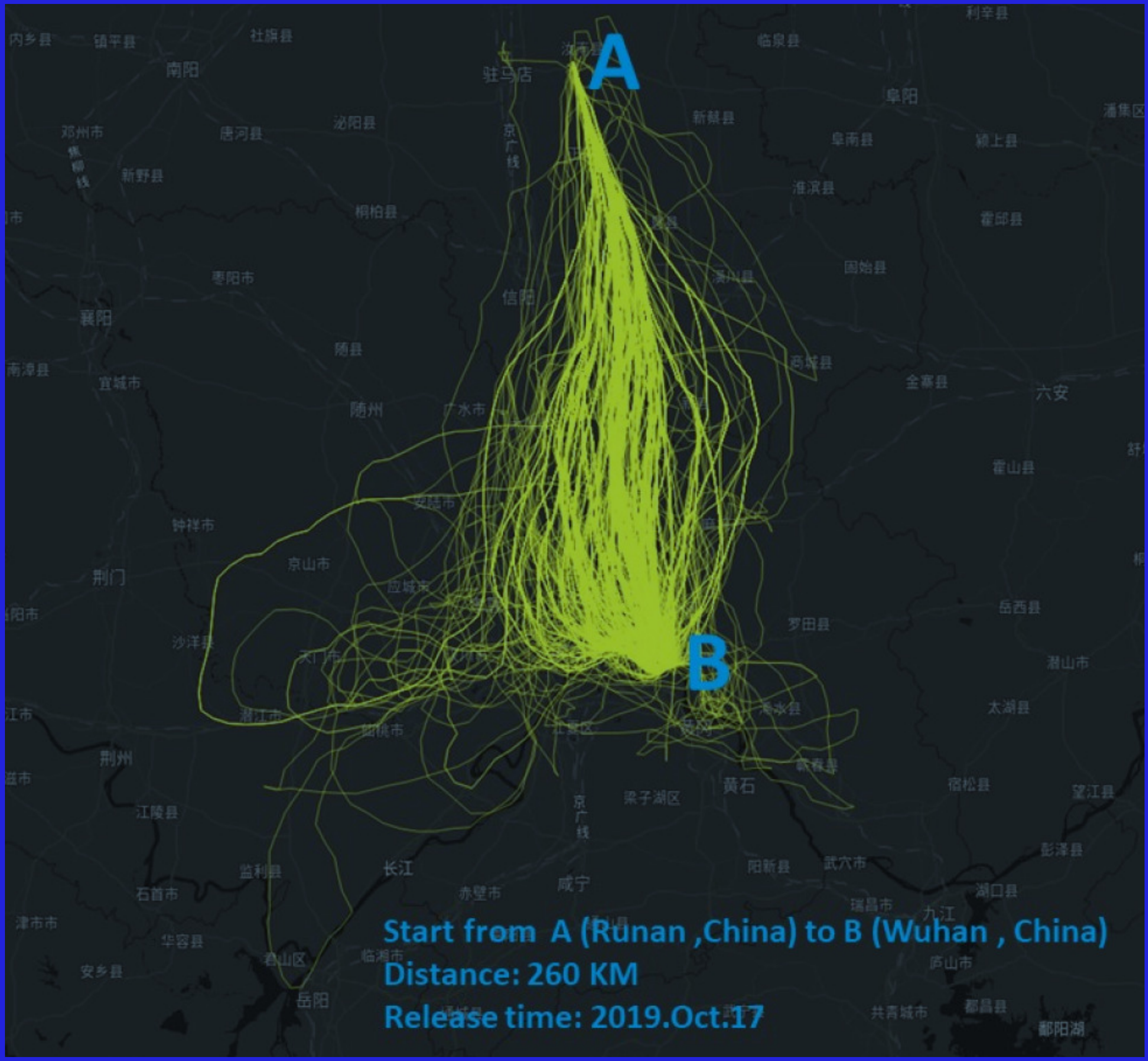
Does Speed Determine the Winner?

The idea that race winners fly the most direct path was recently reinforced with a race flown in China where **all** the birds in the race had GPS trackers!

- The birds were equipped with the Skyleader GPS Tracking System
- The race was 260 Km (162 miles)
- There were 3,363 birds
- The birds flew North to South, it was sunny and breezy
- Consider carefully the next three slides that come from the Skyleader Facebook page.

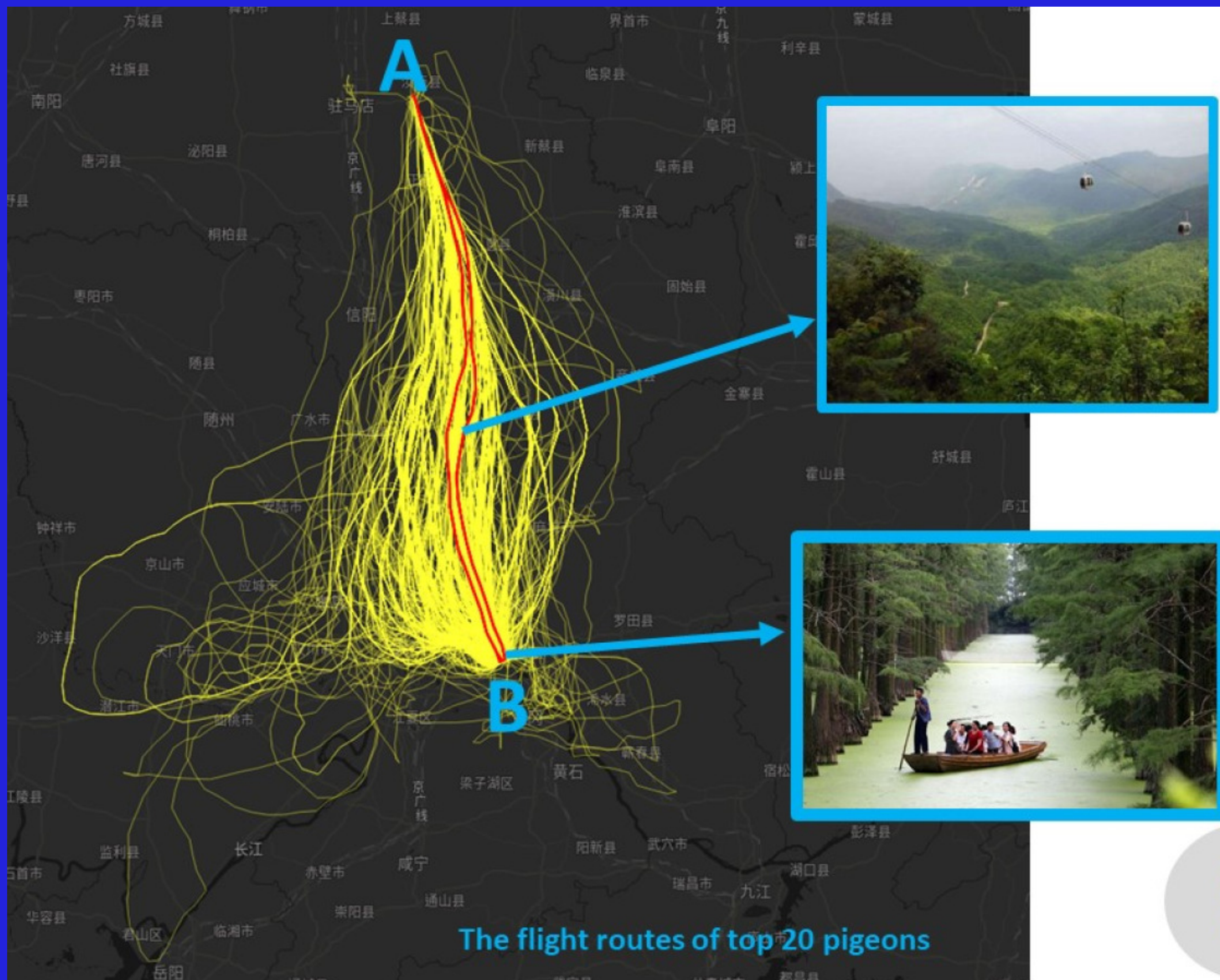
Does Speed Determine the Winner?

