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Diagnosis Of Skills For Using Genetic Concepts In Biology Classes At School.

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ABSTRACT

The aim of the study is to diagnose and assess the level of knowledge and skills of 10th grade students acquired in the area of *Heredity and Variation* in the subject *Biology and Health Education*. The results were obtained through a criterion-based test, processed by means of mathematical and statistical methods, and represented in graphs. The analysis shows that the average grade of students from the experimental group is Good 4 in the field of *Heredity and Variation*, in terms of both *level of knowledge*, and *grasp of the subject*. The analysis of the *transfer of knowledge* indicator reveals that students have difficulty analysing and understanding new information.

Keywords: biology, students, diagnosis of knowledge and skills, secondary school.

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INTRODUCTION

Modern education involves the use of up-to-date and reliable methods for controlling and assessing students' achievements which correspond to the challenges of today's technology-based society. Diagnosing students' knowledge and skills helps teachers guide and focus students' learning processes so as to compensate for the established deficits.

The concept of "diagnostics" is of Greek origin ("dia" - between, after, through, and "gnosis" - knowledge ("diagnostikos" - capable of recognising). It was widely used in Renaissance medicine for recognising diseases, and in the 20th century it found application in many other sciences, such as psychology and technology [3].

The term *pedagogical diagnostics* is interpreted differently. It is used in the sense of 'measuring' (as a process), in the sense of 'theory' (testing methodology), and in the sense of pedagogical research procedure for obtaining the results of the pedagogical process.

In the theory of pedagogical research, the term *pedagogical diagnostics* is perceived as a set of control and evaluation methods used for improving the learning process, differentiation of pupils, and for improving teaching syllabuses and methods of pedagogical impact [3].

In didactics, the test is a set of questions that meet certain quality requirements. The type and content of these requirements depends on the type of test.

The questions in criterion-based didactic tests must meet the following four requirements: 1) correspondence between the question and the learning objective which it is intended to measure; 2) sensitivity of the question to teaching or the extent to which a question differentiates between students who have studied some subject matter and those who have not done it, and what is meant in these tests by 'discriminatory force'; 3) optimal difficulty; 4) optimal distractors [2].

Criterion-based tests measure achievement through a criterion related to the learning objectives formulated in the curriculum for the respective subject matter. If the norm is form is established based on the learning outcomes of a group of students, the criterion is external and unrelated to these achievements. Therefore the criterion is called an *absolute measurement*.

The teaching objectives for the *Heredity and Variation* section in the subject *Biology and Health Education* for grade 10 students are:

- To form a system of concepts for heredity, variation, mutation, genotype, phenotype, allele, complete and incomplete dominance and interaction between the genes;
- To acquire knowledge about the genotype and phenotype of hereditary diseases in humans;
- To develop skills for presenting the results of mono- and dihydrate crossing, by interaction of the genes (alleles and non-alleles);
- To develop skills for applying knowledge from other subjects in presenting the inheritance of characteristic features.

The teaching objectives are achieved through learning content which covers single topics and larger units of the following groups: Groups 1. Multiple organism (mesosystem: structure and processes); Group 3. Observations, experiments, research (Table 1 and 2).

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Table 1. Unit 1. Multi-cell organism (mesosystem: structure and processes).

Curriculum-based Standards and expected results	Topics and expected results (for each topic)
Standard 2. Students can: • describe and show (on a scheme or model) interactions between genes, stages of organisms' individual development, and features, such as heredity and variation. • present interaction between genes through text or symbols. • correctly trace stages of individual development of animals and human beings. • clarifies the role of heredity and variation in living organisms. Standard 3. Students can: • recognise (in a text or picture) basic concepts related to heredity and variation in organisms. • identify heredity and variation according to certain features irrespective of the mode of representation (text or model).	Topic 2. Heredity and variation. Students can: • define genotype, phenotype, allele, complete and partial domination. • present in a scheme results of mono- and dihybrid crossing, and interaction of genes (allele and non-allele). • list and exemplify different types of variation. • trace and give examples of hereditary diseases in man, based on geno- and phenotype.

