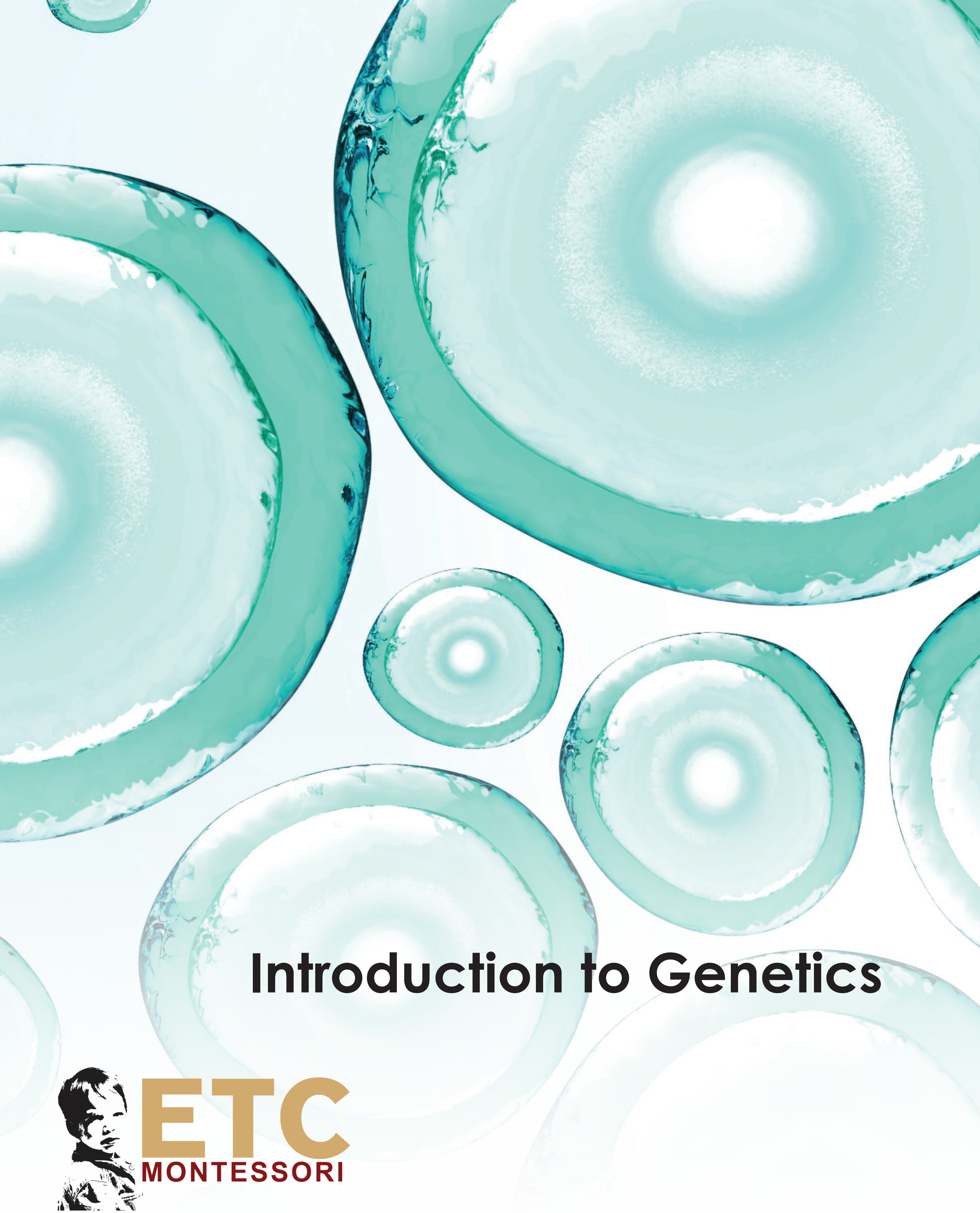

Introduction to Genetics

ETC MONTESSORI

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Core Standards

NGSS

MS-LS1-5
Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

MS-LS3-1
Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.

MS-LS3-2
Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

MS-LS4-4
Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

3-5-ETS1-2
Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

MS-ETS1-4
Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

4-PS4-3
Generate and compare multiple solutions that use patterns to transfer information.

CONNECTIONS:

Science

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Social Studies

WHST.6-8.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

WHST.6-8.9 Draw evidence from informational texts to support analysis reflection, and research.

Language Arts

SL.8.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.

RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.

RI.4.9 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably.

Math

6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.

6.SP.A.2 Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.

6.SP.B.4 Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

6.SP.B.5 Summarize numerical data sets in relation to their context.

