PHILADELPHIA ZOO

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Genetics (9th-12th)

Objectives

1. See a general overview of the study of genetics.
2. Discover why genetics is an important part of learning about biodiversity and planning for conservation of at-risk species.
3. Learn how zoos around the world use genetics to save species from extinction.

Vocabulary

Gene: a unit of heredity that is transferred from a parent to offspring and determines some characteristic of the offspring

Allele: one of a number of alternative forms of the same gene or genetic locus. The alleles present in DNA form the genotype, which is responsible for the phenotype.

Genotype: a combination of alleles that determines a specific trait

Phenotype: the physical appearance of an organism as determined by its genetic makeup

Gene Frequency: the ratio of a particular allele to the total of all other alleles of the same gene in a given population

Homozygous: having identical alleles for a given gene

Heterozygous: having non-identical alleles for a given gene

Population: in ecology, a group of organisms of one species that interbreed and live in the same place at the same time

Recommendations

Read:

"Finding Genes that Fit" – An article about conservation of the critically endangered Florida panther.

Center for Conservation and Evolutionary Genetics – A website for a faction of the Smithsonian conservation Biology Institute that works with zoos and other *ex situ* wildlife populations to preserve species. Includes a large number of articles regarding genetic research and conservation.

Research:

-Species that are extinct in the wild, and how their populations are being saved. There are 4 such animals at the Philadelphia Zoo: Micronesian kingfishers, Guam rails, Mhorr

gazelles, and Panamanian golden frogs. Other examples can be found at other institutions around the world.
-Species that are critically endangered in the wild and the efforts to manage their populations. What results are seen when population management techniques are successful?
-Different lab techniques associated with genetics research. How are these techniques used in conservation biology?

Discuss:

Why is it important to conserve species?
Is it worth it to save a species if it means introducing members from outside the critical population? For example, if a species of island tortoise is on the brink of extinction, but the only way to keep that population extant is to interbreed it with another closely related species or subspecies, what is the right choice?

Classroom Activity

Use the included lesson plan to introduce students to the topic of conservation biology as it relates to genetics.

Standards

PA Academic: 3.1 B1, 3.1.B.B1, 3.1.B.B2, 3.1 B3, 3.1 B5, 3.1.B.B5, 3.1.B.C1, 3.1.B.C2, 4.4 D

Next Generation Science: HS-LS1-1, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-LS4-2, HS-LS4-3

New Jersey Core Curriculum: 5.1, 5.3A, 5.3D, 5.3E

Common Core: CCSS.ELA-LITERACY.RST.4, CCSS.ELA-LITERACY.RST.7, CCSS.ELA-LITERACY.W.7, CCSS.ELA-LITERACY.SL.1

Genetics and Population Ecology

- Works for groups or individuals
- Time needed: **45 minutes** (group), **60 minutes** (individuals)
- Materials needed: calculators, writing utensils

Background Information and Questions

One of the many techniques used by conservation biologists to monitor populations is DNA analysis to check for genetic diversity. DNA samples can be taken from many individuals within a population and then analyzed for the presence of specific alleles. Looking at the frequency of alleles in the current population can help conservation biologists predict how the genetic diversity of that population may change over the next few generations. It can also help us determine how much diversity we have to work with, which is particularly important when deciding how best to manage a critically endangered population.

When DNA is analyzed for the presence of alleles, two processes, called PCR and gel electrophoresis, are used. This allows a small section of DNA to be amplified many times, then run through a gel for a determined length of time. The distance the DNA moves down the gel is compared to a known DNA 'ladder', and that tells us what alleles are present in that sample. The charts used in this activity are sample charts based off this procedure. Conservation biologists choose a certain genetic marker to look for – it could be a specific gene that is particularly rare, a lethal gene, or mitochondrial DNA to get an idea of lineage – and amplify that piece of DNA for analysis. Looking at this marker gives us an idea of the amount of diversity present in the population, or whether a population may be at risk for collapse.

