Using Genetics to Breed Champion Racing Pigeons
利用基因技术培育冠军赛鸽的理论及应用

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The Rule of Seven 七种因素

- There are seven factors which determine how well you and your birds will perform in pigeon racing. 有七种因素会决定您和您赛鸽在比赛中的成绩。
- **One is beyond your control**. 其中一种因素您无法控制。
- **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. 在这项运动中，有五个完美无瑕，以至于它们实际上已经成为合格 / 不合格的产品。 您要么胜任地掩盖他们，要么甚至在比赛开始之前就已经从获胜位置中被淘汰。
- **One has almost no limit** to its potential and is **largely unrealized** by most fanciers. 七种一个因素对赛鸽的潜力几乎没有限制，而且大多数鸽友几乎没有意识到这一点。

The Rule of Seven 七种因素

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. 首先超出我们控制范围的因素就是运气。好运气，坏运气，老鹰，电线，风向，篮子在卡车上的位置，沿途的坏天气，沿途的好天气等等。这些影响着我们所有人，所以我们应该尽量克服，并继续做好我们能控制的事情。

2) **Condition** (pass/fail) 环境（通过 / 失败）

3) **Training** (pass/fail) 训练（通过 / 失败）

4) **Fuel (aka Nutrition)** (pass/fail) 能量供给（通过 / 失败）

5) **Motivation** (pass/fail) 动机（通过 / 失败）

The Rule of Seven 七种因素

6) **Health** (pass/fail though too many flyers are still failing on this one) 健康状况（通过 / 失败 尽管有很多赛鸽在这一点失败了）

7) **Genetics** 遗传因素

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.”

当 **Louis Van Loon** 被问到“你用什么方法来得到这些结果？他严肃地看着这位先生说：“记住这一点，只有一件事是重要的，那就是要有好鸽子。”

Moving On to Factor Seven (Genetics)
因素七：遗传

- While environmental factors will always play a major part in contributing to race performance, the **genetic component is both real and significant**. （尽管环境因素将始终在鸽子的比赛表现中发挥重要作用，但遗传因素既真实又重要。）
- Genetic progress **takes time, focus and effort**, but it is completely possible. 基因改良需要时间、精力和付出，但这是完全可以做到的。
- Breeders who seriously commit to genetic improvement now, have the potential to enjoy a sizable competitive advantage for years to come. 现在认真致力于遗传改良的育种者，有潜力在未来几年中获得巨大的竞争优势。

Racing Ability is Polygenic
赛鸽的竞翔能力由多个基因决定

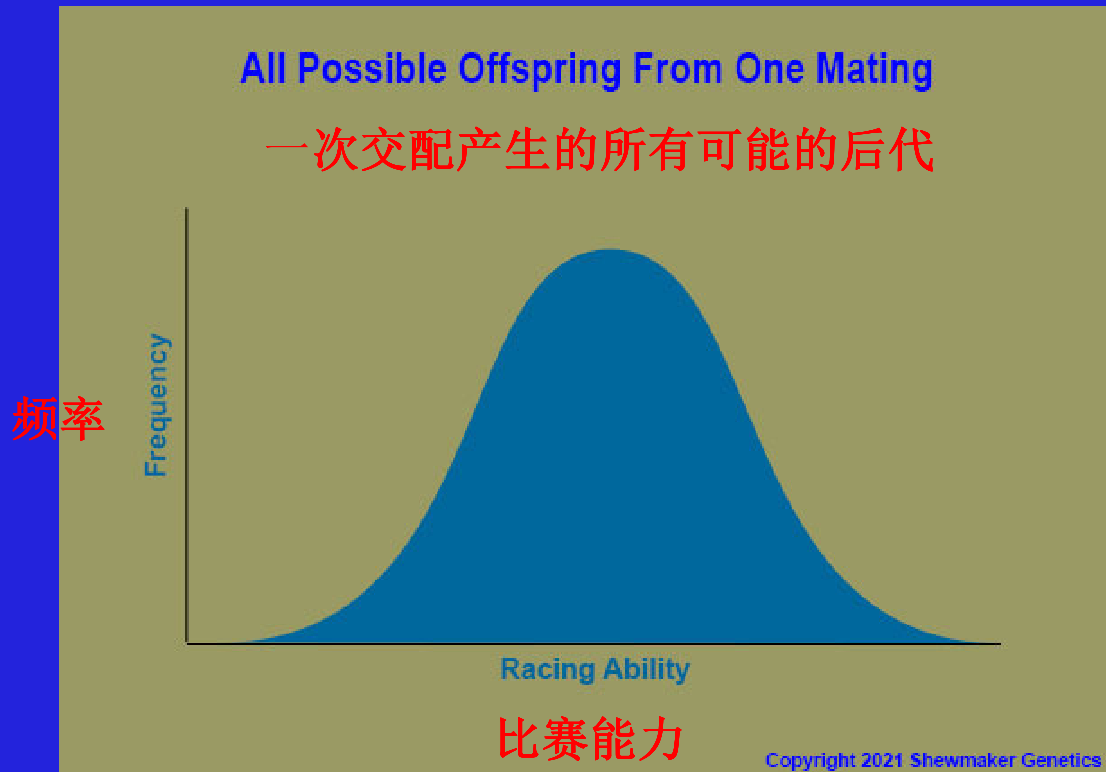
- Many fanciers are familiar with the Punnett Square for visualizing the possible outcomes of a particular mating. 许多鸽友对旁氏表都很熟悉，可以直观地观察到特定交配的可能结果。
- Here is a Punnett Square for a mating of a Blue Bar hen and a heterogygous Blue Check cock (where C is the allele for Check and + is the allele for Bar). 这是蓝条雌鸽和异形蓝格雄鸽交配的旁氏表（其中 C 是雄鸽的等位基因，+ 是雌鸽的等位基因）。
- On average 2 out of every 4 offspring will be Blue Bars and 2 will be Blue Checks. 平均而言，每 4 个后代中就有 2 个是蓝条，而 2 个是蓝格子。

Sire's sperm Dam's egg	C	+
+	+ C	+ +
+	+ C	+ +

Racing Ability is Polygenic
赛鸽的竞翔能力由多个基因决定

- However, there are many genes that influence racing performance (probably at least 100). 然而，影响竞翔成绩的基因有很多 (可能至少有 100 个) 。
- The visual representation of all possible offspring of a mating for a polygenic trait is a bell curve: 多基因性状交配的所有后代的表现可能是抛物线 :

