

What is a Histogram?

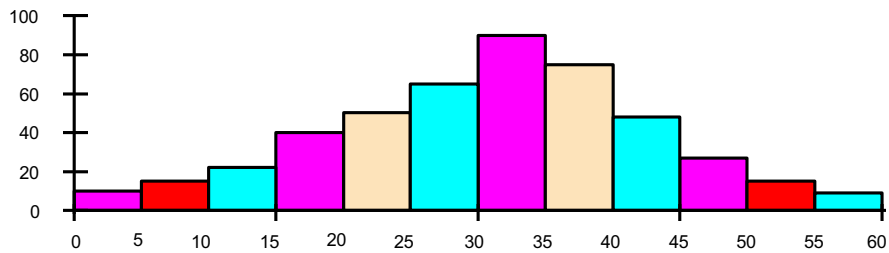
A Histogram is a vertical bar chart that depicts the distribution of a set of data. Unlike Run Charts or Control Charts, which are discussed in other modules, a Histogram does not reflect process performance over time. It's helpful to think of a Histogram as being like a snapshot, while a Run Chart or Control Chart is more like a movie (Viewgraph 1).

When should we use a Histogram?

When you are unsure what to do with a large set of measurements presented in a table, you can use a Histogram to organize and display the data in a more user-friendly format. A Histogram will make it easy to see where the majority of values falls in a measurement scale, and how much variation there is. It is helpful to construct a Histogram when you want to do the following (Viewgraph 2):

- Summarize large data sets graphically. When you look at Viewgraph 6, you can see that a set of data presented in a table isn't easy to use. You can make it much easier to understand by summarizing it on a tally sheet (Viewgraph 7) and organizing it into a Histogram (Viewgraph 12).
- Compare process results with specification limits. If you add the process specification limits to your Histogram, you can determine quickly whether the current process was able to produce "good" products. Specification limits may take the form of length, weight, density, quantity of materials to be delivered, or whatever is important for the product of a given process. Viewgraph 14 shows a Histogram on which the specification limits, or "goalposts," have been superimposed. We'll look more closely at the implications of specification limits when we discuss Histogram interpretation later in this module.
- Communicate information graphically. The team members can easily see the values which occur most frequently. When you use a Histogram to summarize large data sets, or to compare measurements to specification limits, you are employing a powerful tool for communicating information.
- Use a tool to assist in decision making. As you will see as we move along through this module, certain shapes, sizes, and the spread of data have meanings that can help you in investigating problems and making decisions. But always bear in mind that if the data you have in hand aren't recent, or you don't know how the data were collected, it's a waste of time trying to chart them. Measurements cannot be used for making decisions or predictions when they were produced by a process that is different from the current one, or were collected under unknown conditions.

What Is a Histogram?



- A bar graph that shows the distribution of data
- A snapshot of data taken from a process

HISTOGRAM

VIEWGRAPH 1

When Are Histograms Used?

- Summarize large data sets graphically
- Compare measurements to specifications
- Communicate information to the team
- Assist in decision making

HISTOGRAM

VIEWGRAPH 2

What are the parts of a Histogram?

As you can see in Viewgraph 3, a Histogram is made up of five parts:

1. Title: The title briefly describes the information that is contained in the Histogram.
2. Horizontal or X-Axis: The horizontal or X-axis shows you the scale of values into which the measurements fit. These measurements are generally grouped into intervals to help you summarize large data sets. Individual data points are not displayed.
3. Bars: The bars have two important characteristics—height and width. The height represents the number of times the values within an interval occurred. The width represents the length of the interval covered by the bar. It is the same for all bars.
4. Vertical or Y-Axis: The vertical or Y-axis is the scale that shows you the number of times the values within an interval occurred. The number of times is also referred to as "frequency."
5. Legend: The legend provides additional information that documents where the data came from and how the measurements were gathered.

How is a Histogram constructed?

There are many different ways to organize data and build Histograms. You can safely use any of them as long as you follow the basic rules. In this module, we will use the nine-step approach (Viewgraphs 4 and 5) described on the following pages.

