Student Guide

Questions 1–7 (SG pp. 224–225)

1. Estimates will vary, but will most likely be too low.

2.* **A-B.** See data table in Figure 2 of Lesson Guide 3.

3.* Descriptions will vary. Some possible patterns include: the number of grains of wheat added each day doubles each day; the total number of grains of wheat grows very quickly; the exponent in the second column is one less than the number of days; and the total number (T) in any row is one less than the number added (N) in the following row.

4.* **A.** 131,072

B. 262,143

5.* Total number of grains of wheat will reach 1,000,000 on Day 20.

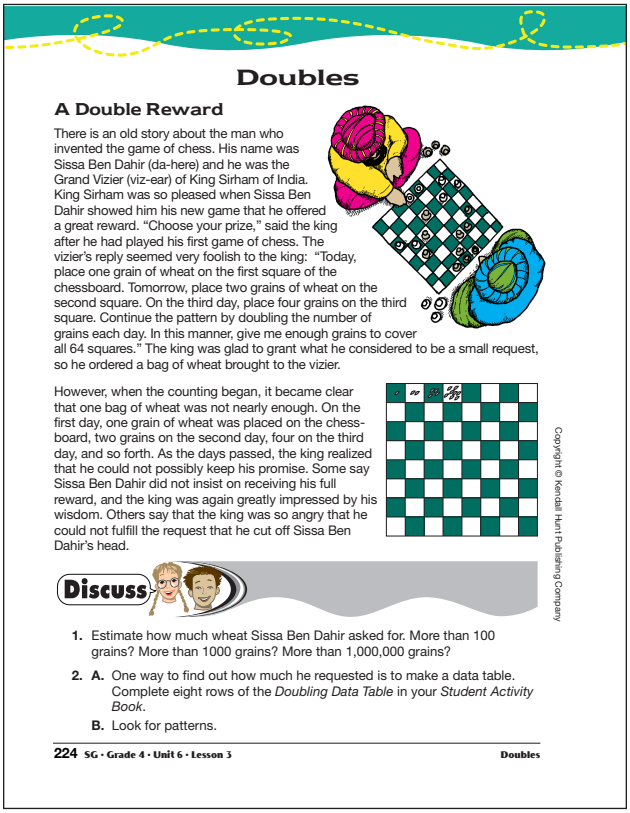
6.*

D Time in Days	N Number of Grains of Wheat Added	P Previous Day's Total	T Total Grains of Wheat $N + P$ = Total
1	1	0	1 + 0 = 1
2	$2^1 = 2$	1	2 + 1 = 3
3	$2 \times 2 = 2^2 = 4$	3	4 + 3 = 7
4	$2 \times 2 \times 2 = 3^3 = 8$	7	8 + 7 = 15
5	$2 \times 2 \times 2 \times 2 = 2^4 = 16$	15	16 + 15 = 31
6	$2^5 = 32$	31	32 + 31 = 63
7	$2^6 = 64$	63	64 + 63 = 127
8	$2^7 = 128$	127	128 + 127 = 255
9	$2^8 = 256$	255	511
10	$2^9 = 512$	511	1023
11	$2^{10} = 1024$	1023	2047
12	$2^{11} = 2048$	2047	4095
13	$2^{12} = 4096$	4095	8191
14	$2^{13} = 8192$	8191	16,383
15	$2^{14} = 16,384$	16,383	32,767
16	$2^{15} = 32,768$	32,767	65,535
17	$2^{16} = 65,536$	65,535	131,071
18	$2^{17} = 131,072$	131,071	262,143
19	$2^{18} = 262,144$	262,143	524,287
20	$2^{19} = 524,288$	524,287	1,048,575
21	$2^{20} = 1,048,576$	1,048,575	2,097,151

7.* See Figure 5 in Lesson 3.

A. No

B. Descriptions will vary. Students should see that the points fall on a curve or that the points tend to go uphill slowly at first, then very quickly.



Doubles

A Double Reward

There is an old story about the man who invented the game of chess. His name was Sissa Ben Dahir (da-here) and he was the Grand Vizier (viz-ear) of King Sirham of India. King Sirham was so pleased when Sissa Ben Dahir showed him his new game that he offered a great reward. "Choose your prize," said the king after he had played his first game of chess. The vizier's reply seemed very foolish to the king: "Today, place one grain of wheat on the first square of the chessboard. Tomorrow, place two grains of wheat on the second square. On the third day, place four grains on the third square. Continue the pattern by doubling the number of grains each day. In this manner, give me enough grains to cover all 64 squares." The king was glad to grant what he considered to be a small request, so he ordered a bag of wheat brought to the vizier.

