Chapter 11  Genetics

Introduction

Most of our agricultural products came about through the process of selective breeding. Records show as far back as 5,000 years ago people deliberately used cross-breeding to improve palm trees and animal stocks. Details of grape growing figure in mosaics of the Fourth Dynasty of Egypt (2440 B.C.) and later (Winkler et al., 1962). By the early 1900's, the use of plant breeding was wide spread. Studies into the genetics of disease resistance in cereal rusts by researchers (1905) and into wilt diseases of cotton, watermelon, and cowpea by an other research led to the selection and breeding of resistant varieties of these and other crops (Agrios, G.N., 1978). However, the forgoing research might not have been possible except for the scientific works of Gregor Mendel who layed the foundations for experimental design and experimentations on inheritance.

Outcomes:

1. Understand genetic terms
2. Demonstrate the use of a Punet square as related to Mendelian genetics
3. Describe and understand the use of Mono- and Di-hybrid crosses.
4. Be able to demonstrate the use of Test Crosses
5. Be able to interpret a pedigree charts

I. Terms used in genetics

A. Genes - units of information (Biochem info)
   1. Locus - each gene has position on its chromosome
   2. Alleles - differing molecular forms of a gene
      a. Alleles are denoted as: ‘a’, ‘b’, ...... ect....
      b. Homozygous - both alleles are the same
         c. Heterozygous - both alleles are different
      d. Dominant - an allele is said to be dominant (A) if its effects on a trait masks the effects of the corresponding recessive (a) allele
      e. Homozygous dominant = AA; Homozygous recessive = aa  Heterozygous = Aa
         Homo = meaning the same
         Hetero = meaning different

B. Traits
   1. Genotype - genes present in an individual
2. Phenotype - observable traits of an individual or how these traits are expressed (What you see)

C. inheritance of traits

1. $P$ parental generation
2. $F_1$ first-generation of offspring
3. $F_2$ second-generation of offspring

II. THEORY OF SEGREGATION

A. Theory of segregation

1. $2n$ organisms inherit 2 alleles per trait on a pair of homologous chromosomes
2. During meiosis the 2 chromosome segregate such that each gamete receives only one chromosome

B. Monohybrid crosses

1. Assumption: Each $2n$ organism (i.e. pea plant) inherits 1 allele for a gene trait from each parent
2. Outcome of crosses
   a. Two parents that are true-breeding with differing traits for the same gene are said to be a Heterozygous condition

   1) The first trait made of a set alleles can be:
      
      $aa$ (recessive)
      
      while the second trait can be a set of alleles:
      
      $AA$ (dominant)
      
      b. Trait 1 ($aa$ recessive) is not expressed in the first generation ($F_1$)

1) Now back cross $Aa$ with results of $F_1$ generation

Note: We use a math trick to calculate our probabilities of outcome. In Genetic we call this trick a Punnet Square.

WHAT DO WE GET ?????

<table>
<thead>
<tr>
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<th>A</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>AA</td>
<td>Aa</td>
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<tr>
<td>a</td>
<td>Aa</td>
<td>aa</td>
</tr>
</tbody>
</table>

Multiply the top row by the side column and place alphabet letters in side box. This inside box represents a possible Diploid offspring of the 2 gametes as represented by the top row by side column.

2) The recessive trait shows up in the next generation ($F_2$) or a 3:1 ratio

3. Do the math analysis of $F_2$ generation with use of a
‘Punnet Square’

a. Conclusion - - - -> Genes do not blend
b. Offspring show a 3:1 phenotypic ratio of segregation

D. How can we test the concept of segregation of genes?

1. Test crosses are made

   a. Cross the progeny of the \( F_1 \) generation with a known homozygous recessive individual

   b. The resulting 1:1 ratio of recessive to dominant phenotypes supports the argument of gene segregation

III. INDEPENDENT ASSORTMENT

A. Dihybrid crosses

1. What is a dihybrid cross??

   a. Experiments involving 2 non-linked traits (ask yourself: what are linked traits?)

      Such as flower color and plant height

      1) Parent #1 - purple flowers and tall \((AABB)\)

      2) Parent #2 - White flowers and short \((aabb)\)

   b. The dominant gene in the \( F_1 \) generation will for purple flowers and tallness

   c. Do genes for flower color and height travel together??

      1) Testing of the hypothesis

         a) Back cross the \( F_2 \) generation with itself and examine the outcome

         b) Genes on non-homologous chromosomes segregate independently of each other giving a phenotypic ratio of 9:3:3:1

IV. DOMINANCE RELATIONS

A. Incomplete dominance

1. A dominant allele cannot completely mask the expression of another allele

   Case in point: Snapdragon flower color of red and white phenotype resulting in pink expression