EXAMPLE: The following scenario will be used as an example to provide data as we go through the process of building a Histogram step by step:

During sea trials, a ship conducted test firings of its MK 75, 76mm gun. The ship fired 135 rounds at a target. An airborne spotter provided accurate rake data to assess the fall of shot both long and short of the target. The ship computed what constituted a hit for the test firing as:

From 60 yards short of the target

To 300 yards beyond the target

Constructing a Histogram

- Step 1 - Count number of data points
- Step 2 - Summarize on a tally sheet
- Step 3 - Compute the range
- Step 4 - Determine number of intervals
- Step 5 - Compute interval width

HISTOGRAM

VIEWGRAPH 4

Constructing a Histogram

- Step 6 - Determine interval starting points
- Step 7 - Count number of points in each interval
- Step 8 - Plot the data
- Step 9 - Add title and legend

HISTOGRAM

VIEWGRAPH 5

Step 1 - Count the total number of data points you have listed. Suppose your team collected data on the miss distance for the gunnery exercise described in the example. The data you collected was for the fall of shot both long and short of the target. The data are displayed in Viewgraph 6. Simply counting the total number of entries in the data set completes this step. In this example, there are 135 data points.

Step 2 - Summarize your data on a tally sheet. You need to summarize your data to make it easy to interpret. You can do this by constructing a tally sheet.

- First, identify all the different values found in Viewgraph 6 (-160, -010. . .030, 220, etc.). Organize these values from smallest to largest (-180, -120. . .380, 410).
- Then, make a tally mark next to the value every time that value is present in the data set.
- Alternatively, simply count the number of times each value is present in the data set and enter that number next to the value, as shown in Viewgraph 7.

This tally helped us organize 135 mixed numbers into a ranked sequence of 51 values. Moreover, we can see very easily the number of times that each value appeared in the data set. This data can be summarized even further by forming intervals of values.

How to Construct a Histogram

Step 1 - Count the total number of data points

Number of yards long (+ data) and yards short (- data) that a gun crew missed its target.

-180	30	190	380	330	140	160	270	10	- 90
- 10	30	60	230	90	120	10	50	250	180
-130	220	170	130	- 50	- 80	180	100	110	200
260	190	-100	150	210	140	-130	130	150	370
160	180	240	260	- 20	- 80	30	80	240	130
210	40	70	- 70	250	360	120	- 60	- 30	200
50	20	30	280	410	70	- 10	20	130	170
140	220	- 40	290	90	100	- 30	340	20	80
210	130	350	250	- 20	230	180	130	- 30	210
-30	80	270	320	30	240	120	100	20	70
300	260	20	40	- 20	250	310	40	200	190
110	-30	50	240	180	50	130	200	280	60
260	70	100	140	80	190	100	270	140	80
110	130	120	30	70					

TOTAL = 135

HISTOGRAM

VIEWGRAPH 6

How to Construct a Histogram

Step 2 - Summarize the data on a tally sheet

DATA	TALLY	DATA	TALLY	DATA	TALLY	DATA	TALLY	DATA	TALLY
- 180	1	- 20	3	90	2	190	4	290	1
- 130	2	- 10	2	100	5	200	4	300	1
- 100	1	10	2	110	3	210	4	310	1
- 90	1	20	5	120	4	220	2	320	1
- 80	2	30	6	130	8	230	2	330	1
- 70	1	40	3	140	5	240	4	340	1
- 60	1	50	4	150	2	250	4	350	1
- 50	1	60	2	160	2	260	4	360	1
- 40	1	70	5	170	2	270	3	370	1
- 30	5	80	5	180	5	280	2	380	1
								410	1

HISTOGRAM

VIEWGRAPH 7

Step 3 - Compute the range for the data set. Compute the range by subtracting the smallest value in the data set from the largest value. The range represents the extent of the measurement scale covered by the data; it is always a positive number. The range for the data in Viewgraph 8 is 590 yards. This number is obtained by subtracting -180 from +410. The mathematical operation broken down in Viewgraph 8 is:

$$+410 - (-180) = 410 + 180 = 590$$

Remember that when you subtract a negative (-) number from another number it becomes a positive number.

Step 4 - Determine the number of intervals required. The number of intervals influences the pattern, shape, or spread of your Histogram. Use the following table (Viewgraph 9) to determine how many intervals (or bars on the bar graph) you should use.