Table 2. Unit 3. Observations, experiments and research

Curriculum-based Standards and expected results	Topics and expected results (for each topic)
Standard 2. Students can: • read schemes, tables, diagrams; systematise data and transform information into tables (graphs) and vice versa. • present through symbols and schemes interaction between genes, as well as micro- and macroevolution processes. • write descriptions based on information from tables and graphs.	Topic 2. Heredity and variation. Students can present in a scheme the results of mono- and dihybrid crossing and interaction of genes (allele and non-allele).

Heredity and Variation section plays an important role in the development of students' skills to:

- evaluate and predict the appearance and development of certain signs in organisms, including human beings;
- apply mathematical knowledge to present the laws of transmission of different hereditary features.

The acquired knowledge and intellectual skills contribute to enhancing students' motivation to master biological knowledge, as biology and knowledge of heredity and variation of organisms in particular, play a key role in modern medicine, agriculture and selection practices.

The aim of the present work is to establish and evaluate the level of students' knowledge and skills on topics from the *Heredity and Variation* section, related to using basic genetic concepts in teaching *Biology and Health Education* to 10th grade students.

The aim can be accomplished through the following *tasks*:

1. To study and analyze the normative documents related to the teaching of *Biology and Health Education:* curricula, textbooks, instructions, in accordance with the State Educational Requirements.
2. To analyse the content in the *Heredity and variation* section which is part of *Biology and Health Education* subject, in order to achieve the expected results of the curriculum and help students master the basic concepts.
3. To analyse the literature related to the organization, methodology and implementation of pedagogical diagnostics of the teaching process.
4. To design a diagnostic test and verify its relevance to teaching particular classes.
5. To conduct a diagnostic test.
6. To process, analyze and present the results of the diagnostic test and draw conclusions.

MATERIAL AND METHODS

Object of the study: Students' achievements in the subject *Biology and Health Education* for the 10th grade at Hristo Botev school in the town of Kubrat.

Subject of the study: Students' acquired knowledge, skills and habits in the area of *Heredity and variation*.

Methods of the study: theoretical analysis, observation, didactic tests for assessment of the acquired system of knowledge, skills and habits, mathematical and statistical methods for processing and analysing results, graphic representation of results.

The study was conducted in the *Biology and Health Education* classes with students from the 10th grade, obligatory preparation at Hristo Botev school in the town of Kubrat, in 2016/2017 school year.

Organization and Methodology of the Diagnostic test: A diagnostic test which contains 12 tasks (Appendix 1) on the topics from the *Heredity and Variation* section, was devised to establish the level of students' knowledge and competence to operate with concepts presented in a text and scheme in the *Heredity and variability* section of the 10th grade *Biology and Health Education* Curriculum. The diagnostic testing was conducted with 44 students from 10th grade.

The test was designed so that it can be done for one lesson (40 minutes), and included tasks corresponding to the main indicators *level of knowledge*, *grasp of the subject* and *transfer of knowledge* in accordance with the State Educational Standards.

The diagnostic test included tasks and evaluation criteria from the State Matriculation Exam in *Biology and Health Education* from previous years, and a scale for measuring achievement by means of grades from 2 to 6. The tasks in the test check the students' abilities to analyze, compare, identify causal links; work out and justify a solution to the task. The tasks included in the test have the following characteristics:

- Tasks with a given response (multiple choice) tasks. Each task contains 4 possible answers, indicated by a) b) c) and d), of which only one is correct (tasks 1, 2, 5 and 7);
- Tasks of the same type (but with a combination) containing 4 elements combined in 4 possible responses.

Responses are marked in the same way, and only one of them is correct (tasks 3, 4, 6, 8 and 9);

The tasks from 1 to 9 are aimed to the following cognitive levels: knowledge, understanding, and application.

- Tasks with an open response that enable self-sufficiency, creativity and resourcefulness (tasks 10, 11, and 12).

These tasks have the following characteristics:

Task No. 10 requires a brief answer to four questions and aims to test the application of knowledge about the dominant allele and recessive allele, the use of correct symbols, and the presentation of inheritance patterns by a ratio.

