Breeding honeybees on a small scale, Part 1

Dr. Dorian Pritchard

Introduction
According to Ruttner, you need a minimum of 40 colonies to breed bees successfully. However, with an open mating system I find you can manage with a tenth of that number, just four. Also, as a geneticist I can tell you that a knowledge of genetics is a sophistication you do not need in order to breed animals successfully. The breeding of our farm and domestic animals was begun and carried forward successfully by Neolithic farmers 10,000 years ago. They knew absolutely nothing about genetics and yet produced many productive animal breeds sufficiently manageable to work alongside ourselves. However, you do need to think like a geneticist. The rule of the early farmers was: "breed from the ones you like; eat the ones you don't". Their main principle was to eliminate negative influences and, as I will describe, if you do that and no more, your bees should slowly improve.

When you watch a highly competent beekeeper handling superlative bees your reaction may well be: "I must get some of those bees!" But that, I would say is the wrong message to pick up. What you should be thinking is: "I must learn how he/she does it and do the same myself!" These two articles present methods by which you also can breed better bees and do so even with only a small number of hives.

Basics
First, why not ask a beekeeper with excellent bees to give you some of his and save yourself the work?

1. Because you cannot expect people to give or even sell you their best stock unless they are getting out of beekeeping.
2. Because if you lack the knowledge to produce good bees yourself you may well soon lose them, so you need to develop the necessary techniques.
3. Because if you move bees to a new location they usually under-perform and may even do less well than those you already have.
4. Because exotic drones produced by introduced queens could upset the breeding programmes of your neighbours.
5. Because to do so would be to chicken out of a worthy challenge and miss out on a lot of fun!

Line breeding
Progressive genetic improvement by selective breeding within a strain is called "line breeding". It can work very well, but it comes with a very important proviso: you must confine your operations to a restricted gene pool. By that I mean you will make only slow progress if you introduce mating partners that have not been subjected to the same prior selection regime.

To illustrate several alternative breeding strategies, imagine you are set the task of creating a superior breed of police dog. It would need formidable physique, strength, courage, motivation, intelligence, athleticism, a good nose, good eyes, a strong bite, good hip structure, trainability, handsome appearance and so on, and there are several ways you could approach the problem.

1. You could collect up strays at the local dog shelter, let them breed at random, select out the best and keep repeating that process. In a few hundred years you might reach your objective! (This is the approach adopted by most beekeepers with their bees.)
2. You might recognise that, whereas the British police force uses German Shepherd dogs (or Alsatians), police forces elsewhere use other breeds, like Rottweilers, Dobermans and Giant Schnautzers. Imagine you had the bright idea of crossing a very good German Shepherd with a very good Giant Schnautzer. You could expect a litter of excellent puppies in the first (or F1) generation, but if you tried to breed from them you would get an unpredictable range of "grandpuppies" and breeding from the latter would not improve matters. You would in fact be little better off than with strays from the dog shelter.
would have one set of Alsatian chromosomes and one of Schnautzer, a combination reproducible by repeat matings with other animals. This is called "cross-breeding" and it generally produces excellent F1 hybrids, renowned for "hybrid vigour". However, when you breed from F1 hybrids, you get all manner of new combinations, as the Shepherd and Schnautzer chromosomes cross over, break and rejoin in potentially millions of ways. The sperm and eggs produced by crossbreeds carry completely unpredictable combinations of genes and it would take many generations of selective breeding before they fell into a pattern. (Buckfast queens are sometimes advertised for sale as already mated with Carniolan drones. Their female offspring are inter-strain hybrids – displaying hybrid vigour, but useless for breeding, although their sons should be pure Buckfast.)

3. A third approach would be to identify a dog of a very different breed that is exceptionally gifted in one aspect, perhaps a Springer Spaniel as these are widely employed as "sniffer dogs" at airports. You could try to cross their superior alleles for smell sensitivity into your best family of German Shepherds. Unfortunately however, those breeds are also only distantly related, so that would also put things back many generations. But if you repeatedly backcrossed the hybrid F1 offspring to the Alsatian background, you should reduce the Spaniel component by 50% each time, i.e. from 50% to 75%, to 87.5%, then 94%. etc. After 7 backcrosses there should be better than 99% identity with the pure Alsatian. (This is essentially the approach adopted by Brother Adam in late development of the Buckfast strain.)