If you have this many data points:	Use this number of intervals:
Less than 50	5 to 7
50 to 99	6 to 10
100 to 250	7 to 12
More than 250	10 to 20

For this example, 10 has been chosen as an appropriate number of intervals.

How to Construct a Histogram

Step 3 - Compute the range for the data set

Largest value = + 410 yards past target

Smallest value = - 180 yards short of target

Range of values = 590 yards

Calculation: $+ 410 - (- 180) = 410 + 180 = 590$

HISTOGRAM

VIEWGRAPH 8

How to Construct a Histogram

Step 4 - Determine the number of intervals required

IF YOU HAVE THIS MANY DATA POINTS	USE THIS NUMBER OF INTERVALS:
Less than 50	5 to 7 intervals
50 to 99	6 to 10 intervals
100 to 250	7 to 12 intervals
More than 250	10 to 20 intervals

HISTOGRAM

VIEWGRAPH 9

Step 5 - Compute the interval width. To compute the interval width (Viewgraph 10), divide the range (590) by the number of intervals (10). When computing the interval width, you should round the data up to the next higher whole number to come up with values that are convenient to use. For example, if the range of data is 17, and you have decided to use 9 intervals, then your interval width is 1.88. You can round this up to 2.

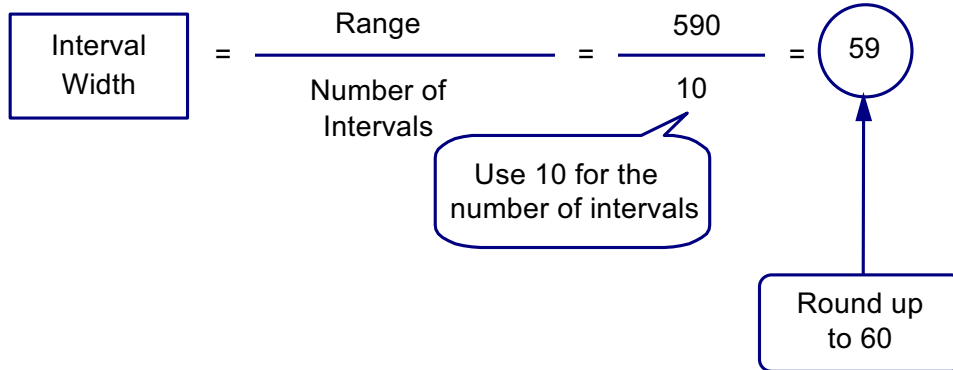
In this example, you divide 590 yards by 10 intervals, which gives an interval width of 59. This means that the length of every interval is going to be 59 yards. To facilitate later calculations, it is best to round off the value representing the width of the intervals. In this case, we will use 60, rather than 59, as the interval width.

Step 6 - Determine the starting point for each interval. Use the smallest data point in your measurements as the starting point of the first interval. The starting point for the second interval is the sum of the smallest data point and the interval width. For example, if the smallest data point is -180, and the interval width is 60, the starting point for the second interval is -120. Follow this procedure (Viewgraph 11) to determine all of the starting points ($-180 + 60 = -120$; $-120 + 60 = -60$; etc.).

Step 7 - Count the number of points that fall within each interval. These are the data points that are equal to or greater than the starting value and less than the ending value (also illustrated in Viewgraph 11). For example, if the first interval begins with -180 and ends with -120, all data points that are equal to or greater than -180, but still less than -120, will be counted in the first interval. Keep in mind that EACH DATA POINT can appear in only one interval.

How to Construct a Histogram

Step 5 - Compute the interval width



HISTOGRAM

VIEWGRAPH 10

How to Construct a Histogram

Step 6 - Determine the starting point of each interval

Step 7 - Count the number of points in each interval

<u>INTERVAL NUMBER</u>	<u>STARTING VALUE</u>	<u>INTERVAL WIDTH</u>	<u>ENDING VALUE</u>	<u>NUMBER OF COUNTS</u>
1	-180	60	-120	3
2	-120	60	-060	5
3	-060	60	000	13
4	000	60	060	20
5	060	60	120	22
6	120	60	180	24
7	180	60	240	20
8	240	60	300	18
9	300	60	360	6
10	360	60	420	4

Equal to or greater than the STARTING VALUE

But less than the ENDING VALUE

HISTOGRAM

VIEWGRAPH 11

Step 8 - Plot the data. A more precise and refined picture comes into view once you plot your data (Viewgraph 12). You bring all of the previous steps together when you construct the graph.

