Script for honey bee breeding and selection

Tim opening statement Bees working flowers HB C100 D Summer 18 TC 38;19;26 to 38;28;24 — 41;06;24 to 41;30;25 coming in and out of the hive, bees on comb – queen walking, queen laying an egg HB C100 D Summer 18 TC 36;29;00 to 36;40;03 — 36;50;10 to 36;58;16 Points on screen	00:00 honey bees are fascinating animals to work with and essential to pollination of our food supply. Currently faced with many challenges, one of our most important tools for long-term sustainability and improved honey bee health is a program of selection for stock that is hearty, productive, winters well, and has a reduced susceptibility to pests and pathogens. 00;22;27 00;22;28 beekeepers recognize the need for more rigorous programs to select, improve and maintain their breeding stocks. The varroa mite and the movement of africanized honey bees adds to this urgency. 00;35;07 00;35;24 the principles discussed here serve as a guide to develop and establish a successful and practical breeding program with a focus on the traits you choose to enhance is your breeding population. The basic prerequisites for a bee breeding program are: 1) Maintain of a diverse population to provide the basis for selection 2) A proficiency in queen and drone rearing 3) Establish a selection index of desired traits 4) Careful record keeping 5) Control of pests and diseases, and 6) A method of controlled mating 01;10;04
Sue on Screen - holding frame with bees Points on screen with Sue reading in background	01;10;14 the honey bee colony is a superorganizm and this complicates the selection process. Keeping your breeding program simple is key. Genetic diversity within the colony as well as within the population increases honey bee fitness. Several mechanisms contribute to this diversity: 1. The high mating frequency of the queen. 2. Semen storage - after mating only about 10 % of the semen collected migrates to the spermatheca, although this represents each drone she has mated with.

Queen Mating video or swarm of drones	3.the high rate of recombination. a queen can mate with up to 60 drones, though typically mates with 15 to 20 drones. This mating behavior seems risky and inefficient, though is very successful in creating a genetically diverse superorganism, the colony. The many subfamilies of worker bees represented by the different drones mated, subfamilies specialize in different traits, which together contribute to colony fitness. The high rate of recombination, (description) this provides the potential to test new genetic combinations that may increase resistance to pests and diseases and the ability to adapt to a changing environment. 01;38;00
note - explain sex determination, with diagram.	1;38;06 honey bees have a haploid(hap-loid) diploid (dip – loid) sex determination system. Drones or males have one set of chromosomes – meaning they develop from unfertilized eggs. They have a mother but no father – workers and the queen are produced from fertilized eggs – thus they have both a mother and a father. 1;55;16
Steve	02;15;15 one of the challenges of honey bee breeding is that honey bees are sensitive to inbreeding. This occurs when the female mates with males that are closely related to her. 02;28;00 02;28;10 in the case of honey bees that leads to inviable brood. So one of the mechanisms for what we call out crossing is the fact that the queen mates with multiple males. So if she mates with 20 males and one of them is closely related to her that is not such a deleterious effect on the whole colony. 02;47;27 02;48;07 in general you have to be aware of the relatedness among all of the bees involved in a breeding program. 02;57;00
Sue	02;57;20 honey bee breeding can be challenging because of these unique features that must be understood and considered in the

	development of a breeding system. 03;06;00
Sue narration HB Osmo summer 18 TC 02;09;50–2;17;07 HB C100 D Summer 18 TC 14;35;21 to 15;03;14 HB C100 D Summer 18 TC 25;35;29 to 26;06;09 – 28;39;06 to 29;00;16 – 29;14;11 to 29;58;16 – 30;25;06 to 30;46;03 Or HB C100 D Summer 18 TC 31;24;12 to 32;50;06 – 33;13;25 to 34;00;16	03;06; 20 an essential component of any breeding program is control of the mating. Geographical isolation and drone saturation can be used and will provide partial control. Instrumental insemination provides complete control. However, this technique is a specialized skill and requires training. 03;25;26
Steve	03;26;16 with instrumental insemination it is fairly easy because we can control the males that the queen mates with and we can make sure, you know, that they are not from closely related lineages. But in the open mating or natural mating situation you have to make sure you have adequate genetic diversity in the mating yard. 03;48;08
Steve – queen yard	03;48;26 another one of the differences in breeding honey bees 03;51;26 03;51;27 is that the unit of selection for us is the colony. Because the colony itself with all the different groups of workers and all the tasks they undertake, is how we measure the quality and viability of the sort of unit. 04;13;13 04;14;05 you have to realize that involves the genetics of the queen plus the ten to twenty males she's mated with – so it effectively makes a colony that's composed of a number of sub-families – each fathered by a drone honey bee and the way that unit works together gives you the traits you use for selection. 04;39;01
Apiary, close up bees foraging	04;39;15 to ensure colony fitness, selection for a variety of traits such as productivity, temperament, overwintering ability, etc. Must also be considered. Avoid selection for a single limited characteristic – 4;52;03