Racing Ability is Polygenic 赛鸽的竞翔能力由多个基因决定

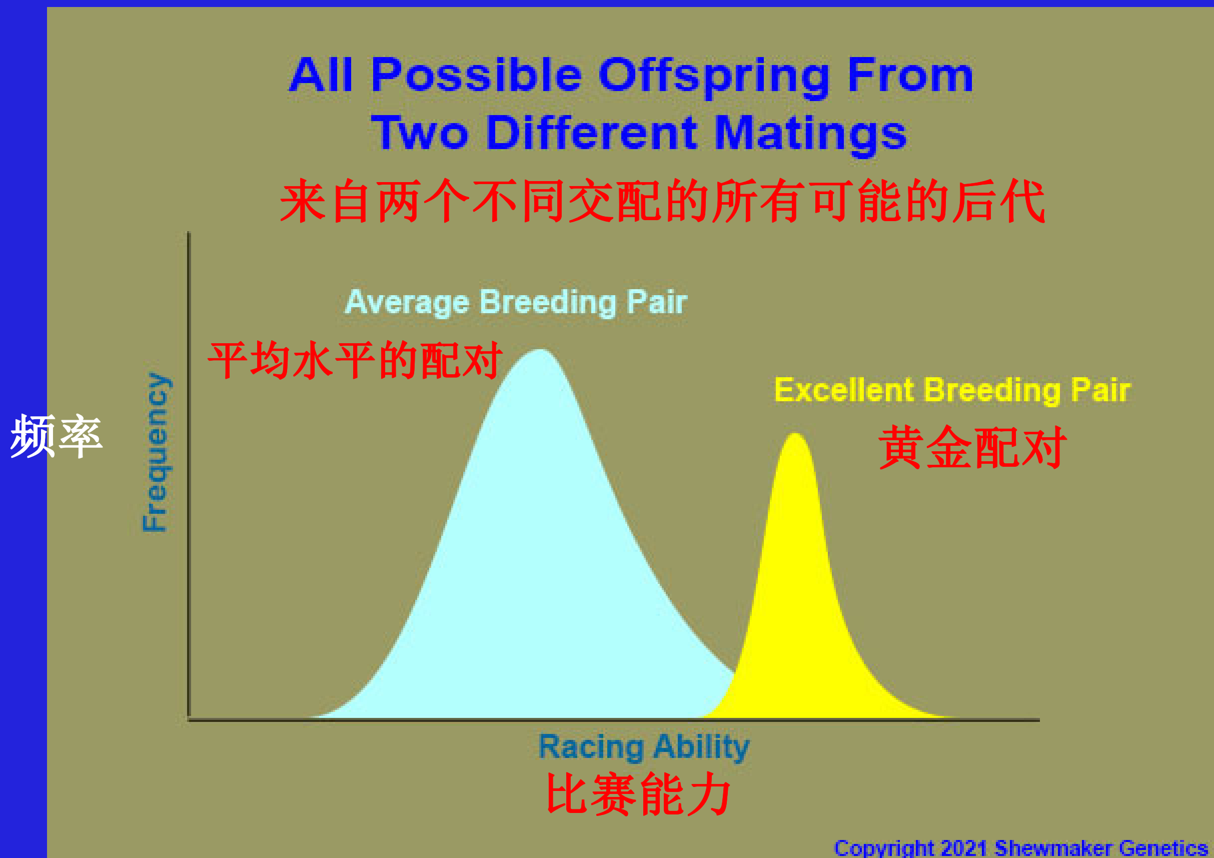


Even though two siblings have the same parents, there **can** be a significant difference in their racing ability, 即使两个兄弟姐妹有相同的父母，比赛能力和水平也会有很大的差异，

•AND there **can** be a significant difference in their genetic ability to pass racing ability on to the next generation. 同时它们的将比赛能力遗传给下一代的能力会有很大的不同。

Racing Ability is Polygenic 赛鸽能力的多基因性

Just as each individual pigeon has a unique genetic makeup, each mating has a unique bell curve of possible offspring. 就像每一只鸽子都有独特的基因组成一样，每一次交配所可能产生的后代都具有独特的钟形曲线。



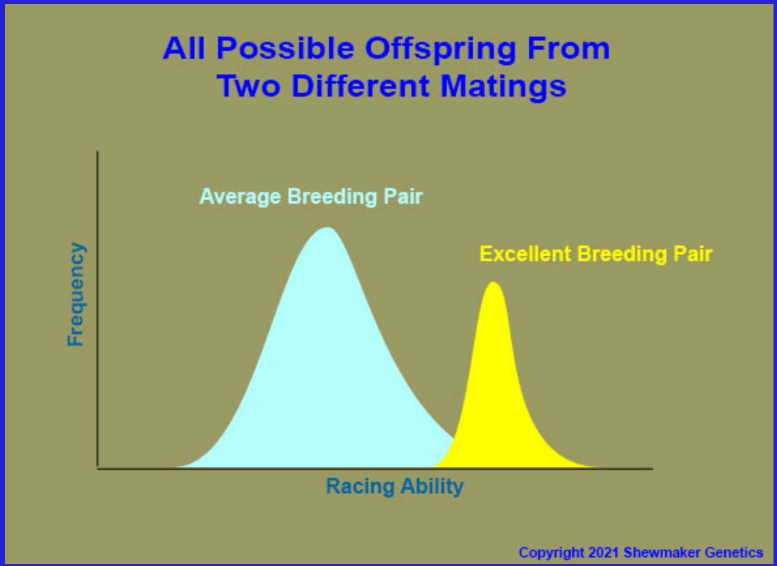
Racing Ability is Polygenic

These different bell curves vary in two important ways: 这些不同的钟形曲线以两种重要方式呈现：

- The **center** point of the curve gives us an indication of the average racing ability for that particular mating. 曲线的中心点为我们指明了该特定交配的平均比赛能力
- The **width** of the curve is an indication of the uniformity of the offspring produced: 曲线的宽度表示所产生后代的均匀性：

A mating with a wide curve produces a **diverse** set of offspring that have great variation in their racing ability. 曲线较宽的交配会产生多种后代，这些后代的比赛能力差异很大。

- A mating with a narrow curve produces offspring that are more **similar** in their racing ability. 而曲线较窄的黄金配对所产生子代的比赛能力更加相似。



Genes Affecting Racing Ability 基因影响其飞行能力

While we can not currently identify all of the specific 100 or so genes that influence racing performance, we can group them into several functional traits that we can relate to race performance.

尽管目前我们无法确定所有能够影响成绩的 **100** 多个特定基因，但我们可以将它们分为与比赛表现相关的几个功能性状。

These traits are shown on the next slide. 这些特性将在下一张幻灯片中显示。

Notice that seven of the eight can not be evaluated by “grading” or handling of the pigeon. Only Number 2 is related (at least partially) to physical qualities that might be successfully evaluated by “grading”. These would include feather quality, wing structure, muscle structure and so on. 要注意，八个特性中有七个特征不能单纯对鸽子进行“评分”或评估。 只有第二个特性（至少部分的）与身体素质有关，可以通过“评分”来进行评估。 包括羽毛质量，翅膀结构，肌肉结构等。

As much as we might think that perfect conformation is all that is needed for a champion racer, the reality is that (while conformation certainly helps), it is but a small portion of all that is important. 尽管我们可能认为完美的构造是赛鸽比赛所需要的一切，但事实是（虽然构造确实有帮助），它只是所有重要构造中的一小部分。

Genes Affecting Racing Ability 影响比赛能力的基因

There are several distinct traits which positively influence racing performance. All of these traits are strongly influenced by the environment, but they also have a significant genetic component. Winning birds have the:

有几个明显的基因特征会影响比赛表现。 所有这些特征当然都受会到环境的强烈影响，但它们也具有重要的遗传成分。获奖赛鸽具有以下特性：

1) **ability to orient** quickly at the time of release AND maintain the proper orientation on the flight home. 放飞后能够快速定向，并在返航时保持正确的定向能力。
2) **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. 具有与其他赛鸽竞争的飞行速度和持续飞行的能力。例如，许多短距离赛鸽就没有参加长距离比赛的能力。
3) **desire to want to get home quickly** (as opposed to just plodding along until they get there). 渴望尽快回家（而不是步履蹒跚地走到家）。
4) **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). 具有解决在某些比赛中出现的不可避免的挑战的智力（强风或风暴会破坏鸽群并将其吹离航线）。

