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**Department of Fundamental Medical Disciplines of Uzhhorod National
University
MEDICAL BIOLOGY PRACTICALS. GENETICS.**

Practical 2. Solution of problems in Medical Genetics. Mendelian inheritance of human traits. Dihybrid Genetics.

Compiled by B.M. Sharga, Y.P. Sanislo, M.Y. Hliudzyk, D.B. Pilipiv, V.P. Feketa

Dihybrid Genetics studies what happens in crosses, in which pure parental lines differ in two genes that control two different characters.

To indicate the genotypes of pea seed color Gregor Mendel used *Y* and *y* for yellow and green seeds and *R* or *r* for round or wrinkled seeds, respectively. When he crossed two lines *RRyy* and *rrYY*, round yellow seeds were obtained, as expected for F₁. The F₂ result is summarized in Fig.1. In this and other similar experiments using other pairs of traits in many dihybrid crosses in each case he obtained 9:3:3:1 ratios. Mendel discovered that ratio of 3:1 for each of the traits in each of the crosses is preserved. By using square of Punnett we can follow the Mendel's analysis of F₂.

<p>P.: <i>RRyy</i> × <i>rrYY</i> round, green wrinkled, yellow</p> <p>Gametes: <i>Ry</i> <i>rY</i></p> <p>F1: <i>RrYy</i> (round, yellow)</p> <p>F1 × F1</p> <p>F2:</p> <table><tr><td>315 round, yellow</td><td>9</td></tr><tr><td>108 round, green</td><td>3</td></tr><tr><td>101 wrinkled, yellow</td><td>3</td></tr><tr><td>32 wrinkled, green</td><td>1</td></tr><tr><td>556 seeds</td><td>16</td></tr></table>		315 round, yellow	9	108 round, green	3	101 wrinkled, yellow	3	32 wrinkled, green	1	556 seeds	16	<table><tr><th>♀ ♂ G:</th><th><i>RY</i> ¼</th><th><i>Ry</i> ¼</th><th><i>rY</i> ¼</th><th><i>ry</i> ¼</th></tr><tr><th><i>RY</i> ¼</th><td><i>RRYY</i> round, yellow, 1/16</td><td><i>RRYy</i> round, yellow, 1/16</td><td><i>RrYY</i> round, yellow, 1/16</td><td><i>RrYy</i> round, yellow, 1/16</td></tr><tr><th><i>Ry</i> ¼</th><td><i>RRYy</i> round, yellow, 1/16</td><td><i>RRyy</i> round, green, 1/16</td><td><i>RrYy</i> round, yellow, 1/16</td><td><i>Rryy</i> round, green, 1/16</td></tr><tr><th><i>rY</i> ¼</th><td><i>RrYY</i> round, yellow, 1/16</td><td><i>RrYy</i> round, yellow, 1/16</td><td><i>rrYY</i> wrinkled, yellow, 1/16</td><td><i>rrYy</i> wrinkled, yellow, 1/16</td></tr><tr><th><i>Ry</i> ¼</th><td><i>RrYy</i> round, yellow, 1/16</td><td><i>Rryy</i> round, green, 1/16</td><td><i>rrYy</i> wrinkled, yellow, 1/16</td><td><i>rryy</i> wrinkled, green, 1/16</td></tr></table> <p>Round, yellow – 9/16; wrinkled yellow – 3/16; round, green – 3/16; wrinkled green – 1/16. Total genotypes – 16. Round : wrinkled, 12 : 4 = 3 : 1; Yellow : green, 12 : 4 = 3 : 1.</p>					♀ ♂ G:	<i>RY</i> ¼	<i>Ry</i> ¼	<i>rY</i> ¼	<i>ry</i> ¼	<i>RY</i> ¼	<i>RRYY</i> round, yellow, 1/16	<i>RRYy</i> round, yellow, 1/16	<i>RrYY</i> round, yellow, 1/16	<i>RrYy</i> round, yellow, 1/16	<i>Ry</i> ¼	<i>RRYy</i> round, yellow, 1/16	<i>RRyy</i> round, green, 1/16	<i>RrYy</i> round, yellow, 1/16	<i>Rryy</i> round, green, 1/16	<i>rY</i> ¼	<i>RrYY</i> round, yellow, 1/16	<i>RrYy</i> round, yellow, 1/16	<i>rrYY</i> wrinkled, yellow, 1/16	<i>rrYy</i> wrinkled, yellow, 1/16	<i>Ry</i> ¼	<i>RrYy</i> round, yellow, 1/16	<i>Rryy</i> round, green, 1/16	<i>rrYy</i> wrinkled, yellow, 1/16	<i>rryy</i> wrinkled, green, 1/16
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Fig.1. Analysis of F2 generation resulting from a dihybrid cross experiment, carried out by Gregor Mendel.