Flight paths of all birds in the race.



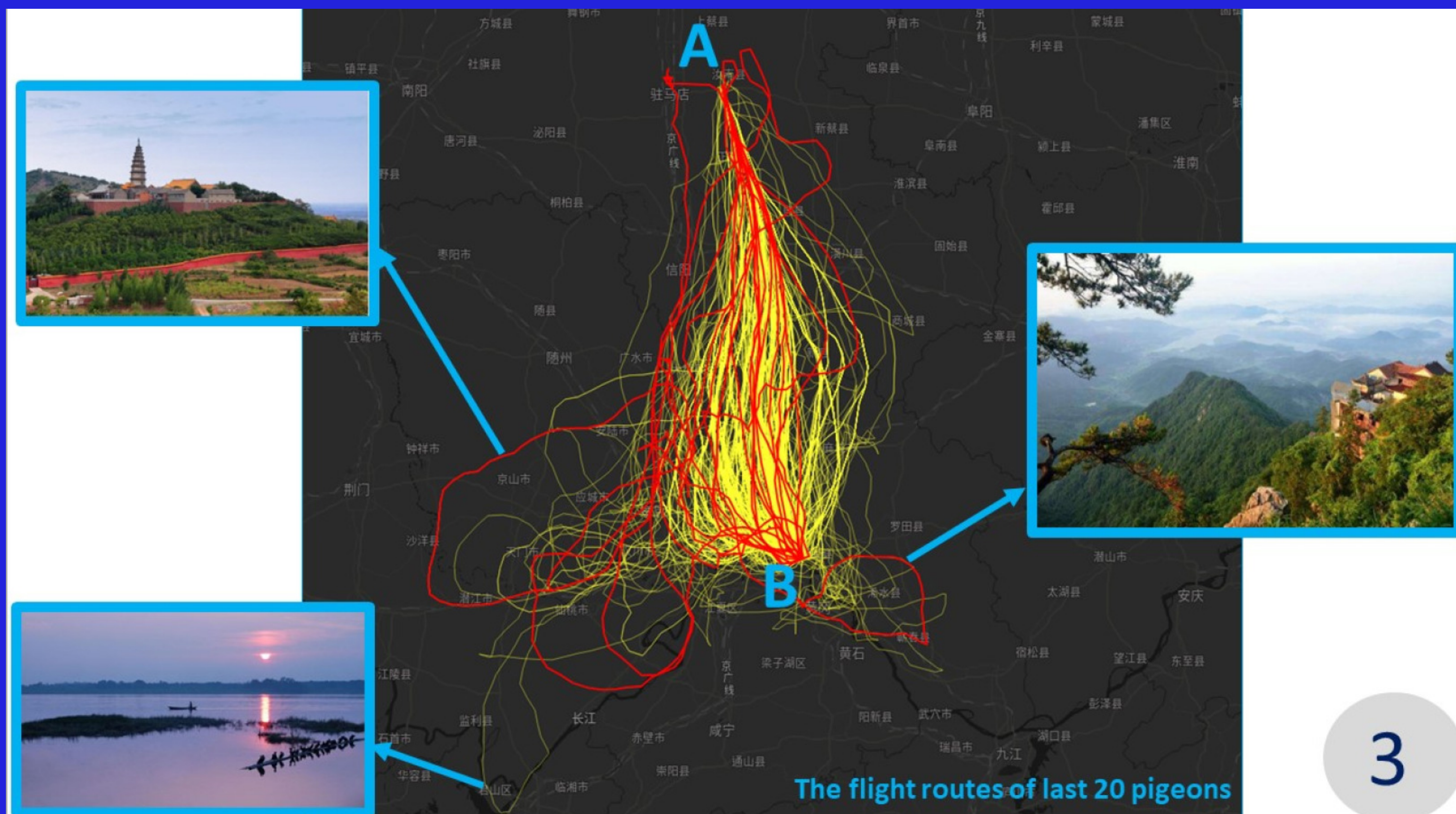
Does Speed Determine the Winner?

Flight paths of the first 20 birds (between the two red lines).



Does Speed Determine the Winner?

Flight paths of the LAST 20 birds (in red).



Does Speed Determine the Winner?

- Interestingly, one of the last place birds clocked a top speed of 2100 m/min while the top speed clocked by the 1st place bird was 1740 m/min.
- So, “winning” a race is the **net** result of a number of different contributors and not just the speed it flies:

  1) The time spent circling before breaking for home

     - which is related to the time needed to orient AND
     - the time spent waiting for others (i.e. grouping)

  1) The directness of the path flown

  2) The average speed of flight

  3) The speed with which it clocks once getting home

Does Speed Determine the Winner?

- Each of these 4 contributors are strongly affected by “motivation” (Factor 5) which we usually think of as being an environmental influence, but they are also strongly influenced by genetics.
- **Example 1:** While all of our various tricks for motivating will work, birds vary in their need for this motivation.
- Some birds won't race well at all without some form of environmental motivation (i.e. racing home to eggs).
- There are other birds that will race reasonably well with little to no environmental motivation. True those birds will race even better with the motivational tricks, but their genetic need to come home is strong enough to do the job alone.

Does Speed Determine the Winner?

- **Example 2:** The willingness of a bird to break for home (as opposed to wanting to wait for a group to form – remember they are strongly gregarious by nature) may be strongly shaped by genetics.
- We will discuss this later when we consider the DRD4 gene.
- **Example 3:** The ability to home from great distances and from release points where they have never been before is clearly genetic.
- However, this genetic ability does vary greatly from bird to bird and requires selection if one wants to breed birds capable of winning.

Does Speed Determine the Winner?

- So, does speed determine the winner of a pigeon race?
  - It certainly is a factor, but only one of many.
  - There are MANY genes (at least 100) that influence the racing ability of pigeons.
  - Many of these genes affect traits that are not visible and no amount of handling or grading can evaluate them.
  - DNA testing can currently evaluate 2 to 4 of the 100 genes.
  - The basket continues to be the best evaluator.

Simple Genetics

- Pigeons have 40 pairs of unique chromosomes for a total of 80 chromosomes.
- On the chromosomes, reside genes. You can think of them as being like beads on a string. The individual beads are the genes and a particular string of these genes is a chromosome.
- The genes are the precise blueprint for every trait of an individual.
- These traits range from what we can easily observe (like the color of the eye) to less discrete and intangible things like mental attitude.

Simple Genetics

- During fertilization, each parent contributes one chromosome of each of the 40 pairs.
  - One of these pairs (the Sex Chromosomes W and Z) is unique in that the W chromosome contains no genes. Cocks are ZZ and hens are WZ. So for a small number of genes (1/40th or 2.5%) hens did not receive a contribution from their mother. These are referred to as “sex linked traits”.
  - I do not subscribe to the theory that the hen is more important than the cock because she contributes the mitochondrial DNA (e.g. the majority of mitochondrial processes are coded for by nuclear DNA and with the low rate of mutation and no mechanism for recombination, I suspect there is very little variation in the mitochondrial DNA among hens). In the absence of data to support this claim, I think you should avoid placing any disproportionate value on the dam.
  - Due to cross over during meiosis, grandparents DO NOT equally contribute 25%.

Simple Genetics

- Each trait is coded for by one or more pairs of genes.
- A given gene resides on a specific location of a specific chromosome. This location is known as a locus (the plural form is loci.)
- While an individual will have exactly two genes for each locus (one coming from each parent), there are multiple versions of that gene within the gene pool (the breeding population). Each different version is known as an allele.

Simple Genetics

- For example, the trait “feather color pattern” has at least four alleles (Dark Check, Check, Bar and Barless) for which a given bird will have at most two.
- All four of these phenotypes are coded for by a single pair of genes on one of the chromosome pairs. If the parents both contributed the “Bar” gene (+) the resulting pigeon will have a Bar color pattern. However, if both parents contributed the “Check” gene, the resulting pigeon will have a Check color pattern.
- When genes for a given pair are of the same type (allele) the pair is said to be homozygous. If the pair consists of two different alleles the pair is said to be heterozygous.