4. A fourth approach would be to identify families of German Shepherds that over recent generations have routinely produced many excellent dogs and bitches. If you then identified any slight deficiencies in each family and other families with compensatory strengths, you could mate them selectively. In very few generations you might derive a line of Shepherds superior in all considered respects and all the puppies should be at least as good as their parents.

In this last approach you started with animals carrying genes that have already been selected very strongly for the characters that interest you: the dogs are already perhaps 90% of the way toward your goal. By line breeding, you retain most of this pool of very favourable alleles and just re-shuffle the pack to give yourself a slightly better hand. By further selection and shuffling you would eliminate any remaining weaknesses. Line breeding is the surest way of producing a sustainable stock of good quality and is the approach advocated by Beowulf Cooper, the founder of BIBBA, for improving our "village bees."

In summary, if you want to create a stock of honeybees superior to all others available and capable of surviving indefinitely, you should start off with bees that are already a long way along the path you want to take and as mating partners you should use only similar bees. In practice, in Britain, this means basing your operation on *Apis mellifera mellifera*, the Dark North European Honeybee.

*Apis mellifera mellifera* is the only subspecies selected over 10,000 years by and for the British climate and is the only pure subspecies capable of indefinite survival here in the wild. I suggest the most sensible starting point for honeybee breeding anywhere is generally the bee native to that area, and if you do that, most of the mating partners it is likely to meet are usually genetically broadly similar to itself.

What if you can't find native honeybees in your area? When I started I had the same problem, but you can do as I did and resurrect the native from near-native hybrids. If such hybrids are present then most of the native genes are probably still there and it is simply a matter of recombination and selection to re-assemble the native genome. This is what I set out to do.

1. **My breeding objectives**

My general aim has always been for self-sufficient, gentle bees of the native subspecies, with little requirement for feeding, disease or swarm control. I would like a reliable honey yield of 150lbs per hive and, for manipulative convenience I would prefer them to be happy with a brood nest of a size that can be accommodated in a single National broodbox. Among my dozen or more colonies I now have most of these capacities, though reduction in brood nest size is still proving difficult. My current aim is
Breeding honeybees on a small scale, Part 1

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1. Introduction

To combine their best features into a single uniform stock while retaining sufficient genetic heterogeneity to maintain vigour. My major obstacles in this endeavour are my own deficiencies as a beekeeper, uncontrolled matings and the summer weather.

2. Management issues

The native bee reveals its unique strengths in situations where they become vital for its survival, so pressure may be necessary to reveal the best stocks. The aim is to recreate, or exaggerate selection by natural forces. Every modern introductory textbook written for British beekeepers instructs you how to keep Mediterranean honeybees alive through the British winter, with the implication that this is what you should do. I believe this instruction may be to blame more than any other factor for the demise of the native bee in these islands. In contrast, I try to create conditions that are favourable to survival of the native, but incompatible with that of the exotics, and Winter is my main weapon.

Although weaknesses are most apparent in winter survival this relates also to the pre-winter build-up. My bees over-winter best on heather stores and I feed them sugar only in emergency, or to reduce the glucose content of the ivy honey they would collect if they don’t go to the heather. (NB: The hydrogen peroxide produced by honey – as compared to sugar syrup! – is the bees’ best protection against varroa-borne viruses.)

I use National hive single brood boxes and for winter, remove all supers and stand them over an empty shallow to allow space for them to cluster. To promote air circulation I remove both end frames, so their stores are reduced to 9 deep frames. I also remove the summer insulation and the entrance block and pin on a mouse guard. This forces them into hibernation mode, which preserves stores, avoids the need for cleansing flights and extends the brood-rearing break, which probably discourages foulbrood and varroa.

I carry out the Spring inspection when the American Currant comes into flower and usually find no more than 4 or 5 dead bees on the floor. About a third of honey stores are usually left and this is all close to the brood.

