Chapter 8: sHeredity and Genetic Variation;
Biology Lecture 8.1 – 8.11

IN: Explain in your own words:
1. What particular traits (give two) have you inherited from your parents (from whom? mom or dad)?
2. How do you think you inherited those traits (process)?

Sect. 8.1: Genes Determine Biological Potential

Recall that:

I. DNA – **D**eoxyribo**N**ucleic **A**cid; the **hereditary molecule** in cells.

- DNA is made up of a sequence of molecules that we call ***GENES*(are made of nucleotides)**
- Chromosomes are tightly coiled DNA molecules seen during cell division.
- DNA(genes) are passed on from one generation to the next, ie. traits such as eye color
- The human genome consists of ~ 30,000 genes!
- **Heredity** - is the transmission of genetic information from one generation to the next.
- **Genetists** – study heredity and the visible effects of genes in individuals and populations.

II. Structure of Chromosomes (DNA/Genes) and a Karyotype:

- **Nucleotides** – the information in genes; small bits of information "a molecular code"
- **Genes** – are made of a **specific nucleotide sequence** and direct all cellular processes involved with the development and function of an organism.
- Genes are passed along through reproduction and provide continuity of species so that it may better survive in a particular environment.
- **Probability** – an area of mathematics that **predicts** the chances that a certain event will occur – NOT a Guarantee! Genetists use probability to predict the outcomes of mating. Eg, what are the odds of a couple having an albino kid? 1 out of 4 or ¼, of their offspring.

Sect. 8.2: Mendel's Work Led to the Concept of the Gene

I. Genes bring about the production (synthesis) of certain proteins, such as an enzyme, muscle, or skin pigment.

- It is the production of certain proteins that indirectly results in your specific characteristic or traits, such as eye color, voice, muscle mass.

II. Gregor Mendel(1822) the father of *Genetics* – the study of heredity; the passing on of characteristics from parents to offspring. See Figure 8.2, page 185

- Revolutionized the science of genetics.
- He mathematically explained how traits were transferred from one generation to the next using probability.
- He kept careful records (data).
- He recognized patterns of inheritance throughout his experimentation.

III. Mendel chose Pea Plants as subjects because:

1. wide variety of traits in peas: round seeds, purple flowers, etc. (See figure 8.4, page 186)
2. are small & easy to grow.
3. flowers are *bisexual*; can self-fertilize (self-pollinate) to give a true-breeding plant. (See figure 8.3, page 185)
4. have egg & sperm (pollen)…. *Gametes*

IV. Mendel's 1st Experimental Design: See Figure 8.5; page 187

- He allowed pea plants to self-pollinate for several generations to ensure *true-breeding plants, ie. they will produce only one trait,*
  Example, true-breeding for tall plants or true-breeding short plants.
- He conducted crosses between plants exhibiting alternative traits.
  eg. *purple X white*, or *round seed X wrinkled seed*
- Mendel quantified his work! He counted the # & type (traits) in each offspring!

A. Mendel's Monohybrid Crosses (one trait):
Mendel crosses alternative traits to produce *monohybrids*- the offspring from a cross from parents of differing traits- *seed shape:*

P_1 (parent generation): *true-breeding round X true-breeding wrinkled*

1. The first generation (F_1-first filial):
- the f_1 generation looked like one parent; *all round seeds* - no intermediates
- he referred to these traits as- *Dominant* and the alternate trait as- *Recessive* (recessive - the trait not expressed at all or much less than the other); eg. Brown eyes vs. Blue eyes
- Mendel collected the seeds from f_1 (all tall)
- he allowed them to self-pollinate (have sex with themselves) & produce offspring

2. The second generation (F_2-second filial):
F_2 Generation: F_1(round) X F_1(round)

- He counted over 1000 offspring in f_2
- He found the recessive trait to **re-appear in the f_2**
- He found the # of *round to wrinkled* was 3/4 round to 1/4 wrinkled or **3:1**
- He tested the other 6 traits and the result was **3:1 too!**
- He concluded "the rule of dominance" dom. genes over-ride the recessive genes

Sect. 8.3: Mendel's Identified the Unit of Heredity

I. **Mendel proposed:**
1. Parents transmit their traits(genes) in encoded bits of info. called *factors* (we call them "*genes*")
2. Alternative forms of a trait(gene) are called *alleles* and the position on a chromosome where a gene is located is called a *loci* (location)
3. For every trait in an org., there are 2 genes which may or may not be the same, eg, a plant may have one allele for tallness and one for shortness. **RR or Rr or rr**
4. Only one copy of a "factor" goes into a sperm or egg when gametes are formed, ie, one allele is contributed from mom and the other allele from dad.

