Final Exam

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Plant Breeding 11:776:406
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1. The basic plant breeding algorithm is germplasm → controlled mating and selection → testing → release. Describe **where or how you would obtain germplasm**, and **what mating and selection schemes** you would employ for the following crop species:

	GERMPLASM AVAILABILITY	MATING AND SELECTION SCHEMES
Tomato	Northern Andean and other SA landraces	Recurrent selection
Pome fruits (e.g. apples)	Landraces, elite germplasm, wild/weedy relatives	Modified backcross
Stone fruits (e.g. peaches)		Recurrent mass selection, mutation breeding
Cranberries		
Blueberries		
Hazelnuts	accessions are held in germplasm banks	Backcross
Creeping bentgrass	International, genetic stocks etc.	Recurrent Selection, CMS

2. Choose one scientist who was influential in the field of plant breeding, describe their contributions, and the impacts their work has had.

Wilhelm Johannsen – laid the foundation in modern genetics with his studies with beans and showing the difference between a genotype and a phenotype (words he coined).

Johannsen's Bean experiment showed that mixed population of a self-pollinated crop can be separated into different pure lines. For this selection was effective in the first few generations, and further selection within a pure line was ineffective. Overall the variation is due to genes and environment.

Details:
Phaseolus vulgaris L. was used (beans) which are a highly self-pollinated crop. Johannsen experimentally proved that variation for seed size in the original variety was due toht ejoint effects of heredity and the environment. The latter was shown as a highly-self pollinated pure line was developed and there was still variation involves, and the only cause is the environment. (GXE)

3. Citrus species are known to exhibit apomixis, with up to 10 seeds per fruit containing adventitious nucellar embryos, in addition to the one true sexual embryo.

As a plant breeder, how would you determine which of the seeds contained an embryo from a fusion of gametes vs. from apomixis?

Apomixis: A type of asexual reproduction where seeds are developed but there is no recombination
**Fusion of gametes:** when two gametes fuse, the fusion product is a diploid spore -> zygote. There is competition among gametes for fusion partners which induces sexual selection.

Though both are a form of asexual reproduction, apomixis seeds are not selected for at all, while fusion of gametes alters the gene pool. Apomixis seeds are true to the parental type, more than fusion of gametes.

A more invasive study would involve SSRs or RAPDs for verification.

4. You are a squash breeder who decides to embark on a population improvement program for higher levels of fruit soluble solids (SS). You have too highly inbred populations, one that has good overall attributes and a mean SS value of 3.0, the other a wilder type that has a mean SS value of 5.2. The F1 population has a mean of 24, and the the F2 segregates for SS as follows:

Number of F_2 plants with SS value

3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
5	23	40	28	4
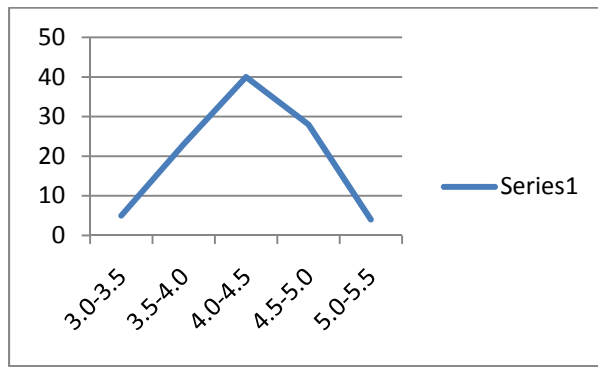
(a) In general terms, how would you characterize the inheritance of SS in squash?

Genetic, mendalian polygenic.

(b) Approximately how many genes do you think are involved, and why?

Inconclusive: N=(3-5.2)^2/(8*((15.44345^2)-(21.01111^2))) = -0.00298

Te F_2 population is subjected to selection, with all individuals with SS of **4.5** or higher allowed to intermate randomly. The subsequent population is observed to have the following SS values:

Number of F2 plants with SS value

3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5	5.5-6.0
0	1	12	50	35	2
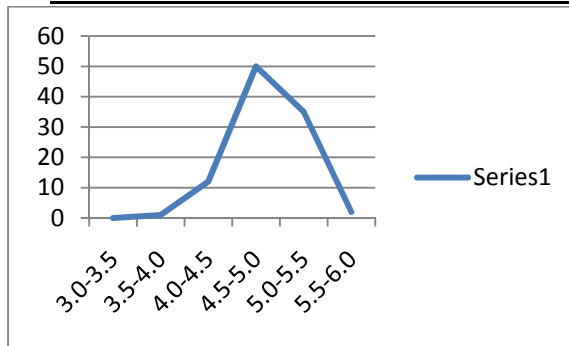
(a) What was the selection pressure that you applied?
    2/5 = 10%

(b) Calculate the heritability of SS in these populations of squash
(c) Is this broad or narrow sense heritability? Explain

(d) As a breeder, what factors can you control to affect heritability?
A breeder has the most effect on the environment, as this is a factor in all heritable studies.
(e)

