Part I: Data Analysis

Name: ____________________

The Big Question: How do we determine parentage?

Lise Watson, species coordinator and record keeper for all zebra sharks in North American institutions, must always be mindful of maintaining a healthy, genetically diverse population. Recently, three shark pups were produced and their parents were unknown. Blood samples from all individuals that inhabit the tank were sent to the laboratory for genetic analysis to determine who produced these pups. In the data provided below, there are individuals from the F1 generation and their offspring, F2 individuals which are shaded below. Seven (7) genes were genotyped and numbers were assigned. Look for patterns in the data that can help you determine parentage.

ID number	Name	Sex	Generation	Gene 1	Gene 2	Gene 3	Gene 4	Gene 5	Gene 6	Gene 7
SF03-07	Yin	F	F1	191/203	215/233	334/366	218/250	277/309	150/162	178/196
SF03-06	Yang	F	F1	177/199	227/229	334/338	214/218	269/285	150/162	168/182
SF06-10	Ping	F	F1	199/227	213/237	362/362	246/246	285/293	150/150	158/160
SF97-02	Pong	F	F1	189/197	227/227	334/350	218/234	297/313	150/162	194/196
SF06-11	Jaws	M	F1	197/223	201/233	350/366	234/250	277/281	150/150	182/202
SF12-12	Quinn	F	F2	197/197	227/227	334/350	218/218	313/313	150/162	196/196
SF13-109	Grace	F	F2	199/199	227/227	334/334	218/218	269/269	150/150	182/182
SF13-243	Ariel	F	F2	189/189	227/227	350/350	234/234	313/313	150/150	194/194

The goal of the aquaria across the country is to produce sharks through sexual reproduction so that the gene pool is diverse and each individual has a different complement of genes to pass on to their own offspring. It is their hope that this male, Jaws, fathers offspring that contain some of his unique genes. Discuss this data with your group, using the questions below to help guide your analysis.

Q1: What does heterozygous mean? ____________________

Write one heterozygous genotype from Individual SF06-11 here: ____________________

Q2: What does homozygous mean? ____________________

Write one homozygous genotype from Individual SF06-11 here: ____________________

Q3: What patterns did you observe among the F2 offspring in the data table? ____________________

____

Q4: What do the patterns mean? ____________________

____

Q5: Write two questions that came up in your group discussion regarding these sharks:

1. ____________________
2. ____________________

Making Sense of the Data

To determine the parents of each of the F2 individuals, their genotypes must match with one allele from each of the genotypes of the parent. For Quinn, Grace and Ariel, look at F1 individuals and find the mother first. Then determine if the father contributed any alleles to the offspring.

Q3: Who is the mother of Quinn?______________________________

How do you know? ______________________________

____

Q4: Is Jaws the father of Quinn? YES NO (Circle one)

How do you know?______________________________

____

Q5: Who is the mother of Grace? ______________________________

How do you know? ______________________________

Q6: Is Jaws the father of Grace? YES NO (Circle one)

How do you know? ______________________________

Q7: Who is the mother of Ariel? ______________________________

How do you know?______________________________

Q8: Is Jaws the father of Ariel? YES NO (Circle one)

How do you know?______________________________

Construct a Scientific Explanation

Below, you will construct a well-written, scientific explanation that takes the responses to your questions above and the original data set into account. You must include in your explanation a possible answer to the original Big Question. Be thorough and read your statement aloud to your group members so they can offer feedback on its quality.

Part II: Further Analysis

Name: ______________________

Q1: Look again at the F2 shark pups in the data table. What do all of the F2 individuals have in common?

____

Q2: Based on your answer to the last question, what does this trend tell us about this gene pool?

____

Q3: What could this trend do to the gene pool over time? ______________________________

____

____

Q4: What would the researchers want the F2 generation to look like? ______________________

____

____

Q5: What must be occurring for the F2 generation to look the way it does? ________________

What is your evidence? ____

Q6: Below, draw a flow chart on the left that shows the major reproductive steps in producing the F1 offspring shown in the data table. Then, on the right, draw a similar flow chart showing the reproductive steps you think occurred in order to produce the F2 generation

Reproductive Steps for F1 Generation	Reproductive Steps for F2 Generation

Part III: Some Background Research

Name: ______________________

Did I Have a Daddy? A Parthenogenic Problem

What Is Parthenogenesis?