II. Mendel concluded:
The Law of Segregation: Mendel's 1st Law
* Mendel's explanation of the 3:1 ratio of dominant & recessive traits:
a. *alleles* (members of a gene pair, Rr) segregate (separate) from one another **during cell division (meiosis = making egg and sperm). Occurs during Anaphase!**
b. each gamete has equal probability(chance) of possessing either member of an *allele* pair (50-50 chance)

ie, a plant with the *allele* pair Tt can pass on <u>one</u> of either two traits to its offspring. Its gametes will have either **T or t**

***See figure 8.5, page 187**
Heterozygous - not the same..... Rr
Homozygous - the same ..... RR or rr
Homozygous dominant - RR
Homozygous recessive- rr

III. <u>Punnett Squares</u>: (See Figure 8.5, page 187 shows how probability is calculated).
A short-hand method for:

- A <u>mathematical prediction using probability to determine the possible outcomes</u> for genotypes/phenotypes of the offspring; ie, 1/4 chance of producing a wrinkled seeds.
- The genotypes of the parents must be known. **eg Rr X Rr**

Patterns of Inheritance;
Biology Lecture 8.4 – 8.7
Pages 188–195

Sect. 8.4: <u>Dihybrid Crosses Produce a Distinctive Pattern</u>

I. <u>Mendel's Dihybrid Crosses</u>- crosses involving **two traits**, eg, seed color and seed shape.

- Mendel wanted to investigate whether or not different genes (traits) segregate independently of one another or do they stay together?

For example, if a pea seed is <u>wrinkled</u> will it always be <u>green</u>?

A. *Mendel proposed the following*:

- According to his 1st experiment, <u>recessive traits</u> appeared in the **f_2** generation 1/4 or 25% of the time. So, if traits sort (segregate) independently of one another the probability of that would be the product of the two individual probabilities! ie. (1/4)(1/4) = 1/16

  ie, A Theoretical ratio of 9 : 3 : 3 : 1 for the following phenotypes

  9 round yellow : 3 round, green : 3 wrinkled yellow : 1 wrinkled green

B. <u>Mendel's 2nd Experimental Design:</u>
*** See Figure 8.6; page 189**

1. Established *true-breeding* plants that differed only with respect to seed color & seed shape. RR or rr or YY or yy
2. Crossed contrasting pairs. ie. **round yellow & green wrinkled.**
   P_1: RRYY X rryy
3. Allowed the f_1 generation (all round yellow; RrYy) to self-fertilize.
   f_1: RrYy X RrYy

<u>Mendel concluded:</u>

- Mendel's f_2 **observations were very close to the theoretical** 9:3:3:1 ratio.
- Thus, the two traits were segregating(separating) from one another during meiosis(cell division of gametes)!

C. Mendel's 2nd Law: Independent Assortment

States: Genes for *different traits* (eg, *seed shape & color*) are inherited independently of each other during meiosis (cell division). [In other words, if a seed is wrinkled it can be yellow or green. The traits are not linked to one another.]

Question? How do the 2 experiments differ from one another?

1. The Law of Segregation – alleles of a gene pair separate from one another. eg. RR = R + R or Rr = R + r etc…

2. The Law of Independent Assortment – genes for different traits are inherited independently. eg. RrYy = Rr(shape) + Yy(color)

USE AS AN OUT??

II. Mendel's findings apply to humans too!

Consider Lisa, the little girl with *cystic fibrosis* @ the beginning of the chapter. Genetists now know that this disease is a recessive disorder. Her parents, Bob and Mary do not have the disease.

Questions: (use ***F*** and ***f*** for *cystic fibrosis* gene)
- What are the genotypes of Bob, Mary and Lisa?
- What can the genetic counselor tell Bob and Mary about the probability of their next child having cystic fibrosis?

Sect. 8.5: Gene Expression Can Reveal or Hide the Phenotype of Genetic Inheritance

Mendel worked with traits that showed clear dominant or recessive inheritance. ie, purple or white This is not always the case!