Variance	Standard dev	
238.5	15.44345	F1
441.4667	21.01111	F2

5. Explain how the following factors can affect gene frequencies in plant populations:

	Definition	Effect on gene frequencies	Example
Inbreeding	Mating between relatives	o Frequency of heterozygous offspring less than in random mating, results in excess of homozygotes o With repeated self-fertilization (promotes inbreeding) the frequency of heterozygous genotypes is reduced by ½ by each successive generation. o This overall increases the frequency of homozygotes with respect to the declining heterozygotes -> Aa needs other Aa to produce more Aa. o Diploidy offers heterozgygote protection against recessive lethal alleles; consequently inbreeding increases the risk of a homozygous recessive lethal allele.	4 generations of self-fertilization reduces the heterozygosity as such: (½)*(½)*(½)*(½)=(½)^4 = 0.0625
Mutation	Spontaneous heritable changes in genes	o Mutation is the ultimate source of genetic variation o May replenish harmful alleles that were eliminated by selection o Weak force for changing allele frequency	Natural rate of mutation is 10^-5 to 10^-10 per locus per generation
Selection	Any process (natural or artificial) that permits an increase in the proportion of certain genotypes or groups of genotypes in succeeding generations	o Artificial selection: Different levels of reproductive successes are introduced with selection o Natural selection: favors genotypes that are better able to survive and reproduce.	Evolution = natural selection + genetic variation
Population size	Group of organisms from the same species	o A small population size is not immune to fluctuations in allele frequencies (genetic drift) o A large group of interbreeding individuals o Bottleneck effect decrease heterozgyosity	Plant breeding changes the effects the changes in the genetic structure of plant populations
Linkage	Alleles that are 'linked' stay together in	o Simply put: Linked genes are inherited together because they	

	meiosis and in heritance	are located near each other on the same chromosome	
		o Recombination can recover genotypes	

6. Cole crops, including broccoli, exhibit flowers that have a sporophytic self-incompatibility system. Assuming the following hypothetical interaction of alleles at the S-locus, predict the outcomes of the listed crosses (incompatible or compatible)

Allele	Pollen	Style
S_A	Dominant to S_B Codominant to S_C	Recessive to S_B Codominant to S_C
S_B	Dominant to S_C	Codominant to S_C

(a) $S_A S_B$♀ x $S_A S_B$♂ ~ SA x SB -> **incompatible**
(b) $S_A S_C$♀ x $S_B S_B$♂ ~ SASC x SBSB -> **compatible**
(c) $S_B S_C$♀ x $S_A S_B$♂ ~ SB x SB -> **incompatible**
(d) $S_B S_C$♀ x $S_A S_C$♂ ~ SBSC x SASC -> **compatible**

Answers: a & c -> incompatible, b&d -> compatible

7. While collecting and characterizing germplasm for use in your breeding program, you collect seeds of five wild populations that closely resemble a domestic/cultivated species you are working with. To determine whether these wild species will be of any use for breeding, you attempt to cross hybridize them with a cultivated species

(A), exhibiting a genome formula of 2n=2x=10, and observed the following:

A x Species B (2n=20): Hybrids 2n=15, sterile, chromosome pairing observed but irregular
A x Species C (2n=10): Hybrids 2n=10, mostly fertile, 4 bivalents + 2 univalents
A x Species D (2n=30): Hybrids 2n=20, partially fertile, 5 bivalents + 10 univalents
A x Species E (2n=10): Hybrids 2n=10 completely fertile, 5 bivalents
A x Species F (2n=12): No hybrids could be obtained

a. Describe the likely genome structure of each wild species (B, C, D, E, and F) relative to the cultivated species of interest:

Genome formula	Genome structure
A: 2n=2x=10	diploid
B: 2n=2x=10	
C: 2n=2x=10	
D: 2n=2x=30	
E: 2n=2x=10	
F: 2n=2x=12	

8. Seymour Mendel, a descendent of his famous great great great uncle, has returned to his nodulated roots in pea breeding. A terrible disease is ravaging the pea crop in Austria, and the populace is clamoring for Seymour to take action. He works with a noted plant pathologist, Wilt Blackleaf to screen all of the *Pisum sativum* germplasm in his collection for genetic resistance. One population, a weedy wild type, is found that appears to be resistant to the responsible pathogen.

Seymour crosses his best variety with the apparently resistant line and observes the following:

Number of plants with disease severity*:

Population	1	2	3	4	5	6
Commercial variety					2	8
Wild population	6	4				
F_1	5	5				
F_2	45	30			6	19

*1=no symptoms; 6=dead

(a) What is the probable mode of inheritance of disease resistance?

(b) Would you describe this as an example of horizontal or vertical resistance – why?

(c) Seymour contemplates possible breeding strategies for the incorporation of disease resistance into the commercial type variety. Since the populace is clamoring for such a new variety, and funds are readily available to operate the program, what would be the best method or combination of methods for Seymour to take (use what you know about the mating system in peas)?