In this activity, students will be looking at gel electrophoresis results of a gorilla population. They will use these charts to determine frequency of a few alleles of one gene. After finding the frequency for each allele, have students answer the following questions:

1. The data collected in this activity is a snapshot of the genetic diversity of the entire gorilla population from this region. If this population is connected with a nearby, but currently isolated, population, what effects will that have on the genetic diversity? The nearby population has the following allele frequencies present:

185: 6.67%	**193:** 11.67%	**201:** 14.17%	**214:** 17.50%
189: 7.50%	**197:** 12.50%	**209:** 14.17%	**217:** 15.83%

2. Are any alleles relatively underrepresented in the population? Should this be treated as a concern?
3. 185 is a lethal allele when homozygous. A population with a frequency for 185 above 30% is susceptible to collapse within 5 generations. If this gorilla population is split in half by deforestation, separating groups A, B, and C from D, E, and F, is either of the two

new populations at risk for collapse? What implications would this have for the overall conservation of the species?

Instructions

1. Hand out the worksheets for gorilla groups A-F. Students can work on teams or individually.
2. Students should count the number of bands that represent each allele and record it in the table. Remember, if there is only one band present for a gorilla, that means the allele is homozygous and there are two copies of it. For example, in group B, gorilla #4 is homozygous for allele 214. Including the copies from Gorilla #3 and Gorilla #10, the total number of copies of allele 214 in Group B is 4.
3. Once the alleles are counted, they should complete the calculation for the frequency of each allele. Frequency should be recorded as a percentage with two decimal places.
4. After each group is complete, students should gather all data together to figure out the frequency for the entire population using the 'Population Data' worksheet.
5. Have students work through the answers to three included questions. An answer key is provided.
6. An additional data sheet, 'Split Population Data,' is included for question #3.

Answer Key

Group A:

185	2	10%
189	3	15%
193	3	15%
197	4	20%
201	2	10%
209	3	15%
214	3	15%
217	0	0%

Group B:

185	3	15%
189	3	15%
193	0	0%
197	4	20%
201	5	25%
209	4	20%
214	1	5%
217	0	0%

Group C:

185	2	10%
189	4	20%
193	1	5%
197	2	10%
201	5	25%
209	4	20%
214	2	10%
217	0	0%

Group D:

185	6	30%
189	2	10%
193	2	10%
197	1	5%
201	4	20%
209	1	5%
214	4	20%
217	0	0%

Group E:

185	6	30%
189	5	25%
193	2	10%
197	2	10%
201	2	10%
209	0	0%
214	3	15%
217	0	0%

Group F:

185	7	35%
189	2	10%
193	0	0%
197	4	20%
201	3	15%
209	2	10%
214	2	10%
217	0	0%

Population:

185	26	21.67%
189	19	15.83%
193	8	6.67%
197	17	14.17%
201	21	17.50%
209	14	11.67%
214	15	12.50%
217	0	0.00%

Split Group A,B,C: D,E,F:

185	7	11.67%		19	31.67%
189	10	16.67%		9	15.00%
193	4	6.67%		4	6.67%
197	10	16.67%		7	11.67%
201	12	20.00%		9	15.00%
209	11	18.33%		3	5.00%
214	6	10.00%		9	15.00%
217	0	0.00%		0	0.00%

Follow-up Questions:

1. The data collected in this activity is a snapshot of the genetic diversity of the entire gorilla population from this region. If this population is connected with a nearby, but currently isolated, population, what effects will that have on the genetic diversity? The nearby population has the following allele frequencies present:

185: 6.67%	**193:** 11.67%	**201:** 14.17%	**214:** 17.50%
189: 7.50%	**197:** 12.50%	**209:** 14.17%	**217:** 15.83%

   Answer: The overall impact will be more genetic diversity in the entire population. The second group has a much more evenly distributed allele frequency, and has a new allele in 217, and thus would help balance some of the extremes we see in the first population.