However, when the counting began, it became clear that one bag of wheat was not nearly enough. On the first day, one grain of wheat was placed on the chessboard, two grains on the second day, four on the third day, and so forth. As the days passed, the king realized that he could not possibly keep his promise. Some say Sissa Ben Dahir did not insist on receiving his full reward, and the king was again greatly impressed by his wisdom. Others say that the king was so angry that he could not fulfill the request that he cut off Sissa Ben Dahir's head.

Discuss

1. Estimate how much wheat Sissa Ben Dahir asked for. More than 100 grains? More than 1000 grains? More than 1,000,000 grains?
2. **A.** One way to find out how much he requested is to make a data table. Complete eight rows of the *Doubling Data Table* in your *Student Activity Book*.
   B. Look for patterns.

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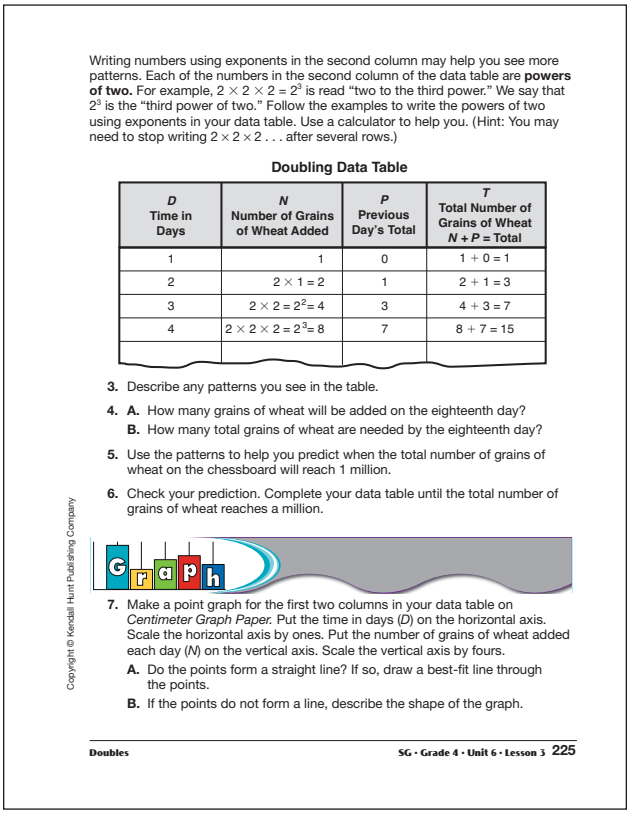

Writing numbers using exponents in the second column may help you see more patterns. Each of the numbers in the second column of the data table are **powers of two.** For example, $2 \times 2 \times 2 = 2^3$ is read "two to the third power." We say that 2^3 is the "third power of two." Follow the examples to write the powers of two using exponents in your data table. Use a calculator to help you. (Hint: You may need to stop writing $2 \times 2 \times 2 \ldots$ after several rows.)

Doubling Data Table

D Time in Days	N Number of Grains of Wheat Added	P Previous Day's Total	T Total Number of Grains of Wheat $N + P$ = Total
1	1	0	1 + 0 = 1
2	$2 \times 1 = 2$	1	2 + 1 = 3
3	$2 \times 2 = 2^2 = 4$	3	4 + 3 = 7
4	$2 \times 2 \times 2 = 2^3 = 8$	7	8 + 7 = 15

3. Describe any patterns you see in the table.
4. **A.** How many grains of wheat will be added on the eighteenth day?
   B. How many total grains of wheat are needed by the eighteenth day?
5. Use the patterns to help you predict when the total number of grains of wheat on the chessboard will reach 1 million.
6. Check your prediction. Complete your data table until the total number of grains of wheat reaches a million.

Graph

7. Make a point graph for the first two columns in your data table on *Centimeter Graph Paper.* Put the time in days (D) on the horizontal axis. Scale the horizontal axis by ones. Put the number of grains of wheat added each day (N) on the vertical axis. Scale the vertical axis by fours.
   A. Do the points form a straight line? If so, draw a best-fit line through the points.
   B. If the points do not form a line, describe the shape of the graph.