3. Progress

Over a period of 15 years, from 1984 I succeeded in deriving a stock of bees that closely resembles the British native, by back-breeding from local bees that originally had wing morphometry and other features suggesting they were near-native hybrids; local wisdom held them to be French Blacks. At that time I usually over-wintered just four colonies, selecting for body colour, low temperature flight, low swarm cell number, good honey yield, white honey cappings, low aggressive/defensive behaviour and, as judged at the Spring inspection, large brood nest and fewest dead bees on the floorboard.

As the seasons went by the average brood nest size at Spring inspection progressively increased from four to eight frames, while the number of dead bees decreased. Honey yield increased from a maximum of 30lbs to around 100lbs in the best colonies by 1999, while the number of swarm cells was reduced from sometimes 20 to 4 - 6. After a time, all colonies produced white instead
Above: super comb with white cappings typical of many native strains. The air space helps retard moisture absorption and fermentation. Compare cappings without air space, below.

Above: Comb from native colony showing pollen stored alongside and below brood, with honey stores to rear of hive. Photos: B.A.Cooper

of the former grey cappings and after 13 years I noticed pollen stored below the brood (a native character) in one hive. Two years later all four colonies were storing pollen below the brood. When rape first appeared I selected and selectively bred from colonies that produced the most delicious honey and noticed that the responsible bees were collecting pollen of the greatest variety. A later check on wing morphometry showed one of the two lines I was by then maintaining to have the *mellifera* wing vein pattern and mitochondrial DNA analysis later revealed this line to be *Apis mellifera mellifera* of British ancestry, in fact closely related to Albert Knight’s bees in Derbyshire.

I was approaching most of my breeding objectives, but had made little progress with aggressive/defensive
Breeding honeybees on a small scale, Part 1

Dr. Dorian Pritchard

behaviour until I found a wild native stock so gentle it could be worked without smoke or gloves. In a few years I had selected gentle colonies from among my resurrected natives.

In the year 2000 varroa arrived in Northumberland, in 2001 Foot and Mouth Disease caused a standstill on hive movements and in the Spring of 2002 my colonies failed to build up. I later deduced this was because F and M had prevented the bees getting their pre-winter heather harvest and they had filled up with ivy honey and pollen which had set solid. However, I was persuaded to treat them all with Bayvarol, although only one colony had an appreciable infestation of varroa mites.

Over the next two years I saw a total of three mites, on two newly mated queens, but since October 2002 I have seen virtually none on my bees, though there are plenty in the area. This Spring (2006), for the first time, I examined the floor scrapings. One colony, headed by a newly acquired ginger coloured queen, had 2-300 dead mites, many damaged, apparently by biting. However, the other 8 colonies, all with black queens, had an average of 6.4 dead mites per hive, three colonies having none. Since the Spring we have seen only three live mites in 14 brood boxes, these colonies all led by dark, native queens of three or four different local strains.

All but one colony have therefore been virtually free of varroa for four years without treatment of any kind and I conclude they must have a high degree of natural resistance to varroa, apparently at least partly due to grooming behaviour. I anticipated this possibility as the gentle, wild strain was notably free of Braula when I first obtained it. The ease with which resistance to varroa has been acquired astonishes me in view of the difficulties reported by others. I suspect causation by a dominant allele, but my management technique may also be important, especially the enforced extension of the winter brood rearing break and avoidance of sugar feeding.

I know of no other instance of a native subspecies being re-created by selective breeding, but by the strategy described I succeeded in deriving bees that were indistinguishable from natives in appearance, behaviour and morphometry. Unfortunately, due to a combination of adverse circumstances I lost that line, but not before I had had its pedigree checked by mitochondrial DNA analysis. My present stocks no doubt include their genes, but are founded on other queen lines that I have since discovered near my home.

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To be continued

Above: Resurrection of the native bee: brood nest size at first inspection (between the dates of 31st March and 20th May) over the period 1989-2000. Scale at left shows No. of frames with brood.

Opposite: Use of wing morphometry in selection of native-type strains. Cubital Index was plotted against Discoidal Shift for samples of 15 bees from each stock.