2. Are any alleles relatively underrepresented in the population? Should this be treated as a concern?

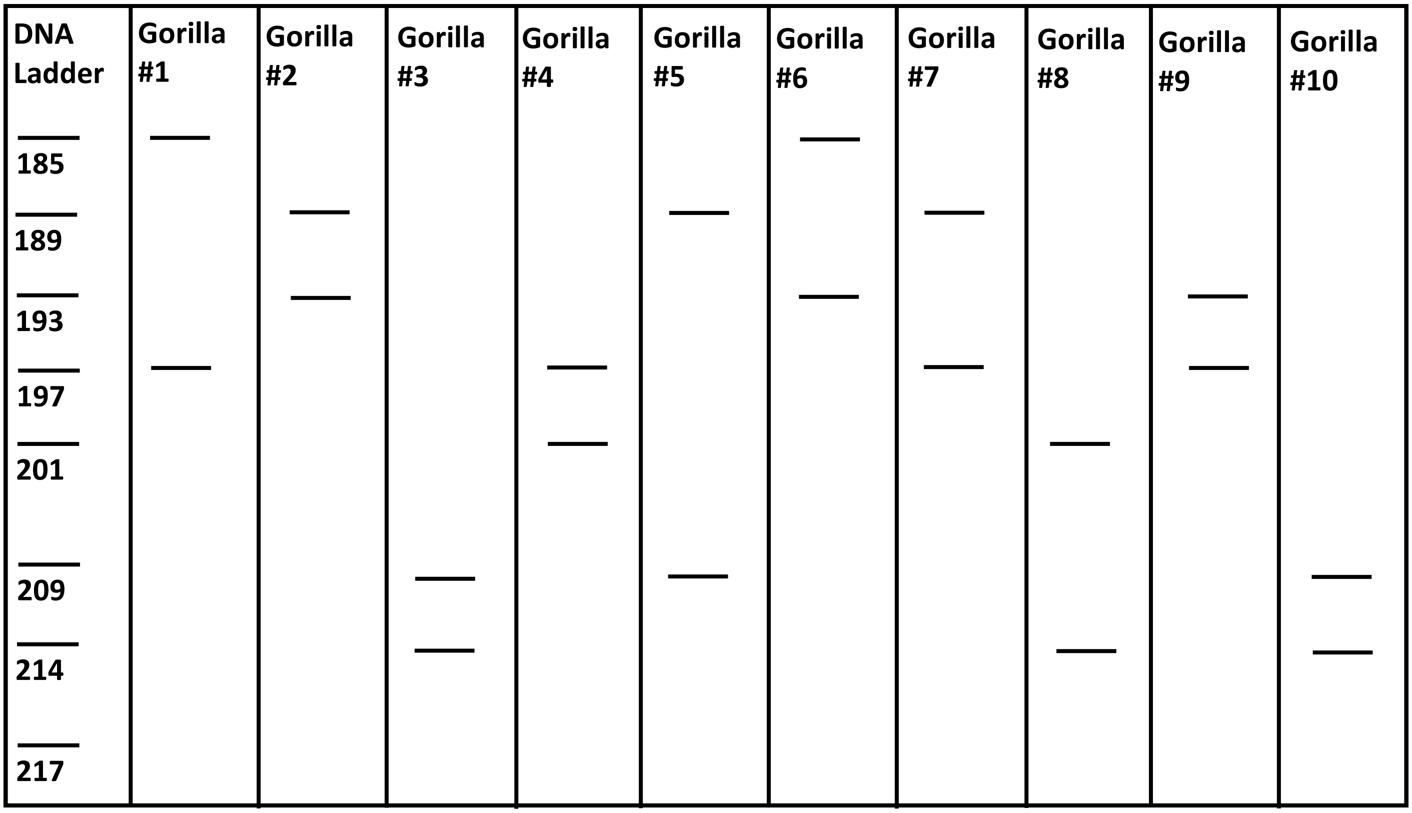
   Answer: Yes. Allele 193 is underrepresented compared to the rest, and allele 214 is not present at all. This is not necessarily a problem, but it is closely linked to the real issue of an overall lack of genetic diversity. While the absence of specific alleles is likely not an issue, the overall homogeneity of the population is.

3. 185 is a lethal allele when homozygous. A population with a frequency for 185 above 30% is susceptible to collapse within 5 generations. If this gorilla population is split in half by deforestation, separating groups A, B, and C from D, E, and F, is either of the two new populations at risk for collapse? What implications would this have for the overall conservation of the species?

   Answer: The new population containing groups D, E, and F is at serious risk for collapse as they have a frequency of 31.67% for allele 185. If this population were split in this way, that half of the population would likely go extinct over the next few generations. This would very quickly cut this current population in half. While this may not be a large loss overall for the species, it is likely not an isolated incident. When we examine one population of gorillas, we use that data to extrapolate to the national or global population. Any devastating losses to a small portion of the population can occur to population as a whole as well.