Tim in apiry then cut to different bee photos such as Queen on frame of bees –laying a egg, frame of pollen, nectar, etc. – varroa mites other diseases	04;53;05 worldwide the focus of many beekeepers is to increase resistance to varroa mites. Selection for resistance to varroa is complex and probably requires a suite of traits, which all have yet to be identified. Single trait selection programs, such as varroa sensitive hygiene or vsh and grooming behavior have value but are difficult to maintain and the traits are highly variable. These traits can and should be selected or added to your breeding population. The goal must remain selection for overall high performance of colonies in the breeding population. Your selection is a balance of maintaining genetic diversity to enhance fitness and increase the frequency of traits that contribute to resistance. In the selection for high colony performance, you may bring along traits for resistance to pests and pathogens, including some we may not yet have identified. 05;47;06
Still photos of beekeepers of the past selecting stock (as available)	06;20;22 beekeepers and bee researchers have been selecting the honey bee for many years – some of the earliest attempts included attempting to mate bees in a confined enclosure or by hand .discoveries in the queens anatomy and physiology led to the first break through in controlled mating of honey bees with instrumental insemination. 06;41;10
Sue working a bee hive	06;53;25 we owe a lot to some of the early pioneers in bee breeding like laidlaw, watson, mackensen, roberts and many others. 07;01;13

	
Steve	07;01;27 we talked about genetic diversity which is what you need as the raw material for artificial selection for selecting bees so you need that diversity, yet within the stock you are trying to produce a large honey crop you don't want bees that don't produce much honey, so you are trying to have certain traits in high frequency – that type of diversity is different than within colony diversity. 07;36;01 07;36;02 I mentioned that honey bee queens mate with multiple males. It has been shown where the different sub-families within the colonies are quite diverse – is actually a much more stable colony able to deal with stress and diseases, than say a colony that is fathered by say several drones or drones that are very closely related. 08;05;18 08;05;18 intra colonial diversity – diversity within the colony is a very good thing, and that is the reason we seek to have a diverse drone pool – and allow the queens to be well mated. 08;20;27

	08;20;30 some times in poor weather – when mating is difficult – queens will come back and begin laying after mating with only several males and in general those colonies aren't as viable as those where the queen fully mated with a diversity of males. 08;41;04
Sue holding a frame of carniolan bees	08;41;24 the success of the closed population breeding program is based upon simple evaluation and selection criteria and a propagation program, repeated annually. The goal is to maintain selection pressure on the population over time.08;57;18
Photos of varroa and diseased brood, pms.	08;58;18 as new issues arise new selection criteria can be added. 09;02;05
Photos to laidlaw and page - and system schematic Field shot of evalauting colonies, with clipboard	09;02;28 the page-laidlaw closed population breeding program is one of the most successful practical breeding systems used. The system basically is how most beekeepers approach selection - choose the best and propagate from these. The key component is an annual selection program supported with controlled mating and record keeping. 09;23;02
	09;23;20 beekeepers rely on natural selection pressure to increase desirable traits in the population. The goal of the closed population breeding program is to increase the selection pressure and the frequency of desirable traits in the breeding population. Given the behavioral complexity of honey bees this can be a challenging process. To be successful and give the program, longevity, it must be simple and repeatable.09;49;23
Sue with balloon demonstrating the concept	09;50;05 rob page described the selection process as a huge balloon you are trying to keep in a shape. Too much pressure on one side results in an unexpected shape. Your job is to constantly apply this pressure and constantly correct it over time, to maintain and increase the consistency of valued traits. 10;05;11