Key: PR1: parent near-native interracial hybrid colony; PR1AA, PR1B, PR1C: descendent strains: ON1: true native Northumbrian strain collected from the wild. Colony PR1C was rejected.
Breeding Honeybees on a Small Scale, Part 2

Breeding strategies and the social conscience

Introduction

Genetic improvement of all species can be achieved by following three common strategies: eliminate negative heritable influences, promote positive heritable influences and avoid inbreeding. However, because of the unusual genetic basis of sex determination in honeybees and the queen's capacity for multiple mating, breeding honeybees demands specialized approaches.

1. Eliminate the negative

By eliminating the negative I mean removing the genetic influence of queens heading colonies with weak or undesirable characteristics and avoiding mating by drones with similarly undesirable features.

In the 1930's Haydak in Minnesota classified 20 or so colonies in his apiary as "poor", "good" and "best", on the basis of honey yield. The "poor" category had collected a disappointing 100 lbs of honey that season; the "good" ones about 200 lbs, the "best" around 300. Then and every season thereafter he culled the queens in the poorest category. Ten years later, all his colonies were in the "best" category and each now yielded an astonishing 400 lbs! What is more, the honey yields of his neighbours' bees had also increased.

You can eliminate alleles of negative influence in several ways:
1. Destroy the queens of the poorest colonies.
2. Destroy their drone brood (perhaps as an aspect of varroa control), or confine the drones when virgin queens are flying.
3. Prevent poor queens raising daughter queens.

I suggest you cull the poorest 25% of queens, along with their drone brood, every season and encourage your neighbours to do the same. NB: a queen that comes from good breeding stock can produce good drones even if she is badly mated.

What you consider a negative character will depend on your stage in the breeding programme. Initially your concept of an undesirable colony might be one whose bees attack or follow you, that cannot survive the winter without feeding, or rapidly goes down with disease. Perhaps you have to wear gloves when you handle them, they are low in stores when other colonies are strong, or they emerge weakly in Spring when others are strong. Perhaps they are slow to draw foundation, or reluctant to enter supers, they swarm at the slightest excuse, or you find it impossible to raise daughter queens.

If your breeding project is successful, your standards will advance. Your bees perhaps now all emerge from winter reasonably strong. They still swarm, but this is usually controllable; they become defensive if you are clumsy, or the day is cool, but otherwise you can work confidently without gloves; they rarely show signs of disease and what there is is controllable; they produce moderate-to-good honey crops and you can raise young queens at will from those you choose as breeders; they draw foundation as necessary and enter the supers without problem. You recognise the improvements are partly because your management has improved, but now, remarkably, you rarely see a bad colony! The bees themselves have actually improved!

The issue now is to maintain this happy situation. To help in this you could in theory "fix" highly desirable alleles (i.e. make them homozygous) by using drones whose mothers share a grandmother with your virgin queen.

Perhaps at around this stage you see or hear of other beekeepers who have bees so gentle they use no protection or no smoke; their bees move slowly and confidently over the comb; their honey crops are double yours; they don't lose swarms and they are free of all disease. You recognise that the management of these bees is exceptionally well considered, but the bees themselves are also outstanding. The keepers of these bees have garnered together all the good qualities of those in their neighbourhood and united them in the one stock. However, they actually achieve more, because these bees now exceed all previous standards. By having bees superbly adapted to their own circumstances and a manager who recognises the subtleties of their success, they have ascended to a realm above what might previously have seemed reasonable to expect. Like a superlative football team, the whole has become more than the sum of its parts.

2. Accentuate the positive

By accentuating the positive I mean consciously spreading the alleles of the best bees to a higher proportion of colonies. Like the negative criteria, you will probably refine your concept of what constitutes a desirable character as your bees get closer to the goal, although your methods need not change:
1. Re-queen poor colonies from good ones. The easiest way to do this is at swarming time: allow, or encourage, your bees to commence swarming behaviour, but destroy the queen cells.
in the poor colonies and replace them with those from the good.

2. Raise many queens from your best and use them to found new colonies.

3. Strengthen colonies that have desired characteristics by transferring sealed worker brood from less favoured colonies.