Task No. 11 requires a brief answer to three questions and tests skills for understanding schemes and transferring information related to the terms *karyotype*, *haploid* and *diploid chromosomal set, homogamete* and *heterogamete sex*, *chromosomal gamete set* .

Task No. 12 tests the application of knowledge and skills needed to present through text and scheme the main points in the topic *Heredity and variation* - identification and recording of *genotype* and *phenotype*, recording gametes according to given criteria.

Part 1 of the test (tasks 1-9) includes multiple-choice tasks with one correct answer. The content of the tasks is determined by Standard 2 and Standard 3 in the 10th grade *Biology and Health Education* Curriculum. They measure pupils' achievements by the amount of knowledge indicator, i.e. students' knowledge of concepts, laws and mechanisms: clear line / homozygous genotype; epistatic interaction; modifications; inheritance patterns of hemophilia; differentiation of mutations from modifications in given examples; recognition of full dominance and the corresponding patterns of inheritance in a diagram; use of concepts such as sex chromosomes and a mechanism for gender determination in a human being; operating with concepts related to dihydrate crossing; applying knowledge and distinguishing between full dominance, incomplete dominance, and patterns of inheritance.

Part 2 contains tasks with open-ended responses (Tasks 10, 11 and 12). They give students the opportunity to manifest independence, creativity and resourcefulness. These tasks measure pupils' achievement in terms of meaningfulness and knowledge transfer, namely: skills for applying inheritance rules for monohybrid crossing; demonstrating skills to operate with symbols and presenting regularities; application of knowledge of karyotype, sex chromosomes and autosomes, haploid and diploid chromosome set; and creating a scheme based on a description. The tasks are defined by Standards 2 and 3 of the 10th grade *Biology and Health Education* Curriculum.

Criteria and indicators for evaluation of results: Criteria are a measurement through which we determine the learning outcomes of a pedagogical study. They are qualitative and quantitative determinants of the changes in the studied dependent variables which characterise the subject of the study. They must meet certain requirements: comprehensiveness, clarity, and constructiveness, while reflecting the essence of the research process. They determine the relationship between plan and achievement.

The tasks of the criterion-based test are prepared in accordance with Bloom's taxonomy of educational objectives, and report and evaluate student performance in terms of certain indicators: quantitative - *level of knowledge*, and qualitative - *grasp of the subject* and *transfer*:

- level of knowledge - determining the volume of students' knowledge in the subject *Heredity and variation*, i.e. knowledge of concepts, laws and mechanisms;
- grasp of the subject - a qualitative characteristic showing the level of understanding of the acquired knowledge and concepts of heredity and variation. They relate to the students' skills to reproduce information, and correctly differentiate between correct and incorrect assertion. It is achieved through tasks in which students identify, distinguish and classify objects, phenomena, concepts. The level of acquisition allows them to reproduce and analyze information, to solve different types of tasks on various aspects of the subject matter without assistance or prompts. The tasks involve completing words, sentences, formulas or other essential elements of the text, etc.
- transfer of knowledge - a qualitative characterization of pupils' ability to reproduce and transform information independently, analyze and access new information, and apply their knowledge in diverse, atypical, real situations [4].

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The distribution of the test tasks on the topic *Heredity and variation* by indicators is as follows: the level of knowledge is assessed through tasks 1, 2 and 3; students' grasp of the subject - through tasks 4, 5, 6, 7 and 8; and the transfer of knowledge - through 9, 10, 11 and 12.

The quantitative assessment of pupils' knowledge is based on the responses to each test task. Each task carries a certain number of points. Correct answers to tasks from 1-9 give one point; correct answers to Tasks 10 and 12 are evaluated by 4 points, and the correct answer to task 11 gives 3 points. The total number of points for each task is calculated by adding the points of each of the components of the task. The total number of points for each student is then transformed by means of a scale into a numerical grade which reflects the corresponding level of education [1].