7.RP.A.2 Recognize and represent proportional relationships between quantities.

3.OA.A.1 Interpret products of whole numbers, e.g., interpret 5×7 as the total number of objects in 5 groups of 7 objects each.

3.OA.A.2 Interpret whole-number quotients of whole numbers, e.g., interpret $56 \div 8$ as the number of objects in each share when 56 objects are partitioned equally into 8 shares, or as a number of shares when 56 objects are partitioned into equal shares of 8 object

3.OA.A.3 Use multiplication and division within 100 to solve word problems in situations involving equal groups, arrays, and measurement quantities.

3.OA.A.4 Determine the unknown whole number in a multiplication or division equation relating three whole numbers.

3.OA.B.5 Apply properties of operations as strategies to multiply and divide.

3.OA.B.6 Understand division as an unknown-factor problem.

3.OA.C.7 Fluently multiply and divide within 100, using strategies such as the relationship between multiplication and division (e.g., knowing that $8 \times 5 = 40$, one knows $40 \div 5 = 8$) or properties of operations.

3.OA.D.8 Solve two-step word problems using the four operations. Represent these problems using equations with a letter standing for the unknown quantity.

3.OA.D.9 Identify arithmetic patterns (including patterns in the addition table or multiplication table), and explain them using properties of operations.

4.OA.A.1 Interpret a multiplication equation as a comparison, e.g., interpret $35 = 5 \times 7$ as a statement that 35 is 5 times as many as 7 and 7 times as many as 5. Represent verbal statements of multiplicative comparisons as multiplication equations.

4.OA.A.2 Multiply or divide to solve word problems involving multiplicative comparison, e.g., by using drawings and equations with a symbol for the unknown number to represent the problem, distinguishing multiplicative comparison from additive comparison.

4.OA.A.3 Solve multistep word problems posed with whole numbers and having whole-number answers using the four operations, including problems in which remainders must be interpreted.

4.OA.B.4 Find all factor pairs for a whole number in the range 1–100. Recognize that a whole number is a multiple of each of its factors. Determine whether a given whole number in the range 1–100 is a multiple of a given one-digit number.

4.OA.C.5 Generate a number or shape pattern that follows a given rule. Identify apparent features of the pattern that were not explicit in the rule itself.

5.OA.A.1 Use parentheses, brackets, or braces in numerical expressions, and evaluate expressions with these symbols.

5.OA.A.2 Write simple expressions that record calculations with numbers, and interpret numerical expressions without evaluating them.

5.OA.B.3 Generate two numerical patterns using two given rules. Identify apparent relationships between corresponding terms. Form ordered pairs consisting of corresponding terms from the two patterns, and graph the ordered pairs on a coordinate plane.

Vocabulary

Genotype: The letters we use to indicate the genetic makeup of an individual. i.e. RR or rr

Phenotype: The physical characteristics or the physical manifestation of a trait. i.e. Tall or Short

Dominant Trait: When comparing two traits, then the trait that overpowers the recessive trait is the one that will be expressed. Dominant traits are usually symbolized using a capital letter.

Recessive Trait: When comparing two traits, then the trait that is overpowered by the dominant trait is the one that will not be expressed. Recessive traits are expressed only if the dominant trait is not present or if the chromosome has two alleles where they are both recessive.

Homozygous: The two alleles of a trait are the same. ie TT or tt

Heterozygous: The two alleles of a trait are not the same. ie Tt

Purebred trait: Individuals of this genotype are homozygous and will only make one type of gametes. ie TT will always produce TT and tt will always produce tt. Purebred traits are also known as true breeding.

Gamete: Also known as sex cells. They are represented by the letter N and they are haploid since they contain only half of the chromosomes that other cells contain.

P Generation: The parental generation.

F_1 Generation: The very first generation of offspring from the P generation.

F_2 Generation: The second generation of offspring from the P generation.

Monohybrid Cross: A single factor cross. Only one trait is used in this genetic cross. ie T tall, t short.

Dihybrid Cross: A two factor cross. Two traits are used in the genetic cross. ie T tall, t short, L long fur, l short fur.

Incomplete Dominance: Given two alleles, one of them is not completely dominant over the other. ie, white flower crossed with a red flower and yields a pink flower.

Co-dominance: Both alleles contribute to the phenotype. ie R red hair, r white hair, then Rr yields a roan hair color. where both the red hair and the white hair is present.

Sex linked trait: Genes that are located on the sex chromosome X or Y

X chromosome: Alleles that are present on the X chromosome. In males this allele will alway be expressed because males don't have a second X chromosome.