Group Data Worksheet

Group A

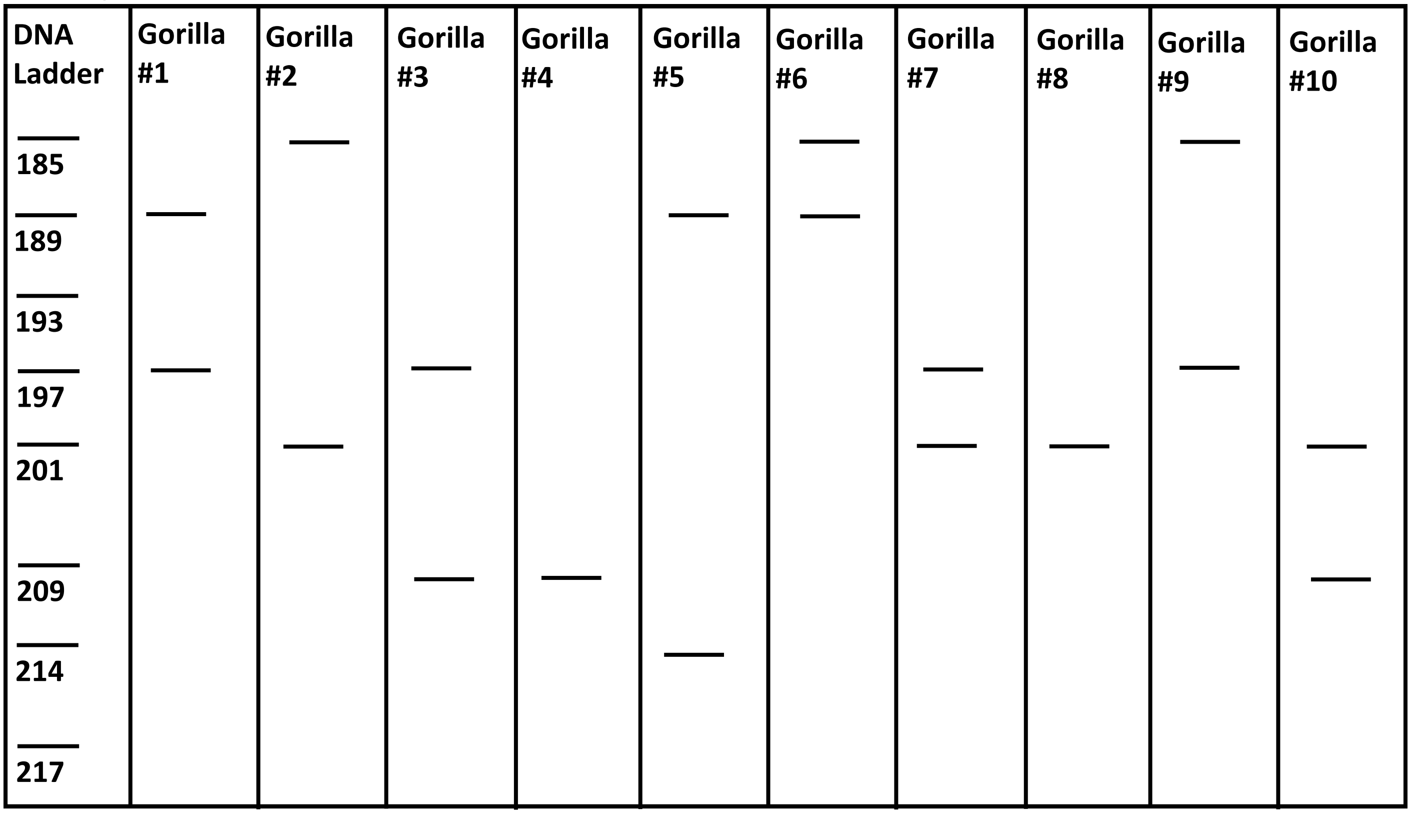


1. Count the number of each allele present in the group and record it in the table below. If a gorilla has only one band present, that means the gorilla is homozygous for that allele and there are two copies present.
2. Work through the frequency calculation for each allele using the provided formula. The blank space should be filled with the Number Present for each allele. Record frequency as a percentage with two decimal places.