The result - P is calculated according to the formula: **$P = N_1 / N \times 100\ \%$,** where: N_1 is the number of points received, N is the maximum number of points for a correct answer.

The conversion of the resulting score into a six-point grade with a maximum score of 20 points is as follows: from 0 to 32% - 1-5 points is Fail (2); from 33 to 49% - 6-9 points is Average (3); from 50 to 66% - 10-12 points is Good (4); from 67 to 83% - 13-16 points is Very Good (5); from 84 to 100% - 17-20 points is Excellent (6).

RESULTS AND DISCUSSION

Analysis of the overall results of the test

Figure 1 presents the results of the students who participated in the study, expressed in points. Figure 2 presents the same results expressed as six-point numerical grades.

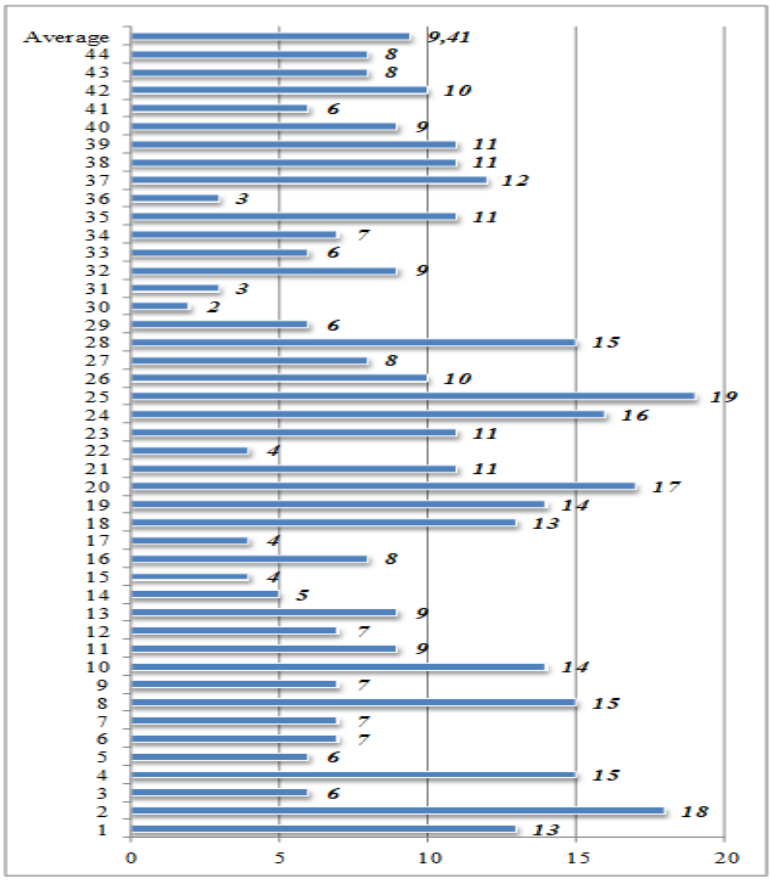

Fig. 1. Students' test results in points

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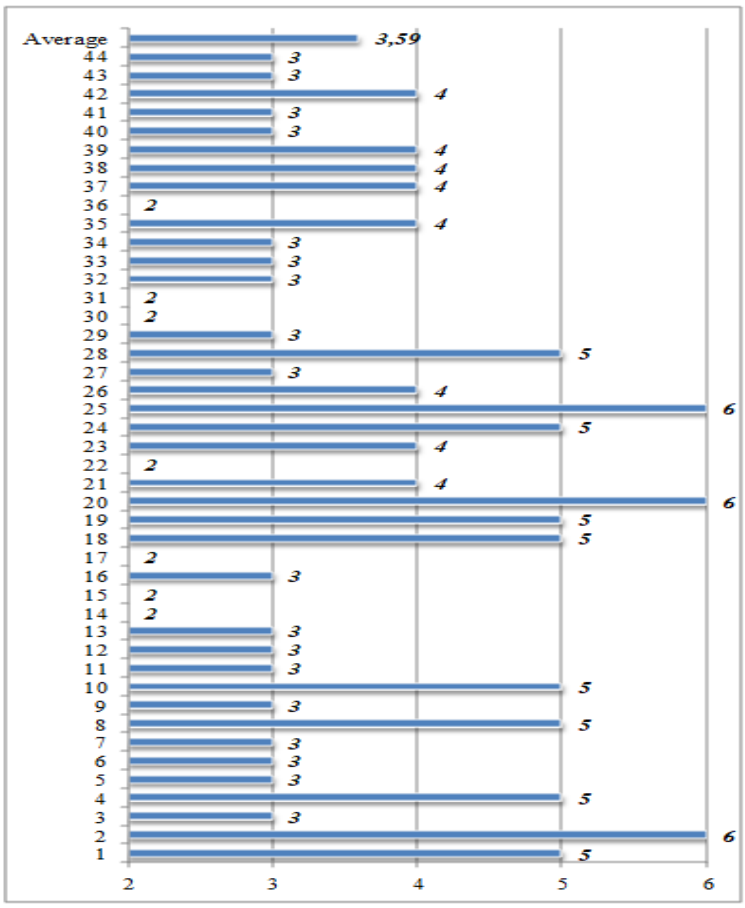

Fig. 2. Students' test results in a 6-grade scale

The figures shown in Fig. 1. and Fig. 2. give reason to determine students' achievement as relatively successful. The analysis shows that 37 out of a total of 44 students, which is 84%, achieved a positive result in the test which measures the level of their knowledge of *Heredity and Variation*.

Analysis of pupils' performance by indicators

The results of the test on *Heredity and variation* are presented in Table 3 and 4.

Table 3. Statistical results based on test indicators

Indicators	№ of test task	Absolute frequency f					$\bar{x}$	M_o
		2	3	4	5	6		
Level	1	6	0	0	0	38	5, 45	6
Level	2	24	0	0	0	20	3, 82	2