(d) Gretchen, a graduate student working for Seymour has identified 65 polymorphisms using RAPDs, RFLPs, and SSRs that distinguish these two populations. She intends to map these markers for her thesis study, but these results will take many years to complete. Can you devise a way to use these polymorphisms in the near term to accelerate the above breeding program?

(e) What are the advantages and disadvantages of each type of molecular marker system that Seymour's student utilized?

a. The most probable mode of inheritance of disease resistance is possibly environmental or genetic (GXE) as all *populations* in the F2 are susceptible to disease.

b. **Vertical** = specific 'gene for gene' confers complete resistance to a single or few pathogen races and **Horizontal** = partial, durable, confers tolerance but not complete resistance to most if not all races – controlled by a number of genes.
   Horizontal resistance is most likely the cause (more information is needed)

c. Because of the need for genetic precision (peas are monogenic) a pedigree breeding program is proposed.

d. Gretchen's polymorphisms can be applied to QTL studies which are rapid (take about a year to complete). QTL mapping = associating a marker with a particular phenotype that you can measure.

e. See table:

	Advantage	Disadvantage
RAPDs, Random Amplification of Polymorphic DNA	o PCR based o Co-dominant* (mapping & DNA fingerprinting)	o Expensive, need proper instruments
RFLPs, Restriction fragment length polymorphism	o different fragments o lengths of DNA resulting from a digest with a o restriction endonuclease.	o Not PCR based o Time consuming o Laborious
SSRs, Simple Sequence Repeats	o PCR based o Co-dominant*	o Expensive, need proper instruments

Co-dominant = can distinguish a homozygote from a heterozygote*

9. You land a job as a plant breeder in equatorial Gabon, Africa, and are charged with the evaluation and development of new economic plant species for local farmers to grow profitably.   Following several forays into the rain forest, seeds and live plant specimens of five candidate species are successfully collected. Now the fun begins:

(a) How would you go about determining the unknown species is self or cross pollinated?
(b) Explain how you would go about characterizing the basic genome structure and behavior of each species (e.g. diploid, polyploidy, etc.)?
(c) How would you determine whether the unknown species exhibits heterosis and inbreeding depression?

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a. self-pollinated species are physiologically different from cross-pollinated. Take note on the inflorescence, and level of perfection of the flower parts. Apomictic species produce seeds but are asexual, therefore if the progeny = parental, this type is not cross-pollinated.

b. The basic genome structure can be characterizing by looking at the nuclear genome in a microscope (cytology => karyotype) polyploidy usually results in a larger plant cell, and may not be fertile. Genetic markers (SSRs and RFLPs) can be used to identify genotype (homozygous => inbreeding). These are expensive though.

c. highly self-pollinated crops can tolerate inbreeding. If this unknown is cross-pollinated, then it will lose 50% of vigor in successive generations (inbreeding depression).

In summary: a progeny test is preformed for a & c.

Alternative: Contact the U.S. National Plant Germplasm System (NPGS) and ask them for information.

10. Ideally, the breeder uses natural plant infection processes under standard production practices to screen for disease resistance.
(a) What are the inherent problems associated with simply planting in a field and using naturally-occurring infestations for this purpose?
(b) What measures would you propose to alleviate these problems?
(c) Do your proposed measures also potentially create new problems? Describe

Natural plant pathogen environments, offer patterns to predict the severity or the occurrence of disease. This is associated to the gene-for-gene theory that conceptualizes that for every gene that is a dynamic equilibrium between a pathogen and its host for the two have been coevolving to survive.

The theory states that two genes interact to confer virulence or resistance, and the outcome is based strictly on whether these genes are present. Thus there is a nature and a pattern for disease, since a pathogen is able to cause disease when it is virulent and the host is not resistant. But disease is not always present, regardless of how large a population may be, this is because resistance and avirulence genes are dominant, and disease may not occur under the presence of these genes, regardless of how favorable environmental conditions may be (Agrios 140).

a. Disease resistance is a complicated process as avirulence genes are dominant. However, virulence may result and may cause entire cultivars to be destroyed – an economic devastation and a risk. Disease resistance overall is a quantitative trait which is difficult to improve. There may be different types of infections based on the environment (disease triangle) that are different each year.

b. To alleviate this problem, more varieties of diseases must be introduced to the cultivar to promote disease resistance.

c. this proposal for a variety of pathogen::cultivar testing promotes new problems as a cultivar may be resistant to the introduced pathogens but a new disease stikes which it is completely susceptible to. Also, linked genes may produce inferior cultivars that are immune to disease but lack quality in other areas (physiology, taste etc.)

11. Potatoes are currently propagated asexually, by tubers. In fact, many important potato cultivars are sexually sterile. Breeders have been attempting for many years to introduce a genetic system for sexual propagation by true seed. Explain the genetic advantages and disadvantages of switching from asexual to sexual propagation in potatoes.