Genes Affecting Racing Ability 影响比赛能力的基因

There are several distinct traits which positively influence racing performance. All of these traits are strongly influenced by the environment, but they also have a significant genetic component. Winning birds have the: 有几个明显的特征会影响比赛表现。 所有这些特征都受到环境的强烈影响，但它们也具有重要的遗传成分。获胜赛鸽具有以下特性：

5) **ability to learn** from their experiences and their mistakes. 从经验和错误中学习的能力。

6) **mindset of a leader** as opposed to that of a follower (which is somewhat at odds with their normal gregarious nature). 具有一个领导者的心态，而不是一个追随者的心态（这与他们通常合群的天性有些矛盾）。

7) **willingness to take risks** such as starting for home before the pack is ready or to break from a group during the race. 愿意冒险，比如在队伍准备好之前就出发回家，或者在比赛中从队伍中脱离出来。

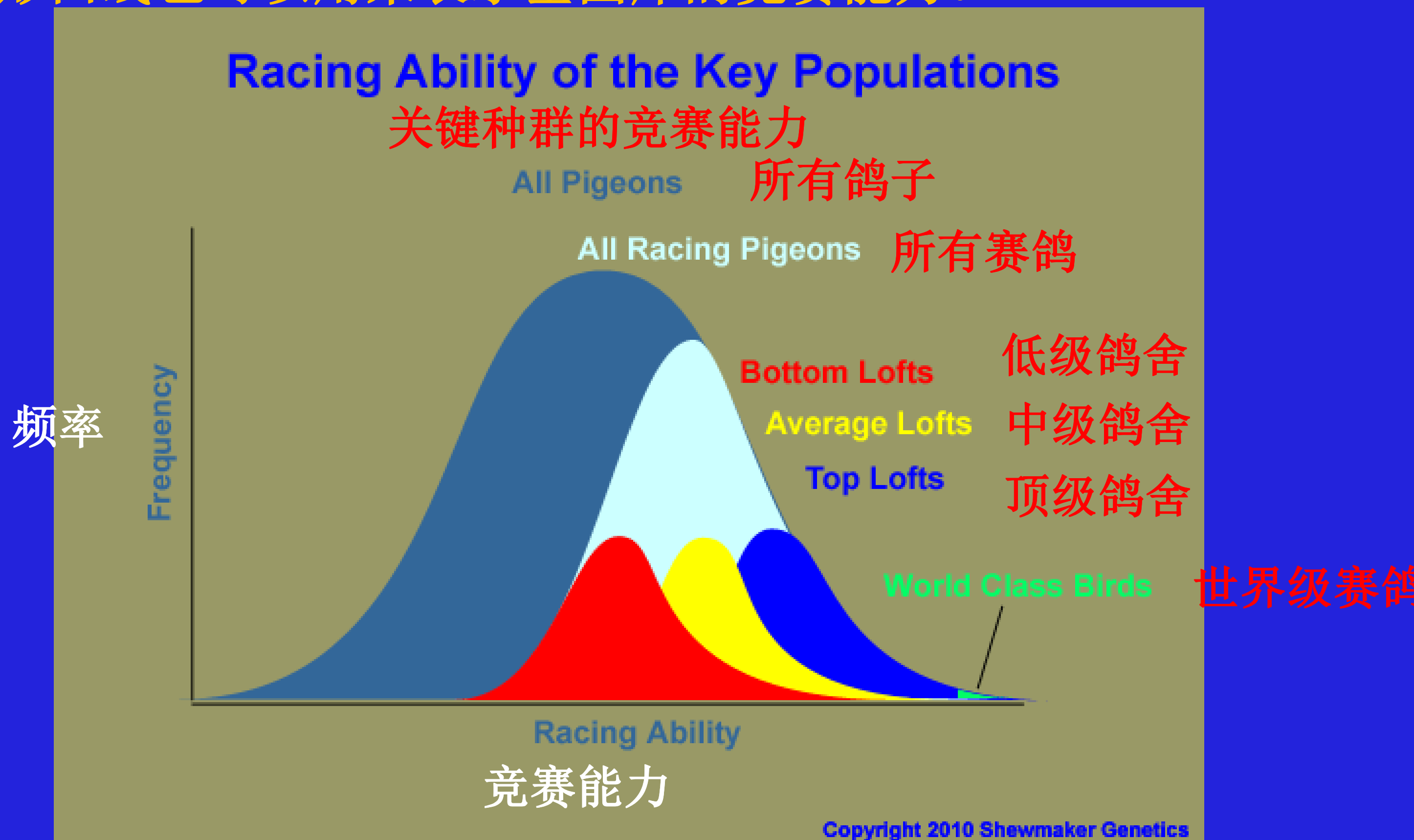
8) **strongest possible homing instinct** so that they return home even on races where they don‘t place (birds that come home after disasters are able to race another day!) 强烈的归巢本能使它们即使在没有归宿的地方也能回到家中（灾难过后回到家中的鸽可以改天再比赛！）

Manage the Gene Pool 管理赛鸽的基因库

- Understanding genetics can be challenging. 搞懂遗传学具有挑战性。
- Many people get lost in the minutia of the details - DNA, genes, alleles, cross over, mutations and the like. 很多人都迷失在细节中—— DNA 、基因、等位基因、杂交和突变等等。
- While such details are indeed import, 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. 尽管这些细节确实是重要的，但了解全局更为重要。要记住，了解手表的工作原理是很好的，但大多数人只需知道如何报时就可以得到更好的服务。
- 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 *population* of racing pigeons – specifically those in your loft. 一般来说，不要从单个基因、单个染色体甚至单个鸟类的角度来考虑。任何事情都应该从赛鸽数量的角度来考虑——特别是那些在你的鸽舍里的鸽子。
- Focus on managing the **gene pool** in your loft. 集中精力管理你鸽舍里鸽子的基因库。