As we can see, there is nothing difficult in dihybrid crosses. They can be regarded as two combined monohybrid mating.

Similarly, by using the Punnett square you can work out the probabilities of particular genotypes and phenotypes that children will have at particular marriages.

During solution of problems in Genetics it is often necessary to calculate the **probability** of particular genotypes. The probability, *p* is defined as:

$$p = \frac{\text{Number of times an event is expected to happen}}{\text{Number of opportunities for an event to happen (or number of trials)}}$$

For instance, the probability of rolling a 5 on a die in a single trial is written $p(\text{of a } 5) = 1/6$, because the die has six sides. Thus on the average one 5 should turn up for each six rolls.

The probability that two independent events will occur simultaneously is the *product* of their respective probabilities. For example, rolling of 5 on a die twice is 2 independent events, and

$$p(\text{of two times } 5) = 1/6 \times 1/6 = 1/36 \text{ (The product rule)}$$

When two dice are rolled together, the probability either one of two independent events is equal to sum of their individual probabilities:

$$p(\text{of two } 4\text{s or two } 5\text{s}) = 1/36 + 1/36 = 1/18 \text{ (The sum rule)}$$

The F_2 profile from the pea dihybrid cross can be predicted if the mechanism for placing R or r is independent from placing of Y or y into the gametes. The frequency of gamete types can be calculated by determining their probabilities according to the rules just given. Thus, if you pick a gamete at random, the *probability* of picking a certain type of gamete is the same as the frequency of that type of gamete.

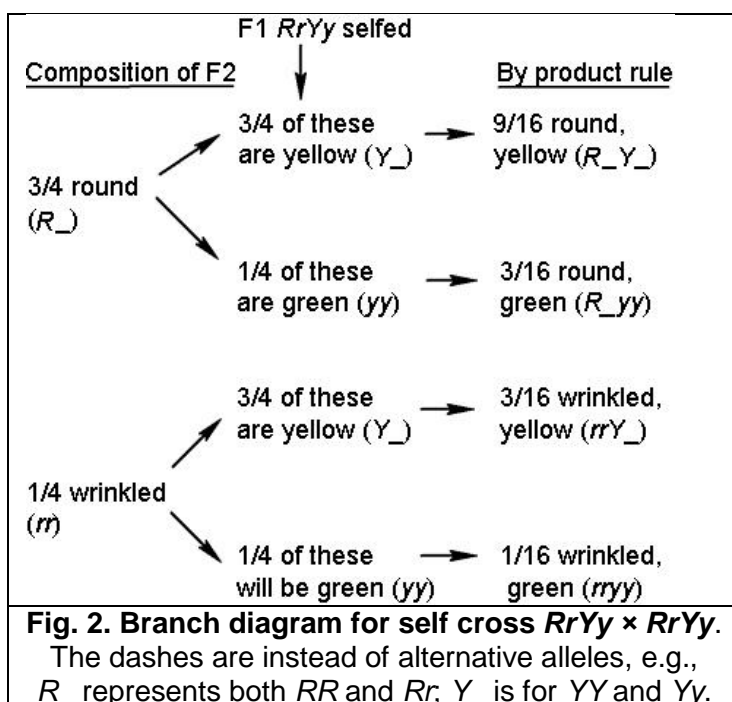
According to Mendel's first law, the heterozygote produces gametes in the proportions

$$R \text{ gametes} = r \text{ gametes} = 1/2; Y \text{ gametes} = y \text{ gametes} = 1/2$$