B. Co-dominance

1. More than two forms of alleles exist at a given locus
Case: Humans have more than 4 phenotypic blood types

A, B, AB, and O

V. MULTIPLE EFFECTS OF A SINGLE GENE

A. Pleiotropy

1. A single gene affects two or more traits of an observed phenotype

2. The gene for sickle-cell anemia codes for a variant form of hemoglobin

Heterozygous \((Hb^A/Hb^S)\) few symptoms

Superscript \(^A\) and \(^S\) refer to normal/abnormal hemoglobin respectively

Homozygous \((Hb^S/Hb^S)\)

   a. Shape of altered hemoglobin greatly affected resulting in clumping and capillary blockage

   b. Impaired gas flow damages the body’s tissues

References:


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Biology 101
Chapter 11
OBSERVABLE PATTERNS OF INHERITANCE

Describe the following -

genes:

__________________________

__________________________

alleles:

__________________________

__________________________

true-breeding lineage:

__________________________

__________________________

hybrids:

__________________________

__________________________

homozygous dominant:

__________________________

__________________________

homozygous recessive:

__________________________

__________________________
heterozygous:

__________________________

__________________________
genotype:

__________________________

__________________________

phenotype:

__________________________

__________________________
P, F1, F2:

__________________________

__________________________
monohybrid crosses:

probability:

Punnett-square method:

testcrosses:

segregation:

dihybrid crosses:

independent assortment:

monohybrid crosses:

probability:

Punnett-square method:

testcrosses:

segregation:

dihybrid crosses:

independent assortment:
Matching

Choose the most appropriate answer for each.

1. _____ genotype
   A. Parental, first-generation, and second-generation offspring

2. _____ alleles
   B. All the different molecular forms of the same gene

3. _____ heterozygous
   C. Particular location of a gene on a chromosome

4. _____ dominant allele
   D. Describes an individual having a pair of nonidentical alleles

5. _____ phenotype
   E. An individual with a pair of recessive alleles, such as aa

6. _____ genes
   F. Allele whose effect is masked by the effect of the dominant allele paired with it

7. _____ true-breeding lineage
   G. Offspring of a genetic cross that inherit a pair of nonidentical alleles for a trait

8. _____ homozygous recessive
   H. Refers to an individual’s observable traits

9. _____ recessive allele
   I. Refers to the particular genes an individual carries

10. _____ homozygous
    J. When the effect of an allele on a trait masks that of any recessive allele paired with it

11. _____ P, F1, F2
    K. When both alleles of a pair are identical

12. _____ hybrids
    L. An individual with a pair of dominant alleles, such as AA

13. _____ diploid organism
    M. Units of information about specific traits; passed from parents to offspring

14. _____ gene locus
    N. Has a pair of genes for each trait, one on each of two homologous chromosomes

15. _____ homozygous dominant
    O. When offspring of genetic crosses inherit a pair of identical alleles for a trait, generation after generation

16. _____ homologous chromosomes
    P. A pair of similar chromosomes, one obtained from the father and the other from the mother

Matching

Choose the most appropriate answer for each.

1. _____ Independent assortment
   A. Used to determine the genotype of an individual when it displays the dominant phenotype

2. _____ Probability
   B. The mathematical chance that a given event will occur

3. _____ Punnett-square method
   C. The separation of traits during a genetic cross

4. _____ Testcross
   D. Genetic crosses that examine the inheritance of a single trait

5. _____ Monohybrid cross
   E. The process by which each pair of homologous chromosomes is sorted out into gametes

6. _____ Dihybrid cross
   F. Genetic crosses that examine the inheritance of two traits

7. _____ Segregation
   G. A graphic means of representing the distribution of gametes and possible zygotes in a genetic cross
Problems
8. In garden pea plants, tall (T) is dominant over dwarf (t). In the cross Tt x tt, the Tt parent would produce a gamete carrying T (tall) and a gamete carrying t (dwarf) through segregation; the tt parent could only produce gametes carrying the t (dwarf) gene. Use the Punnett-square method to determine the genotype and phenotype probabilities of offspring from the cross Tt x tt.

a. phenotype:______________________________________________________

b. genotype:______________________________________________________

Although the Punnett-square (checkerboard) method is a common method for solving single-factor genetics problems, there is a quicker way. Only six different outcomes are possible from single-factor crosses. Studying the following relationships allows one to obtain the result of any such cross by inspection:

a. AAXAA=a11AA (Each of the four blocks of the Punnett square would be AA.)
b. aa X aa = all aa
c. AAXaa’=allAa
d. AA X Aa = 1/2 AA; 1/2 Aa orAa x AA (Two blocks of the Punnett square are AA, and two blocks are Aa.)
e. aa X Aa = 1/2aa; 1/2ula or Aa X aa
f. Aa X Aa 1/4 AA; 1/2 Aa; 1/4 aa  
(One block in the Punnett square is AA, two blocks are Aa, and one block is aa.)
Complete the Table

9. Using the gene symbols (tall and dwarf pea plants) from question 8, determine the genotypic and phenotypic ratios of the crosses below. For assistance, apply the six Mendelian ratios listed above.