Manage the Gene Pool

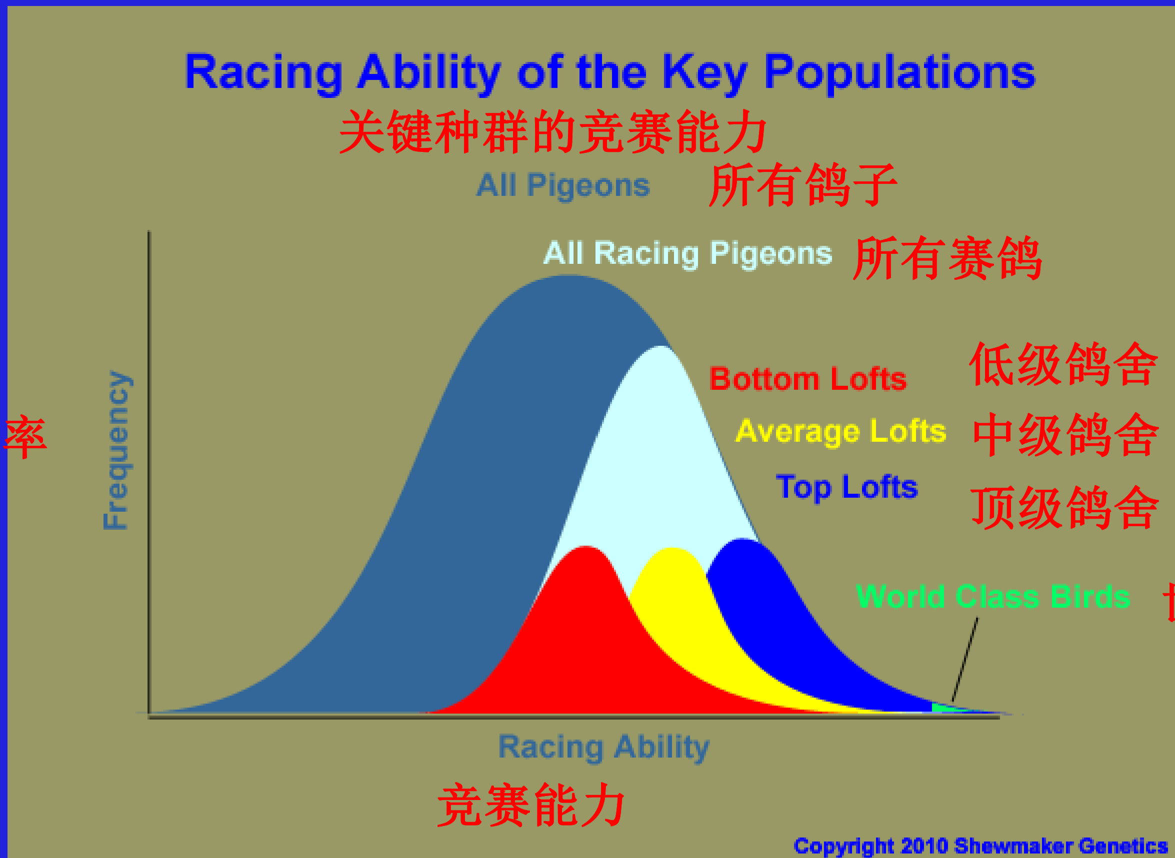
- The bell curve can also be used to represent the racing ability of a gene pool. 钟形曲线也可以用来表示基因库的竞赛能力。



- The next five slides are the most important of the whole seminar.

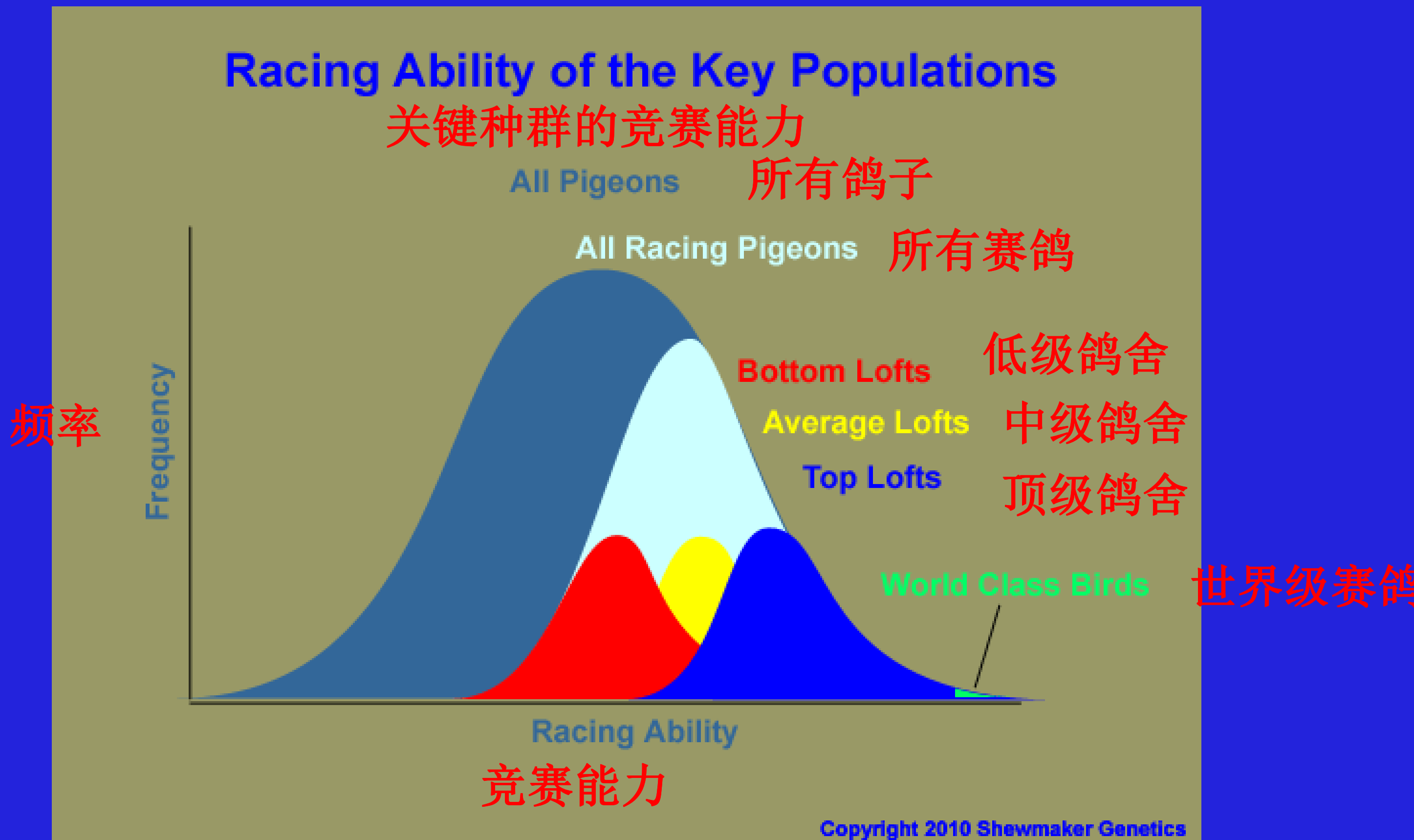
接下来的五张幻灯片是整个报告中最重要的内容。

Manage the Gene Pool



- 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. 要注意，"低级鸽舍"和大多数"中级鸽舍"甚至可能没有繁育世界级赛鸽所需的基因。

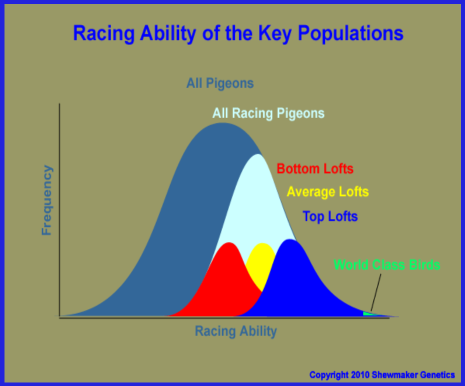
Manage the Gene Pool



- 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.