Simple Genetics

- When heterozygous, there are two possible ways the trait might be expressed (though it will always be expressed the same way for a particular gene pair).
  - Complete dominance is when one allele determines the phenotype (dominant) and the other allele is completely masked (recessive) as if it didn't even exist. What we see is the phenotype and what is actually there in the genes of the cells is known as the genotype.
  - Incomplete dominance is when the gene expression is intermediate in the heterozygous state (the gene locus for Grizzle is one example).

Simple Genetics

- Lets look at our example of feather color pattern. There are four possible alleles.

Allele Symbol		Expression
C^T	(known as the T-pattern check)	Dark Check 
C	(Uppercase)	Check 
+		Bar 
c	(lowercase)	Barless 

- C^T > C > + > c   or in other words -
  - Dark Check is dominant over Check, Bar and Barless
  - Check is dominant over Bar and Barless
  - Bar is dominant over Barless

Simple Genetics

These are all the possible ways the alleles can be paired up.

Genotype	Phenotype
C^T C^T	Dark Check
C^T C	Dark Check
C^T +	Dark Check
C^T $\underline{c}$	Dark Check
C C	Check
C +	Check
C $\underline{c}$	Check
+ +	Bar
+ $\underline{c}$	Bar
$\underline{c}$ $\underline{c}$	Barless

Simple Genetics

- This is why you can't get a Check or a Dark Check when you mate two Bars together. If you see such a situation in a pedigree you might suspect there is a mistake somewhere (be careful though because people will sometimes call a light Check a Bar).

Sire / Dam	+	+
+	+ + 	+ + 
+	+ + 	+ + 

Example of a Bar cock with the ++ genotype mated to a Bar hen also with the ++ genotype. The mating will produce 100% Bars.

Simple Genetics

- But you can get Bars from the mating of two Checks.

Sire / Dam	C	+
C	C C 	C + 
+	+ C 	+ + 

Example of a Check cock with the C+ genotype mated to a Check hen also with the C+ genotype. The mating should produce 75% Checks and 25% Bars.

Simple Genetics

- Though some Checks when mated will not ever produce a single Barred offspring.

Sire / Dam	C	C
C	C C	C C
C	C C	C C

Example of a Check cock with the CC genotype mated to a Check hen also with the CC genotype. The mating will produce 100% Checks.

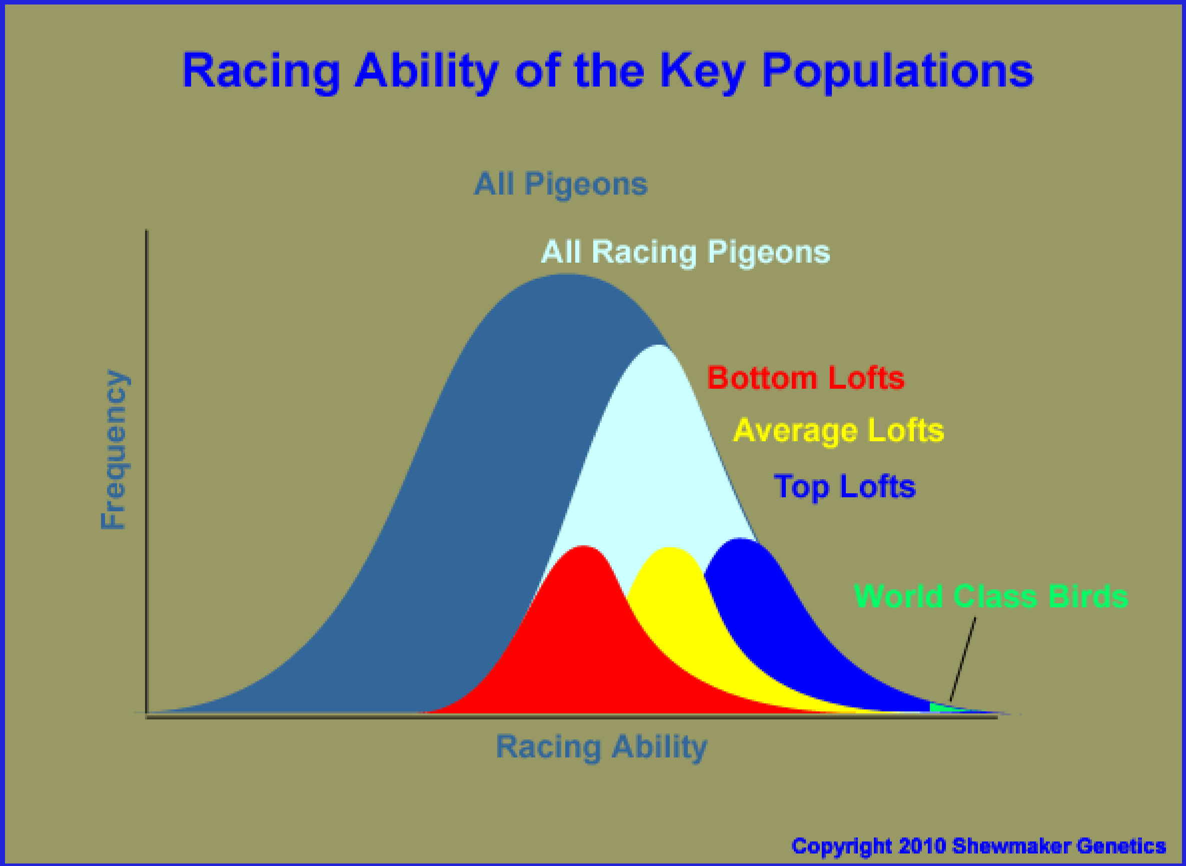
Our Concern Is With The Big Picture

- Genetics though is <u>much</u> more complicated than what we have explained so far for a simple pair of genes.
- This leads many people to get lost in the minutia of DNA, genes, mutations and such.
- It is much more important to understand the big picture. Remember, it is fine to understand how a watch works, but most people are better served by simply knowing how to tell time.
- In general, don't think in terms of individual genes, individual chromosomes or even individual birds. Everything should be approached from the point of view of the *<u>population</u>* of racing pigeons – specifically those in your loft and those in the rest of the sport.

Understand Its a Bell Curve

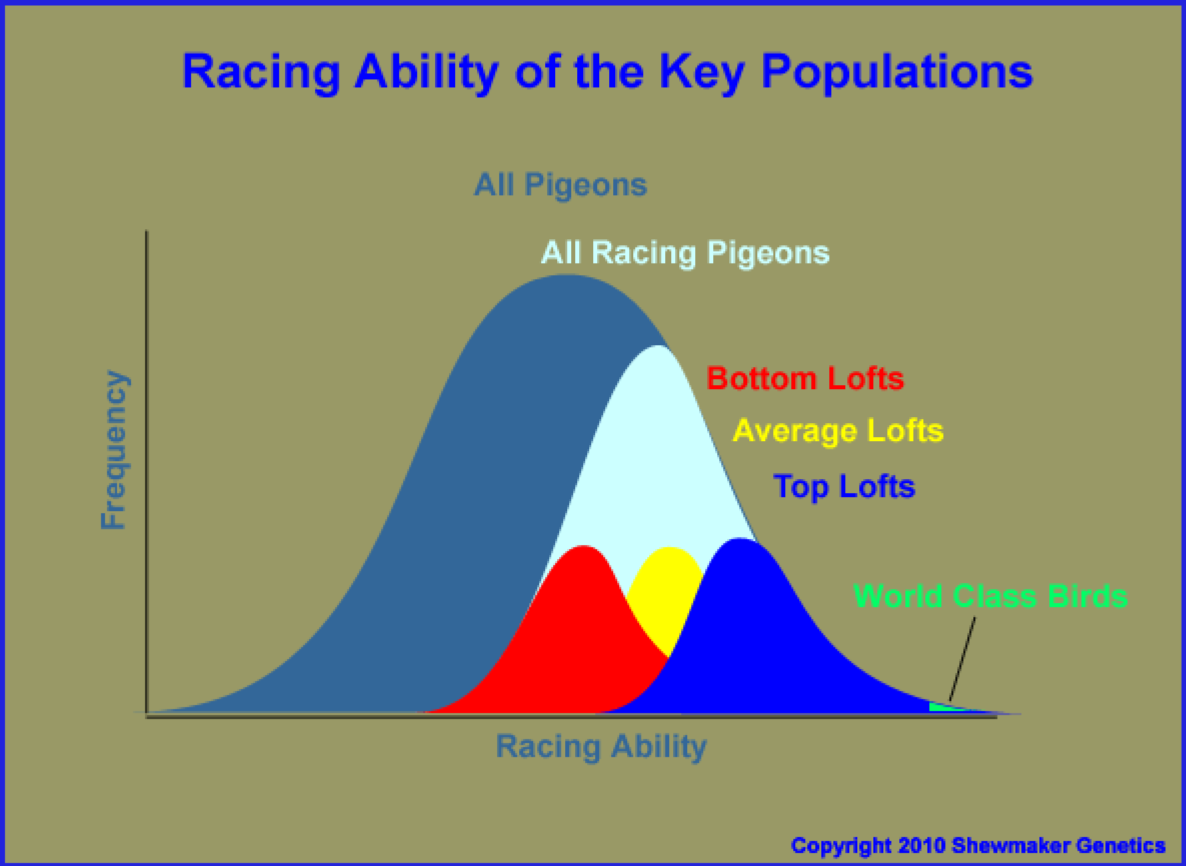
- For many traits, genetic expression is actually determined not by the action of a single pair of genes but multiple pairs – two, three, dozens and perhaps even hundreds in the case of those non-discrete traits like "height" or "body weight" or in our case "racing ability".
- If you do the math and graph outcomes of various matings using many genes, instead of a box where 75% are Checks and 25% are Blues (as on Slide 34), we get a distribution that is known as a bell curve.
- The next five slides are the most important of the whole seminar.