An $RrYy$ plant forms 4 types of gametes. The probability of each gametic combination (also present in Punnet square in Fig. 1) can be calculated according to the *product rule*:

$$p(RY) = 1/2 \times 1/2 = 1/4; p(Ry) = 1/2 \times 1/2 = 1/4; p(ry) = 1/2 \times 1/2 = 1/4; p(rY) = 1/2 \times 1/2 = 1/4.$$

Branch diagram is also useful to solve some problems. For instance, the phenotypic ratio 9:3:3:1 can be pictured as branch diagram with application of the product rule to estimate frequencies (Fig.2). The diagram can be extended to trihybrid cross if draw another set of branches at the end. However, the branch chart becoming complicated when we analyzing polyhybrid cross with many of alternative characters. The number of phenotypes and genotypes are calculated as 2^n and 3^n , where n is a number of segregating gene pairs.



In these cases we are using the product and sum rules. For example, what proportion of the progeny from the cross $AaBbCcDdEeFfGg \times AaBbCcDdEeFfGg$ will be $aaBbccDdeeffgg$ if alleles assort independently? The solution is easy obtained if we apply the product rule. Thus, $1/4$ of the progeny will be aa , $1/2 Bb$, $1/4 cc$, $1/2 Dd$, $1/4 ee$, $1/4 ff$, $1/4 gg$. We obtain the answer by multiplying these frequencies:

$p(aaBbccDdeeffgg) = 1/4 \times 1/2 \times 1/4 \times 1/2 \times 1/4 \times 1/4 \times 1/4 = 1/4096$. The inheritance of allelic segregation is called independent assortment and its general statement is known as **Mendel's second law**: during gamete formation the segregation of alleles of one gene is independent of the segregation of alleles of another gene.

To test this law G. Mendel crossed F1 dihybrid $RrYy$ with recessive double heterozygote $rryy$. The progeny phenotypes reflected the gametic types of $RrYy$ parent, because recessive homozygous parent contribution (ry) does not alter the phenotype indicated by the other gamete. G. Mendel predicted and obtained 1:1:1:1 ratio of $RrYy$, $Rryy$, $rrYy$ and $rryy$. He got the same ratio results when he tested the concept of independent assortment on 4 different combinations of characters [1]. These experiments proved the concept of equal segregation and independent assortment. The actual mechanisms of the phenomenon were unknown in that time. However, now we can explain it by chromosomal location of genes that is responsible for their equal segregation and independent assortment into gametes.

The Mendel's results were rediscovered in 1900. Later the ratios 3:1, 1:1, 9:3:3:1 and 1:1:1:1 were reported for different eukaryotic organisms. This confirmed the Mendel's laws as genetics laws for eukaryotes in general and, particularly, for human. However, in many plants and animals selfing is not possible. This problem can be overcome by crossing identical genotypes. For instance, the F1 animal resulting from pure lines cross can be mated with its F1 siblings (brothers and sisters) to produce F2. The F1 animals are identical for the genes of interest, so this F1 cross is equivalent to self-pollination in plants.

Problem 1. Use the Punnett square to determine all possible genotypes from the following marriages (and their relative frequencies):

a. ♀ $AaBb \times \text{♂} AaBb$

b. ♀ $AaBb \times \text{♂} aabb$

c. ♀ $AaBb \times \text{♂} Aabb$

Solution: Punnett squares for marriages a, b, c

Marriage a. ♀ $AaBb \times \text{♂} AaBb$

♀G: \ ♂G:	AB	Ab	aB	ab	
AB	AABB	AABb	AaBB	AaBb	AABB – 1, AABb – 2, AAbb – 1, AaBB – 2, AaBb – 4, Aabb – 2, aaBB – 1, aaBb – 2, aabb – 1, out of 16 genotypes. <u>Answer:</u> relative frequencies AABB – 1/16, AABb – 2/16, AAbb – 1/16, AaBB – 2/16, AaBb – 4/16, Aabb – 2/16, aaBB – 1/16, aaBb – 2/16, aabb – 1/16.
Ab	AABb	AAbb	AaBb	Aabb	
aB	AaBB	AaBb	aaBB	aaBb	
ab	AaBb	Aabb	aaBb	aabb	

Marriage b. ♀ $AaBb \times \text{♂} aabb$

♀G: \ ♂G:	ab	
AB	AaBb	AaBb – 1, Aabb – 1, aaBb – 1, aabb – 1 out of 4. <u>Answer:</u> all in frequency 1/4.
Ab	Aabb	
aB	aaBb	
ab	aabb	