但也请注意，在“顶级鸽舍”中，很少有“世界级赛鸽”，许多类似鸽舍的水平都与“低级鸽舍”和“中级鸽舍”相当。

Manage the Gene Pool



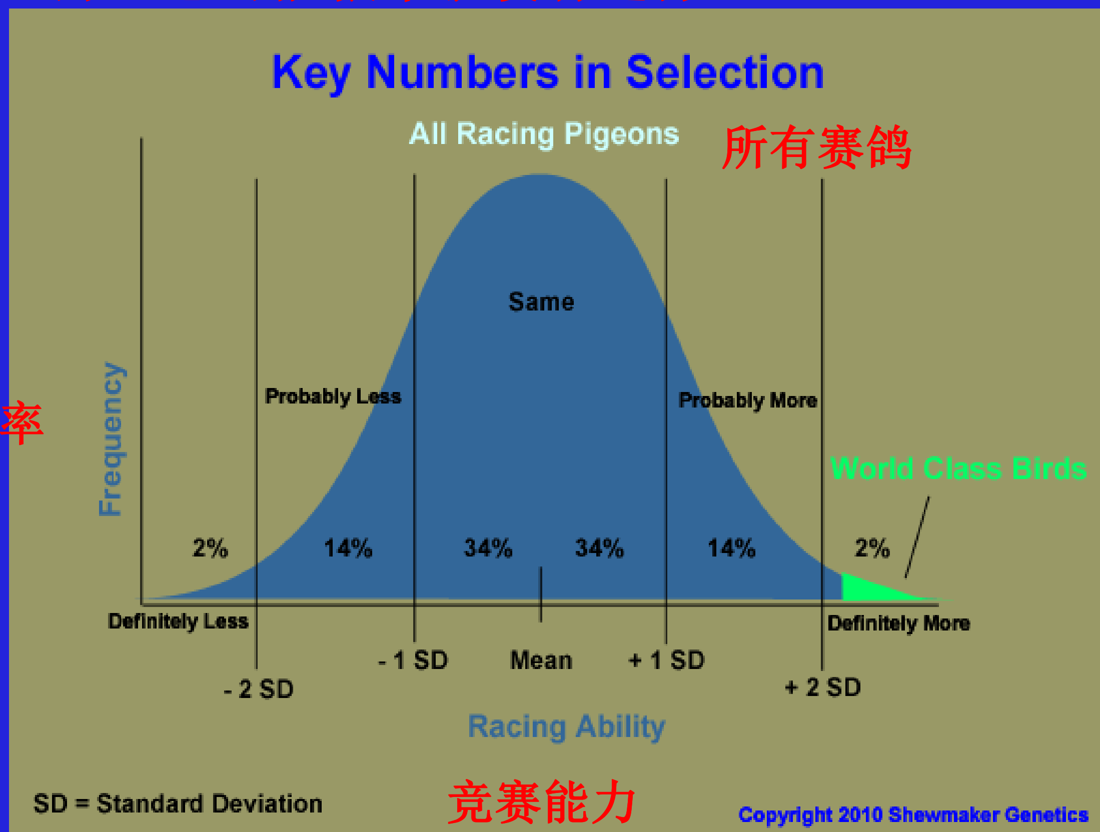
Here is the hard cold fact – most of our pigeons are not genetically up to our assumptions and expectations. 这是一个冷酷的事实——我们大多数的鸽子在基因上都不符合我们的假设和期望。

•***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. 如果你拥有"顶级鸽舍"和几羽"世界级赛鸽"，那么可能只会产生十分之一的顶级鸽子，应该用于育种下一代。

•If you are in the "Average Loft" category truly outstanding birds are 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. 如果是在"中级鸽舍"类别中，真正优秀的鸽子可能接近百分之一，而在"低级鸽舍"接近千分之一，甚至万分之一。

Manage the Gene Pool

- If you aren't selecting your breeders from at least the top 16% *<u>you probably aren't selecting at all</u>*. 如果你没有从至少前 16 %的赛鸽中选择育种者，那么您可能根本就没有选择。



频率

世界级赛鸽

- **If you really want to make progress you need to be selecting at least from the top 2%**. 如果你真的想取得成功，你需要至少从前 2% 中选择。

Manage the Gene Pool

- **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. 要明白这一点：从前 2% 的信鸽中挑选出来的后代都有自己的钟形曲线。虽然这条新的钟形曲线的中点很可能会右移，但它不会只包括那些和你选择的 2% 一样优秀的信鸽。新的钟形曲线很可能会延伸到（甚至超越）普通范围。
- 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. 如果你选择育种的 2 %的信鸽确实是非常好的种鸽，那么他们最多只能生产十分之一的优秀种鸽，这足以让你的鸽舍繁育继续下去。
- So, an untested breeder “Bred for Stock” has at least a 90% chance of being a mistake. Stock untested youngsters from a pair of “bred for stock” breeders and the odds the wrong ones were selected jumps to at least 99%. 因此，一个未经测试的“为优良基因库而繁育”的育种者至少有 90% 的错误几率。从一对“为优良基因库而繁育”的育种者中选出未经训练的幼仔，选错幼仔的几率跃升到至少 99% 。
- 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). 对于“为优良基因库而繁育”的这种做法有它的风险，应该小心管理 (如跟踪测试产生的后代，以确认留种是否正确) 。

The Progress Equation

- Your ability to make genetic progress and the speed at which you make this progress is **absolutely** related to these four factors (*memorize this slide*!): 获得遗传改良和速度的能力与以下四个因素有关（请记住这张幻灯片！）：
  - The **accuracy** of your selection 筛选的准确性
  - The **intensity** of your selection 筛选的强度
  - The **time** interval over which you do the selection 筛选的时间间隔
  - The **frequency** of the desired alleles in your gene pool 基因库中所需等位基因的频率

The Progress Equation

- The **accuracy** of your selection 筛选的准确性
  - *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.* 因此，如果你认为脚趾颜色与出色的比赛能力有关，而这正是你选择脚趾颜色的原因，那么你可能没有根据比赛能力进行任何选择。在我看来，最准确的选择标准是（很大范围内）是同一鸽舍赛鸽的比赛结果。没有什么比这更接近了。
- The **intensity** of your selection 筛选的强度
  - *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%.* 从前 16% 中选择的鸽子远没有从前 2% 中选择的激烈得多，而从前 2% 中选择也远没有从前 1% 中选择激烈得多。
- The **time** interval over which you do the selection 进行选择的时间间隔
  - *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* 一季的选择是不够的，但两三个会让你大吃一惊。但是每隔几年就换一个流行的新品种 (或一个新的家庭)，这将阻断遗传改良的进程。
- The **frequency** of the desired alleles in your gene pool

  基因库中所需等位基因的频率
  - *The desired alleles must actually be in the gene pool of your loft*

    所需的等位基因必须存在于鸽舍的基因库中

The Progress Equation

- Progress = (accuracy)(intensity)(time)(frequency)
  进展 = （精度）（强度）（时间）（频率）
- If you want to **increase** the speed of the genetic progress in your loft, you need to increase one or more of these four factors.
  如果要提高鸽舍遗传改良的速度，则需要增加这四个因素中的一个或多个。

If you **decrease** one, you will have to increase one or more of the others just to maintain the rate of your current progress. 如果你减少了一个，就将不得不增加一个或多个其他的因素来保持你当前的水平。

If any of these factors equals **zero**, you will make zero progress.
如果这些因素中的任何一个等于零，就不会取得任何进展。

- The **accuracy** of your selection 筛选的准确性
- The **intensity** of your selection 筛选的强度
- The **time** interval over which you do the 筛选的时间间隔
- The **frequency** of the desired alleles in your gene pool
  基因库中所需等位基因的频率