Multiple alleles: There are more than two choices for alleles. ie There are more than two blood types so that I^A, I^B, and I. This gives us the four combinations: A, B, AB, and O.

Genotype ratio: The ratio of genotype from the cross.

Phenotype ratio: The ratio of the different phenotypes expressed from the cross.

Scope and Sequence

I. The work of Gregor Mendel
   a. Use a Punnett square to explain how pairs of genes segregate during the F1 generation.
   b. Use a Punnett square to show a two factor cross.

II. Helpful Science Terms for students to research on their own.
   c. Heredity
   d. Genetics
   e. Self-pollination
   f. Cross-pollination
   g. Purebred
   h. Trait
   i. Gene
   j. Allele
   k. Dominance
   l. Dominant
   m. Punnett square
   n. Gamete
   o. Phenotype
   p. Genotype
   q. Homozygous

III. Application of Mendel's work to understand probability of traits
   r. What are the expected results of a cross
   s. Discuss what factors might change the expected results
   t. Show how a Punnett square can be used to make predictions

IV. Meiosis
   u. Why is it needed?
   v. Phases of Meiosis

V. Helpful Science Terms for students to research on their own.
   w. Homologous
   x. Diploid
   y. Haploid

Introduction

How are traits passed on from one person to another, or from one generation to the following? This kind of questions have been fascinating human beings for centuries. However, it's only been recently that we have been able to fully understand some of the aspects relating to the genetic code and how characteristics are passed on to individuals from generation to generation.

It was the work of Gregor Mendel that shed the initial light into genetics. Today Mendel is considered as the father of genetics. Through his work with the common garden pea, he was able to develop a clear understanding of how traits were passed on. He was also able to show how one factor was able to completely mask the effects of a second factor. It was also Mendel that suggested that pairs of factors separated in the formation of reproductive cells, thus enabling the offspring to receive a set of factors from each parent.

The word factor has now been replaced, in modern genetics, with the word gene. However, it is the same principles that governed genes in Mendel's time that still govern and determine the probabilities of an individual inheriting one gene or another. We can make these predictions through a device known as the Punnett square.

The sex cells, also known as gametes, are formed during a very special type of cell division known as meiosis. During this process the number of chromosomes in each cell are reduced by half. Through fertilizations the full number of chromosomes is restored.

Introductory Activity:

Have students bring in pictures of individuals they think they most closely resemble. Allow each student to say why they believe they are like the people in the picture. The goal is to bring to the forefront and discuss the following ideas.

- Why do some traits appear in them and never seen before?
- Have they heard of traits in their family, that seem to "skip a generation".
- What traits are they aware of that seem to be passed along from one generation to another?

NOTE: This activity should be voluntary, and you will need to be sensitive to those students who do not have biological parents, or who have difficulty knowing or talking about their biological parents.

Modern Genetics. Opening Activities:

Today's geneticists no longer do experiments using pea plants. Ask questions so that students may be led to conclude that todays studies of genetics have progressed. Begin with the general question of what they might think would make an optimal candidate in modern genetics research.
Organisms must reproduce quickly so that the effects of traits may be studied.
Organisms should be easy to care for. This will allow for large numbers of individuals to be kept and be readily available for studies.
The number of chromosomes (diploid number) should be relatively small. This will allow for an easy identification

and the creation of Punnett squares that easy to manipulate. In addition, modern genetics use stains to identify genes. A small number of chromosomes will make it easy to stain and identify.

Historical Background

Following Darwin's announcement and publication of his books, several scientists question his theory of "survival of the fittest" using the idea that the special characteristics for which nature favored could be blended away and would eventually disappear. (At this point it is beneficial to have students research the theory of Darwin, and what led to its formulation).

Ask the question if this is true. Can a trait be "blended away"? No. This is not true. Mendel's research proved that genes were passed on to offspring without them being "blended away". Without this research Darwin's theory would have been considered invalid and would have been dismissed.

Concept Development

How did Mendel discover which of the "factors" were dominant and which were recessive? Mendel was able to observe that by crossing pure tall plants with pure short plants the offspring exhibited certain characteristics. Therefore, if all the offspring looked tall, he was able to deduct that the tall factor was the dominant factor.

Even though the F_1 generation appeared to all be tall were they "pure" for tall trait? No, they would carry both the tall trait and the short trait. They are what we call in modern genetics "hybrids". Make sure that students understand the difference between cross pollination and self-pollination. Mendel used cross pollination so that he could control what traits he was crossing. This is a concept that needs to be reinforced.