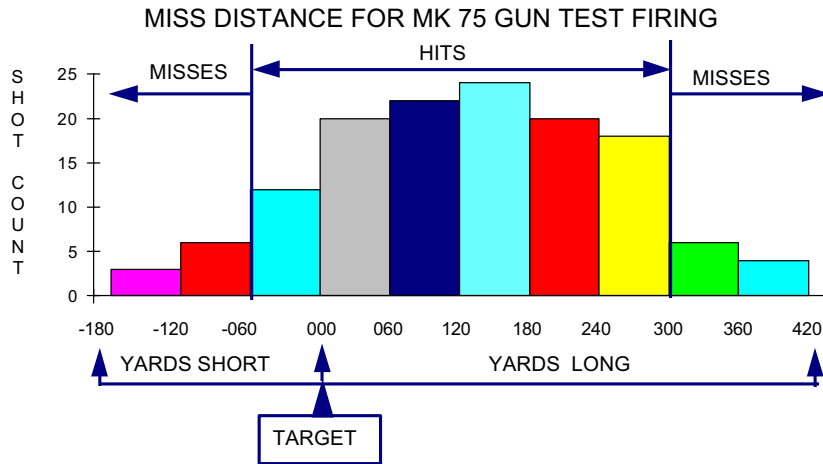
- The horizontal scale across the bottom of the graph contains the intervals that were calculated previously.
- The vertical scale contains the count or frequency of observations within each of the intervals.
- A bar is drawn for the height of each interval. The bars look like columns.
- The height is determined by the number of observations or percentage of the total observations for each of the intervals.
- The Histogram may not be perfectly symmetrical. Variations will occur. Ask yourself whether the picture is reasonable and logical, but be careful not to let your preconceived ideas influence your decisions unfairly.

Step 9 - Add the title and legend. A title and a legend provide the who, what, when, where, and why (also illustrated in Viewgraph 12) that are important for understanding and interpreting the data. This additional information documents the nature of the data, where it came from, and when it was collected. The legend may include such things as the sample size, the dates and times involved, who collected the data, and identifiable equipment or work groups. It is important to include any information that helps clarify what the data describes.

How to Construct a Histogram

Step 8 - Plot the data

Step 9 - Add the title and legend



LEGEND: USS CROMMELIN (FFG-37), PACIFIC MISSILE FIRING RANGE, 135 BL&P ROUNDS/MOUNT 31, 25 JUNE 94

HISTOGRAM

VIEWGRAPH 12

How do we interpret a Histogram?

A Histogram provides a visual representation so you can see where most of the measurements are located and how spread out they are. Your Histogram might show any of the following conditions (Viewgraph 13):

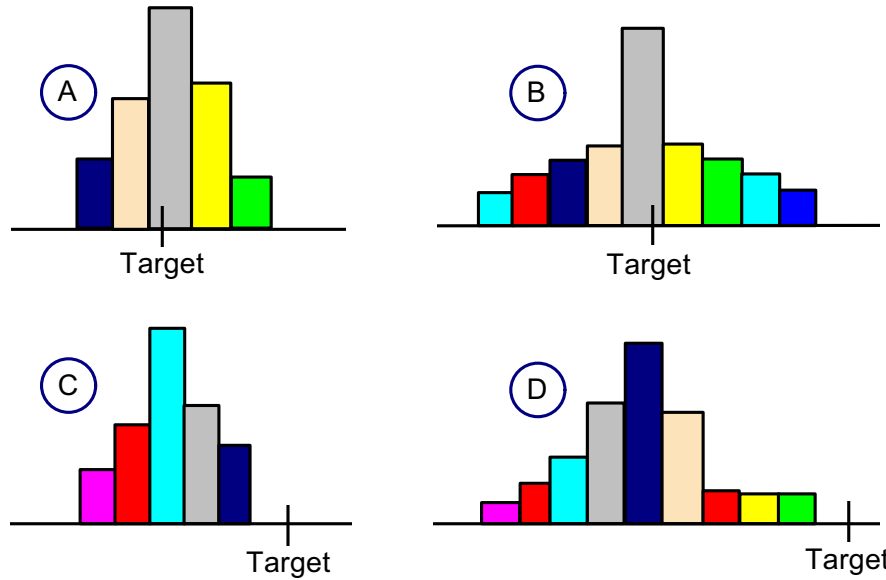
- Most of the data were on target, with very little variation from it, as in Viewgraph 13A.
- Although some data were on target, many others were dispersed away from the target, as in Viewgraph 13B.
- Even when most of the data were close together, they were located off the target by a significant amount, as in Viewgraph 13C.
- The data were off target and widely dispersed, as in Viewgraph 13D.