The Progress Equation

- Revisiting our “Bred for Stock” discussion, stocking the wrong bird means your selection accuracy was zero. 再来看看我们关于“为优良基因库而繁育”的讨论，如果你养错了鸽子，那就意味着你的选择精度为零。
- So while you got the wrong bird, the bell curve for your population would not likely have shifted (i.e. you were neither selecting for or against the desired alleles). 所以，当你选错鸽子的时候，你的种群的钟形曲线不太可能发生变化（你既没有选择合适的等位基因，也没有选择不合适的等位基因）。
- 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. 如果你对计划中繁殖了过多的“为优良基因库而繁育”的鸽子而感到困惑，请意识到关键的等位基因可能仍然在你的基因库中，只是不在一只鸽子中，也没有我们试图达到的高频率。
- 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). 要纠正这种错误，需要对所有幼鸽进行测试，并只保留最好的幼鸽（我的建议是前 2 %）。

The Progress Equation

- •Revisiting our “Bred for Stock” discussion (continued) ...
再次回顾我们关于“为优良基因库而繁育”的讨论(续)……
- •Realize though that in a small loft, low frequency alleles can be lost from the gene pool through non-selection events such as race losses and deaths. 但要知道，在一个小鸽舍里，低频率的等位基因可能会在非筛选事件中失去，比如比赛失败和死亡。
- •For this reason, it is critical to avoid scenarios where selection accuracy is very low or zero. 因此，避免出现选择准确率很低或为零的情况至关重要。
- •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. Such a 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 “Bred for Stock” birds. 如果想从发生过多“为优良基因库而繁育”的鸽舍中收购鸽子，那就不要只收购一两只鸽子。这样的基因库样本可能不足以捕获所需的等位基因。与一两个高价位的“为优良基因库而繁育”鸽子相比，购买一组由 10 只相对较便宜的鸽子组成的群体将是一个更好的主意。

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. 让我们来看一个例子。我们将大大减少繁殖时间，以便 (迅速) 看到一个显著的时间间隔 (即 7 代) 是如何在达到繁殖目标方面带来巨大进步的。
- 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 where I get my test birds out to 60 miles by 60 days of age. 我对这个例子的了解使我在种鸽比赛中拥有了巨大的优势。 这让我有勇气去相信方程式进度，去完成我的“ 60×60” 计划，在这个计划中，我的测试鸽子到 60 天龄时可以达到 60 英里。
- 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. 作为鸽子育种者，我们通常将一年作为一代。因此我们要花多长时间才能培育出一只幼鸟，并使其成长到可以繁殖的年龄。
- Bacteria under ideal laboratory conditions have a generation time of about 20 minutes! 细菌在理想的实验室条件下产生复制一代的时间约为 20 分钟 !
- 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. 这意味着一天 24 小时内，一个细菌种群可以繁殖 72 代 ! 这比大多数鸽子一生能繁殖的后代还要多。

The Progress Equation – A Powerful Example

- For this example, we are going to breed some bacteria just like we breed our pigeons. 在这个例子中，我们要繁殖一些细菌就像我们繁殖鸽子一样。
  - 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. 就像鸽子一样，我们要有一个育种目标，并牢记这一目标来选择下一代育种者。 然后继续繁育七代，以便我们了解方程式进度的工作原理。
  - Breeding Objective: Breed a line of bacteria that is resistant to an antibiotic. 育种目标：培育对抗生素有抗药性的细菌。
  - First some basics about growing and breeding bacteria!

首先是一些关于细菌生长和繁殖的基础知识！

The Progress Equation – A Powerful Example

•This is what a sterile petri dish with no bacterial growth looks like. It is clear and transparent:
这是一个没有细菌生长的无菌培养皿。表明清晰透明：

•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:
这是在培养皿上散布 3 亿个细菌并孵育过夜后的样子。表面覆盖白色涂层，不透明：

•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: 如果我们只在培养皿中放置 8 个细菌并培养过夜，它就会像这样有 8 个白色斑点。每个斑点都是一个由数百万细菌组成的菌落，它们都是最初放置在那个位置的细菌的后代：

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. 现在让我们取一种细菌溶液 (第 0 代) 和一种低浓度抗生素溶液混合。
- Lets then put about 300 million bacteria from this mixture on a sterile petri dish and incubate it overnight. 然后我们把混合物中的 3 亿个细菌放在无菌培养皿中，培养一夜。
- 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. 第二天，我们将看到少数菌落。 这些菌落（第 1 代）均来自突变的细菌，该突变使其对低浓度的抗生素具有抗性。

You will notice that in this example that we are exercising extreme **selection intensity** (8 or so out of 300 million). 你会注意到，在这个例子中，我们正在进行极端的选择强度 (3 亿中选 8 个左右)。

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. 现在让我们拿一个无菌仪器，把它放在第 1 代菌落上，然后在无菌培养基中旋转。将接种过的培养基孵育过夜。
- This time instead of a weak antibiotic solution we are going to add an antibiotic solution that is 10X stronger to the bacterial solution. 这次，我们将添加比细菌溶液强 10 倍的抗生素溶液，而不是低浓度抗生素溶液。
- Repeat the earlier process by placing about 300 million bacteria from this "generation 1" solution on a sterile petri dish and incubate it overnight. 重复前面的过程，将"第 1 代"溶液中的约 3 亿细菌置于无菌培养皿中，然后将其孵育过夜。
- 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 likely arose at some point during the previous incubation period when billions of cell divisions occurred. 第二天我们将再次看到少数菌落。每个菌落 (第 2 代) 都是由一种突变的细菌产生的，这种突变使其对更强的抗生素产生了抗药性。这种突变可能是在前一个潜伏期的某个时间点出现的，并在当时发生了数十亿次细胞分裂。

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. 再重复此过程 5 代（每个周期将抗生素的浓度提高 10 倍），将得到一个有多个菌落的培养皿，每个菌落均对抗生素具有 100 %的抗性。
- There is a wonderful video from the the Harvard Medical School which demonstrates this example with a slightly different (but much more eloquent) setup 哈佛医学院有一段很棒的视频，它用一个稍微不同（但更有说服力）的试验来演示这个例子。

www.youtube.com/watch?v=plVk4NVIUh8

- What have we learned? 我们从中学到了什么呢？

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. 在我们的筛选中使用高水平的精确性和强度，仅用了 7 代就取得了显著的结果。
- The **accuracy of our selection** was pretty clear – the bacteria were exposed to the antibiotic and if they were susceptible, they died. 对于选择的准确性十分明确——细菌暴露在抗生素下，如果他们对抗生素敏感，就会死亡。
- The **selection intensity** was extreme (8 or so out of 300 million). 筛选强度极高（3 亿个中的 8 个左右）。
- This example dramatically illustrates how genetic progress is indeed a function of accuracy, intensity, time and frequency. 这个例子生动地说明了遗传改良的确是准确度，强度，时间和频率的函数。
- It also underscores the importance of selection accuracy, selection intensity and allele frequency since there isn‘t that much we can do to change the time interval available to each of us. 这也强调了筛选准确性，筛选强度和等位基因频率的重要性，因为我们没有太多办法去改变时间间隔。

Know Your Goals and Objectives 清楚目标

- There are many ways to breed champion racing pigeons. No one way is necessarily better than another. 有很多种方法可以繁育冠军赛鸽。没有哪一种方法一定比另一种更好。
- It is more of a question as to what are your goals and objectives and what is the best way to meet them. 问题更多的是你的目的是什么，实现它们的最佳方式是什么。
- The successful breeder has very specific end points in mind and a well thought out plan for getting there. 成功的繁育者有着非常明确的目标和经过深思熟虑的计划。
- The successful breeder does not randomly buy good birds every year and then randomly mate them, hoping to win some races. 成功的育种者不会每年随机购买好鸽子，然后随机交配，希望去赢得一些比赛。
- One of the key objectives a breeder must resolve in their mind is this - do they want to breed that **one in a million** great racing bird or do they want to breed **many** very good racing birds? 育种者必须解决的一个关键目标是——他们是想繁育出百万分之一的赛鸽，还是想繁殖许多优秀的赛鸽？