I. Codominance - when both alleles contribute to the phenotype of a heterozygote. The morning glories exhibit **codominance**. See figure 8.7, page 190.

Example: P_1 **RR X rr** or (red flower X with white)

F_1 **all Rr** or (all pink)

II. Multiple Alleles – more than two alleles for a trait; type of **codominance**, eg. ABO blood types.

Multiple alleles (genes) encode for an enzyme to add sugar molecules to the surface of RBC's which act as recognition marker (ID tags) for our immune system ... called = *cell surface antigens*

GENOTYPE	PHENOTYPE
$I^A I^A$ or $I^A I^i$	A

$I^A I^B$	AB (universal recipient)
$I^B I^B$ or $I^B I^i$	B
$I^i I^i$	O (universal donor)

A. Transfusions & Blood Compatibility: "In theory not in practice"
*An immune response to a foreign (antigen) cell surface markers. The body responds to the antigen by producing antibodies (defense cells) which clot the blood = *agglutination*
eg. "A" blood receiving "B" blood could cause *agglutination* = serious consequences!!

III. Multi-factorial Inheritance – causes a continuous variation for a trait. eg, there is more than one phenotype for height, so there is a broad range of heights in people. Most human traits, such as height, weight, intelligence, hair color, and eye color do not occur in an either/or condition.
See figure 8.8, page 190.

- the interactions of many genes involved for a trait, along w/ environmental factors produce the many different phenotypes of hair color, skin color, body weight, etc..

QUESTION:
What types of environmental factors might influence one's skin color, or body weight?

NOTE: Codominance, Multiple Alleles and Multi-factorial Inheritance do not display the same ratios as Mendel's simply crosses, but are still considered a form of *Mendelian inheritance* ie, genes being passed on through meiosis and sex.

Sect. 8.6: X-Linked Traits Show a Modified Pattern of Inheritance

Remember that:

- Genes occur in matching pairs.
- When chromosomes are stained they show "unique" banding patterns – **cool stripes**!
- Chromosome pairs have similar size, length, and stripes. ie, **homologous chromosomes**

I. **Karyotype** – a photograph of all homologous chromosomes arranged from 1 to 22 + 23rd pair

- Detects any missing, damaged, or extra chromosomes. eg, Down's Syndrome
- Humans have 23 pairs of chromosomes
- **Autosomes** – chromosome pairs #'s 1 – 22; the same in both sexes.
- **Sex chromosomes** – pair # 23. **MALE = XY** **FEMALE = XX**
- The "Y" chromosome is highly condensed w/few of its genes used; determines maleness.

*Hey Cool! Not all organisms have an X-Y system for **Sex Determination**.
Some insects have X- ∅ system where females have XX and males have X∅, no Y chromosome.
Birds, some fish, some insects have Z-W system, where females have ZW, and males have ZZ.
Most plants and some animals do not have sex chromosomes; sex is determined by a pair of alleles!

QUESTION:
Who determines the sex of the offspring in humans, mom or dad? Set up a Punnett Square to find out.

II. Thomas Morgan's Experiment (1900's): X–Linked Traits in Fruit Flies (*Drosophila*)?
*See figure 8.11a, page 192.

- He observed that some flies had different features from the other flies. *Example:* white eyes instead of the normal red eyes.
- Morgan said the 100's of differences were "mutations"

Mutation – variations of the "normal" genetic information.
- They are not all harmful – many mutations are beneficial.
- Mutations result in alternative forms of a gene, eg. **A vs. a**
- Mutations are how new alleles come to be.
- Mutation leads to genetic variability; genetic variability leads to natural selection; natural selection leads to evolution!

Morgan's Experiment:
- They tested each mutation by mating mutant with non-mutant, eg. red eyes X white eyes
- The F_1 had only red-eyed flies, white must be recessive. This showed Mendel's patterns?
- The F_2 generation showed the expected 3:1 ratio of red-eyed to white-eyed flies.
- Morgan noticed something unusual: Only males show the white-eyed form! No girls!
- He eventually got some white-eyed females.
- He crossed: **white-eyed female X red-eyed male** *See figure 8.11b, page 192.
- The F_1were: **white-eyed males** and **red-eyed females**

Morgan concluded:
- The gene for eye color is on the X chromosome and that there is no corresponding gene on the Y chromosome.
- The Y chromosome does not contribute to eye color in flies, a single allele for a recessive form, if on a male's X chromosome, could result in a **white-eyed male**.
- A **white-eyed female** would have to have an allele (2) on both X chromosomes.