This information helps you see how well the process performed and how consistent it was. You may be thinking, "So what? How will this help me do my job better?" Well, with the results of the process clearly depicted, we can find the answer to a vital question:

Did the process produce goods and services which are within specification limits?

Looking at the Histogram, you can see, not only whether you were within specification limits, but also how close to the target you were (Viewgraph 14).

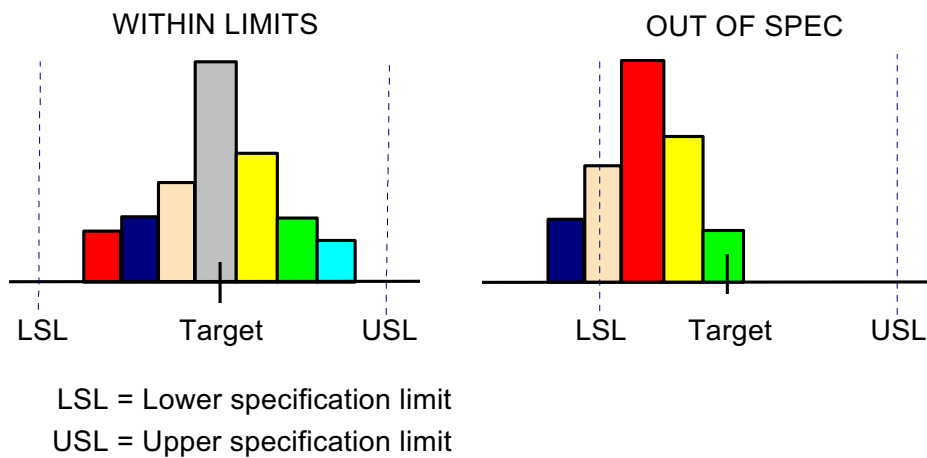
Interpreting Histograms Location and Spread of Data



HISTOGRAM

VIEWGRAPH 13

Interpreting Histograms Is Process Within Specification Limits?