Allele	Number Present	Calculation	Frequency
185		(______ / 20) x 100 =	
189		(______ / 20) x 100 =	
193		(______ / 20) x 100 =	
197		(______ / 20) x 100 =	
201		(______ / 20) x 100 =	
209		(______ / 20) x 100 =	
214		(______ / 20) x 100 =	
217		(______ / 20) x 100 =	

Group Data Worksheet

Group B

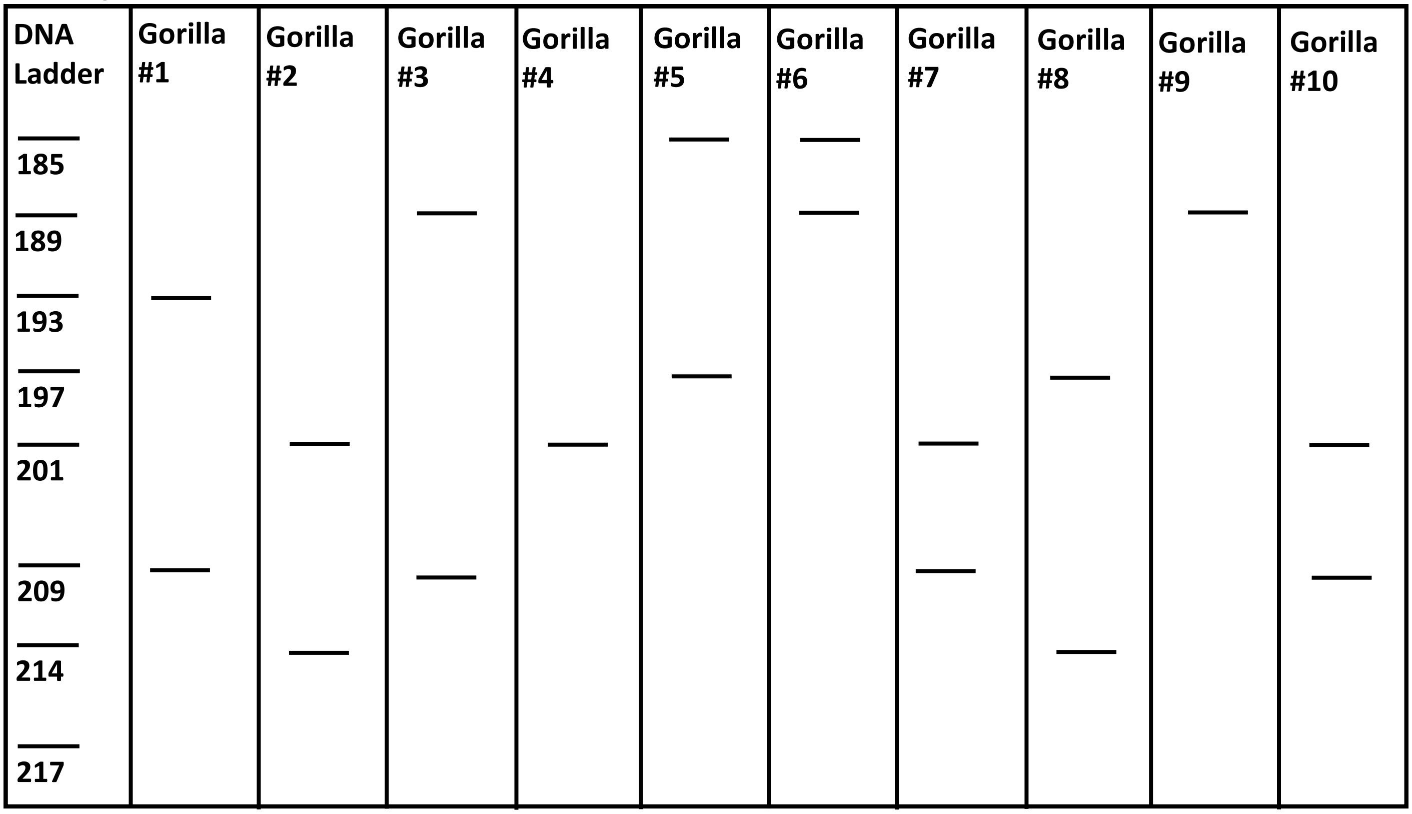


1. Count the number of each allele present in the group and record it in the table below. If a gorilla has only one band present, that means the gorilla is homozygous for that allele and there are two copies present.
2. Work through the frequency calculation for each allele using the provided formula. The blank space should be filled with the Number Present for each allele. Record frequency as a percentage with two decimal places.