Parthenogenic species have the ability to reproduce asexually, without need of a male, mating or pollination. Parthenogenesis comes from the Greek words parthenos meaning "maiden" or "virgin" and genesis meaning "origin" or "birth." In parthenogenic animals, the offspring are usually all the same sex, and in certain species like whiptail lizards, the entire species is female. Parthenogenesis often happens where there are few or no males of a species in the area. In some cases, should males make a reappearance, the species can still make use of sexual reproduction. Recently in zoos, reptiles like komodo dragons and file snakes were discovered to be capable of this reproductive back-up plan.

Q1: Why is parthenogenesis considered an adaptation?: ____

____

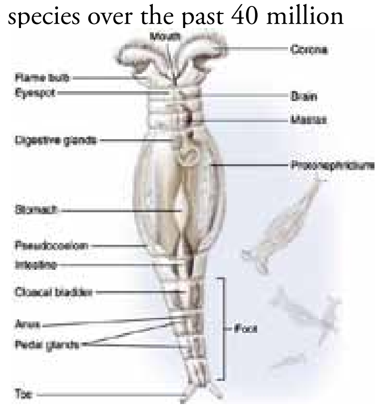
____

What species use parthenogenesis?

This reproductive strategy has been seen in many species, but never mammals. Much of our knowledge about parthenogenesis has come from observing animals in managed settings like zoos where single sex populations are sometimes kept and offspring are surprisingly produced. Here are some examples of species that have been documented as parthogenic:

Bdelloid Rotifers

Rotifers are a group of microscopic aquatic animals that have evolved into many separate species over the past 40 million years without sexual reproduction. The research has focused on bdelloid rotifers, which live in ponds, rivers, and occasionally wet habitats like soils, mosses, and lichens. Biologists Ridego Fontaneto from the University of Milan and Timothy Barraclough from Imperial College London found evidence of distinct species of the bdelloid rotifers by comparing DNA sequencing and jaw measurements of animals living across the U.K., Italy, and other parts of the world. Asexual animals can evolve and mutate over time, but usually do not diversify or last long. However, records of the bdelloid rotifers show they have been around for more than 40 million years and they have evolved into hundreds of species individually adapted the their environments allowing some to now live in hot springs or the Antarctic waters.



Komodo Dragons

Komodo dragons, the largest of the lizards, are under threat as wild populations become smaller. Two female Komodo dragons have been kept at separate zoos and have produced offspring, having always been isolated from males. One of these females then produced additional offspring sexually after being introduced to a male. This indicates that Komodo dragons can switch between asexual and sexual reproduction. One of the dragons had never been kept with a male but has produced a clutch of 25 eggs, of which 11 seemed to be viable. Three of the eggs collapsed but the remaining eight eggs developed normally. The parthenogenic adaptation creates homozygous populations in zoos and drastically decreases genetic diversity in these populations.

Whiptail Lizards

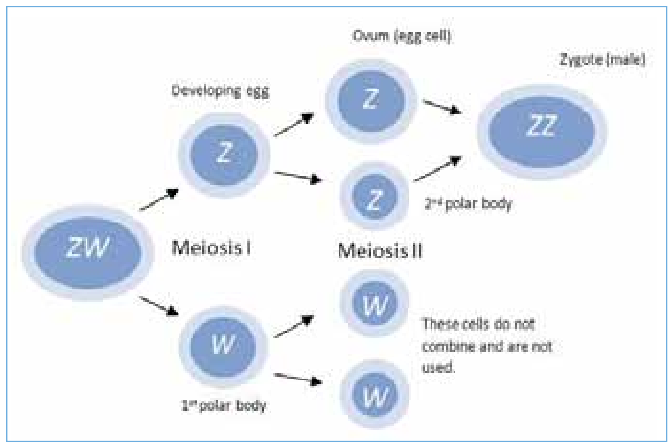
Whiptail lizards (genus Aspidoscelis) from Mexico and southwestern U.S. are made up entirely of females and manage to produce well-bred offspring without the aid of male fertilization. The new research by Peter Baumann of Stowers Medical Research Institute reveals that these lizards maintain genetic richness by starting the reproductive process with twice the number of chromosomes as their sexually reproducing cousins. This asexual species resulted from the hybridization of different sexual species, a process that instills the parthenogenic lizards with a great amount of genetic diversity at the beginning. And the researchers found that these species could maintain their genetic diversity by never pairing their homologous chromosomes (as sexual species do by taking one set of chromosomes from each parent during meiosis) but rather by combining their own sister chromosomes instead through fusing two of their own reproductive cells together.