<table>
<thead>
<tr>
<th>Cross</th>
<th>Phenotype Ratio</th>
<th>Genotype Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Tt × tt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. TT × Tt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. tt × tt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Tt × Tt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. tt × Tt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. TT × tt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. TT × TT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. Tt × TT</td>
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When working genetics problems dealing with two gene pairs, you can visualize the independent assortment of gene pairs located on nonhomologous chromosomes into gametes by using a fork-line device. Assume that in humans, pigmented eyes (B) (an eye color other than blue) are dominant over blue (b) and that right-handedness (R) is dominant over left-handedness (r). To learn to solve a problem, cross the parents BbRr X BbRr. A 16-block Punnett square is required, with gametes from each parent arrayed on two sides of the square (refer to Figure 11.9 in the text). The gametes receive genes through independent assortment using a fork-line method, as follows.

10. Array the gametes at the right on two sides of the Punnett square; combine these haploid gametes to form diploid zygotes within the squares. In the blank spaces below, enter the probability ratios derived within the Punnett square for the phenotypes listed.
   a. pigmented eyes, right-handed
   b. pigmented eyes, left-handed
   c. blue-eyed, right-handed
   d. blue-eyed, left-handed
Complete the Table

Complete the following table by supplying the type of inheritance illustrated by each example. Choose from these gene interactions: pleiotropy, multiple allele system, incomplete dominance, codominance, and epistasis.

Type of Inheritance | Example
--- | ---
a. | Pink-flowered snapdragons produced from red- and white-flowered parents
b. | AB type blood from a gene system of three alleles, A, B, and O
c. | A gene with three or more alleles such as the ABO blood typing alleles
d. | Black, brown, or yellow fur of Labrador retrievers and comb shape in poultry
e. | The multiple phenotypic effects of the gene causing human sickle-cell anemia

Problems

2. Genes that are not always dominant or recessive may blend to produce a phenotype of a different appearance. This is termed incomplete dominance. In four o’clock plants, red flower color is determined by gene R and white flower color by R’, while the heterozygous condition, RR’, is pink. Complete the table below by determining the phenotypes and genotypes of the offspring of the following crosses:

<table>
<thead>
<tr>
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<th>Genotype</th>
</tr>
</thead>
</table>
a. RR x R’R’ = | | |
b. R’R’ x R’R’ = | | |
c. R’R x RR = | | |
d. RR x RR = | | |
Self-Quiz

_____ 1. The best statement of Mendel’s principle of independent assortment is that
a. one allele is always dominant to another
b. hereditary units from the male and female parents are blended in the offspring
c. the two hereditary units that influence a certain trait separate during gamete formation
d. each hereditary unit is inherited separately from other hereditary units

_____ 2. All the different molecular forms of the same gene are called ________________
  a. hybrids
  b. alleles
  c. autosome
  d. locus

_____ 3. If two heterozygous individuals are crossed in a monohybrid cross involving complete dominance, the expected phenotypic ratio is ________________
  a. 3:1
  b. 1:1:1:1
  c. 1:2:1
  d. 1:1
  e. 9:3:3:1

_____ 4. In the F2 generation of a cross between a red-flowered snapdragon (homozygous) and a white-flowered snapdragon, the expected phenotypic ratio of the offspring is ____________.
  a. 3/4 red, 1/4 white
  b. 100 percent red
  c. 1/4 red, 1/2 pink, 1/4 white
  d. 100 percent pink

_____ 5. In a testcross, F1 hybrids are crossed to an individual known to be ____________ for the trait.
  a. heterozygous
  b. homozygous dominant
  c. homozygous
  d. homozygous recessive

_____ 6. The tendency for dogs to bark while trailing is determined by a dominant gene, S, whereas silent trailing is due to the recessive gene, s. In addition, erect ears, D, is dominant over drooping ears, d. What combination of offspring would be expected from a cross between two erect-eared barkers who are heterozygous for both genes?.
  a. 1/4 erect barkers, 1/4 drooping barkers, 1/4 erect silent, 1/4 drooping silent
  b. 9/16 erect barkers, 3/16 drooping barkers, 3/16 erect silent, 1/16 drooping silent
  c. 1/2 erect barkers, 1/2 drooping barkers
  d. 9/16 drooping barkers, 3/16 erect barkers, 3/16 drooping silent, 1/16 erect silent

_____ 7. If a mother has type O blood, which of the following blood types could not be present in her children?
  a. type A
  b. type B
  c. type O
  d. typeAB
  e. all of the above are possible

_____ 8. A single gene that affects several seemingly unrelated aspects of an individual’s phenotype is said to be ____________.
  a. pleiotropic
  b. epistatic
  c. allelic
  d. continuous

_____ 9. Suppose two individuals, each heterozygous for the same characteristic, are crossed. The characteristic involves complete dominance. The expected genotype ratio of their progeny is ____________.
  a. 1:2:1
  b. 1:1
  c. 100 percent of one genotype
  d. 3:1
10. If the two homozygous classes in the F1 generation of the cross in exercise 9 are allowed to mate, the observed genotype ratio of the offspring will be
   a. 1:1
   b. 1:2:1
   c. 100 percent of one genotype
   d. 3:1

11. Applying the types of inheritance studied in this chapter of the text, the skin color trait in humans exhibits
   a. pleiotropy
   b. epistasis
   c. environmental effects
   d. continuous variation
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