Marriage c. ♀ $AaBb \times \text{♂} Aabb$

♀G: \ ♂G:	Ab	ab	
AB	AABb	AaBb	AABb – 1, AAbb – 1, AaBb – 2, Aabb – 2, aaBb – 1, aabb – 1 out of 8. <u>Answer:</u> AABb – 1/8, AAbb – 1/8, AaBb – 2/8, Aabb – 2/8, aaBb – 1/8, aabb – 1/8.
Ab	AABb	Aabb	
aB	AaBb	aaBb	
ab	Aabb	aabb	

Problem 2. A blue-eyed and right-handed man had married a dark-eyed right-handed woman. One of their three children is blue-eyed and right-handed, while the other two are dark-eyed and left-handed. The man marries again. This time he has right-handed and dark-eyed wife. They have 11 children, all right-handed and dark-eyed. Estimate the genotypes of the husband and his wives.

Solution: From our life experience there not much left-handed people among us. The right-handedness is dominant allele – R , and left-handedness, r is recessive allele in human populations. The dark eyes, D allele, are dominant over blue eyes (d allele). Thus, genotype of man is R_dd . Both wives were right-handed and dark-eyed (dominant traits): $R_D_$. Man has one right-handed, blue-eyed child (R_dd) and two left-handed, dark-eyed children ($rrDd$) from first marriage. The only way to have a left-handed child is if both parents have a left-handed allele, r . So, parents in first marriage are heterozygous with respect to handedness (Rr). The only way to produce a blue-eyed child is if both parents possess a blue-eyed allele, d . Thus, first wife must be heterozygous (Dd) with respect to eye color. The father's eye color genotype is dd .

Therefore the genotypes must have been as follows: man – $Rrdd$, first wife – $RrDd$.

The second marriage produced 11 right-handed and dark-eyed children. If new wife were heterozygous for either character, chances for recessive phenotypes existed. However, none of the recessive trait exhibited in the offspring. Taking to the account this fact, the second wife must be homozygous dominant for both characters ($RRDD$).

Answer: Man is heterozygous on right-handedness and recessive homozygous for eye color – $Rrdd$, his first wife is heterozygous by both genes – $RrDd$, second wife is dominant homozygous – $RRDD$.

Problem 3. The family of healthy man and women have deaf albino child. Write the genotypes of the parents and child.

Solution: C – normal pigmentation; c – albino; D – normal hearing; d – deafness.

The parents are heterozygous by both genes, otherwise they can't produce the deaf albino children. Thus the genotypes of the family are: parents, P: ♀ $CcDd$ × ♂ $CcDd$. They both are producing same (for these particular genes) gametes, G: CD , Cd , cD , cd . They have homozygote child, F: $ccdd$.

Answer: The parents have heterozygous genotype on both genes- $CcDd$, and child has $ccdd$, the recessive homozygote genotype.

Problem 4.

The man with 'eagle' nose and straight hair had married woman with wide, flat nose and super curved hair. They have 12 children and all of them are with 'eagle' nose and super curved hair. Determine the genotypes of parents and genotypes of children.

Solution: The eagle nose is dominant, E - eagle nose, and wide, flat nose is recessive, e .

The super curved hair is dominant trait – C , and straight hair is recessive, c .

For this marriage we can write: Parents, P: ♀ $CCee$ × ♂ $ccEE$

Gametes, G: Ce Ec

Children, F: $CcEe$

Answer: The parents are homozygous by one dominant and one recessive gene: wife is $CCee$ and husband is $ccEE$ and all possible children are heterozygous by regarded traits – $CcEe$.

Problem 5. Large eyes and thick lips are dominant traits. A man with small eyes and thin lips have wife with large eyes and thick lips. They have a son with large eyes and thick lips. Son had married woman with large eyes and thin lips. They produced 2 children: boy with large eyes and thin lips and girl with small eyes and thick lips. Determine the genotypes of all the parents.

Solution: E – large eyes; e – small eyes; L – thick lips; l – thin lips.