Allele	Number Present	Calculation	Frequency
185		(______ / 20) x 100 =	
189		(______ / 20) x 100 =	
193		(______ / 20) x 100 =	
197		(______ / 20) x 100 =	
201		(______ / 20) x 100 =	
209		(______ / 20) x 100 =	
214		(______ / 20) x 100 =	
217		(______ / 20) x 100 =	

Group Data Worksheet

Group C

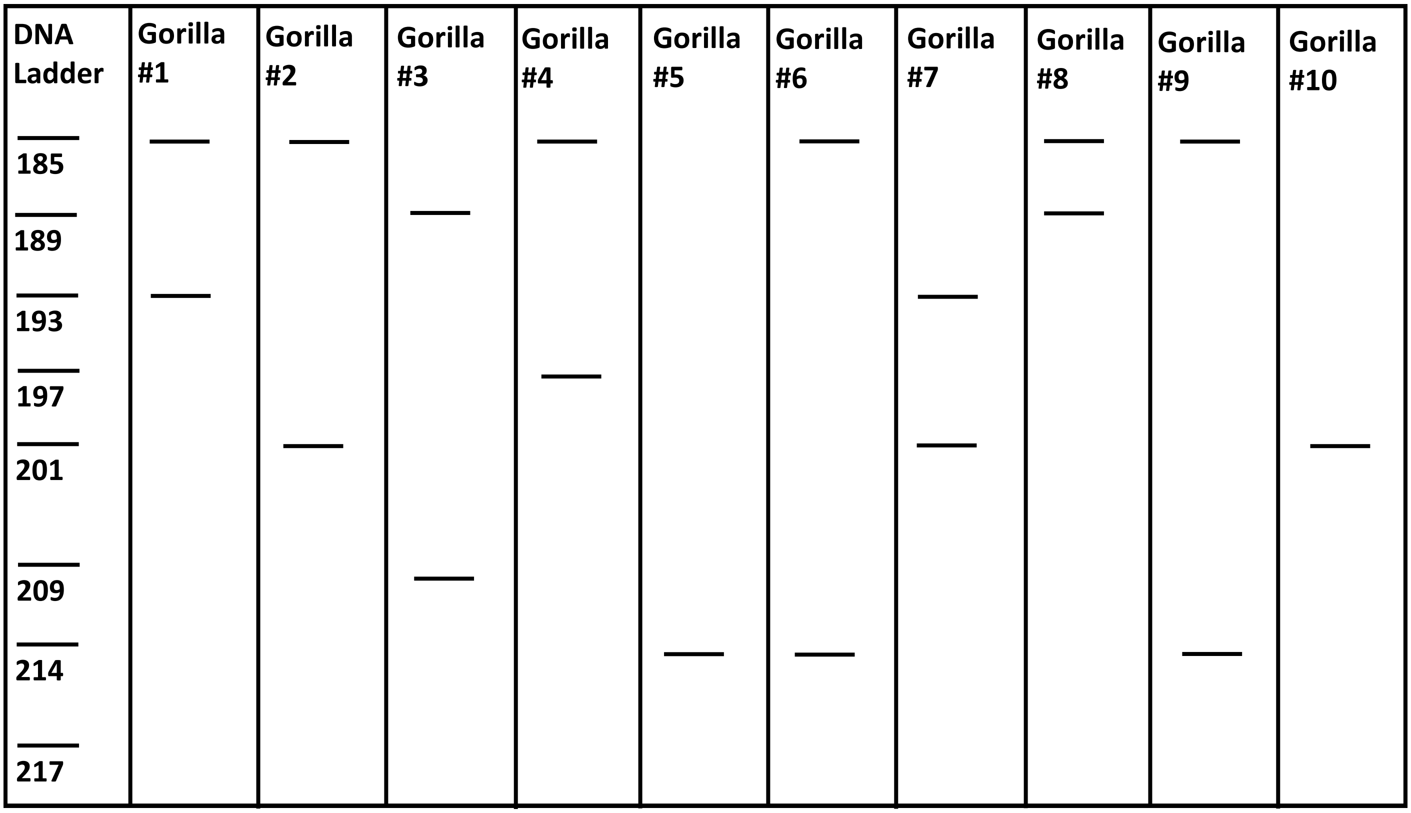


1. Count the number of each allele present in the group and record it in the table below. If a gorilla has only one band present, that means the gorilla is homozygous for that allele and there are two copies present.
2. Work through the frequency calculation for each allele using the provided formula. The blank space should be filled with the Number Present for each allele. Record frequency as a percentage with two decimal places.