Close up shots of bees working on comb	10;06;00 given the complexity of a honey bee colony, the and high genetic diversity within the colony as well as within the population - the goal of selection and breeding of honey bees can seem daunting. 10;16;22
Close up of uniform carniolan bees	10;18;00 but honey bees respond to selection and we are just trying to enhance and speed up this process to increase general fitness. A successful, healthy and productive colony has the traits we value, including reduced susceptibility to pests and diseases. 10;32;06
	10;33;11 as researchers discover and develop simple selection criteria, such as tests for hygienic behavior and grooming behavior to reduce pests & disease, these can be incorporated into the program. 10;44;17
Sue in bee yard,	10;45; 06 the effects of a changing environment and nutritional conditions must also be considered in the selection process.10;51;18
Steve	10;52;10 one thing you have to realize when you are talking about breeding or selection for traits you want, it's a balancing act between the fact that you need genetic diversity to have the raw material for selection, because you want to select for example, bees that fight off disease; bees that are gentle; bees that produce a lot of honey; bees that overwinter well; a lot of traits you are trying to more or less fix or have occur in a high frequency in the population, and at the same time you need to have the diversity which to select these things. 11;34;00 11;34;10 so if you make the genetic pool too narrow then you run into the problem of inbreeding that we talked about. Another thing to realize especially when comparing bees from different locations is there are definite environmental effects. You may have a colony that looks very strong and wonderful, and you say ah i will breed from that colony and you make a lot of daughters and you put them in another location and they don't produce a lot of honey and it's because of the phenotype – or what you see in a colony – is a combination of the genotype of the bees or the genetics, plus the environmental interaction. 12;23;02

	12;23;15 so if you are in a very poor location even if you have wonderful genetics the colonies won't look very good. That is why we have to compare our genetic lines at the same locations to get over that stumbling block. 12;40;22
Sue	12;41;06 there are many ways to accomplish stock selection. Our goal is to provide a practical starting point, open to modifications that will serve your beekeeping operation and management system. 12;51;04 Cut
Close up of queen cells on a frame (lots of bees on frame)	12;58;02 with any breeding program there are numerous steps requiring a keen sense of observation. A critical aspect is rearing high quality and well mated queens. Queen rearing methods will not be reviewed here, but note the basic requirements - to produce quality queens that have been reared in optimal conditions. 13;17;11
Sue , pulling a drone comb from the colony., and collecting drones	13;17;18drone production is critical and too often an overlooked aspect. During peak season they are plentiful, yet to supply a plentiful supply of mature drones from the desired stock takes some advanced planning. Drones are slow to develop, and their peak maturity is 3 wks post emergence. Drones are also highly susceptible to stressors: pests and pathogens, chemical residues, poor nutrition, temperature extremes, etc. If conditions are not optimal, they disappear or are compromised. Older drones will be eliminated from the colony in favor of rearing a new batch of drones for the future. So be sure drones are reared in strong, well fed, healthy colonies. 13;58;07
Tim in bee yard on goals and objectives of a breeding program	13;58;10 one of the first things you need to do before starting your breeding program is to determine what are your goals and objectives, what do you want to achieve ? What will your time and resources allow? You can start slowly

	with limited numbers of colonies and build this up, or you can jump in with a large and highly diverse population to select from. 14;19;16 14;19;00 you may have generations of bees that you or your family have maintained but want to increase resistance or other valued traits in the population. Or perhaps you want to select stock adapted to the microclimate and forage you have locally. 14;35;06 14;35;15 what do you want to improve and focus on - the more variables you include the more difficult achieving those objectives will be. 14;42;24
??	14;44;00 one of the most important considerations in a honey bee breeding program is the understanding that you are working with a population of bees not just individuals. 14;52;10
Going through several colonies, looking at behavior	14;53;00 a colony may not express a desired trait because the frequency of this behavior is low. The goal is to increase the frequency of expression of several desired traits within the population and decrease the undesirable traits. This requires maintaining selection pressure on the population over time. 15;11;17
Walking through bee yard Box or frame of queens Installing pkg bees.	15;12; 00 what type of stock will you choose? Consider the strains of bees and their characteristics, your beekeeping needs and climate. If in a northern climate, a strain adapted to a long cold winter with fast spring buildup may be preferable. If in a temperate climate, a more broody strain that produces a lot of bees for packages or nucleus colonies may be preferable. 15;34;07 15;35;00 first you will want to establish the basic stock. Focus on a few general traits: such as productivity, wintering, gentle temperament, etc. Add a few specific traits, such as increased resistance to pests & disease. Keep in mind - the more variables you include in the selection criteria the more labor intensive and slower the