Understand Its a Bell Curve



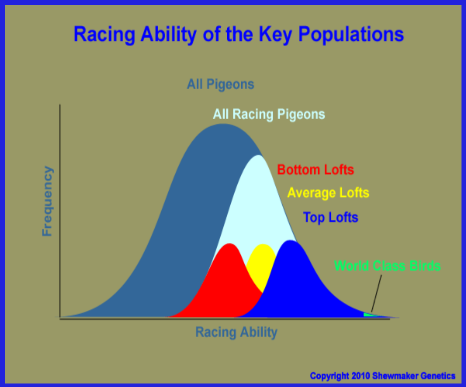
- Notice that the "Bottom Lofts" and most of the "Average Lofts" may not even have the necessary genes in their pool to breed world class birds.

Understand Its a Bell Curve



- But also notice that in the “Top Lofts”, few of the birds are “World Class” and many are on a par with the “Low” and “Average” lofts.

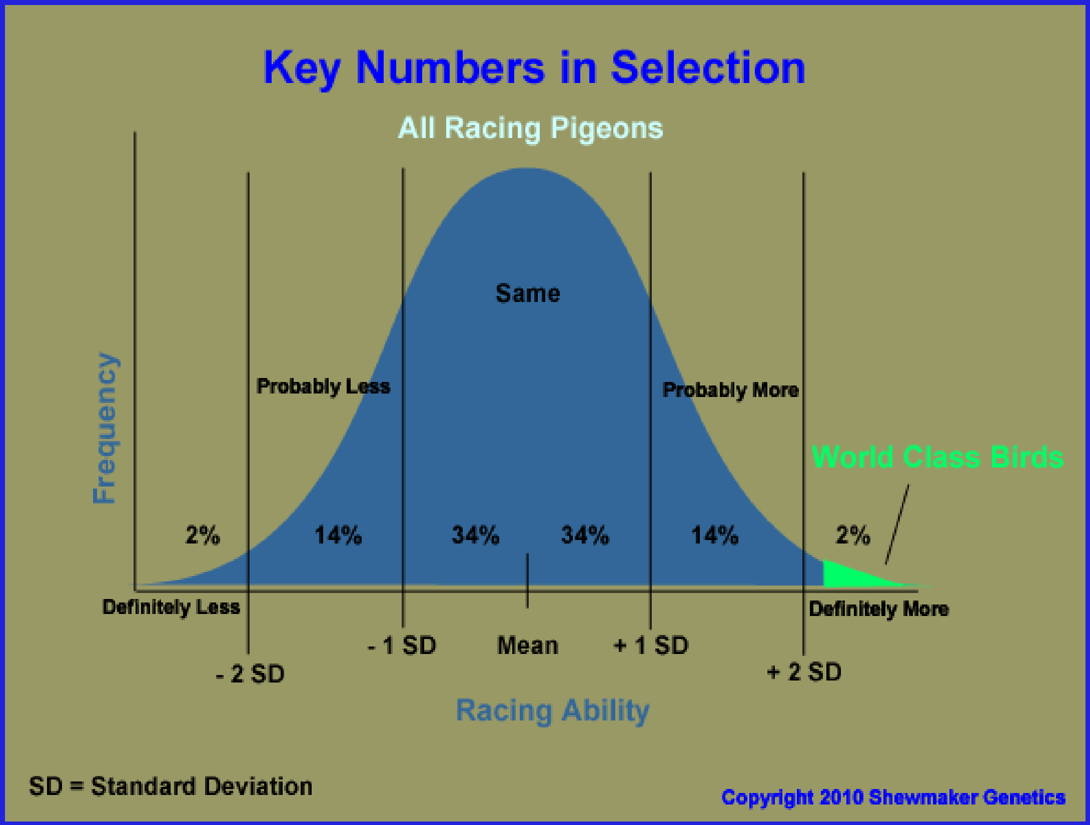
Understand Its a Bell Curve



- **Here is the hard cold fact** – most of our pigeons are not genetically up to our assumptions and expectations.
- ***IF*** you have a "Top Loft" complete with a few "World Class" pigeons, you ***MIGHT*** produce **1 in 10** birds which should be kept to breed the next generation.
- If you are in the "Average Loft" category it is probably closer to 1 in 100 and in the "Bottom Lofts" it is closer to 1 in 1000 or maybe even 1 in 10,000.

Understand Its a Bell Curve

- If you aren't selecting at least the top 16% *you probably aren't selecting at all*.



- **If you really want to make progress you need to be selecting at least the top 2%.**

Understand Its a Bell Curve

- **UNDERSTAND THIS**: birds selected from the top 2%, breed offspring who have their own bell curve. While the mid point of this new bell curve will very likely be shifted right, it will NOT consist only of birds that are as good as the 2% ones you selected. The new bell curve will likely extend well into (and perhaps beyond) the mediocre range.
- If the 2% birds you selected to breed are indeed very good breeders, they still are, at best, going to produce only 1 in 10 that will be good enough to carry your breeding effort forward.
- So, a generation of "Bred for Stock" has at least a 90% chance of being a mistake and two generations of "Bred for Stock" has at least a 99% chance of being a mistake.
- There is a place for "Bred for Stock" but the practice has its risks and should be carefully managed (like following up with testing of the offspring produced to verify you stocked the right one).

The Progress Equation

- Your ability to make genetic progress and the speed at which you make this progress is **absolutely** related to these three factors (*memorize this slide*!):
  - The **accuracy** of your selection
    - *So if you think toe color is related to superior racing and this is what you select for, you are probably not really doing any selection at all with respect to racing ability. In my view the most accurate selection criteria (by a wide wide margin) is **race results to the same loft**. Nothing else comes close.*
  - The **intensity** of your selection
    - *Selecting from the top 16% is far less intense than selection from the top 2% which in turn is far less intense than selecting from the top 1%*
  - The **time** interval over which you do the selection
    - *One season is not enough, but two or three will surprise you. Changing to a new fad (or a new family) every few years will doom any real progress.*

The Progress Equation

- Progress = (accuracy)(intensity)(time)
- If you want to increase the speed of the genetic progress in your loft, you need to increase one or more of these three factors.

  If you decrease one, you will have to increase one or both of the others just to maintain the rate of your current progress.

  If any of these factors equals zero, you will make zero progress.