Level	3	26	0	0	0	18	3, 64	2
	Total:	**56**	**0**	**0**	**0**	**76**	**4, 30**	**6**
Grasp	4	25	0	0	0	19	3, 73	2
Grasp	5	22	0	0	0	22	4, 00	6
Grasp	6	29	0	0	0	15	3, 36	2
Grasp	7	4	0	0	0	40	5, 64	6
Grasp	8	17	0	0	0	27	4, 45	6
	Total:	**97**	**0**	**0**	**0**	**123**	**4, 24**	**6**
Transfer	9	21	0	0	0	23	4, 09	6
Transfer	10	4	20	9	6	5	3, 73	3

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Indicators	№ of test task	Absolute frequency f					$\bar{x}$	M_o
		2	3	4	5	6		
Transfer	11	21	21	0	2	0	2, 61	3
Transfer	12	9	8	6	13	8	4, 07	5
	Total:	**55**	**49**	**15**	**21**	**36**	**3, 63**	**2**

Table 4. Frequency and per cent distribution of students' grades based on test indicators

Indicator	№ of task	Measured values									
		2		3		4		5		6	
		f	f'	f	f'	f	f'	f	f'	f	f'
Level	**1**	6	13,63	-	-	-	-	-	-	38	86,36
	2	24	54,55	-	-	-	-	-	-	20	45,45
	3	26	59,01	-	-	-	-	-	-	18	40,99
	Total	**56**	**42,42**	**-**	**-**	**-**	**-**	**-**	**-**	**76**	**57,58**
Grasp	**4**	25	56,82	-	-	-	-	-	-	19	43,18
	5	22	50,00	-	-	-	-	-	-	22	50,00
	6	29	65,91	-	-	-	-	-	-	15	34,09
	7	4	9,09	-	-	-	-	-	-	40	90,91
	8	17	38,64	-	-	-	-	-	-	27	61,36
	Total	**97**	**44,09**	**-**	**-**	**-**	**-**	**-**	**-**	**123**	**55,91**
Transfer	**9**	21	47,73	-	-	-	-	-	-	23	52,27
	10	4	9,09	20	45,45	9	20, 45	6	13,64	5	11,36
	11	21	47,73	21	47,73	-	-	2	4,54	-	-
	12	9	20,45	8	18,18	6	13,64	13	29,55	8	18,18
	Total	**55**	**31,25**	**49**	**27,84**	**15**	**8,52**	**21**	**11,93**	**36**	**20,46**

The data show that students received fair or good grades for their knowledge and skills on *Heredity and Variation*.