Asexual -> sexual propagation in potatoes

ADVANTAGES	DISADVANTAGES
o Sexual reproduction produces new alleles o Diversity of potato is maintained in the number of germplam stored -> motivation for breeding programs o Economically very important	o Clonally propagated cultivars are susceptible to diseases such as blights that may wipe out an entire field due to <u>specific</u> plant versus pathogen interactions o (e.g. potato murrain, caused by *Phytophthora infestans*) o About four cultivars account for about 75% of the potato acreage in the US o There is a considerable amount of predictability that asexual propagation offers and is valuable economically.

12. Wheat and barley are close relatives in the family *Gramineae*. Wheat is an allohexaploid (2n=6x=42) while barley is considered a diploid (2n=2x=14).
What are the important considerations in embarking on a **mutation breeding program** in wheat as compared to barley?

Mutations are generally random effects unless they are artificially induced. Mutation breeding is the use of mutagenic agents to increase the frequency of mutant plants useful in the breeding of improved cultivars.

Allopolyploidy: Multiples of chromosome sets from different species

As there are no phylogenetic barriers to gene flow, a mutation breeding program may work:

Ploidy change can be induced in a mutation breeding program by many chemical agents. For example, Use of colchicine to induce chromosome doubling. This can be induced on the diploid barley to promote allohexaploidy. This would be phenotypically visible as ploidy change usually means a larger somatic cell.

Side effects: cell division errors, chemical potency can induce undesirable effects.

12. Louis de Vilmorin initiated the first organized sugarbeet (*Beta vulgaris*) breeding program in the 1850s in France. Without any knowledge of the principles of genetics, he successfully converted sugarbeets fodder crop used to feed animals into a bona fide sugar producing crop. Prior to that point in history, sugar was imported from the tropics, extracted from sugarcane. Hence, the world sugar market was undermined by unstable governments, and catastrophic weather events. **Vilmorin proposed to increase the total sugar content of the sugarbeet taproot substantially, reducing the overall cost of sugar to Europeans and growing it closer to home, ensuring a more reliable supply.**

When Vilmorin started, the expressed juice of the best sugarbeet varieties was 7.5% sugar. The method he used was mass selection.

If the **narrow sense heritability of sugar content is 30%** and the selection differential is 2.0% per generation, **predict what should be the mean sugar content of the population after 5 generations.**

Selection differential = **S** = 2.0% per generation
NSH = h^2 = 30%
Ratio of R/S = equal to the slope of the line or the heritability
Response to selection = R = **7.5%**

R/S ratio	h^2	Generation #
7.5%/2%	3.75	1
3.75%/2%	1.875	2
1.875%/2%	0.9375	3
0.9375%/2%	0.46875	4
0.46875%/2%	**0.234375**	**5**

After 5 generations, the sugar content would be 23%.
The mean of 30% and 23% = 25%

13. The total phenotypic variation for sorghum grain protein content in a randomly mating population was partitioned as follows:

V_G = 3.5 V_A = 3.2 V_E = 1.6 (a) What is V_T? (b) What is broad sense heritability? (c) What is narrow sense heritability?	(d) How can you use this information in planning the most effective breeding program to increase grain protein content in sorghum?

a. $V_T = V_G + V_E$ = 3.5+1.6 = **5.1** = phenotypic variance (almost half due to environment and genetics) = V_P

b. Broad-sense heritability (H) = estimate of the total genetic variance
    H = V_G/V_T = 3.5/5.1 = **0.69**

c. Narrow-sense Heritability (h^2) = amount of additive genetic variation within the total phenotypic variation
    $h^2 = V_A/V_T$ = 3.2/5.1 = **0.63**

d. There are many uses for calculating heritability: 1. it determines the relative importance of genetic effects that can be transferred to progeny (F1), 2. It determines the best selection procedure to improve a trait and lastly 3. It can be used to predict gain from selection. If heritability is high, then selection of any kind if more effective as this means that the environmental effects are not responsible for the phenotype.

    The narrow-sense heritability is most important as it measures additive gene effects which can present false positives. Since both of the heritability equations yield results that are not too strong (not close to 1) it is best to increase the sample size to yield better results as a breeding program is quite a financial and timely investment.

    For this breeding program, if a pretty liberal selection intensity was used to counteract the low heritability results, the following would be the Expected Gain from Selection:
    Gs = (i) (√V$_P$)(h2 or H)
    i = constant based on selection intensity = 20% = **1.400**
    Vp = phenotypic variance = **5.1**
    h2 or H = heritability
    Gs = gain from selection from Broad-sense Heritability = (1.400)(5.1^(1/2))(0.69) = **2.18**
    (best for asexual plants)

Since sorghum is predominantly self pollinating, this aspect of inbreeding can be used to drive to genetic fixation or homozygosity and then check the progeny with heritability testing to further check the effect of the environment.

14. You are a soybean breeder at the initial stages of planning a breeding program for the enhancement of a specific trait. The trait is known to be **polygenic** and it is suspected that many of the **desirable alleles are linked in repulsion**. Would the pedigree or single seed descent method be the best choice under these circumstances?