Bonnethead Sharks *(and other shark species)*

Female sharks of several species have been observed producing young in institutions like Chicago's Shedd Aquarium where no males were present. Shark pups have been analyzed genetically and the results of these findings have led scientists to believe that this process occurs more often in the wild than many have thought. Parthenogenesis in sharks raises concerns for shark scientists and researchers. With increased fishing and capture of sharks, the male population has decreased over recent years. Sharks have XY and XX sex chromosomes and females can only produce XX (females) with parthenogenesis. This means that sharks cannot restore the depleted male population with parthenogenesis alone, and must use sexual reproduction to produce more males.

Which species discussed above can produce through either sexual or asexual means? How does having these options benefit these species?

Why One Sex?



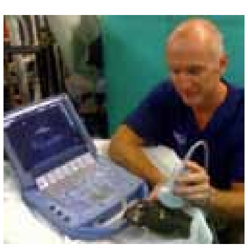
Since species have differences in sex chromosomes, it impacts the sex of the offspring if produced asexually. For example, like humans and other mammals, a female shark is XX and males are XY. Since a female only has a pair of X chromosomes, she can only produce XX offspring (female).

Not all species follow the XX/XY design. Reptiles, for example, are the opposite of mammals. Females are XY (called ZW) and males are XX (called ZZ). A female komodo dragon is ZW so she can produce ZZ zygotes and WW zygotes after her chromosome pairs divide in meiosis. Since all organisms need a Z chromosome (or an X chromosome), then zygotes that are WW do not develop. Therefore, all offspring produced by a female (ZW) komodo dragon through parthenogenesis will be male (ZZ). Thus, female reptiles produce male offspring.

A Cartilagenous Conundrum

Sharks and rays are different from other fish as their skeletons are composed of cartilage, not bone. They live in many different types of aquatic ecosystems around the world and have adapted to a host of different environmental conditions. These organisms have been kept in zoos and aquaria and studied but still continue to surprise researchers, especially when it comes to how they reproduce.

Zebra sharks are long and sleek, allowing them to wriggle into reef crevices and caves to hunt for their food. Barbels (fleshy feelers) on their snouts help them search for their prey. Zebra sharks hunt at night; in the daytime they usually rest quietly on the bottom, "standing" on their pectoral (side) fins. To reproduce, male sharks use claspers (modifications of the pelvic fins) to transfer sperm into the female's reproductive tract. The zebra female lays fertilized eggs in tough capsules covered with tufts of filaments, which attach the eggs to the seafloor. But these eggs are certainly not like the eggs most recognize! These are opaque and in a tough casing that protects the shark embryo and its yolk during development.



Pictured left: Researcher performing ultrasound on shark egg.
Pictured right: Developing shark embryo with yolk within egg.

Part IV: Additional Data

Name: ______________________

Shedd'ing Some Light on Paternity

At the John G. Shedd Aquarium, many successful shark offspring have been produced. However, in an effort to limit inbreeding and maintain genetic diversity in the managed population, paternity and maternity must be known so that relatedness can be determined. The data below came from one aquarium's population of zebra sharks to determine (1) if the sharks were produced through sexual reproduction or parthenogenesis (asexual), and (2) who the father was if sexual reproduction occurred. Also, pay careful attention to the hatch dates and determine if there were any changes in parentage over time.