When analyzing the results it was found that the students from the strong extreme group had a median score of 12, 86 points (64%) and an average grade of Very good (4, 50), while students from the weak extreme group had a score of 5, 95 points (29, 77%), which corresponds to Poor 2, 68 on the sixth-point grade system. Students in the measured group achieved a mean score of 9, 41 (47, 04%), which corresponds to a grade of Good 3, 59. The analysis of the difficulty of the tasks shows that tasks with numbers 2, 3, 4 and 6 have a low index of difficulty, and they were not very difficult for the pupils. Tasks with Nos. 4 and 9 have an optimal discriminatory power.

Of all 44 students who participated in the study, no one achieved the maximum number of points on the test. Three students received just over 85% of the maximum number. One of the participants received only two points, which is the lowest recorded score.

CONCLUSIONS

The results of the diagnostic procedure lead to the following conclusions:

- The pupils of the target group have an average grade of Good 4 for their knowledge of the basic concepts in the field of *Heredity and variation* from the *Biology and Health Education* subject for the 10th grade.

- The analysis of the level of students' knowledge in *Heredity and variation* shows that they achieved a score of 0, 57. The relative frequency of the correct answers for this indicator is 57, 58%, which is a good achievement. The average score is Good 4, 30.
- For the quality indicator of students' grasp of of knowledge, the average score of the students is 0, 11. Of all the students who participated in the test, 55, 91 % achieved the maximum score for this indicator, which is considered a good achievement. The average score for this indicator is Good 4, 24.
- For the ability to reproduce and convert information independently the students received a score of 0, 41. The average grade was Good 3, 63. Only 20, 46% of the participants achieved excellent results on this indicator. The analysis of the *Information transfer* indicator shows that students have difficulty analyzing and understanding of new information.
- The use of the criterion-based didactic test (Appendix 1) made it possible to determine the level of student learning in the *Heredity and variation* section of 10th grade students in the subject *Biology and Health Education*, as well as their skills to use basic genetic concepts in accordance with the State Educational Requirements. It also allowed us to assess students by means of a sixth-grade evaluation scale.

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APPENDIX №1

Test on *Heredity and Variation*.
10th grade *Biology and Health Education*

Name …… № …… grade …..

Dear students, there are 12 tasks in this test. In **part 1** the tasks have only one correct answer. In tasks 3.,4., 6., 7. and 8. you have to choose from combinations of possible answers. In **part 2** the tasks require an open response which you arrive at by following the instructions. Each correct answer gives you 1 point. The maximum total number of points for the test is **20**. You have **40 min** to do the test.

Part 1

1. Which of the examples below presents crossing of two pure lines (homozygous specimens)?
A) AA x Bb **B)** Aa x BB **C)** aa x Bb **D)** AA x bb

2. The interaction between alleles of two genes in which an allele of one gene supresses the phenotype manifestation of an allele of another gene is known as:
A) complete dominance
B) incomplete dominance
C) epistatic dominance
D) complementary interaction

3. Modifications:
1) are inherited
2) are related to genotype
3) are reversible changes
4) are accommodative changes
A) 1 and 2 **B)** 3 and 4 **C)** 1, 2 and 3 **D)** 1, 3 and 4

4. Healthy parents have a son who suffers from hemophilia. Which of the following statements are correct?
1) The father carries the disease.
2) The mother carries the disease.