Know Your Goals and Objectives

- A **gene pool with a narrow bell curve** will tend to
  具有窄钟形曲线的基因库将倾向于：
  - produce a crop of offspring that are more **uniform** in their racing ability, but at the same time,
    繁育出的后代在比赛能力上更加统一，但同时，
  - this **lack of variation** makes it less likely that the pool will produce those extremely exceptional racers that represent the far right of the bell curve for the population of "all racing pigeons". 这种基因多样性的缺乏，使得这个基因库中不太可能产生那些极其出色的赛鸽（代表"所有赛鸽"的钟形曲线中的极右部分）。
- A **gene pool with a wide bell curve** will tend to
  具有宽钟形曲线的基因库将倾向于
  - produce a crop of offspring with much more variation in their racing ability (compared to the narrow pool) and
    产生的后代在其比赛能力上有更多的变化（与较窄的基因库相比），并且
  - the good ones might be better, they will be fewer in number. 好的可能会更好，但数量会更少。

The Basic Tools 基本方法

1) "Contemporary Group" data "当代群体"数据

- Only race and test data from flights to the same loft should be used for genetic evaluation. This normalizes environmental influences. 仅将来自同一鸽舍且飞行中赛鸽的比赛和测试数据用于基因评估。以排除环境影响。
- Use relative measurements such as percentiles and not absolute measurements such as speed or race position.
  使用相对测量值，如百分位数，而不是绝对测量值，如速度或比赛位置。
- Value birds with multiple instances of notable race performances. 关注具有多项出色比赛成绩的赛鸽。
- Value birds whose relatives also performed well.
  重视其亲戚也表现出色的鸟类。

The Basic Tools 基本方法

2) **Inbreeding and linebreeding** (a form of inbreeding) 近亲繁殖和血系繁殖（近亲繁殖的一种形式）

- Used to concentrate desirable alleles and narrow a gene pool. 用来集中理想的等位基因并缩小基因库。
- Testing and strict culling are particularly important when inbreeding. 近亲繁殖时，测试和严格的选育尤为重要。

3) **Outcrossing** 远亲繁殖

- Used to add specific alleles to the pool or
  用于将特定等位基因添加到库中或
- to increase diversity when progress has plateaued.
  在进展趋于平稳的情况下增加基因多样性。

4) **Crossbreeding** 杂交繁育

- Used to get an edge when racing by maximizing vitality
  在比赛中通过最大化活力获得优势
- Crossbred birds should not normally be put in the breeding program. 杂交鸟通常不应该被放入繁殖计划中。

The Basic Tools 基本工具

5) **DNA testing** for performance alleles 等位基因的 DNA 检测

- Used to increase the frequency (ultimately to 100%) of the desirable alleles of certain genes affecting race performance (LDHA and DRD4 as of right now). 用于增加某些理想等位基因的频率（最终达到 100 %），这些基因会影响比赛表现（截至目前为 LDHA 和 DRD4 ）。
- While potentially very important, LDHA and DRD4 represent just 2 of the approximately 100 genes that influence race performance. Fanciers should be careful not to place an unreasonably heavy emphasis on these 2 genes at the expense of the other 98. 虽然 LDHA 和 DRD4 可能非常重要，但它们仅代表影响比赛表现的大约 100 个基因中的 2 个。爱好者们应该小心，不要过分关注这两个基因，而牺牲了其他 98 个基因。
- The subject of LDHA and DRD4 testing is examined further in an appendix to this presentation.

对于 LDHA 和 DRD4 的这部分内容将在本报告的附录中进行进一步的探讨。

The Basic Tools

6) Artificial Insemination 人工授精

- Semen can be collected and frozen allowing us to preserve the genetics of the very elite long after their natural reproductive life is over. 精液可以被收集和冷冻，这样我们就可以在这些精英赛鸽自然生命结束的后很长时间内保存他们的基因。
- Semen can also be collected and frozen from race team cocks during and between race seasons. This is huge. 在赛季之间以及比赛期间，也可以从比赛的雄鸽身上收集并冷冻精液。 这十分重要。
  - 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 它能让我们在继续信鸽竞赛和收集数据的同时，保存这些精英鸟类的基因。在过去，我们常常不得不在训放和比赛之间作出选择，
  - stocked too early before their true racing value was accurately established, or
    这导致一些信鸽要么在准确确定其真正的比赛价值之前被过早的冻存精液，

  sent to one too many races wherein a valuable bird was lost.
  要么被送往多场比赛中，而失去了一只有价值的赛鸽。

The Needed Next Step 展望

- The sport of pigeon racing has been dramatically evolving in recent years to include many large one loft races.
  赛鸽运动在最近几年有了很大的发展，包括许多大型的赛鸽比赛。
- These races offer a unique opportunity for genetic improvement:
  这些比赛为遗传改良提供了独特的基因改良机会：
  - The birds entered into a one loft race are a good contemporary group so that the race results largely represent genetic data somewhat reasonably normalized for environmental influences. 参加一次鸽舍比赛的鸽子是一组很好的同辈鸽群，因此比赛结果在很大程度上代表了排除环境影响后的遗传数据。
  - If these large one loft races were to require a one generation pedigree for each bird entered into the race and
    如果这些大型的鸽舍比赛要求每只进入比赛的信鸽都有一代的血统
  - if an organization were to gather this data from all or many of these large one loft races, 如果一个组织要从所有或许多大型鸽舍竞赛中收集这些数据，
  - it would be possible to identify the top breeding cocks and hens in the sport. 那么在这项运动中就有可能鉴别出最优秀的繁育雄鸽和雌鸽。
- It is long shot given the amount of work and cooperation that would be required, but it is intriguing to consider the possibilities! 考虑到需要进行大量的工作和合作，这是遥不可及的，但是考虑到各种可能性还是很有趣的！

A Road Map for Genetic Improvement 基因改良路线

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 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. 建立一个合适的基因库。但不要认为你必须去买新的信鸽。虽然我们可能都需要剔除大部分基因，但赛鸽的基因库非常丰富，除非你进行了一个公平的测试，否则你真的不能说你没有合适的基因。
2. Roll, roll, roll the dice!!! 掷，掷，掷骰子!!
   - If the genes are in the pool, your job is to assemble them all in one bird. 如果基因库中有这些优秀基因，你的工作就是将它们全部整合到一羽鸽子身上。
   - Breed, test and cull until you get one. Then do it again to get another one. 繁殖，测试和筛选，直到你得到一个。然后再来一次，再来一次。
   - Change the matings and do it again. 改变配对方式，再来一次。
   - Use linebreeding to try to concentrate the genes of elite birds. 利用品系育种来集中优良赛鸽的基因。

A Road Map for Genetic Improvement 基因改良路线

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). 出于筛选的目的，只使用同辈群体测试结果（同辈群体是指群体中每个成员的环境因素尽可能相等的信鸽群体）。

   - **Loft** results for Young Bird and Old Bird races (Combine wins are great for bragging rights and marketing, but useless for genetic selection) 幼鸽和成年鸽比赛的鸽舍成绩 (组合获胜有利于炫耀和营销，但对基因选择毫无用处)
   - Training tosses 投掷训练
   - One Loft Races 鸽舍比赛
   - Your own Contemporary Group Tests 同辈群体测试

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.