	progress may be achieving the objectives. 15;57;25
Close up of a carniolan queen	15;58;13 your initial objective should be to establish and maintain productive stock. Over time and changing situations, you can begin to include selection for resistance to diseases and pests. For example, from within your population, test for hygienic behavior , and select against colonies showing signs of disease, such as chalkbrood, sac brood, foul brood etc 16;22;16
Bee yard	16;23;08 using the closed population system , pool your best colonies and select the best and graft a few queens from each of these. These virgins are then mated to the pool of select colonies to establish the foundation stock. . 16;37;09 16;38;00 establsih a large population , about 200 colonies . 16;45;04
Graphic depiction of the process Score sheets Preseletion data Overall selection Mating nucs in various stages with - pi cages, queen excluders, new queens laying. Yard of single deeps showing pool of new potentail breeders	16;46;00 from this base population of 200 hives , again, select the top performers based on basic traits.. We call this the pre-selection test. You may initially screen that number down to the top 75 or more colonies. From these, select and further screen colonies choosing the top 30 to 50 colonies as breeders, based on their productivity 17;03;04 17;03;20 from this selected group produce a few queens from each of the top colonies and mate these virgin queens with a representative sample of drones from the selected pool of colonies. Here instrumental insemination will give you the best overall results 17;27;09 17;27;20 or, use an isolated mating area. Produce about 200 queens , establish these in uniform nucleus colonies and allow them to build up on their own populations. These then become the base stock for the following years generation to select, and the process is Repeated. . 17;43;21

	17;44;10 using a large population will prevent and increase the life of the breeding program. 17;49;24 17;50;10 annually, a new generation of queens are reared, mated with a known pool of select drones and , established in full size colonies and evaluated in the field. 17;58;23 A few exceptional "rockstar" select breeders from previous years can also be included. This may help increase the frequency of valued traits and also longevity 17;59;00 the success of your breeding program is dependent upon a long-term commitment to rigorous evaluation and careful record keeping. If this effort is relaxed the expression of selected traits and the productivity of the stock will revert to mediocrity. 18;13;28 18;14;02 general overall productivity should be your main goal. This is often based on a complex of traits. Consider honey production and resistanc to pests and disease . Many traits contribute. It is not necessary and not practical to measure each contributing factor. Simply, selecting for general high performance and low varroa levels ~18;30;10 20;24;01 choosing the top performing colonies allows us to select for the combination of characteristics responsible for high production without detailed and tedious measurements of numerous specific traits responsible 20;36;17
Sue in queen yard	18;30;30 environmental conditions and seasonal effects vary in different locations and this needs to be considered so that colonies can be compared. Therefore, scoring should be adjusted to reflect these conditions and selection priorities. 18;43;11

	More detail - yard scoring: 18;44;00 to ensure and extend the longevity of the program, a large base population is maintained and occasionally new sources can be tested and added to enhance the gene pool. These sources must be subject to the same rigorous selection process before incorporation into the program. Care must be taken to add these sources slowly and cautiously to prevent major changes in the stock. If an undesirable trait is added inadvertently, this can be difficult to remove. 19;13;05 23;29;13 to add a new stock, set up a test yard and observe the performance of this stock and its combining ability with the foundation stock before this is added to the gene pool.~ make reciprocal crosses and test these. 23;43;18
Footage of drones flying in and out Multiple drones cages used for insem.	23;43;21 to expand the gene pool and avoid major changes in the performance of the foundation stock, seed in a few drones. This will enhance genetic diversity . .23;51;11 Here semen from several cages of drones, representing differnt aparies with select queens are being collected to mate with the pool of select virgins.
Tim in bee yard	19;13;15 selection is based upon colony performance. The interaction of genetic makeup of the colony, the environmental influences and beekeeper management practices must be considered. To observe genetic variability and effectively make selections based upon this requires that environment factors and management practices be as uniform as possible. All colonies must be treated equally regardless of their performance. This is a comparison test. It is important that all colonies being evaluated are