Allele	Number Present	Calculation	Frequency
185		(______ / 20) x 100 =	
189		(______ / 20) x 100 =	
193		(______ / 20) x 100 =	
197		(______ / 20) x 100 =	
201		(______ / 20) x 100 =	
209		(______ / 20) x 100 =	
214		(______ / 20) x 100 =	
217		(______ / 20) x 100 =	

Group Data Worksheet

Group D

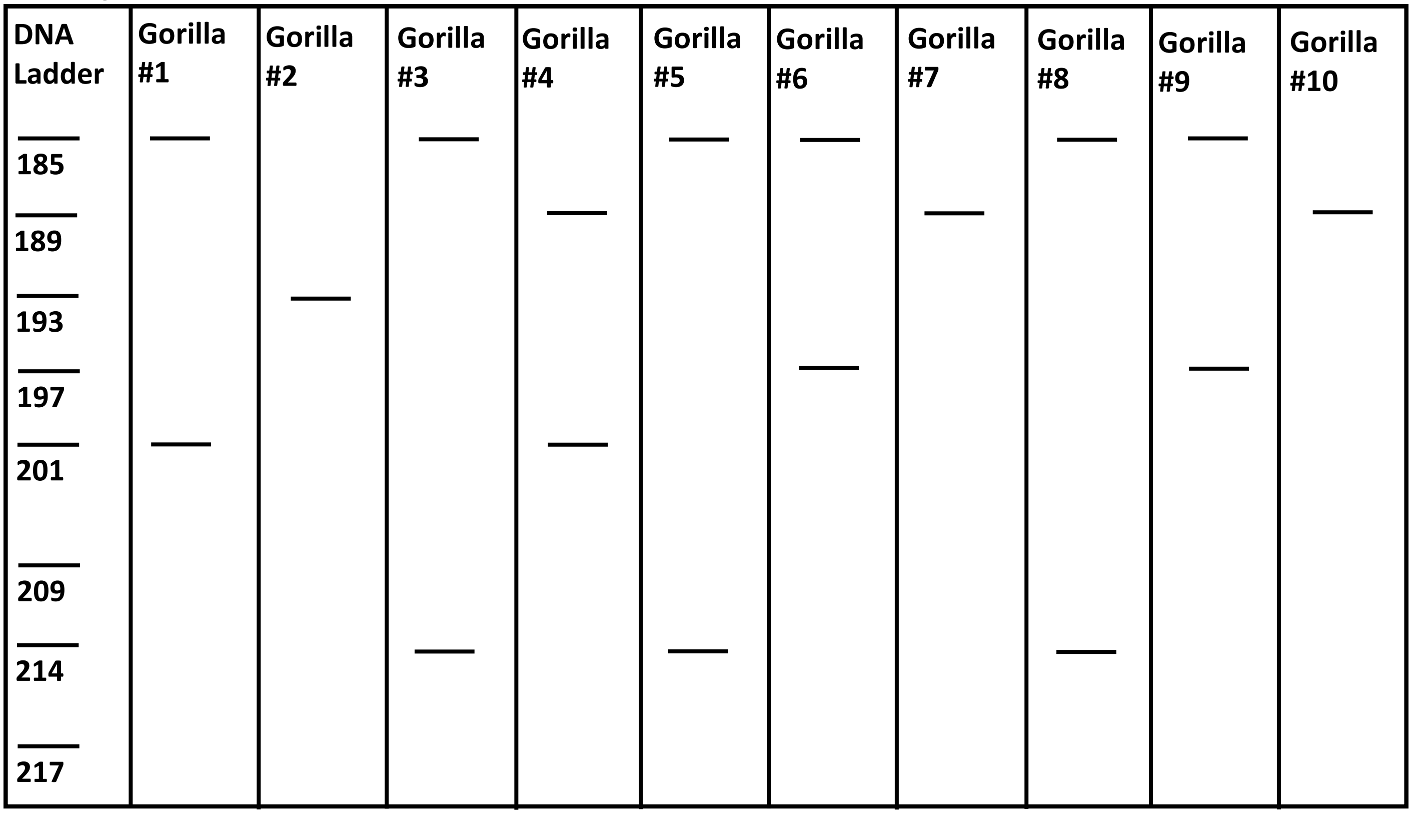


1. Count the number of each allele present in the group and record it in the table below. If a gorilla has only one band present, that means the gorilla is homozygous for that allele and there are two copies present.
2. Work through the frequency calculation for each allele using the provided formula. The blank space should be filled with the Number Present for each allele. Record frequency as a percentage with two decimal places.