III. **X-Linked Traits, aka. Sex-Linked Traits** – a trait whose genes are on the X chromosome.
- The traits are "linked" to sex chromosomes. *See figure 8.12, page 193.

A. Red/Green Colorblindness -
- sex-linked recessive; 8% of US men; 0.4% of US women.
- inability to detect reds & green light wavelengths.
- lack the gene that encodes for light receptors(cones) in the retina of the eye.

$\mathbf{p_1}$ $\mathbf{X^cX^\varnothing}$ (normal mom) **X** $\mathbf{XY}$ (normal dad)

B. Hemophilia - blood is slow to clot or not at all. eg, The Royal Hemophilic Family (Queen Victoria)
- sex-linked trait
- lack a protein clotting gene

QUESTION:
If a recessive trait is on the X chromosome, will a male show the recessive trait in his phenotype?

Example: X^cY

Sect. 8.7: Abnormal Chromosomes Can Affect Patterns of Inheritance

Review:

- 46 chromosomes - 1956; 23 pairs
- **Autosomes** – chromosome pairs #'s 1 – 22; the same in both sexes.
- **Sex chromosomes** – pair # 23. **MALE = XY** **FEMALE = XX**
- Some birth defects are caused by abnormal numbers of chromosomes or damaged chromosomes in each cell.

I. Chromosomal abnormalities are present from birth and occur at fertilization.

1. **Monosomic** - missing an autosome. Death; still born
2. **Trisomic** - an extra autosome. Usually death or miscarriage; some exceptions.
3. **Polyploidy** – 69 chromosomes! wow… vary rare; miscarried.

Caused by:
Nondisjunction - failure of the homologous chromosomes to separate during Anaphase of meiosis.
*See Figure 8.14, page 194.

QUESTION:
Why must there be **at least two of each type** of chromosome in every cell for the embryo to survive?

II. Autosomal Abnormalities: (pairs #1- 22)
Down's Syndrome aka, **Trisomy 21** (3 - # 21's); they have 46 + 1 = **47 chromosomes in ea. cell**
*See figure 8.13, page 193

- All have distinct features of the eyes, mouth, hands, and sometimes heart problems.
- All are mentally retarded from varying degrees.
- occurs in all races (chimps too)!
- 1/750 individuals born.

QUESTION:
Why do the risks of having a Down's Syndrome child increase w/the mother's age?

III. Sex Chromosome Abnormalities: 23rd pair; (XX and XY)

- Few severe defects occur like autosomal abnormalities.

A. **XXX "Superfemale"** (47, XXX) – an XX gamete joins an X gamete.

- Sterile female

B. **XXY "Klinefelter's"** (47, XXY) - an XX gamete joins a Y gamete.

- 1/1000 males
- Sterility; low IQ; undeveloped sex organs

C. **∅Y Zygote** - produced from a ∅ gamete fused with a Y gamete.

- nonviable zygote; does not develop. **WHY?**

D. **∅X Zygote "Turner's"** (45, X∅) - produced from a ∅ gamete fused with an X gamete.

- 1/2000 females
- Sterility; webbed neck; low IQ; undeveloped sex organs.

E. **"Supermale"** (47, XYY) – abnormal male gametes are YY fused with an X gamete.

- **Y Chromosome non-disjunction**
- Viable; **XYY** normal males.
- 20/1000 of males in penal institutions; Charles Manson
- Suggests a genetic predisposition to violence?

QUESTION:
Why do most trisomies of autosomes result in death of the fetus, whereas trisomies of sex chromosomes do not result in death? ie, [Trisomy 18 vs. XXY, Klinefelter's]

IV. **Barr Bodies** (discovered by Lyon; 1961) – an **inactivated X chromosome** in all cells of a female.
*See Figure 8.15, page 195.

- A **dark stain** in the nuclei of **all cells** of the female.
- Only one X chromosome remains active in females.
- **Males do not** have Barr Bodies. **WHY?**
- Used in Olympic screening to determine the gender of athletes; (some sex change operations?)