Pedigree (PG)	Single Seed decent (SSD)
- Hybridization is used to generate variety - Breeder keeps records (traceable to parental) - Also, advancement of the program is based on desired results - Genotypic and phenotypic selection - Timeline: 10-12 years	- Attaining homozygosity as soon as possible - Decrease of heterozygosity - Assumes that a single seed represents the genetic base of each F2 progeny. - Loss or potentially desirable recombinants/segregants due to small sample size and lack of selection
Conclusion: Generates more genetic precision than SSD	**Conclusion**: Cheaper than PG

Under these circumstances, the soybean breeding program with a polygenic trait is proposed to adapt the pedigree program as it generates more genetic precision.

15. Dr. Goffreda explained the use of the modified backcross technique in apples.

(a) Diagram a modified backcross program to transfer red fruit into green or yellow varieties

(b) What are the advantages of the modified backcross method as compared to traditional backcross?

a. In order to transfer red fruit to green or yellow varieties, the following procedure is presented (from the breeding process used by Dr. Goffreda)
- Select parents that are red -> Collect pollen
- Emasculate female -> Apply pollen
- Harvest fruit
- Embryo culture.
- Stratify seed -> Plant in GH.
- Screen seedlings -> Transplant to field
- Evaluate.
- Discard undesirable trees -> Propagate and test best trees.

b. A traditional backcross method hopes to replace an undesirable gene with a desirable alternative (like color) while preserving other characteristics = Recurrent (adapted parent) x donor (source of desirable gene). Regular backcrossing may not be possible if there is self-incompatibility.

16. Celery (*Apium graveolens*) is a diploid (2n=2x=22) species that has been found to have the following biological features pertinent to plant breeding:
- Progeny from open-pollinated populations were found to be, on average, about 75% cross pollinated
- Outcrossing in celery is promoted by floral protandry
- Very little inbreeding depression, but a substantial degree of heterosis have been observed
- A cytoplasmic male sterility system has been discovered, but in a wild relative

You accept a new position as a cool-season vegetables breeder for a seed company, and celery is among the crop species cited for improvement. All current celery varieties are open-pollinated populations. The possibility of a hybrid celery variety is suggested by your supervisor.

(a) Why does the company want to invest resources into the development of a hybrid variety, when open-pollinated varieties are so much cheaper and faster to develop?

(b) Is celery a good tentative candidate to consider for breeding a hybrid variety? Why?

(c) What financial equation must be used to determine whether it is feasible to invest resources into the development of hybrid celery?

(d) Diagram a breeding plan for the development of a new hybrid variety of celery that makes use of cytoplasmic male sterility

a. A hybrid cultivar, is the F1 product of the cross between two inbred lines. Although open-pollinated species are cheaper to maintain, they cannot undergo heterosis naturally. Overall hybrids increase the yields of non-hybrid cultivars, an achievement worth an economic investment. Hybrids also offer an increased phenotypic uniforimity which is predictable. There is also protection against proprietary theft.

b. Like all plants, celery is not immune pathogens. If the climate where this breeding program is being proposed has high moisture along with the cool temperature, it is most likely not favorable to grow this crop as it will be susceptible to fusarium yellows and other pathogens.

c. Feasibility of Hybrids vs OP Varieties = (Cost of hybrid seed production) – (Cost of Open Pollinated seed production)

d. A line = male sterile, sterile cytoplasm (S), seed producing parent
B line = male-fertile cytoplasm
C line = restorer of fertility (RR)

Source population female -> inbreed A line and B line separately -> A line x B line => male sterile female from single cross
Source population male -> inbreed C line => male fertile male from single cross

To form the hybrid (male-fertile) celery cultivar: Cross male sterile female from single cross with C line.

17. Draw lines connecting each of the following plant species with the presumed Center(s) of Origin:

a. Kentucky bluegrass   Asia: d, f,i

b. Cranberry   Africa none list here: coffee, melons etc.

c. Tomato   Europe: a, e, j

d. Wheat   South America: c

e. Peach   Australo-Asia, i

f. Asparagus   Hoboken, NJ: b, h

g. Corn   North America: g,

h. Blueberry

i. Apple

j. Bentgrass

18. Describe the salient differences between a Plant Patent and Plant Variety Protection Certificate.

	PVPA (Plant variety)	PPA (Plant Patent)
Cost	$3400	$1500-$8000
Asexual	Yes	Yes
Sexual	Yes	No
Inspected by	Plant Scientists (Research Universities)	Lawyers
Number of varieties	1 only	1 only
Distinctions	Habit, immunity, flower color, flavor, productivity, perfume, just different	

19. What is the difference between overdominance and heterosis?

Heterosis is referred to as hybrid vigor. This is the unexplainable phenomenon where the progeny of the cross between two inbred lines is superior (most often) to ether of the parents. This is also defined by the increase in size, vigor, fertility and overall productivity of the F1 over the average value of the two parents. Such occurs when two inbred lines (of an outbred species) are crossed.