Grandparents, GP: wife ♀ $E_L_$ × ♂ $eell$ (man)

Gametes, G: EL or El , eL or el el

Son, F: $EeLl$

For son marriage: P: ♀ $Eell$ × ♂ $EeLl$

Gametes, G: El , el EL , eL , El , el

Children, F: ♀ $eeLl$ ♂ E_ll

Answer: The persons from this family have next genotypes: man – $eell$, wife – $E_L_$, son – $EeLl$, son's wife – $Eell$, son's children: girl – $eeLl$, boy – E_ll .

Problem 6. The migraine is known a dominant trait, and deafness is recessive trait. In family mother is healthy, and the father suffers on a migraine. However mother is the carrier of deafness recessive allele, the father has normal hearing. He is heterozygous on both genes. What is the birth probability of children with both of these diseases in this family?

Solution: From the problem information: M - a migraine gene, m - a normal (healthy) gene state; H - a gene of normal hearing, h - a deafness gene.

Combinations in gametes: MM or Mm – migraine, mm - no migraine; HH or Hh - normal hearing, hh - deafness

Parents, P: ♀ $mmHh$ × ♂ $MmHh$

Gametes, G: mH , mh MH , Mh , mH , mh

Punnet square:

$\begin{array}{c} \text{♂G:} \\ \text{♀G:} \end{array}$	<i>MH</i>	<i>Mh</i>	<i>mH</i>	<i>mh</i>
<i>mH</i>	<i>MmHH</i> , migraine, normal hearing	<i>MmHh</i> , migraine normal hearing	<i>mmHH</i> , no migraine normal hearing	<i>mmHh</i> , no migraine normal hearing
<i>mh</i>	<i>MmHh</i> , migraine, normal hearing	<i>Mmhh</i> , migraine and deafness (1/8=12,5%)	<i>mmHh</i> , no migraine normal hearing	<i>mmhh</i> , no migraine deafness

Answer. The probability of the child birth with both diseases in this family is 12,5 %.

Problem 7. The glaucoma of adults is inherited by 2 ways. One form is determined by dominant autosomal gene, and another is coded by recessive independent gene. What probability of the child birth with both forms of glaucoma if both parents are heterozygous by alleles of both pathological genes?

Solution: *G* - glaucoma gene; *g* - gene of normal sight; *C* - gene of normal sight; *c* - glaucoma gene
Combinations of gametes: *GG* or *Gg* – glaucoma; *gg* - normal sight;

CC or *Cc* - normal sight; *cc* - glaucoma

To find: probability of the child birth with both kinds of glaucoma?

Parents, P: ♀ *GgCc* × ♂ *GgCc*

Punnet square:

$\begin{array}{c} \text{♂G:} \\ \text{♀G:} \end{array}$	<i>GC</i>	<i>Gc</i>	<i>gC</i>	<i>gc</i>
<i>GC</i>	<i>GGCC</i>	<i>GGCc</i>	<i>GgCC</i>	<i>GgCc</i>
<i>Gc</i>	<i>GGCc</i>	<i>GGcc</i>	<i>GgCc</i>	<i>Ggcc</i>
<i>gC</i>	<i>GgCC</i>	<i>GgCc</i>	<i>ggCC</i>	<i>ggCc</i>
<i>gc</i>	<i>GgCc</i>	<i>Ggcc</i>	<i>ggCc</i>	<i>ggcc</i>

From the Punnett square we receive proportions: Normal sight (*ggCC*, *ggCc*) – 3/16 = 18,75%

Both kinds of glaucoma in child (*GGcc*, *Ggcc*) - 3/16=18.75 %

Answer: The probability of the child births with both kinds of glaucoma is

18,75%.

Problem 8. Sickle cell anemia and talasemia are inherited as incomplete dominance traits. Homozygous individuals early die, while heterozygous on both genes are viable and have a special form of hemoglobin. Malarial plasmodium is not able to feed on this hemoglobin, so heterozygotes do not get sick with malaria. Double heterozygotes develop mild, non-manifested (microdrepanocytary) anaemia. What is the probability of healthy child birth in a family where one parent is heterozygous in respect on sickle cell anemia but normal on talasemia and other is normal in respect on sickle cell anemia, but heterozygous on talasemia?