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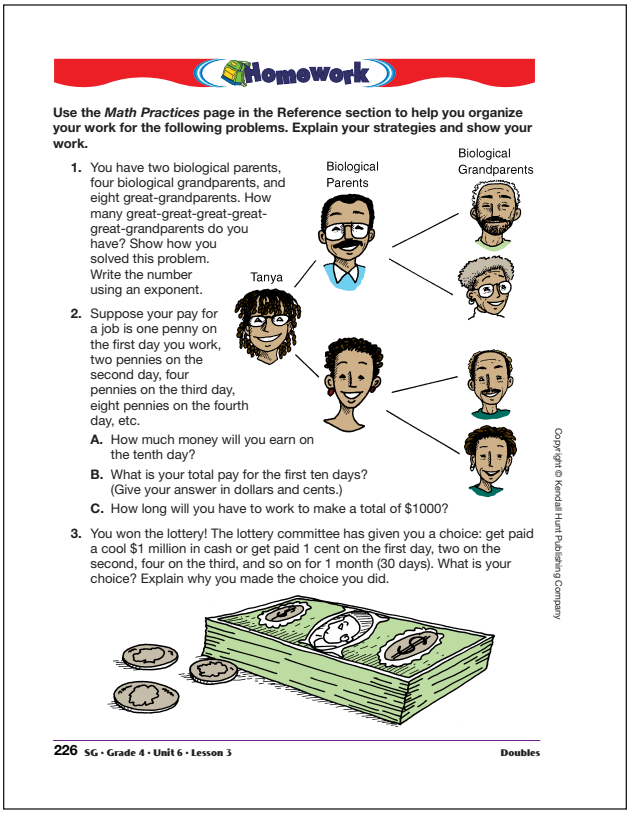
***Answers and/or discussion are included in the lesson.**



Homework

Use the *Math Practices* page in the Reference section to help you organize your work for the following problems. Explain your strategies and show your work.

1. You have two biological parents, four biological grandparents, and eight great-grandparents. How many great-great-great-great-great-grandparents do you have? Show how you solved this problem. Write the number using an exponent.

2. Suppose your pay for a job is one penny on the first day you work, two pennies on the second day, four pennies on the third day, eight pennies on the fourth day, etc.
   - **A.** How much money will you earn on the tenth day?
   - **B.** What is your total pay for the first ten days? (Give your answer in dollars and cents.)
   - **C.** How long will you have to work to make a total of $1000?
3. You won the lottery! The lottery committee has given you a choice: get paid a cool $1 million in cash or get paid 1 cent on the first day, two on the second, four on the third, and so on for 1 month (30 days). What is your choice? Explain why you made the choice you did.

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Homework (SG p. 226)

Questions 1–3

1. $2^7 = 128$ great-great-great-great-great-grandparents. Strategies will vary. Students could make a table similar to what they created for the grains of wheat story.

G Generation	*N* Number	*T* Total	Number Sentence
1	2 parents	2	$1 \times 2 = 2^1$
2	4 grandparents	4	$2 \times 2 = 2^2$
3	8 great grandparents	8	$2 \times 2 \times 2 = 2^3$
4	16 great-great grandparents	18	$2 \times 2 \times 2 \times 2 = 2^4$
5	32 great-great-great grandparent	32	$2 \times 2 \times 2 \times 2 \times 2 = 2^5$
6	32 great-great-great-great grandparent	64	$2 \times 2 \times 2 \times 2 \times 2 \times 2 = 2^6$
7	128 great-great-great-great-great grandparent	128	$2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 2^7$

2.* See Figure 4 in the lesson. Replace grains of wheat with pennies.

A. $5.12

B. $10.23

C. 17 days; $1310.71

3. Answers will vary. Taking one cent on the first day, two on the second, four on the third, etc., will give you more money, but you'll have to wait longer to accumulate it. This is the same problem as the one described in the story of doubling grains of wheat. Following the same pattern, on the 20th day you will have received a total of $10,485.75 with the doubling option. On the 27th day, you will have received more than one million dollars. On the 30th day you will have more than ten million dollars.

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*Answers and/or discussion are included in the lesson.