  - The **accuracy** of your selection
  - The **intensity** of your selection
  - The **time** interval over which you do the selection

The Progress Equation

- Revisiting our “Bred for Stock” discussion, stocking the wrong bird means your selection accuracy was zero.
- So while you got the wrong bird, the bell curve for your population **may** not have shifted.
- If you have been guilty of too much “Bred for Stock” in your breeding program, realize that the key alleles are probably still in your gene pool, just not in one bird and not in as high a frequency as we are trying to achieve.
- To recover from such a mistake, start testing 100% of your youngsters and retain for breeding **only** the very best (the top 2% would be my recommendation).
- If you want to acquire birds from another loft where too much “Bred for Stock” has occurred, don't acquire just one or two birds. Your sample of their gene pool may not be sufficient to capture the desired alleles. Acquiring a kit of 10 less expensive squeekers would be a much better idea than one or two higher priced birds.

The Progress Equation – A Powerful Example

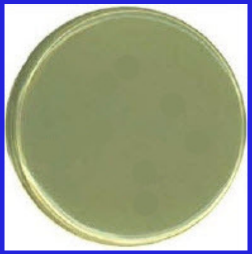
- Lets look at an example. We will greatly decrease the generation time so that we can see (quickly) how a significant **time interval** (i.e. 7 generations) can bring about dramatic progress in meeting a breeding objective.
  - My awareness of this example has given me a tremendous advantage in breeding racing pigeons. It gave me the nerve to trust the Progress Equation and to do my “60 x 60” program.
  - As pigeon breeders we usually think of one generation as a year. This is how long it takes us to breed a youngster and raise it to the age when it can breed.
  - Bacteria under ideal laboratory conditions have a generation time of about 20 minutes!
  - This means that in a single 24 hour day, a bacterial population can progress 72 generations! This is more generations than most pigeon fanciers will be able to breed in their lifetime.

The Progress Equation – A Powerful Example

- For this example, we are going to breed some bacteria just like we breed our pigeons.
  - Just like with pigeons, we will have a breeding objective and we will select the next generation of breeders with this objective in mind. We will continue this for seven generations so that we can see just how the Progress Equation works.
  - Breeding Objective: Breed a line of bacteria that is resistant to an antibiotic.
  - First some basics about growing and breeding bacteria!

The Progress Equation – A Powerful Example

- This is what a sterile petri dish with no bacterial growth looks like. It is clear and transparent:

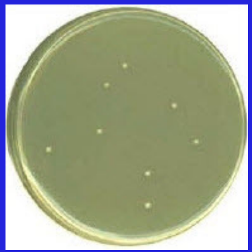


- This is what a petri dish looks like after spreading 300 million bacteria on it and incubating overnight. It is covered with a white coating and is opaque:

- If we only place 8 bacteria on the petri dish and incubate overnight, it will look something like this with eight white spots. Each of these spots is a colony of millions of bacteria all descended from the one bacteria initially placed at that location:

The Progress Equation – A Powerful Example

- Now lets take a solution of bacteria (generation 0) and mix it with a weak solution of an antibiotic.
- Lets then put about 300 million bacteria from this mixture on a sterile petri dish and incubate it overnight.
- The next day we will see a small number of colonies. Each of these colonies (generation 1) grew from a bacteria that possessed a mutation which made it resistant to a weak exposure to the antibiotic.



- You will notice that in this example that we are exercising extreme **selection intensity** (8 or so out of 300 million).

The Progress Equation – A Powerful Example

- Now lets take a sterile instrument and touch it to one of these generation 1 colonies and then swirl it in a sterile nutrient solution. Incubate this inoculated solution overnight.
- This time instead of a weak antibiotic solution we are going to add an antibiotic solution that is 10X stronger to the bacterial solution.
- Repeat the earlier process by placing about 300 million bacteria from this “generation 1“ solution on a sterile petri dish and incubate it overnight.
- The next day we will again see a small number of colonies. Each of these colonies (generation 2) grew from a bacteria that possessed a mutation which made it resistant to the stronger antibiotic. The mutation arose at some point during the overnight incubation period when billions of cell divisions occurred.

The Progress Equation – A Powerful Example

- Repeating this process for 5 more generations (each cycle increasing the strength of the antibiotic by 10 fold) will result in a petri dish with a number of colonies each of which are 100% resistant to the antibiotic.
- There is a wonderful video from the the Harvard Medical School which demonstrates this example with a slightly different (but much more eloquent) setup

    www.youtube.com/watch?v=plVk4NVIUh8

- What have we learned?

The Progress Equation – A Powerful Example

- Using high levels of accuracy and intensity in our selection, it only took 7 generations to achieve a remarkable outcome.
  - The **accuracy of our selection** was pretty clear – the bacteria were exposed to the antibiotic and if they were susceptible, they died.
  - The **selection intensity** was extreme (8 or so out of 300 million).
- This example dramatically illustrates how genetic progress is indeed a function of accuracy, intensity and time.
- It also underscores the importance of selection accuracy and selection intensity since there isn't that much we can do to change the time interval available to each of us.

New Tools – Artificial Insemination

Artificial Insemination is an incredibly powerful tool for the proliferation of the elite birds.

- Fresh semen can typically be collected three times a week, year round.
  - One collection can typically inseminate six to ten hens when used fresh and about three when frozen.
  - Once frozen the semen can be stored indefinitely (literally for decades).

New Tools – Artificial Insemination

Artificial Insemination Advantages (continued).

- Semen can be collected and frozen from race team cocks during and between race seasons. This is huge.
  - It allows us to preserve the genetics of the elite birds while continuing to race them and gather data. In the past we have often had to chose between stocking and racing which resulted in some birds being either
    - stocked too early before their true racing value was accurately established, or
    - sent to one too many races wherein a valuable bird was lost.
- It is expensive and it requires some time, but it is a viable option

New Tools – DNA Testing

The fantastic advances in DNA technology are now available to the sport of pigeon racing!

- DNA Profiling allows us to record the genetic "fingerprint" of a pigeon. This can be very useful later for a variety of verification scenarios.
- Verification of Parentage. While a 100% verification is not possible, the use of at least 16 carefully chosen markers will allow parentage to be verified to a very reasonable degree. www.animalgenetics.com performs this service.
- Sex determination.
- We can now determine the actual genotypes of birds for two genes that have been shown to influence race performance. More are undoubtedly coming.

New Tools – DNA Testing - LDHA

Recent research has shown that the LDHA gene may play a very important role in racing performance of pigeons.

I believe this is a very important topic, but a strong word of caution is in order.

- First and foremost, the LDHA gene is but one of many that contribute to racing ability. Anyone who jumps off the cliff at this point and assumes that LDHA is the secret and exclusive "silver bullet" which will ensure immediate racing success, is almost certainly wrong and will likely end up being very disappointed.
- By the same token, anyone who dismisses these research results as techno babble and irrelevant to real world racing is also very likely wrong and might be missing a significant opportunity to move their gene pool dramatically forward.

New Tools – DNA Testing - LDHA

What is it?

- LDH stands for **Lactate Dehydrogenase**, a group of enzymes that are involved in the conversion of lactate to pyruvate (and vise versa).
- LDH is found in the cells of virtually every living organism (plants, animals and even single cell organisms known as prokaryotes).
- In mammals and birds, there are three different forms of this enzyme that are largely found in specific cell types, reflecting the different functional requirements of those cells. Each type is coded for by a different gene.
- The type **A form** of LDH is found largely in muscle cells and is coded for by the **LDHA gene**

New Tools – DNA Testing - LDHA

What is it?

- When sufficient oxygen is present, muscle cells produce energy from a metabolic process known as aerobic respiration.
- When the exercise is sufficiently intense or prolonged such that there is an **oxygen deficit**, muscle cells use an alternative anaerobic process that **produces lactate (lactic acid)**. Note that pigeons use a metabolic pathway for energy that uses fat and does not produce lactate after the first hour of flight.
- For many years, it was erroneously thought that muscle fatigue during strenuous exercise was due to a build up of lactic acid. We now know that there are several factors that contribute to fatigue, but **how a cell utilizes and/or regulates lactate levels can influence race performance**.