What kind of results would Mendel expect the F1 generation to have if they were allowed to self-pollinate? Answers will vary, so accept all answers.

Based on his observations, what was Mendel able to deduct regarding the number of "factors" that each plant could contribute? Each plant must contain two factors for each trait. One would be passed on from the mother and one would be passed on by the father.

The following crosses are provided as a reference. They are also presented and made available in the research cards.

You will notice that in the crosses that follow we have provided the F1 generation. Work with your students to figure out the F2 generation. Have a discussion on why and how the ratios differ. Any choosing of the parents should be accepted, and answers will vary based on those choices.

Straight Dominant and Recessive Cross (Single trait cross)

ETC MONTESSORI	B	b
B	BB	Bb
b	Bb	bb

Traits:
B - Brown Eye Color
b - Blue eye Color

Cross:
Bb x Bb

F1 Generation

Genotype Ratio: 1 : 2 : 1
BB - 25% Bb - 50% bb - 25%

Phenotype Ratio: 3 : 1
Brown: 75% Blue: 25%

Incomplete Dominance Cross

	R	r
R	RR	Rr
r	Rr	rr

Traits:
RR - Red
rr - White
Rr - Pink

Cross:
Rr x Rr

F1 Generation:

Genotype Ratio: 1 : 2 : 1
RR - 25% Rr - 50% rr - 25%

Phenotype Ratio: 1 : 2 : 1
Red: 25% Pink: 50% White: 25%

Co-dominance Cross

	B	W
B	BB	BW
W	BW	WW

Traits:
BB - Black
BW - Tan
WW - White

Cross:
BW x BW

F1 Generation:

Genotype Ratio: 1 : 2 : 1
BB - 25% BW - 50% WW - 25%

Phenotype Ratio: 1 : 2 : 1
Black: 25% Tan: 50% White: 25%

Sex-linked Cross

	X	X^h
X^h	XX^h	$X^h X^h$
Y	XY	X^hY

Traits:
H - Normal
h - Hemophelia

Cross:
XX^h x X^hY

F1 Generation:

Genotype Ratio: 1 : 1 : 1 : 1
XX^h - 25% X^hX^h - 25% X^hY - 25% XY - 25%

Phenotype Ratio: 1 : 2 : 1
Female carrier: 25% Female hemophilia: 25%
Male normal: 25% Male hemophilia: 25%

Multiple Alleles Cross

ETC MONTESSORI	I^A	I^B
I^A	$I^A I^A$	$I^A I^B$
O	$I^A O$	$I^B O$

Traits:
I^A - Type A Blood
I^B - Type B Blood
O - Type O Blood

Cross:
$I^A I^B$ x $I^A O$

F1 Generation:

Genotype Ratio: 1 : 1 : 1 :1
AA - 25% AB - 25% AO - 25% BO - 25%

Phenotype Ratio: 1 : 2 : 1
Type AB: 25% Type A: 50% Type B: 25%

Straight Dominant and Recessive Dihybrid Cross

	BT	bT	Bt	bt
BT	BBTT	BbTT	BBTt	BbTt
bT	BbTT	bbTT	BbTt	bbTt
Bt	BBTt	BbTt	BBtt	Bbtt
bt	BbTt	bbTt	Bbtt	bbtt

Traits:
B - Brown Eyes b - Blue Eyes
T - Tall t - Short

Cross:
BbTt x BbTt

F1 Generation:

Genotype Ratio: 1 : 2 : 2 : 1 : 4 : 1 : 2 : 2 : 1

Phenotype Ratio: 9 : 3 : 3 : 1

Sex Linked Dihybrid Cross

	X^hB	X^hB	XB	XB
Xb	X^hXBb	X^hXBb	XXBb	XXBb
Xb	X^hXBb	X^hXBb	XXBb	XXBb
Yb	X^hYBb	X^hYBb	XYBb	XYBb
Yb	X^hYBb	X^hYBb	XYBb	XYBb

Traits:

B - Brown Eyes   b - Blue Eyes
H - Normal   h - High Blood Pressure

Cross:

X^hXBB x XYbb

F1 Generation:

Genotype Ratio: 4 : 4 : 4 : 4 or 1 : 1 : 1 : 1

Phenotype Ratio: 4 : 4 : 4 : 4 or 1 : 1 : 1 : 1

Answer Key

Punnett Types:
Cards 1A - 4A

Used for reference.

Overview
Card 1A: Answers will vary

Overview 1B: Glossary is provided in the teacher's Notes. Definitions should be shared with the students or allow them to find their own definition. Regardless, the terms should be used in your everyday conversations while working on this material and concept explorations.