Overdominance occurs when each allele contributes to a separate effect and thus the combined alleles produce an effect that is greater than if it would have occurred separately. Overdominance effects can be fixed only in the progeny hybrid through apomixis. Overdominance is a hypothesis proposed by Shull and East independently, it is also referred to as the interaction of alleles at a single locus. This theory assumes that a heterozygote locus has a greater positive effect and there is superior to homozygote loci.

The difference between these two terms is that overdominance tries to answer the phenomenon of heterosis by being the casual agent in the form of a theory.

20. You are a small grains breeder in developing Central America, and release a 4-component multiline population of wheat to subsistence farmers, who will use a portion of the seed harvested from ensuing generations for the following sowing cycle.

The original composition of the population is 25% each, or equal proportions. Your theoretical experiments give you estimates of selective fitness (as compared to the current standard variety) of each inbred component, or subpopulation, of the multiline as follows:

Subpopulation A: 1.50

Subpopulation B: 1.00

Subpopulation C: 0.75

Subpopulation D: 0.50

After 2 generations, what would be the estimated proportion of each original multiline component?

Type	F1		F2 = 50% of F1	F3 = 50% of F1
A	1.5	25%	0.75	**0.375**
B	1	25%	0.5	**0.25**
C	0.75	25%	0.375	**0.1875**
D	0.5	25%	0.25	**0.125**

Answers, in bold.

21. A backcross breeding program is initiated to transfer a single dominant allele from a wild to a cultivated population. How many generations are needed to exceed a recovery of over 96% of the recurrent parent?

Since 100%-96% = 4%

Generation	Percent genes from parental
1	100
2	50
3	25
4	12.5
5	6.25
6	**3.125**

Answer: about 6 generations are needed.

22. If you start a randomly mating population from 10 individuals, 7 AA and 3 aa, what will be the phenotypic frequencies at Hardy-Weinberg equilibrium?

The Hardy-Weinberg equilibrium is used to calculate genotype frequencies from allelic frequencies. For HWE to be valid there needs to be a random mating (random union of gametes) within the population, since this is true:

Allele frequency of A = 7/10 = 0.7 = p
Allele frequency of a = 3/10 = 0.3 = q

Gene frequency = p+q=1
(allele frequency of 1 = fixed; allele frequency of 0 = lost)

AA: p^2 = $(0.7)^2$ = **0.49**
Aa: $2*p*q$ = $(2)(0.7)(0.3)$ = **0.42**
aa: q^2 = $(0.3)^2$ = **0.09**

Maternal genome	Frequency	Parental gamete	Frequency	Zygote genotype	Frequency at HWE
A	p = 0.7	A	p	AA	p^2 = **0.49**
		a	q	Aa	$p*q$ = **0.42**
a	q = 0.3	A	p	Aa	
		a	q	aa	q^2 = **0.09**

With 100 individuals, 49 would bear the AA dominant-homozygous genotype, 42 would bear the Aa heterozygote genotype and 9 would bear the recessive-homozygous genotype.
There are many gene interactions that are involved in phenotypes; therefore, the phenotypic

23. Which of the following factors do <u>not</u> promote cross pollination in higher plant species (circle all that apply)?

      a. Autogamy (pollen comes from the same flower)

      b. Self-incompatibility (promotes outcrossing by rejecting own pollen)

      c. Cleistogamy (flower fails to open -> Self)

      d. Monoecy (receive pollen from own male flowers)

      e. Heterogamy (both, but doesn't tolerate inbreeding)

Answers: a,c,d.

24. Corn breeders typically devote a considerable proportion of their efforts into population improvement in preparation for the actual breeding program.
In genetic terms, what does accomplish?

Population improvement: mass selection, recurrent selection, inbreeding (self, sib, half-sib) with selection, selection based on progeny tests.

Since all breeding programs (however small or large) are an economic investment, it is essential to scour the best germplasm and select the most useful population to use in the program. This does not always mean look for the most superior variety – this is the goal of the breeding program itself. However, it is best to approach all breeding programs with a goal in mind, especially in programs such as mutation breeding where the outcome is unpredictable.

Genetically, to have a variety of germplasm that can produce the correct types of results. If the species is cross-pollinated, a cyclic selection approach is used for intermating which increases the frequency of favorable quantitative traits.

In summary, interpopulation improvement is suitable for improving populations (overall) where the end product will be a population or a synthetic cultivar, elite pure line, or mixed genotypic cultivar.

25. Which of the following inbreeding methods will lead to allele fixation more quickly? Explain why.

Both of the following methods with regular mating of subs to homozgoisity:
Sib mating.
Half-sib mating (one common parent): 12.5% fixation per locus per generation
Full-sib mating (two common parents): 25% fixation per locus per generation

Self pollination: 50% fixation per locus per generation

Answer: Self-pollination will yield to allele fixation more quickly as it has a 50% fixation per locus per generation. This is because the gamete alleles are duplicated.