New Tools – DNA Testing - LDHA

What did the research find?

- In 2002, two different alleles were found in pigeons for the LDHA gene, A and B. This means the possible genotypes for LDHA in pigeons are BB, AB and AA.
- In 2006, DNA testing was used to determine the frequencies of the A and the B alleles in four groups of pigeons:
  - The group of fancy pigeons (non racing breeds) had an A allele frequency of **0.6%**.
  - A control group of race pigeons (not screened for racing results) had an A allele frequency of **6.5%**.
  - A group of race pigeons from throughout Poland (specifically screened for “top” racing results) had an A allele frequency of **20.3%**.
  - A group of race pigeons from throughout China and Taiwan (specifically screened for “top” racing results) had an A allele frequency of **21.9%**.

New Tools – DNA Testing - LDHA

What did the research find?

- In 2014, another study was done which again demonstrated a correlation between the frequency of the A allele and race performance.
- This 2014 study also raised the possibility that the influence of the AA genotype may exceed that of the AB genotype in races under 250 miles and that the A allele may be less important in the distance races of more than 311 miles.
- At this point there are many unanswered questions. Much additional research needs to be done.

New Tools – DNA Testing - LDHA

What does this all mean?

- In selecting for race performance, pigeon breeders have indirectly been selecting for the A allele of the LDHA gene (along with others of course that have not yet been identified). This is shown by the ten fold increase in the frequency of the A allele of the racing pigeon control group over that of the fancy pigeons in the 2006 study.
- The three fold increase in the frequency of the A allele of “elite” racing pigeons over the racing pigeon control group further supports the notion that the A allele enhances race performance.

New Tools – DNA Testing - LDHA

What does this all mean?

- Today, the LDHA genotype of any pigeon can be determined by a DNA test. In the US, the test can be performed for $20 with the submission of a single secondary feather. (www.genecheck.com)
- Another good U.S. lab is www.animalgenetics.com and in Europe www.pigen.be is excellent.
- It is now possible for the astute breeder to "fix" the A allele of the LDHA gene in their breeding flock, making its frequency 100%. They are then free to focus on additional improvement through the selection of other key genes, knowing the A allele will always be there in any birds they produce.

New Tools – DNA Testing - LDHA

Don't forget – this is an important gene, but it is not the whole story. There are many outstanding birds (both racers and breeders) who are BB.

- Don't make the mistake of culling birds just because they do not carry the A allele.
- Think instead in terms of adding the A allele to improve existing gene pools and then increasing its frequency.

[This is where the seminar ended on this topic last year]

New Tools – DNA Testing - LDHA

In 2013 I bred an incredible bird. His Contemporary Group Test record was unlike any of the thousands of birds I have tested. No other bird has had a record that was even close. He was an off the chart freak!

- His band was 3079-AU-13-SHEW and I named him “The Freak” (sorry Frank McLaughlin, I didn't know at the time you had one with the same name).
- Later when I started testing my birds for the LDHA gene, I assumed he would probably be at least AB and maybe even AA.
- Well he wasn't. He was just a BB.

New Tools – DNA Testing - LDHA

In 2013 I bred an incredible bird... He was an off the chart freak!

- There is this natural tendency when doing gene testing to be disappointed when the results come back without the hoped for (or expected) alleles. Don't let this happen!
- There are probably a hundred (or more) genes that contribute to a pigeon's ability to race. The LDHA gene is important, but it is still just one of at least one hundred.
- If you have an outstanding family of birds and they test out as almost all BB, this is actually a very good thing. It means you have the right alleles for many of the other 99 genes. If you add the A allele for LDHA, it will be like throwing gasoline on a fire – BOOM!!!

New Tools – DNA Testing - DRD4

In 2013 I bred an incredible bird... He was an off the chart freak!

- In 2016 I started to do some DNA testing for another gene that scientists have correlated with race performance in pigeons.
- It is the Dopamine Receptor D4 gene and is commonly called the DRD4 gene.
- It turns out “The Freak” tested CTCT for DRD4 which we will see in a few minutes is super.

New Tools – DNA Testing - DRD4

- The DRD4 gene codes for the D4 dopamine receptor, which is a protein-coupled receptor found on the surfaces of certain cells of the central nervous system. These receptors are activated by dopamine and are part of an elaborate messaging system within the body used to regulate various neurological processes. **DRD4** stands for **D**opamine **R**eceptor **D4**.
- DRD4 has been studied in humans and various mutations of the gene have been linked to a number of neurological and psychiatric conditions such as schizophrenia, certain eating disorders, Parkinson's Disease and even some addictive behaviors. Some studies have suggested it might be related to risk taking (i.e. bungie jumping off a bridge).
- Some have tied certain variants of the DRD4 gene to curiosity, restlessness and the urge to explore.

New Tools – DNA Testing - DRD4

- In 2015, Proskura *et al* published a paper in the journal *Animal Genetics* which studied the association between nucleotide variations at various locations in the DRD4 gene and racing pigeon performance.
- At two of these locations (g.129954 and g.129456) differences in nucleotide sequences were found to be correlated with race performance for race distances of less than 400 km (249 miles).
- The precise mechanism by which the DRD4 gene influences pigeon racing performance is not understood at this time. Given the wide range of effects found in humans for mutations of this gene, this will most likely not be an easy question to answer.

New Tools – DNA Testing - DRD4

- However, the suggestion that some mutations in humans might be related to risk taking intrigues me.
- When I consider the race performance of “The Freak” one explanation would be that once he had oriented, he was ready to start for home and didn't wait for the safety of a group to fly home with. He took the risk of flying home alone. Since he was correct in his orientation, he got a big jump on the rest of the birds and beat them all, along with me.
- This could also explain why some birds I have had were either near the top or near the bottom on many of their races. They might have been risk takers and when they were right about orientation, they won. When they were wrong, they headed off with full gusto in the wrong direction.
- Tom Bishop has said he thinks he loses a higher percentage of his DRD4-T young birds off the landing board during settling. Again, this makes sense if the mutant gene is associated with risk taking. They take the risk of flying off before they really know what they are doing.

New Tools – DNA Testing - DRD4

- Whatever the mechanism, the results of this paper show a correlation and we can use this to our advantage as animal breeders. As was the case with LDHA, additional research is clearly needed.
- The 2015 paper studied race performance for the nine possible genotypes they identified for the DRD4 gene in pigeons:

  CCCC, CCCT, CCTT, CTCC, CTCT, CTTT, TTCC, TTCT, TTTT

- Not all nine genotypes were found in the test population. Of those that were found, there was a statistically significant difference between the race points earned by the **CTCT** birds (68.95) verses the CCCC (29.08), CCCT (35.24), CTCC (30.63) and TTCC (29.24) birds.
- It is possible the TTTT, CTTT, TTCT and/or CCTT genotypes are also beneficial, but they are rare enough that none were found in the test group. Indeed, the TT allele may not exist.

New Tools – DNA Testing - DRD4

Lets look in more detail at the DRD4 genotypes

- I mentioned earlier that there were two locations within the DRD4 gene where nucleotide differences were correlated with race performance. This is a very important point.
- The first location is identified as g.129954 and the second is identified as g.129456. The original scientific paper published by Proskura *et al* used a notation where the genotypes were represented with the g.129954 location first and the g.129456 location second. In other words, when Proskura *et al* referred to a CTCC genotype they meant that at the g.129954 location the bird had C in one gene and a T in the other gene and for location g.129456 both genes had a C. This location order (954 then 456) is the most widely used to this day.

New Tools – DNA Testing - DRD4

Lets look in more detail at the DRD4 genotypes

- HOWEVER, Genecheck, Inc reports their results in the opposite order (though their report is clearly labeled with respect to location). Many people who use Gene Check do not understand this location order distinction and it has lead to some problems.
- For example, two breeders wanted to trade some birds so that they could both breed CTCT birds. One reported that he had some CTCC birds and the other said he had some CCCT birds. Unfortunately they were using different location orders and the breeders actually BOTH had CT(g.129954)CC(g.129456) birds. The trade would have been of no benefit to either breeder.
- ALWAYS be clear about the location order you are using when talking about DRD4 genotypes. For the rest of these slides I will use the subscript $_4$ for location g.129954 and the subscript $_6$ for the location g.129456 (i.e. $C_4C_4T_6T_6$).