	not managed differently. For example colonies cannot be equalized or boosted with the addition of brood or bees. Colonies that do not meet the high standards for performance are simply weeded out of the program. 19;59;20
Tim in bee yard	20;37;00 we recommend a two phase approach to selection be used. The first phase, referred to as pre-selection, is designed to evaluate general performance. At this stage the poor and mediocre colonies are cut from the program. The evaluation and scoring process is designed to be simple. The following protocol is a guideline. You may need to adjust point values and/or priorities to address your conditions and needs. 21;06;04
Sue with clipboard	21;06;18 the pre-selection test uses a selection index to evaluate several traits efficiently in the field. This test is performed twice, once in the fall after colonies have become well established and a second time during the early spring to test buildup and overwintering ability. Colonies must also monitored for pests and diseases. 21;27;19
Graphic of selection index Tim	21;29;00 the pre-selection process consists of observing several traits at a given time and ranking each of these with a numerical point value, scoring the occurrence of each valued trait. The point values of several traits are added and the sum of the total compared among colonies. 21;44;13 21;45;00 several traits are observed quickly and simultaneously, requiring only minutes per colony. A point value system of 1 to 5 is used, 5 being the highest value. A score is given for each trait observed and these are added~ to determine colony rank. Scoring is based upon comparison between colonies. 22;04;00
Sue bee yard	22;05;10 colonies should be evaluated on the same day, by the same person to maintain

	consistency. If colonies are located in different apiaries, a yard average can be used to compare scores between these. Colonies scoring average or above qualify for the second phase of evaluation.22;22;08
Graphic of point system card Point values~ 5 - excellent 4 - good 3 - average 2 - fair 1.poor	22;23;10 the scoring system presented here is based upon a simple selection index with values of~ 1 to 5. 26;51;13 22;29;27 this scoring system is used for the pre-selection traits you are evaluating. Multiple traits are observed and evaluated quickly, and made at the same time. Choose a few key traits, we recommend selecting from 3 to 6 characteristics in your test population, such as brood viability, temperament, pollen hording; colony buildup; and color. 22;53;24 , 22;54;15 a specific trait of concern can be weighted more heavily to give this priority attention.~ for example, if there is a concern the stock is defensive,~ a point value of 1 to 10 can be used to increase the selection pressure for this trait. 23;09;14~
Sue head shot	23;10;00 negative point values can be given for a low incidence of minor disease and reflect the severity of this occurrence. Or, the colony is simply cut from the program.~ 23;21;00
HB C100 D Summer 18 TC 37;26;11 to 37;55;22	23;51;15 selection for high brood viability is essential to maintain the genetic integrity of the population.~ an estimate of brood viability is determined by observing the solidness of the capped brood pattern. Look at several frames as one may appear spotty due to nectar or pollen in the broodnest during a flow. 24;10;25
Contrasting gentle bees with aggressive bees Or, gentle bees , no veil	24;11;10 the bees should be calm and gentle regardless of colony size and most conditions. Temperament can also be noted during general manipulations. This will help eliminate a reaction to any disturbance that may have

	unknowingly occurred before evaluations.~ 24;25;12
Color Show differnt races	24;25;11 color is the easiest trait to select and a good marketing tool. 24;31;00 With proper selection your line will become more consistent in color – it can be an important first impression that beekeepers appreciate – carniolans should look and behave like carniolans, italians like italians, and caucasians like caucasians. Note - should we describe the diff. Races? 24;50;29 becasue the drones are halpoid, color is very easy to select with controlled mating. If selecting within a specific subspecies, queens producing daughters with unacceptable coloration should not be used as breeders. This indicates miss-mating 24;58;27
	Color can also help you to distinguish between the different races – ie the difference between temperate climate bee like the Italian and cool climate adapted bees like the Caucasian or carniolians
Sue in queen yard Score sheet	24;59;03 at this point in the preselection phase, evaluate where you are in the overall selection process - before going on to the next phase where we look at industry or productivity and more specific traits. Make a cut and eliminate the mediocre and poor colonies.. 25;15;29 25;16;09 the pre-selection colony score-sheet allows you to compare and choose the best performing colonies. Based on criteria we have evaluated so far - each colony should have a score of up to 25 points - set a cut off point - say all colonies with a score of 20 or above. These are taken to an historically good honey producing location to test for productivity.. 25;36;27