Solution: *A* - Sickle cell anemia gene; *a* – no anemia, normal blood allele;

T – talasemia gene; *t* – no talasemia, normal blood allele

Combinations of the gametes: *AA* – profound Sickle cell anemia; *Aa* – light, non-clinical form of anemia; *aa* – healthy condition, no anemia; *TT* - profound talasemia; *Tt* - light, non-clinical form of talasemia; *tt* - healthy condition, no talasemia

Parents, P: ♀ *Aatt* × ♂ *aaTt*

$\begin{array}{c} \text{♂G:} \\ \text{♀G:} \end{array}$	<i>At</i>	<i>at</i>
<i>aT</i>	<i>AaTt</i> , 25%, light form of both diseases	<i>aaTt</i> , 25%, light form of talesamia, no anemia
<i>At</i>	<i>Aatt</i> , 25%, light form of anemia, no talesamia	<i>aatt</i> , 25%, healthy in respect to both diseases, but not resistant to malaria

Answer: The probability of healthy child birth is 25%.

Problem 9. In human the right-handedness dominates over left-handedness, and achondroplasia (dwarfness because of limb, feet and hands skeleton poor development) dominates over normal development of a skeleton. In a family where the husband and the wife are right-handed and suffer from achondroplasia (dwarfs), three girls were born: right-handed and left-handed dwarfs and right-handed with a normal structure of a skeleton. Define genotypes of children and parents.

Solution: *A* - right-handedness; *a* - left-handedness;

B - achondroplasia gene; *b* - gene of normal development of a skeleton

Combinations: *AA* or *Aa* - right-handedness *aa* – left-handed *BB* or *Bb* – achondroplasia, *bb* - normal development of a skeleton

Answer: Genotypes of parents and children: mother - *AaBb* and the father – *AaBb*; first daughter - *AABB* (or *AaBB*, *AABb*, *AaBb*); second daughter - *aaBB* (or *aaBb*); third daughter - *AAbb* (or *Aabb*).

Problem 10. Human has two forms is dummy-dumbness which are defined by separate non-linked genes. What is the probability of children birth with both kinds of dummy-dumbness in family, where mother and the father suffer from the same form of dummy-dumbness, and on other form of dummy-dumbness they are heterozygous?

A - a gene of normal audition, *a* - a gene is dummy-dumbness

D - a gene of normal audition, *d* - a gene is dummy-dumbness

Combinations of gametes - genotypes:

Solution: *AA* or *Aa* - normal audition; *aa* - is dummy-dumbness

DD or *Dd* - normal audition; *dd* - is dummy-dumbness

Parents, P: ♀ *Aadd* × ♂ *Aadd*

Gametes, G: *Ad*, *ad* *Ad*, *ad*

Children, F: 1 *AAdd*, 2 *Aadd*, 1 *aadd*

25% 50% 25%

Answer: 1/4 or 25%.

Problem 11. Anomalies of eye lens and eye corneas can be the causes of congenital blindness. These are recessive characters which inherited independently. Mother and father are healthy, but are carriers of recessive alleles of blindness. What probability of healthy and sick children birth?

Solution: *A* - normal lens; *a* - lens problem;

B - normal corneas; *b* – corneas problem

P: ♀ *AaBb* × *AaBb*

♂G:	<i>AB</i>	<i>Ab</i>	<i>aB</i>	<i>ab</i>
♀G:				
<i>AB</i>	<i>AABB</i>	<i>AABb</i>	<i>AaBB</i>	<i>AaBb</i>
<i>Ab</i>	<i>AABb</i>	<i>Aabb</i>	<i>AaBb</i>	<i>Aabb</i>
<i>aB</i>	<i>AaBB</i>	<i>AaBb</i>	<i>aaBB</i>	<i>aaBb</i>
<i>ab</i>	<i>AaBb</i>	<i>Aabb</i>	<i>aaBb</i>	<i>aabb</i>

9 are healthy genotypes; 3 are causing cornea problem only; 3 are causing lens problem only; 1 is causing both: lens and cornea problems (9:3:3:1).

Answer: The probabilities of healthy and diseased children birth are: 9/16 (56,25%) and 7/16 (43,75%), respectively.

Problem 12. At the human some forms of short-sightedness dominate over normal vision and brown eyes dominate over the blue. Genes of both pairs of traits are situated in different chromosomes. What children can be expected from parents, which are heterozygous by both genes?