New Tools – DNA Testing - DRD4

Lets look in more detail at the DRD4 genotypes

- DRD4 gene is not located on the sex chromosome (Z) and so both cocks and hens have two copies of the gene, one each from each parent.
- To date, only three alleles for the DRD4 gene have been observed: C_4T_6, T_4C_6 and C_4C_6. The T_4T_6 allele is theoretically possible, but its theoretical frequency is very low. Until such time as it is actually found, it is best to ignore it.
- This means that there are only six possible genotypes for the DRD4 gene. These are shown on the next two slides.

New Tools – DNA Testing - DRD4

The six possible DRD4 genotypes that can be produced from the three known DRD4 alleles:

- C_4C_6 allele (i.e. sperm) + C_4C_6 allele (i.e. egg) = $C_4C_4C_6C_6$
- C_4C_6 allele + C_4T_6 allele = $C_4C_4C_6T_6$
- C_4C_6 allele + T_4C_6 allele = $C_4T_4C_6C_6$
- C_4T_6 allele + T_4C_6 allele = $C_4T_4C_6T_6$
- C_4T_6 allele + C_4T_6 allele = $C_4C_4T_6T_6$
- T_4C_6 allele + T_4C_6 allele = $T_4T_4C_6C_6$

Note: The order of the C's and T's at a particular location is interchangeable
So, $C_4C_4C_6T_6$ is the same as $C_4C_4T_6C_6$

New Tools – DNA Testing - DRD4

Lets look at the possible offspring from a mating of two $C_4T_4C_6T_6$ birds:

Sperm Egg	C_4T_6	T_4C_6
C_4T_6	$C_4C_4T_6T_6$	$C_4T_4C_6T_6$
T_4C_6	$C_4T_4C_6T_6$	$T_4T_4C_6C_6$

That's interesting! $C_4T_4C_6T_6$ x $C_4T_4C_6T_6$ doesn't breed true (only 50% are $C_4T_4C_6T_6$)!

Is there a mating which will produce 100% $C_4T_4C_6T_6$?

New Tools – DNA Testing - DRD4

Turns out there is! $T_4T_4C_6C_6$ x $C_4C_4T_6T_6$:

Bird 1 / Bird 2	T_4C_6
C_4T_6	$C_4T_4C_6T_6$

So here is what I am doing:

- I am working to eventually get all my families to be 100% either AA $C_4C_4T_6T_6$ or AA $T_4T_4C_6C_6$.
- This will allow me to make my crosses for the races and 100% of the youngsters will be AA $C_4T_4C_4T_4$ and they will have 100% hybrid vigor.
- I say “eventually” because this must not be done at the expense of the other “98” genes! It will be done over time.

New Tools – DNA Testing

Two final points -

1) What would you do with a super performing bird that tested BB for LDHA and CCCC for DRD4 (the lowest performing genotypes) ?

   - **Stock it!** It obviously has the right alleles for many of the other important genes for which we do not yet have DNA tests available. Since we have DNA testing for LDHA and DRD4 these two will be relatively easy to add.
   - At this point it is harder to get the right alleles for the “98” other genes and so efforts on that front should NOT be slowed in an effort to get “A”s and “T”s.

2) At this time there are actually four genes that can be DNA tested in racing pigeons. The other two are related to feather quality (feather keratin or F-KER) and muscling (myostatin or MSTN). I don't test for these yet because the alleles have not been correlated to race performance.

Genes Affecting Racing Ability

There are several distinct traits which contribute to a bird who wins races. All of these traits are strongly influenced by the environment, but they also have a significant genetic component. The bird has to have the:

- **ability to orient** itself quickly at the time of release AND maintain the proper orientation on the flight home.
- **ability to fly** at a speed and for a duration that is competitive with the rest of the birds in the race. Many sprint birds, for example, just do not have the tools for competing in a long distance race.
- **desire to want to get home quickly** (as opposed to just plodding along until it gets there).
- **intelligence to resolve challenges** that inevitably arise at some point during at least some races (*i.e.* strong winds or a storm that breaks up the flock and blows them off course).
- **ability to learn** from their experiences and their mistakes.
- **mindset of a leader** as opposed to that of a follower (which is somewhat at odds with their normal gregarious nature).
- **willingness to take risks** such as starting for home before the pack is ready or to break from a group during the race.
- **strongest possible homing instinct** so that it returns home even on races where it doesn't place (birds that come home after disasters are able to race another day!)

Genes Affecting Racing Ability

There are several distinct traits which contribute to a bird who wins races. All of these traits are strongly influenced by the environment, but they also have a significant genetic component. The bird has to have the:

ability to orient | **ability to fly** | **desire to want to get home quickly**

intelligence to resolve challenges | **ability to learn** | **mindset of a leader**

willingness to take risks | **strongest possible homing instinct**

- I am far more interested in these traits than anything I can see with my eyes or feel with my hands.
- Yes, we all like a good handling bird and yes, there are some valuable handling traits that we can indeed see and evaluate (i.e. wing structure).
- However, given the number of critical traits that can not be observed through handling, race results must always trump handling.
- The two best flying birds I ever raised would have been culled at weaning based on handling qualities (“The Freak” and “Dan's Hen”).
- Try to avoid “Bred for Stock” and “I am looking for a Blue Check”