Possible Parent Sharks (F1 generation)										
ID #	**Dam/Sire**	**Sex**	**Gen**	**Gene 1**	**Gene 2**	**Gene 3**	**Gene 4**	**Gene 5**	**Gene 6**	**Gene 7**
394	Possible dam	F	F1	191/201	243/247	340/376	224/260	291/319	160/164	160/168
393	Possible dam	F	F1	187/193	203/203	336/364	220/248	283/311	152/168	170/178
565	Possible dam	F	F1	179/199	203/229	336/364	220/248	300/316	160/164	180/180
254	Possible sire	M	F1	187/209	205/229	336/368	220/252	291/291	152/164	182/196
395	Possible sire	M	F1	179/179	203/223	336/336	220/220	271/299	164/164	180/182
056	Possible sire	M	F1	199/201	233/235	336/344	220/228	303/315	164/164	174/188
346	Possible sire	M	F1	187/187	203/229	336/336	220/220	283/291	164/168	178/182

F2 Offspring											Sexual or Asexual?
ID#	**Date of Hatch**	**Sex**	**Gen**	**Gene 1**	**Gene 2**	**Gene 3**	**Gene 4**	**Gene 5**	**Gene 6**	**Gene 7**	
419	02/14/13	?	F2	187/187	203/229	336/336	220/248	291/311	164/168	170/178	
420	02/16/13	?	F2	187/187	203/229	336/336	220/248	283/291	152/168	178/182	
421	02/17/13	?	F2	187/187	203/229	336/368	220/252	283/291	152/164	178/182	
422	02/20/13	?	F2	187/193	203/205	336/364	220/248	283/291	152/164	170/182	
423	02/21/13	?	F2	187/193	203/203	336/364	220/248	283/311	152/168	170/178	
424	02/24/13	?	F2	187/193	203/203	336/364	220/248	283/311	152/168	170/178	
425	02/26/13	?	F2	187/187	203/229	336/336	220/220	283/291	164/168	178/182	
277	04/11/13	?	F2	187/199	203/233	344/364	228/248	303/311	164/168	170/174	
298	04/14/13	?	F2	187/201	203/233	336/344	220/228	283/303	164/168	170/188	
283	04/17/13	?	F2	193/201	203/233	336/336	220/220	283/303	164/168	178/188	
534	03/19/14	?	F2	187/193	203/229	336/336	220/220	283/291	164/168	178/182	
538	04/30/14	?	F2	191/209	229/247	Test fail	Test fail	291/319	152/164	168/196	
951	02/28/15	?	F2	199/199	203/203	336/336	220/220	300/300	160/160	180/180	

Q1) What was the most common form of reproduction used to produce the F2 generation?________________

Q2) How did you arrive at your answer for Q1?____

____

____

Q3) Why is this form of reproduction an advantage?____

____

Q4) Propose a hypothesis as to why some offspring may be produced through sexual reproduction and others may not.____

____

Using the genotypes provided on the previous sheet, determine which parent gave each allele to the offspring. In the table below, write the identification numbers for each parent. If there was no father, put ASEXUAL in the box. If you could not definitively determine parentage, write the possibilities in each box.

ID#	Mother ID#	Father ID#
419		
420		
421		
422		
423		
424		
425		
277		
298		
283		
534		
538		
951		

Q5) Which individual(s) was/were produced through asexual means?________________________

Provide evidence for this claim.____

____

Q6) For which individuals was the paternity difficult to determine ?________________________

Explain the difficulties you had when doing your analysis.____________________________

____

____

Q7) For those with questionable paternity, what additional data what you need to make a reliable conclusion.____

____

Q8) Shark pup #951 died relatively quickly after birth. Why do you think this could be the case?________

____

____

Q9) Why is it important to know the genetic diversity of a population, especially one that is managed in a zoo or aquarium setting?____

____

____

Q10) Based on current reproductive technologies that are available today, what could be used with the sharks in order to increase the chances of having offspring through sexual reproduction?____________

____

Explain what would be needed in order for this to be successful:____________________________

____

____

Design a Breeding Plan:

Describe a plan in order to breed the F2 sharks above below. Who would you pair with whom? Which individuals would you breed? Of these chosen individuals, how many different aquaria would you need to ensure that each individual produces offspring to maintain genetic diversity? You can draw out or explain your breeding plan on a separate sheet.