Allele	Number Present	Calculation	Frequency
185		(______ / 20) x 100 =	
189		(______ / 20) x 100 =	
193		(______ / 20) x 100 =	
197		(______ / 20) x 100 =	
201		(______ / 20) x 100 =	
209		(______ / 20) x 100 =	
214		(______ / 20) x 100 =	
217		(______ / 20) x 100 =	

Group Data Worksheet

Group E



1. Count the number of each allele present in the group and record it in the table below. If a gorilla has only one band present, that means the gorilla is homozygous for that allele and there are two copies present.
2. Work through the frequency calculation for each allele using the provided formula. The blank space should be filled with the Number Present for each allele. Record frequency as a percentage with two decimal places.

Allele	Number Present	Calculation	Frequency
185		(______ / 20) x 100 =	
189		(______ / 20) x 100 =	
193		(______ / 20) x 100 =	
197		(______ / 20) x 100 =	
201		(______ / 20) x 100 =	
209		(______ / 20) x 100 =	
214		(______ / 20) x 100 =	
217		(______ / 20) x 100 =	

Group Data Worksheet

Group F

DNA Ladder	Gorilla #1	Gorilla #2	Gorilla #3	Gorilla #4	Gorilla #5	Gorilla #6	Gorilla #7	Gorilla #8	Gorilla #9	Gorilla #10
185	—	—		—	—	—		—	—	
189					—	—				
193										
197	—		—				—			
201		—		—						—
209			—					—		
214									—	—
217										

1. Count the number of each allele present in the group and record it in the table below. If a gorilla has only one band present, that means the gorilla is homozygous for that allele and there are two copies present.
2. Work through the frequency calculation for each allele using the provided formula. The blank space should be filled with the Number Present for each allele. Record frequency as a percentage with two decimal places.

Allele	Number Present	Calculation	Frequency
185		(______ / 20) x 100 =	
189		(______ / 20) x 100 =	
193		(______ / 20) x 100 =	
197		(______ / 20) x 100 =	
201		(______ / 20) x 100 =	
209		(______ / 20) x 100 =	
214		(______ / 20) x 100 =	
217		(______ / 20) x 100 =	

Population Data Worksheet

Allele	Number Present	Calculation	Frequency
185	A+B+C+D+E+F=	(_____ / 120) x 100 =	
189	A+B+C+D+E+F=	(_____ / 120) x 100 =	
193	A+B+C+D+E+F=	(_____ / 120) x 100 =	
197	A+B+C+D+E+F=	(_____ / 120) x 100 =	
201	A+B+C+D+E+F=	(_____ / 120) x 100 =	
209	A+B+C+D+E+F=	(_____ / 120) x 100 =	
214	A+B+C+D+E+F=	(_____ / 120) x 100 =	
217	A+B+C+D+E+F=	(_____ / 120) x 100 =	

Split Population Data Worksheet

Allele	Number Present	Calculation	Frequency
185	A+B+C =	(_____ / 60) x 100 =	
189	A+B+C =	(_____ / 60) x 100 =	
193	A+B+C =	(_____ / 60) x 100 =	
197	A+B+C =	(_____ / 60) x 100 =	
201	A+B+C =	(_____ / 60) x 100 =	
209	A+B+C =	(_____ / 60) x 100 =	
214	A+B+C =	(_____ /60) x 100 =	
217	A+B+C =	(_____ / 60) x 100 =	

Allele	Number Present	Calculation	Frequency
185	D+E+F =	(_____ / 60) x 100 =	
189	D+E+F =	(_____ / 60) x 100 =	
193	D+E+F =	(_____ / 60) x 100 =	
197	D+E+F =	(_____ / 60) x 100 =	
201	D+E+F =	(_____ / 60) x 100 =	
209	D+E+F =	(_____ / 60) x 100 =	
214	D+E+F =	(_____ / 60) x 100 =	
217	D+E+F =	(_____ / 60) x 100 =	