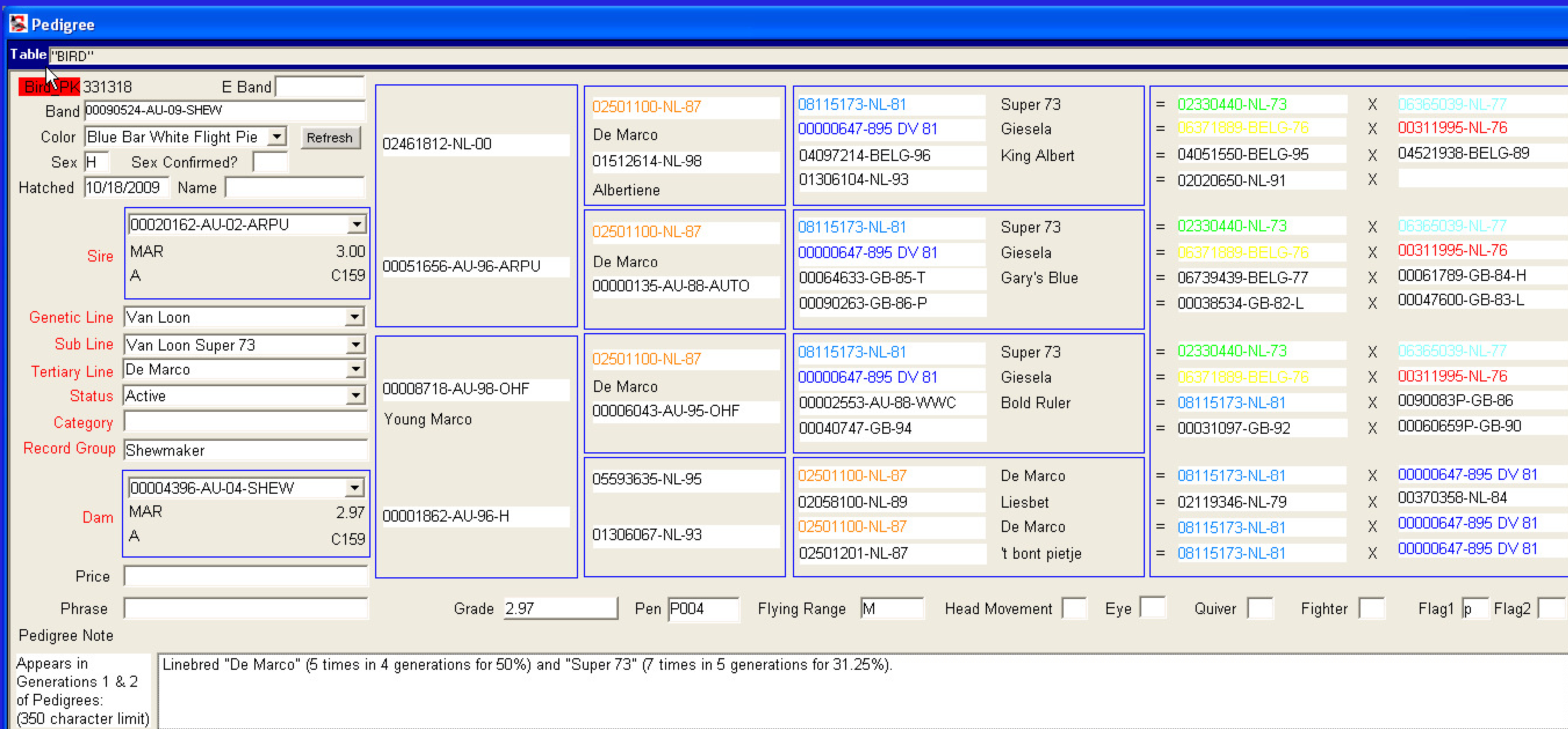
A Road Map for Genetic Improvement

1. Assemble an appropriate gene pool. Don't assume though that you have to go buy new birds. While we all probably need to cull out most of what we have, the American Racing Pigeon Gene Pool is very deep and until you conduct a fair test you really can't say you don't already have the right genes.
2. Roll, roll, roll the dice!!!
   - If the genes are in the pool, your job is to assemble them all in one bird.
     - Breed, test and cull until you get it. Then do it again to get another one.
     - Change the matings and do it again.
     - Use linebreeding to try to concentrate the genes of elite birds.

A Road Map for Genetic Improvement

2. Roll, roll, roll the dice!!! (continued)

- Here is a good example of linebreeding (DeMarco and Super 73):



A Road Map for Genetic Improvement

2. Roll, roll, roll the dice!!! (continued)

- Another good example of linebreeding (Super 73):

Strategic Loft (DSN: SGC/11/PGN_PRD; DB Info: Dev & Prd PGN)

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Ancestors By Percentage

Table "LINEBREEDING PC"

This bird has	this ancestor who appears			this many times	in this # of generations	with this genetic percentage.
00004647-AU-14-SHEW	00050444-AU-05-ARPU		VAN	1	1	50.0000
00004647-AU-14-SHEW	00070267-AU-07-SHEW		VAN	1	1	50.0000
00004647-AU-14-SHEW	08115173-NL-81	Super 73	[illegible]	24	9	31.4453
00004647-AU-14-SHEW	02436201-NL-01	Super Marco	VAN	1	2	25.0000
00004647-AU-14-SHEW	00000016-AU-97-GSF	Sweet 16	VAN	1	2	25.0000
00004647-AU-14-SHEW	00005953-AU-95-OHF	Java - He's Hot!	VAN	1	2	25.0000
00004647-AU-14-SHEW	00003395-AU-03-SHEW		VAN	1	2	25.0000
00004647-AU-14-SHEW	02501100-NL-87	De Marco	VAN	8	8	24.2188
00004647-AU-14-SHEW	02330440-NL-73	De Olieman	JV	20	9	16.7969
00004647-AU-14-SHEW	06365039-NL-77	Crackske		18	9	15.2344
00004647-AU-14-SHEW	00002778-AU-88-WWC	Super 2778	VAN	3	8	13.6719
00004647-AU-14-SHEW	00000647-895 DV 81	Giesela	VAN	9	9	12.8906
00004647-AU-14-SHEW	02591102-NL-98	Evita	VAN	1	3	12.5000
00004647-AU-14-SHEW	00001084-AU-96-GSF		VAN	1	3	12.5000
00004647-AU-14-SHEW	00004484-AU-96-FRC		VAN	1	3	12.5000
00004647-AU-14-SHEW	00000132-AU-88-AUTO		VAN	1	3	12.5000
00004647-AU-14-SHEW	00008303-AU-98-SHEW	Gold Mine	VAN	1	3	12.5000
00004647-AU-14-SHEW	00020163-AU-02-ARPU	Top Marco	VAN	1	3	12.5000

A Road Map for Genetic Improvement

3. For selection purposes, use only contemporary group test results (Contemporary Groups are groups of birds where the environmental factors for every member of the group are as equal as possible).
   - Loft results for YB and OB races (Combine wins are great for bragging rights and marketing, but useless for genetic selection)
   - Training tosses
   - One Loft Races
   - Your own Contemporary Group Tests

A Road Map for Genetic Improvement

4. Perform tough but fair tests. The ideal test is one where only one bird comes in first and is followed over a reasonable period of time with small drops, culminating in all (or at least most) of the birds coming home on the day.

- The worst possible test is a smash where no one comes home.
- The second worst test is where the vast majority of the birds come home in the first drop. (It would be an excellent result for YB or OB race or even a training toss but not for a test. A drop of 16 birds for example that score 1-16 in the club or combine speak highly of the handler, but it is really difficult to known whether you had 1 leader and 15 followers or even if you had a flock of 16 and no one bird capable of doing the same on their own.)

A Road Map for Genetic Improvement

5. Form your conclusions on patterns, not individual results. In general, don't treat anything as significant until you have three or more noteworthy results.

- Don't get attached to the pretty ones or the expensive ones or even the ones with a single win. If the results aren't repeatable, they probably aren't statistically significant from a genetic perspective.
- Two noteworthy results and you may have something.
- Three noteworthy results and you probably do.
- Multiple noteworthy results among relatives is the gold standard!

A Road Map for Genetic Improvement

6. Shoot to limit selection to top 2% or **1% if possible**

- Of course, not every bird you stock will be in the top 2%. There are many reasons for exceptions, just don't make these exceptions without well thought out and solid reasons.
- The message here is not to make it seem impossible, but to emphasize that most of the pigeons we produce and keep are not suitable for moving the flock forward, so be (much) more selective.

A Road Map for Genetic Improvement

7. When you get one of the 1% birds, know it is special and do everything you can to breed (and test) as many of its youngsters as you can. Avoid stocking without testing.

- For 1% cocks:
  - Polygamous breeding
  - Artificial Insemination – 300 youngsters a year possible from a single cock
- For 1% hens:
  - Foster off the eggs to pumper pairs
  - Breed to multiple cocks
- Repeat the mating that produced the bird and variations of the mating using relatives

A Road Map for Genetic Improvement

8. Birds selected for breeding (i.e. the top 2% of racers) have only passed the first test phase. We are really looking for birds that pass Phase 3 Testing:

- Phase 1 - Contemporary Group Testing/Competition.
- Phase 2 – Finding birds that breed the top 2% racers
- Phase 3 – Finding birds that breed birds that breed the top 2% racers.

A Road Map for Genetic Improvement

9. Use your tools as would a craftsman, not a hack:

- Inbreeding & linebreeding to selectively narrow the gene pool, then
- Outcrossing when progress has plateaued.
- Use crossbreeding to get an edge when racing (but know this is a disadvantage for breeding).
- Use DNA testing on your top performers to identify their genotypes for LDHA and DRD4.
- Have a goal. Make a plan. Execute the plan. Be Observant. Keep an open mind & listen to others, but think for yourself. Be honest with yourself. Look to improve.

Closing Thoughts

- Remember genes determine the potential. Environment limits how much of that potential is realized. As people get better and better at perfecting the environmental factors (condition, training, fuel, motivation, health and luck) genetics is the one remaining **but unlimited** area in which improvement can still be made.
- This was a crash course and covered way too much information to be absorbed in a few hours. Reread these slides again in a month. They will always be available at **www.shewmaker.com**.
- I have a group on Facebook called “Shewmaker Genetics” where I occasionally post useful information about genetics and pigeon racing. It is a public group so any racing pigeon fancier is welcome to join. We have fanciers from all over the world that are members.

Closing Thoughts

- Most Importantly -
  - Figure out what ***you*** are trying to accomplish and focus on that.
  - Remember it is a hobby and it is ***your*** hobby. Do it your way.
  - **Enjoy** the sport! Keep it fun for yourself and the rest of us. We all have enough stress at work.