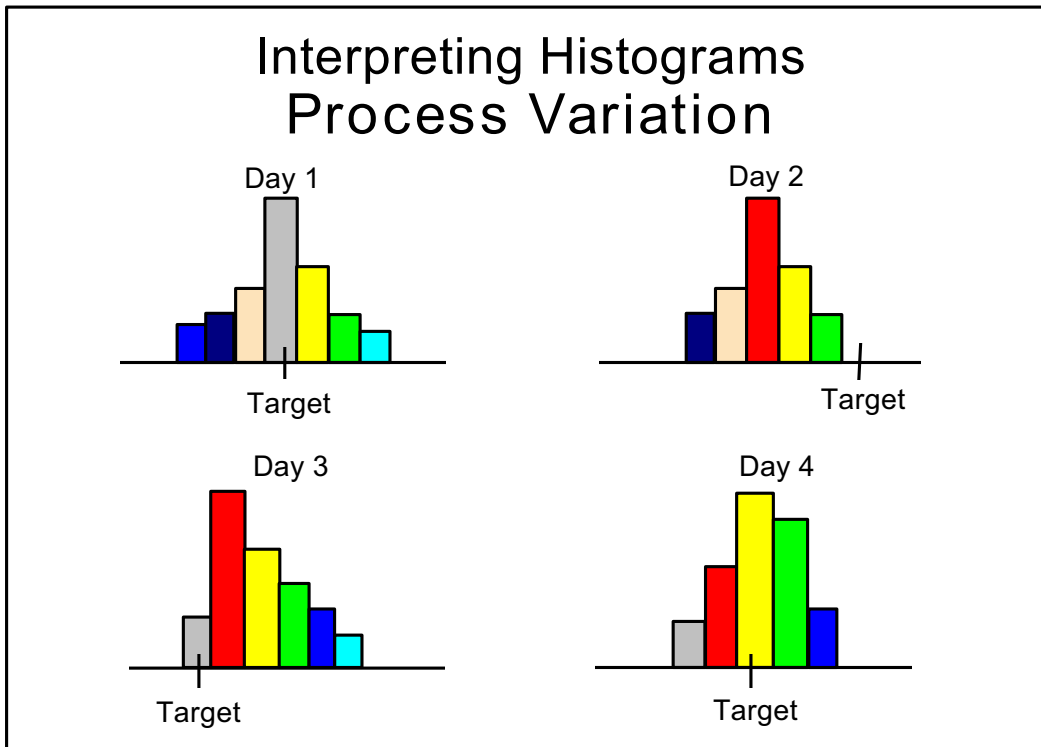
HISTOGRAM

VIEWGRAPH 14

Portraying your data in a Histogram enables you to check rapidly on the number, or the percentage, of defects produced during the time you collected data. But unless you know whether the process was stable (Viewgraph 15), you won't be able to predict whether future products will be within specification limits or determine a course of action to ensure that they are.

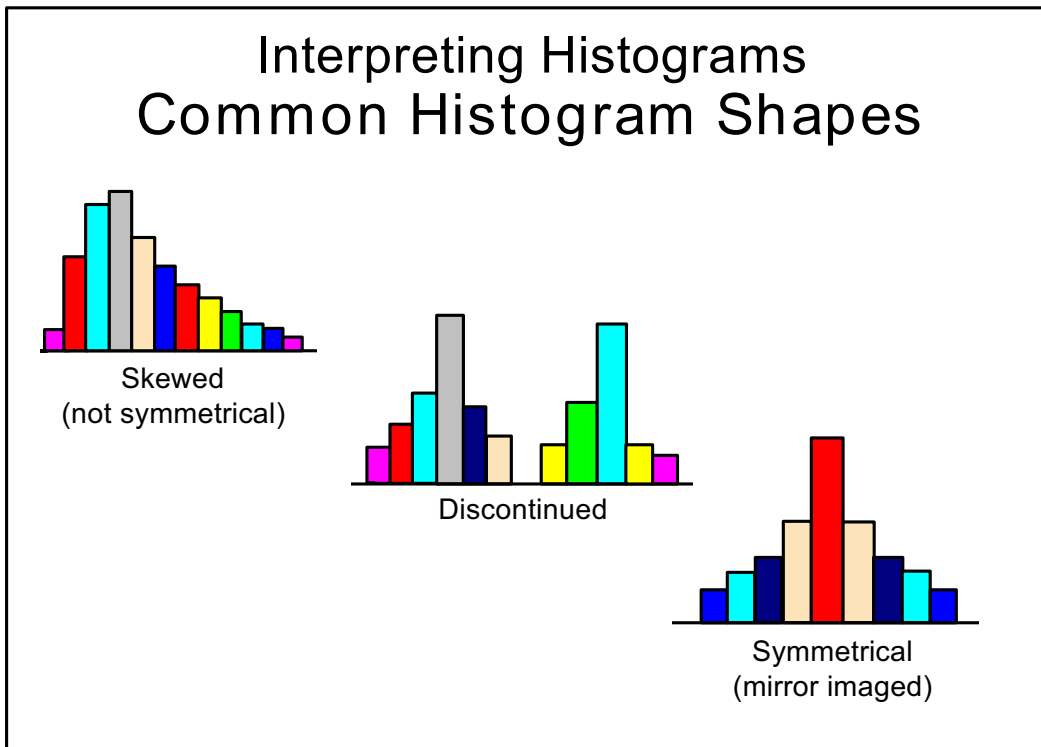
A Histogram can show you whether or not your process is producing products or services that are within specification limits. To discover whether the process is stable, and to predict whether it can continue to produce within spec limits, you need to use a Control Chart (see the Control Chart module). Only after you have discovered whether your process is in or out of control can you determine an appropriate course of action—to eliminate special causes of variation, or to make fundamental changes to your process.