进行严格但公平的测试。理想的测试是，只有一只鸽子先进来，然后在一段合理的时间内跟随其后又有几只降落归巢，最终所有 (或至少大部分) 当天归巢。

- The worst possible test is a smash where no one comes home.
  最糟糕的测试结果是没有鸽子归巢。
- 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.) 第二糟糕的结果是绝大多数鸽子第一次降落就归巢。（这对于 YB 或 OB 比赛，甚至是投掷训练都是一个很好的结果，但对于测试却不是。举例，在团体或组合中得分为 1-16 的 16 只鸽都获得训练员高度评价，但很难知道你是否有 1 个领队和 15 个追随者，或者即使你有 16 只，但没有一羽能够独立完成同样的任务）

A Road Map for Genetic Improvement

5.Form your conclusions based on patterns, not individual results. In general, don't treat anything as significant until you have three or more noteworthy results. 根据标准形式而不是个别结果来得出你的结论。一般来说，在你有三个或更多值得注意的结果之前，不要把任何事情视为是重要的。

- 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. 不要迷恋那些漂亮的，昂贵的，甚至是只赢了一场比赛的赛鸽。如果结果是不可重复的，那么从遗传学的角度来看，它们可能在统计学上并不显著。
- Two noteworthy results and you may have something. 两个值得注意的结果，你可能会有所收获。
- Three noteworthy results and you probably do. 三个值得注意的结果，你可能会这么做。
- Multiple noteworthy results among multiple relatives is the gold standard! 多个同类之间的多个值得注意的结果才是黄金标准！

A Road Map for Genetic Improvement

6.Shoot to limit selection to top 2% or **<u>1% if possible</u>** 如果可能的话，将选择范围限制在 2% 或 1%

- 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. 当然，并不是你所饲养的每羽鸽子都排名前 2 %。 例外的原因有很多，只是没有经过深思熟虑和扎实的理由就不要发生这些例外。
- 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. 这里主要是强调，我们生产和饲养的大多数鸽子都不适合推动鸽群的改良和进步，所以要 (更) 有筛选性。

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. 当你得到那 1% 的鸽子之一时，要知道它是特别的，要竭尽所能繁育 (测试) 尽可能多的幼鸟。避免在没有测试的情况下放养。

- For 1% cocks: 对于 1% 的雄鸽：
  - Polygamous breeding 一夫多妻育种
  - Artificial Insemination – 300 youngsters a year possible from a single cock 人工授精 – 单只雄鸽一年可以繁育 300 只幼鸽
- For 1% hens: 对于 1% 的雌鸽：
  - Foster off the eggs to pumper pairs 培养卵细胞
  - Breed to multiple cocks 繁育多只雄鸽
- Repeat the mating that produced the bird and variations of the mating using relatives 重复产生近亲鸽的交配，并利用近亲交配产生变异

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: 被选中进行繁育的赛鸽（即赛鸽中前 2 %）仅通过了第一个测试阶段。 我们需要寻找能通过第三阶段测试的鸟类：

- Phase 1 - Contemporary Group Testing/Competition.

  第 1 阶段 - 当同辈群体测试 / 竞赛。

- Phase 2 – Finding birds that breed the top 2% racers

  第 2 阶段 - 寻找能繁育出前 2% 赛鸽的鸽子

- Phase 3 – Finding birds that breed birds that breed the top 2% racers. 第 3 阶段 - 寻找这些可以繁育出前 2% 的赛鸽

A Road Map for Genetic Improvement

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

合理运用这些技术：

- Inbreeding & linebreeding to selectively narrow the gene pool, then 通过近亲繁殖和血系繁殖来选择性地缩小基因库，然后
- Outcrossing when progress has plateaued. 当进展平稳时进行杂交。
- Use crossbreeding to get an edge when racing (but know this is a disadvantage for breeding). 在比赛时通过杂交来获得优势（但要知道这对繁殖不利）
- Use DNA testing on your top performers to identify their genotypes for LDHA and DRD4. 对表现最好的鸟进行 **DNA** 检测，以确定他们的 **LDHA** 和 **DRD4** 基因型。
- 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. 有个目标。制定一个计划。并执行计划。注意观察。保持开放的心态，倾听别人的意见，但要为自己着想。对自己诚实。期待改善。

Closing Thoughts 结束语

- 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. 要记住，基因决定了潜力。环境限制了这种潜力的实现程度。随着人们越来越善于完善环境因素(条件、训练、能量、动机、健康和运气)，遗传学是一个仍然可以改进但空间无限的领域。
- This was a crash course and covered way too much information to be absorbed in one sitting. Reread these slides again in a month. They will always be available at **www.shewmaker.com**. 这是一个速成班，涵盖了太多的信息，不能在一次会议上完全理解。可以一个月后再看一遍这些内容。它们将随时提供在 **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. 我在 **Facebook** 上有一个名为“ **Shewmaker Genetics**”的小团队，偶尔会在那里发布有关遗传学和赛鸽的有用信息。这是一个公共团体，所以欢迎任何赛鸽爱好者加入。我们有来自世界各地的爱好者。

Appendix: DNA Testing of LDHA and DRD4

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.
- 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.

Appendix: DNA Testing of LDHA and DRD4

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.

Appendix: DNA Testing of LDHA and DRD4

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**

Appendix: DNA Testing of LDHA and DRD4

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 significantly 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**.

Appendix: DNA Testing of LDHA and DRD4

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%**.

Appendix: DNA Testing of LDHA and DRD4

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.

Appendix: DNA Testing of LDHA and DRD4

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.

Appendix: DNA Testing of LDHA and DRD4

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.
- 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.

Appendix: DNA Testing of LDHA and DRD4

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.

Appendix: DNA Testing of LDHA and DRD4

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.

Appendix: DNA Testing of LDHA and DRD4

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!!!

Appendix: DNA Testing of LDHA and 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.

Appendix: DNA Testing of LDHA and 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.

Appendix: DNA Testing of LDHA and 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

Appendix: DNA Testing of LDHA and 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.

Appendix: DNA Testing of LDHA and DRD4

- Several of my friends and colleagues have said they think they lose a higher percentage of their DRD4-T young birds off the landing board during settling. Again, this makes sense if the mutant gene is associated with risk taking. These youngsters take the risk of flying off before they really know what they are doing.
- This suggests that when selecting for the desired DRD4 alleles, strong selection pressure for homing desire and ability should also be employed.

Appendix: DNA Testing of LDHA and 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.

Appendix: DNA Testing of LDHA and 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.

Appendix: DNA Testing of LDHA and DRD4

Lets look in more detail at the DRD4 genotypes

- HOWEVER, Genecheck, Inc in the U.S. 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. $C_4C_4T_6T_6$).

Appendix: DNA Testing of LDHA and 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.

Appendix: DNA Testing of LDHA and 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, $C_4C_4C_6T_6$ represents the same as $C_4C_4T_6C_6$

Appendix: DNA Testing of LDHA and DRD4

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

Egg \ Sperm	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% $C_4T_4C_6T_6$?

Appendix: DNA Testing of LDHA and 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.

Appendix: DNA Testing of LDHA and DRD4

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.

1)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.