26. What method of breeding would you choose for a self pollinating crop species given the following sets of criteria? <u>Explain why</u>.

a. Only one main trait of interest; simply inherited; immediate demand for results; unlimited budget (including space, labor, etc.)

b. Several traits of primary interest; traits present in two different source populations; traits of varying types of inheritance and heritability; moderately high demand for results; adequate budget for a research farm plot and greenhouse space and 100% of a technician

c. Three traits of interest, all simply inherited; traits present in two different source populations; high demand for results; adequate budget for a research farm plot and greenhouse space and 50% of a technician

d. Several traits of interest; traits present in three different source populations; trait inheritance unknown; moderately high demand for results; adequate budget for a research farm plot and some plot care labor only

Answers:
a. Pedigree analysis is best as it is quicker than the other methods but requires a dedication of finances. However the result generate has a considerable genetic precision.

b. Single-seed decent is best here as there is a variety of heratbility and inheritance. The cost value of such a program is low as well (as opposed to double haploid) also bulk population doesn't yield scientific information for later use (this would render the technician's job useless for later)

c. Bulk population is best here as it can be used effectively with traits of low heritability and it has a relatively low cost.

d.   Bulk population is best here as well as it can be used effectively with traits of low heritability and it has a relatively low cost.

27. All breeding programs typically end with a similar procedure for the final selection of the finished commercial cultivar. Which of the following statements are correct pertaining to these final steps (circle all that apply)?

a. Candidate cultivars are tested in multiple years
b. Candidate cultivars are tested in multiple locations
c. The number of candidate cultivars decreases over time
d. The testing is done using a recognized statistical model for the credible contrasting of relative candidate cultivar performance

a.   e.g. field variety trials,
b.   e.g. Regional Breeding Teams, Extension locations (within geographical latitude and longitude or intercontinental and international locations)
c.   e.g. variety performance
d.   e.g. Mapping QTLs, optimized genetic models

Answers: a,b,c,d

28. Consider this half-diallel in answering the following questions:

Yield in cross A x B

Inbred #	1	2	3	4	(AVG)
1		5	3	7	(5)
2			7	11	(9)
3				7	(7)

a. Which inbred line has the best GCA?
   Inbred #2

b. What inbred cross pair has the lowest SCA?
   Inbred #1

c. What genetic effects are GCA and SCA used to measure?

   o GCA stands for General Combining Ability which measures the performance of the progeny of an individual with respect fo V_A.
      ▪ High GCA confers to being able to produce high performing hybrids with a series of other inbreds

   o SCA stands for Specific Combining Ability which measure sthe performance of the progeny of an individual cross with one specific line = $V_A+V_D+V_I$
      ▪ SCA test to idenfity specific pairs of inbred with exceptional performance in crosses.

29. You are a rice breeder in China running a typical conventional breeding program trying to develop new cultivars with improved drought tolerance. You are aware of the work done at CIMMYT and believe that Quantitative Trait Loci will greatly enhance your plant breeding program. **Describe the steps you would take to incorporate Marker-Assisted selection into your current breeding program? Include possible advantages and disadvantages.**

QTL mapping overall is quicker than other means to identify linkage. It is also reliable and there is an international effort to map QTLs.

Step	Procedure
1	Generate **progeny** from cross between two parents to study recombination
2	have **genetic markers** to create a genetic map in which you can distinguish the two parents genetically (construct a mapping population)
3	**analyze** progeny from that cross both for the trait that you want to select for and for the genetic markers that you have
4	all individuals in the mapping population are **scored** for the phenotype and the marker genotype

-> QTL analysis is conducted

Utilize the markers in the QTL analysis constructed (in your lab etc.) and compare the array of markers on linkage groups of different species as similar results may arise. Synteny data shows possibilities of gene location based upon evolutionary ancestral genomes. However the disadvantage is that this analysis is not always correct as evolution between two species generates considerable variation.

30. As economies around the world become more robust, the demand for aesthetic plant species increases dramatically. You are lured to China to head up a cool season turfgrass breeding program in Harbin, Manchuria. While collecting grasses in the surrounding hillsides, you find a population of *Poa pratensis* that has a highly prostrate, rhizomatous growth habit and deep green color.

Hoping to merge genes for local adaptation with better turf quality, you make crosses to western varieties, using the Chinese population as female parent. The progeny all seem to be of the Chinese type, so you continue with the program, hoping that new segregants will appear.

Following several more generations of intercrossing and selecting among descendents of the original crosses, you are getting nowhere; <mark>while some variation is observed</mark>, all populations still closely resemble the original type that was collected. What do you think is happening?

Poa pratensis is the binomial nomenclature for Kentucky Bluegrass – the most popularly propagated turfgrass in North America.

Size of the breeding program is essential to promoting genetic variability. Breeding programs must have a population size of 100 to reduce sampling errors by assortative mating which occurs when plants are too close to each other.

If there is little variation observed, this would mean that the female (Chinese population) parent is self-fertilizating, even if it may have a perfect flower. The lack of variation is a result of asexual reproduction, where the pollen tube may not be physically capable of promoting sexual reproduction so the female (hermaphrodite) is undergoing asexual reproduction.