Final selection - industry	
Bees supered up on honey flow	26;28;21 the second phase of selection is the weight gain test, indicating colony industry. Colonies scoring average or above based upon the fall and spring pre-selection tests are given the weight gain test. Colonies are tested during the honey flow in late spring or summer dependent upon the flow conditions. 26;46;03 26;46;17short term weight gain during the flow is correlated to colony performance over the entire season. This will provide a good estimate of colony industry. 26;54;21
Bee yard with colonies facing in different directions and with different entrance colors.	26;56;00 when establishing a test yard, care should be taken to minimize drift - place colonies in an irregular pattern or face colonies in different directions, or color code the entrances to minimize drift – 26;05;26
One person with a clip board and another with a sling and scale	36;52;15 an easy and effective way to evaluate industry is is honey production. A quick and reliable way is to do a weight gain test during the flow. . 27;22;22 27;26;16 the amount of weight gain over a short term, a few days to a one week period, correlates how a colony will do over an entire season. We are estimating the initial colony weight and then we will come back in a week and take the second weight to determine the gain over this time peroid.. Rather than trying to pick up the whole colony which can be rather awkward and clumsy, we take the weight on the front of the hive and the weight on the back of the hive, then add these two weights together and this gives you the weight gain . We can now campare the wt. Gain between colonies.. 27;55;16

	After selecting the top preformers for general traits and productivity we can also look for specific traits, such as test for behaviors that will reduce the severity of pests and diseases. There is a high cost to single trait selection, as this greatly reduces genetic diversity which we know is essentail for colony fitness. So, its important to first select for productive colonies, then add selection to increase the frequency of specific traits we know contribute resistance to pests and disease.	
HBC100M summer 2018 TC 26;53;2927;01;26 HBC100M summer 2018 TC 22;43;00 - 22;44;04 22;46;04 -23;14;04 HBC100M summer 2018 TC 28;16;10 - 28;27;11 HBC100M summer 2018 TC 30;00;28 - 30;17;03 ; 30-34;1730;36;12 HBC100M summer 2018 TC 49;59;27-50;21;14 HBC100M summer 2018 TC 54;51;20–55;11;25	25;38;02 one of the earliest examples of selection for a behavorial trait was the work of dr. Rothenbuhler's hygienic behavior test for uncapping and removing dead pupa. This selects of olfactory sensitivity and is now a test most queen producers demand in their stock. It is an important tool for reduce the incidence of brood disease and varroa infestations. It is a common trait found in all colonies, but is often only expressed in about 10 % to 20% of honey bee populations. With selection, the frequency of this trait can be increased. 26;02;01 26;03;00 to be hygienic, a high percentage of bees in the colony must carry this trait. 26;07;21 colonies should be tested twice for hygienic behavior because results can be variable due to environmental and colony conditions. During a honey flow or when there is a large emergence of young nurse bees, colonies will appear more hygienic compared to a different time. Only colonies consistently~ displaying this trait will are considered hygienic.~26;28;05	25;3 for for now stoc bro four pop 26;0 26;0 mus

Hyg scores Screen bottom bd counts - in field – Tim Shoot this shot Mite rolls - in field Example – final colony rank score sheet	scoring for hygienic behavior Testing for varroa levels can be accomplished several ways. A "mite roll" is an easy common test.though consider the time of year and climate to establish a threshold. Mite rolls should be taken several times a year. Mites vector pathogens and at high levels compromise colonies. Harmful viruses can persist for a long time after mite levels have been controlled. A top preforming queen in a heavily infested colony will not thrive. A final colony ranking is made and the breeders selected to establish the next generation.	25;3 for for now stoc bro fou pop 26;(26;(mus 2 h v c is c c b
in field	The cpbp is designed to be a simple, practical, flexible and effective method of selection within a known honey bee population. It is designed to increase the quality and consistancy of valued traits over time in the population. It is closed in the sense of controlling the introduction of unwanted stock , yet allowes the controlled addition of new materail over time to extend the life of the program. The key is the annual evalaution and selection program to maintain selection pressure on the population over time. Keeping this simple is important, as this helps to get the workload accomplished We hope this presentation gives you some insight into how to run a practical selection program.	