QUESTIONS:
1. How many Barr bodies does she have? **XXX** (47, XXX)
2. How many Barr bodies does she have? **X∅** (45, X∅)
3. How many Barr bodies do a normal male have? (46, XY)

V. Abnormalities result when chromosomes are damaged: *See figure 8.16, page 195
1. **Deletion** - a piece of chromosome **missing**, eg. *Cri du chat Syndrome* (cry of the cat)
2. **Duplication** - a piece of chromosome **added** that is missing from its chromosome partner.
3. **Translocation** - a piece of chromosome **added** to a non-partner chromosome.

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VI. Human Genetic Defects – not mentioned in text!

- an allele that causes harmful effects. Most are recessive alleles.

[it has been estimated that nearly 1/3 to 1/2 of all human zygotes fail to develop because of dominant chromosomal abnormalities!]

1. Cystic Fibrosis - 1/20 are carriers. ***Ff***
   - 1/1800 are homo. recessive; common among Caucasians
   - Chloride channels in cell membrane do not function properly as a result, water is prevented from passing from blood to lungs.
   - Mucus in lungs is too thick & clogs airways as well as pancreas & liver; eventual death

2. Sickle-Cell Anemia – 1 million deaths/ year; most in Africa
   - homo. recessive; death @ young age
   - most common among African & black pop. in US.
   - 1/300 a.a is out of sequence for Hb protein
   - Hb is defective, so they can't transport oxygen properly
   - RBC's are sickle shaped, thus have difficulty moving thru blood vessels.

- Heterozygotes show some characteristics of sickle-cell
- Codominant - US = 9% ; Africa = 45%
- Less susceptible to malaria; common in areas of Africa
- Hetero. women are more fertile??

QUESTION:
What is the adaptive advantage for being a carrier for sickle-cell?

3. Tay-Sachs - brain deterioration; death by ~5 yrs. old
   - 1/3600 Jewish infants of East/Central Europe
   - homo. recessive
   - lack an enzyme which breaks down a lipid w/in the lysosomes of brain cells called ganglioside.
   - Brain cells swell & burst releasing enzymes which destroy the brain.

4. PKU (Phenylketonuria) - 1/15,000 infants in US
   - Can't metabolize phenylalanine(an amino acid)
   - Phenylaline is essential for protein synth. & needs to be in our diets. PKU individuals lack the enzyme to convert phenylaline to tyrosine (another a.a)
   - Excess phenylalanine causes the synth. of abnormal products which cause mental retardation.
   - Can be treated w/ a special diet that is phenylalanine free in PKU children.
   - Does not effect adults because brain is already developed.

5. Huntington's Disease - "late onset" 1/10,000
   - dominant allele; every carrier will die
   - progressive deterioration of the brain

6. Achrondoplasia - "Dwarfism"
   - dominant allele; every carrier will be a dwarf
   - 1/10,000 births; autosomal dominant mutation

7. Albanism – white skin, hair, pink eyes
   - a recessive disorder
   - lack the gene that encodes for the enzyme that makes skin pigment.

8. Polydactyly - dominant allele
   - extra fingers and/or toes

VII. Patterns of Inheritance:
A. *Pedigree* - family trees which are used to examine results of crosses that have already been made. Only looks at phenotype.
B. What can they tell you?
1. Can only give info. about the living or who were alive at one time
2. Sex-linked or autosomal
3. Dominant or recessive trait

Biology Lecture 8.8 – 8.10
Pages 196–199

IN: ??????

Sect. 8.8: DNA Is the Genetic Material

- By the early 1900's biologists found evidence of genes; Mendel's "factors"
- The connection between chromosomes, meiosis, fertilization and heredity (genes) was clear.

I. Boveri and Sutton (1902) – both said that, if sperm and egg each contribute the same number of genes; the genes must be located in corresponding parts of the two gametes (egg & sperm).

- Used fruit flies (*Drosophila malanogaster*) in their genetic experiments.

They concluded: The **genes** must be **located in the nucleus** of the egg and sperm.

- **The Chromosome Theory of Inheritance** – genes are functional units on chromosomes.

II. Hershey and Chase (1952) – both wanted to know where on the chromosomes are genes located? Biologists knew that chromosomes were made of DNA and protein, but they did not know whether the DNA or the protein made up the genes.