Probable issues:
- o Self-incompatibly
- o Assortative mating
- o Variation is suppressed due to environment (GXE)
- o Apomixis -> seed is being produced but no genetic recombination

All of these issues can be checked with RAPDs or SSRs (see table in Question 8).

31. If you were a newly selected plant breeder starting a program from scratch, explain how you would go about acquiring germplasm from the USDA National Plant Germplasm System.

Be specific about the resources they offer and the likely procedures that would need to be followed.

Germplasm is Populations of sexually compatible individuals that possess desirable or potentially desirable genes
This is stored in Gene Bank or Repository
1. Look for centers of diversity
2. Look at crop gene pools: breeders must first utilize the germplasm in GP1 and proceed outwards.
3. Collect or request germplasm
   a. To request: U.S. National Plant Germplasm System (NPGS Repositories of germplasm)
   b. To collect: International or intercontinental (funding for trips, GXE)

32. What is a synthetic cultivar? What are the basic techniques involved in synthetic cultivar development? What types of crops is it mainly used for and why?

Synthetic cultivars are obtained from planned mating involving selected genotypes. These types of cultivars are cross-pollinated, open-pollinated, and are artificially produced by the breeder. Cross-pollinated breeding programs tend to focus on improving the population overall.

These cultivars are constructed through a breeding program which goes through the following steps:

1. Selection of germplasm
   a. Heterogeneous -> the product will adapt to environment genotypically (advantage and disadvantage)
2. Phenotypic evaluation of crops (entire gene pool)
   a. Recurrent restricted phenotypic selection
   b. Source population -> offers a wide array of genotypes
3. Plant material is selected based on selection intensity (from turf plots and etc.)
4. Polycross progeny testing formation
   a. Isolated group of clonal lines replicated that each clone will be pollinated by a random sample of pollen from all the other clones. (In theory anyway)
   b. Bias results from non-random mating or self-fertilization
5. Polycross progeny testing
   a. Cross-pollinated seeds are harvested from the clones
   b. Planted for evaluation of yield and other characteristics
6. Plant material is tested for performance in combining ability or with progeny testing
7. Best original clones are selected -> synthetic established
   a. Random pollination is permitted
8. Syn1 generation: results from the equal harvesting of seed from Syn0
9. Syn2 generation: increase the number of seeds for sale
   a. major advantage for synthetic cultivars is the mass production of seeds for testing and for planting
   b. Open pollinated seed is harvested from Syn1

This synthetic cultivar population system is different from a natural cultivar population as it is due to a breeder selected parental germplasm.

The system is used for clonally propagated crops (turfs like *Poa spp.*) and for inbred lines (e.g. *maize*)

33. Be able to describe and interpret this graph.
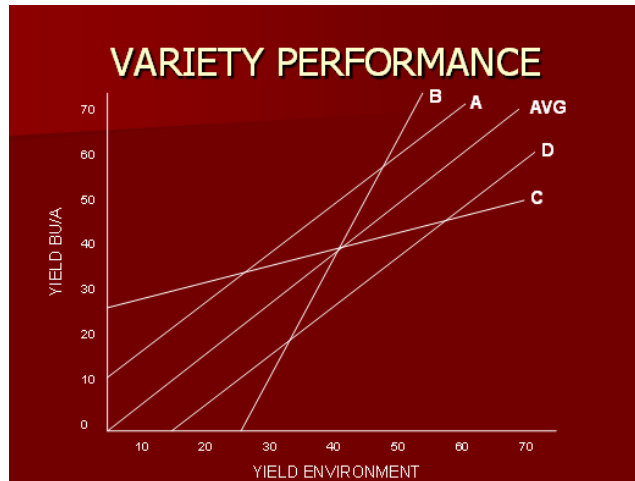
Dr. Helsel argued that Plant Breeding is a numbers game and almost everything can be illustrated in the GXE relationship. The preceding chart shows variety performance with respect to yield in bushels per acre versus yield environment.

Variables:
- o Yield environment = per that piece of land = possibly cubic meters or etc.
- o Yield bushel/*acre* = economic or propagation value

Type	Interpretation
A	o This is a superior variety, which offers consistent high yield from start to finish o A is the best choice in the long run while C is a better choice for the short run (under ~30 yield environment units)
B	o Uniquely adapted with a specific genetic makeup for a particular environment o Out performs all varieties within ~30-~50 yield environments o After or before this threshold, this variety is obsolete (in its considered value anyway)
C	o Fast initial yield per bushel/acre with respect to a high yield environment o Long run, more benefit from D if you extend your yield environment (see intersection of 50 Yield environment) o Short run, more benefit from C is you have a limited yield environment
D	o D represents most likely an older variety which does not provide as much yield as AVG and A, but it offers consistency, stability. o D starts off slow
Average	o The average variety offers stability, and an average yield. o This variety is not at a competitive level but at outperforms some varieties at particular points