Overview 2A: Answers will vary

Overview 2B: Size doesn't matter. This must be reinforced. The idea here is to have the students understand that meiosis is a special type of division that allows for the genes to be brought together during fertilization to complete the diploid number.

1. Mouse 40
2. Grasshopper..............................24
3. Corn 20
4. Potato 48
5. Hamster......................................44
6. Human 46
7. Frog 26
8. Tomato 24
9. Guinea pig 64
10. Goldfish......................................94
11. Dog...78
12. Cat 38
13. Rat 42
14. Onion 16
15. Fruit fly 8
16. Pea Plant 14

It is interesting to note that we refer to diploid numbers as 2N while haploid number is symbolized as N. The idea is to find a formal way of symbolizing double and single. However, this really doesn't make much sense to say haploid. A better word would be monoploid. Instead, haploid should be symbolized as N/2. Regardless, mathematicians and scientists have agreed to refer to them in the current manner. This is an example where the mathematical community and the scientific community have come together and agreed on a way of name or doing things.

Overview 3A: No size doesn't matter. This is reinforced.

Overview 3B:

1. Even though any type of letters may be used to symbolize the alleles we have chosen S and s, and B and b. S is for short hair while s is for long hair. B is for black or banded fur, while b is for hair color like that of a Siamese. Therefore, S is dominant for short hair, and B is dominant for Black, or banded fur.
2. The first cross would have been that of a Siamese cat with genotype SSbb crossed with a gray, black or striped Persian cat ssBB. What they would have come up with was a cat that had genotype of SsBb. They would all have short hair and black or banded in color.
3. This is a two-factor cross, and you should use the two-factor Punnett square. What the scientists crossed were two cats with the following genotype. SsBb and SsBb. This cross will produce 9 short hairs with solid colors, and 3 short hairs with Siamese markings, 3 long hairs with solid or banded colors, 1 long haired with Siamese markings.
4. A Himalayan cat has the genotype of ssbb. A two factor cross (use the Punnett square) between the father and the offspring is necessary. If we did a test cross with the father having a genotype of SsBb and the female with genotype of ssBB, the result would be that this cross will not produce any Himalayans. However, a cross between the male parent with genotype of SsBb and the female having a genotype of ssBb will produce the Himalayan genotype of ssbb.

Problem 2A

Encourage students to use their 2 x 2 Punnett squares to create the tiles for the genes. Assuming we characterize the genes as H for hearing, and h for deaf:

1. HH x hh = 100% of Hh so all the dogs would be able to hear. 0% would be deaf.
2. The phenotype of the F2 generation would be Hh x Hh = 25% HH, 50% Hh, and 25% hh. Therefore, the F2 generation would have 3 dogs that were able to hear and 1 deaf dog.

Problem 2B

Assuming that B black is dominant over brown, b then working with the 2 x 2 simple cross Punnett square the parents are Bb and Bb. This is the only combination that will allow for both colors to be visible.

Problem 3A

1. 4/2 is really a ratio of 2:1. Therefore the genotype of the parents has to be Ss and Ss
2. Answers will vary.
3. Answers will vary. Without knowing the color of the offspring, the male can either be Ww or WW.

Problem 3B

Answers will vary.

Problem 4A

1. 100% of the birds would be normal feathers. 100% would be carriers of the silky feather trait.
2. 75% would be normal and 25% silky or roughly 59 normal and 19 or 20 silky.

Problem 4B
0% chance of getting a chestnut. All would be black, with a genotype of Bb
Since all the offspring from the F1 generation were Bb then the phenotype would 3 black and 1 chestnut. The genotype ratio would 1:2:1 or 1 pure black, 2 hybrid Bb and 1 pure bb.

Problem 5A
Answer will vary.

Problem 5B
This is an advance problem because the student is asked for more than just the resulting ratios. This is part of the reason that genetics problems need to be read carefully and the student needs to understand what is being asked of him/her.

The genotypic ratio is 2/16 : 4:16 : 2/16 : 2/16 : 4/16 : 2/16 or it can be simplified to 2:4:2:2:4:2 or 1:2:1:1:2:1
The phenotypic ratio is 6/16 : 2/16 : 6/16: 2/16 or it can be simplified to 6:2:6:2 or 3:1:3:1

Problem 6A
Answers will vary. The answers should be proven using the Punnett squares in the kit.

Problem 6B
Answers will vary based on observation.
However, it is important to note that the more traits are added the more complicated the Punnett square becomes, and it reaches a point when it isn't practical.

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