***See DNA Molecule!**

- They used viruses because they are similar to chromosomes: they have DNA with a protein coat.
- Viruses reproduce inside of a host cell; causing the cell to make new viruses.
- See Figure 8.18, page 197.

They concluded:

- DNA is the genetic material in chromosomes.
- Genes encode for proteins.

Sect. 8.9: Genes Are Long Chains of DNA Nucleotides

- Once it was known that genes are made of DNA, and genes encode for protein the field of molecular biology exploded!!
- What is the structure (molecules) in a gene?
- How do genes program the structure and function of all organisms?

I. Watson and Crick (1953) – proposed the structure of DNA and how DNA passes information from one generation to the next. [Much of their data was collected by **Rosalind Franklin** – she received little credit].

- "Double Helix" – a long, twisted, double stranded structure. *See Figure 8.19, page198.

Review:

Nucleic Acids: "DNA & RNA"

- *DNA:* Deoxyribonucleic acid
- *RNA:* Ribonucleic acid

*** See figures 4.20 & 4.21; page 98**

GEE WHIZ! ~ 6 ft. of DNA/cell, but only ~1 inch is used!

- Made of repeating subunits(boxcars) = ***nucleotides***

- Nucleotides have 3 parts: **See figure 4.20, page 98**

1) five-carbon sugar
2) phosphate group.
3) one nitrogenous base (C, G, A, T);

- The two strands are said to be – "***Complimentary Strands***" because the bases can pair up only with one other specific base, ie. **A – T and C – G**
- The **chemical bonds** that hold the bases together are very weak; they easily break.

They concluded:

1. Genes duplicate themselves
2. Genes mutate occasionally
3. Genetic info. is passed from one generation to the next through meiosis and fertilization

Sect. 8.10: Many genes Are on Each Chromosome

- There are far more genes than chromosomes, so many genes must be located on each chromosome.
- Genes that are close together on the same chromosome are said to be, ***LINKED***.
- Linked genes are usually inherited together.

Example: Chromosome #9 contains the gene for blood type (ABO gene), and an *oncogene* for a specific type of cancer. A geneticist would find that these two traits were almost always together.

*See Mendel's Pea Plants for Linkage:

Question:
Why did Mendel **not see** *gene linkage* during his 2nd Experiment? He saw the genes sort independently of one another! EXPLAIN.

I. Linked Genes do not always stay together on the same chromosome:
Reasons why: ***See figure 8.20, page 198.**

- During meiosis (gamete formation), the homologous chromosomes:
  1. Crossing-Over and exchange pieces of DNA.
  2. The farther apart the genes are to one another the more likely a break between them will occur.

Critical Point!

- Crossing over produces new combinations "variations" of genes that may be transmitted
- Genetic variation leads to adaptation and evolution.

II. The frequency with which two linked traits become separated provides a way to determine the distance between the two genes for those traits on the chromosome.

Genetic Maps – geneticists construct "maps" showing the sequence of genes on chromosomes.
***See figure 8.21, on page 199**.

Biology Lecture 8.11 – 8.12
Pages 199 – 203

Sect. 8.11: Genes Direct Biosynthesis (protein production)

The study of heredity molecules (chemicals) has come from studies on microscopic organisms like bacteria, viruses, and molds.
Neurospora crassa – a pink mold used in studying genes; reproduces sexually and asexually.

I. Beadle and Tatum – wanted to know if genes encode for enzymes (proteins) synthesis.
- They used radiation to produce *mutated* mold (spores).
- Some of the mutant molds could no longer grow on the original nutrient medium. Apparently, the radiation-induced mutations prevented the synthesis of some nutrients needed to grow.
- Other mutants could grow on nutrient medium if an amino acid or vitamin was added.

Concluded:
1. If enzymes control biological reactions (like biosynthesis), then the mutant mold must lack an essential enzyme. Adding a vitamin supplement to the mutant medium would compensate for the lack of enzyme, and allow the mold to grow.
   - Each gene specifies the synthesis of one enzyme: **One Gene – One Enzyme Hypothesis**
2. They found that mutated genes were passed down to the offspring - like Mendel's Peas
3. There is a chemical basis for dominant and recessive genes. Mutated alleles produced recessive forms, and normal alleles produced dominant forms of the trait.