4. Encourage drone production by the daughters of very good queens. You can do this by putting extra drone comb in their brood nests. The rule for selection of drone producers is to propagate the grandsons of your previous best queens.

NB: One extra frame of drone comb per hive has been shown to cause no reduction in honey yield. (Which raises the interesting possibility that drones may contribute an as-yet-unknown "something" to the economy of the colony, in addition to mating the queens. My friend Christine suggests they keep everyone happy by telling jokes.)

You may find selection within your own stock never turns up some desired aspect of quality or behaviour because the relevant allele simply does not exist in the bees of your area. To remedy this you could send a virgin queen away to be mated elsewhere. "Elsewhere" should not be too far away (e.g. <50 miles) and bees at that apiary should be of excellent native stock and strong in the character yours lack. You then assess the performance of the new colony, but don't allow it to raise daughter queens unless and until that colony proves capable of performing well in your apiary. This prevents the drones of daughter queens disseminating exotic alleles; you should not allow daughter queens to arise until you are quite sure how they perform in your own locality.

3. Control inbreeding

Close inbreeding is harmful to most species because it brings deleterious recessive alleles into the homozygous state in the offspring. It is particularly weakening in bees because determination of female sex requires heterozygosity of the sex gene. The heterozygous combinations: ala2, or ala3, or a2a3 define a worker or queen; haploid: a1, or a2, or a3 defines a normal drone, but the homozygous genotypes: a1a1, a2a2 and a3a3 define "diploid drones". Diploid drones are recognised by the house bees and destroyed as young larvae, creating "pepperpot brood". Rutnatt suggests the degree of inbreeding can be assessed by the percentage of empty cells in 12-day sealed brood. However, some queens lay erratically, some fill up the gaps, and pepperpot brood can arise from disease, so I find this method unreliable.

If you practise instrumental insemination you should avoid inbreeding by using sperm donors from colonies unrelated to the queen. (NB: all the sperm produced by an individual drone are genetically identical.)

If your queens mate free you probably need not worry about inbreeding. However, if you raise many daughter queens from a single breeder queen, this could create problems in subsequent generations. Inbreeding can be avoided by maintaining three unrelated breeder lines, or by incorporating the occasional local swarm.

For long-term conservation of native stocks we must preserve genetic variation, especially of the sex alleles. The long-term viability of a honeybee population theoretically could relate directly to the number of different alleles of the sex gene and we may estimate long-term survival prospects of a wild honeybee population by counting the number of sex alleles it contains. Maintenance of sex gene heterogeneity is promoted by propagating from colonies that reveal no sign of inbreeding.

We must also avoid overdoing the breeder-queen strategy. This rapidly eliminates genetic variation and the mitochondrial DNA markers investigators use to deduce the ancestry and relationships of our bees.

The social conscience

I once counted the beehives within a one mile radius of my home: it was 41. A second count 10 miles away produced the same number. If we assume hives are equally densely distributed over the wider area and that my drones could mate with queens from hives anywhere within a 5-mile radius, using the formula for the area of a circle, \( \pi r^2 \), I calculate that my drones could influence the genetic make-up of perhaps 1000 other colonies. If my drones are mating with queens from hives 10 miles away, the figure rises to 4000. Equally, my queens could be mated by drones from any of those 4000 hives.

Few beekeepers seem to care how their actions may affect their neighbours' bees, but in my opinion it is grossly irresponsible to bring in foreign queens, unless you take steps to prevent them producing drones. The foreign drones produced in a single apiary can cause genetic havoc in all other colonies within a radius of several miles and in one season utterly ruin the life's work of many beekeeping neighbours. Hybrids of Apis mellifera mellifera, especially with Carniolan or Buckfast, are also notoriously quick to sting.

This awareness can however be used to disseminate beneficial qualities. My neighbour, George, was pleasantly surprised to find his bees had become gentle, when they used to be aggressive. This, I think, is solely because I have been deliberately disseminating thousands of extra drones from my gentlest colonies. By propagating drones from my varroa-resistant, gentle colonies I aim to follow this up by creating a varroa-resistant zone around my home.

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