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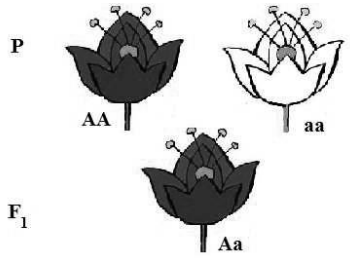
3) The daughters of these parents will be healthy.
4) 50% of the sons might be healthy.
A) 1, 2 and 3 **B)** 1, 2 and 4 **C)** 1, 3 and 4 **D)** 2, 3 and 4

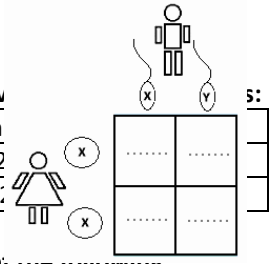
5. An example of mutational variation is:
A) people's skin tanning in summer
B) the lack of skin pigmentation in some people
C) change of some animals' fur in winter
D) accumulation of blubber in animals in winter

6. Which of the statements are true of F_2 in crossing as presented in the following scheme?



1) All specimens will have the same phenotype.
2) All specimens will have the same genotype.
3) The distribution of features according to phenotype will follow the ratio 3:1.
4) The distribution of features according to genotype will follow the ratio 1:2:1.
A) 1 and 2 **B)** 1 and 4 **C)** 2 and 3 **D)** 3 and 4

7. The following scheme presents the possible combinations of gametes at fertilisation in humans. What is the possibility of male offspring?
A) 25%
B) 50%
C) 75%
D) 100%

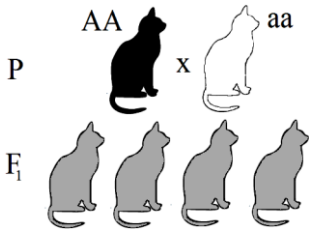


8. Dihybrid crossing of peas plants in F_2 gav s:

Features	Number of specimens in
Colour of the pod	360 with green pods + 12
Length of the stem	360 with a long stem + 1

Analyse the data in the table and decide which of the following statements about this crossing are true:
1) The green colour of the pod and the long stem are recessive features.
2) All pants in F_1 had green pods and long stems.
3) All specimens in F_2 which have yellow pods and short stems are homozygous.
4) All specimens in F_2 which have green pods and long stems are heterozygous.
A) 1 and 2 **B)** 1 and 3 **C)** 2 and 3 **D)** 2 and 4

9. Which of the statements about the crossing presented in the scheme are correct?



1) Both parents are homozygous and have a different phenotype.
2) All specimens in F_1 are identical in their genotype and phenotype.
3) Hybrids differ in their phenotype from their parents, which shows that the feature is inherited through full domination.
4) Heterozygous specimen have average values of the phenotype feature, which shows that the feature is inherited through partial domination.

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A) 1 and 3 **B)** 2 and 3 **C)** 1, 2 and 3 **D)** 1, 2 and 4

Part 2

10. The crossing of two drozophilas with long wings gave offspring f 322 specimens of which 240 had long wings and 82 had short wings. Write down:

A) which of the features is dominant .....

B) genotype of the parents through symbols of your choice .....

C) genotype of the specimens with short wings through symbols of your choice .....

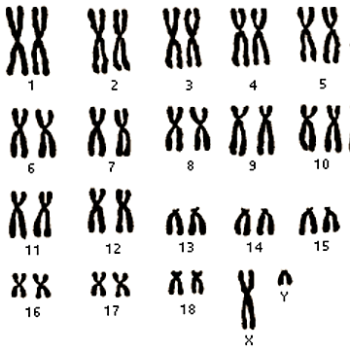
D) differentiation according to phenotype .....

11. Based on the following karyogram of a domestic cat, white down:

1) 2n = ? .....

2) if the specimen is male or female? .....

3) the number of chromosomes in the female sex cell .....



12. The length of a rabbit's ears is defined by a gene with alleles: B – long ears and b – short ears, while the colour of its fur is defined by another gene with alleles: C – black fur, and c – white fur. Write down:

A) the genotype of a specimen with long ears and black fur, homozygous in both genes .....

B) the gametes formed by a specimen which is homozygous in both dominant alleles .....

C) the genotype of a specimen with long ears and black fur, heterozygous in both genes .....

D) the gametes formed by a specimen with phenotype manifestation of recessive features .....

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