Solution: *S* - short-sightedness; *s* - normal vision; *B* - brown eyes, *b* – blue eyes.

P: ♀ *SsBb* × *SsBb* ♂

♂G:	<i>SB</i>	<i>Sb</i>	<i>sB</i>	<i>sb</i>
♀G:				
<i>SB</i>	<i>SSBB</i>	<i>SSBb</i>	<i>SsBB</i>	<i>SsBb</i>
<i>Sb</i>	<i>SSBb</i>	<i>Ssbb</i>	<i>SsBb</i>	<i>Ssbb</i>
<i>sB</i>	<i>SsBB</i>	<i>SsBb</i>	<i>ssBB</i>	<i>ssBb</i>
<i>sb</i>	<i>SsBb</i>	<i>Ssbb</i>	<i>ssBb</i>	<i>ssbb</i>

From the Punnet square four genotypes (*ssBB*, *ssBb*, *sSbB*) provide normal vision and brown eyes. The genotype *ssbb* provides information for blue eyes and normal vision. All other genotypes code for the short-sightedness: 3 - in blue and 9 - in brown eyes; 9+3=12.

Answer: Short-sightedness is expected in 12 out of 16 genotypes. The probability of short-sighted children is 12/16 or 75%.

Do solve the problems alone:

Problem 13. How many phenotypic and genotypic classes can be produced in dihybrid mating where one parent is homozygous and another is heterozygous for both pairs of genes?

Problem 14. Rough fur and black coat color are the dominant traits for guinea pigs, the laboratory animal often used to study human diseases. The albino, rough guinea pig was mated with a black, smooth guinea pig. The offspring types produced over a period of several years after multiple matings are black, rough and black, smooth only. What are the genotypes of parents?

Problem 15. Over 100 human disease genes were studied with use of transgenic mouse as laboratory animal. Brown (*C*) is dominant to albino (*c*) (no pigment) in coat and eyes and rough coat (*R*) dominates over smooth coat (*r*) in mouse. Two animals are selected for breeding and their genotypes are *CCR*R and *ccrr*. Determine the expected genotypic and phenotypic ratios for F1 and F2 generations and in cross between an F1 mouse and a mouse with the genotype *CcRR*.

Problem 16. Two individuals who are heterozygous for dark and light hair color and the ability to taste Phenylthiocarbamide (PTC) are just married. List all possible genotypes and phenotypes of their children, taking to the account that ability to taste PTC and dark color of the hair are dominant traits.

Problem 17. Both parents have no hearing problems. One of them has smooth hair and another has curling hair. Their first child was born deaf with smooth hair. Their second child has curling hair and good hearing. Both pairs of genes located in different chromosomes. What is the probability of the next birth of deaf children with curly hair in the family, knowing that the curly gene dominates over the gene of smooth hair, and deafness is recessive trait?

Problem 18. In humans there are two types of blindness and each is determined by their autosomal recessive gene. Genes of these two types of blindness are situated in different pairs of chromosomes. What is the probability of blind child birth, if

- a) the mother and father suffer from the same type of hereditary blindness and they are normal in respect to the pair of genes coding for other type of blindness?
- b) the mother and father are suffering from different types of hereditary blindness they are homozygous in both pairs of these pathological genes?
- c) the parents are sighted, however, both grandmothers suffer from the same type of hereditary blindness, and by the second pair of genes they are normal and homozygous. There was no blindness found in grandfather's pedigree
- d) the parents are sighted, however, both grandmothers suffer from different types of hereditary blindness, and by the second pair of genes they are normal and homozygous. There was no blindness found in grandfather's pedigree.

Problem 19. The marriage of man and woman of unknown genotypes resulted in birth of black haired, hazel-eyed boy; black haired, blue-eyed boy; bright haired, blue-eyed boy and bright haired, hazel-eyed boy. Determine the phenotypes and genotypes of parents. Dark hair and hazel eyes are dominant traits.

Problem 20. Mother has free earlobe (dominant trait) and smooth chin, while father has attached earlobe and hole onto chin (dominant trait). Their son has free earlobe and hole onto chin, while daughter has the mother's traits. Write possible genotypes of these parents and children.

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