There are times when a Histogram may look unusual to you. It might have more than one peak, be discontinued, or be skewed, with one tail longer than the other, as shown in Viewgraph 16. In these circumstances, the people involved in the process should ask themselves whether it really is unusual. The Histogram may not be symmetrical, but you may find out that it should look the way it does. On the other hand, the shape may show you that something is wrong, that data from several sources were mixed, for example, or different measurement devices were used, or operational definitions weren't applied. What is really important here is to avoid jumping to conclusions without properly examining the alternatives.



HISTOGRAM

VIEWGRAPH 15



HISTOGRAM

VIEWGRAPH 16

How can we practice what we've learned?

Two exercises are provided that will take you through the nine steps for developing a Histogram. On the four pages that follow the scenario for Exercise 1 you will find a set of blank worksheets (Viewgraphs 17 through 23) to use in working through both of the exercises in this module.

You will find a set of answer keys for Exercise 1 after the blank worksheets, and for Exercise 2 after the description of its scenario. These answer keys represent only one possible set of answers. It's all right for you to choose an interval width or a number of intervals that is different from those used in the answer keys. Even though the shape of your Histogram may vary somewhat from the answer key's shape, it should be reasonably close unless you used a very different number of intervals.

EXERCISE 1: The source of data for the first exercise is the following scenario. A list of the data collected follows this description. Use the blank worksheets in Viewgraphs 17 through 23 to do this exercise. You will find answer keys in Viewgraphs 24 through 30.

Your corpsman is responsible for the semiannual Physical Readiness Test (PRT) screening for percent body fat. Prior to one PRT, the corpsman recorded the percent of body fat for the 80 personnel assigned to the command. These are the data collected:

PERCENT BODY FAT RECORDED

11	22	15	7	13	20	25	12	16	19
4	14	11	16	18	32	10	16	17	10
8	11	23	14	16	10	5	21	26	10
23	12	10	16	17	24	11	20	9	13
24	10	16	18	22	15	13	19	15	24
11	20	15	13	9	18	22	16	18	9
14	20	11	19	10	17	15	12	17	11
17	11	15	11	15	16	12	28	14	13

WORKSHEET

Step 1 - Count the number of data points

TOTAL NUMBER =

HISTOGRAM

VIEWGRAPH 17

WORKSHEET

Step 2 - Summarize the data on a tally sheet

VALUE	TALLY	VALUE	TALLY	VALUE	TALLY	VALUE	TALLY	VALUE	TALLY

HISTOGRAM

VIEWGRAPH 18

WORKSHEET

Step 3 - Compute the range for the data set

Largest value = _____

Smallest value = _____

Range of values = _____

HISTOGRAM

VIEWGRAPH 19

WORKSHEET

Step 4 - Determine the number of intervals

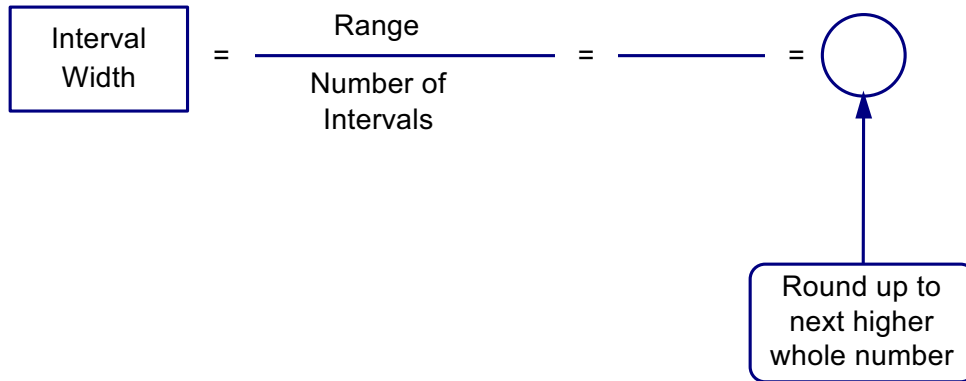
IF YOU HAVE THIS MANY DATA POINTS	USE THIS NUMBER OF INTERVALS:
Less than 50	5 to 7 intervals
50 to 99	6 to 10 intervals
100 to 250	7 to 12 intervals
More than 250	10 to 20 intervals

HISTOGRAM

VIEWGRAPH 20

WORKSHEET

Step 5 - Compute the interval width



HISTOGRAM

VIEWGRAPH 21

WORKSHEET

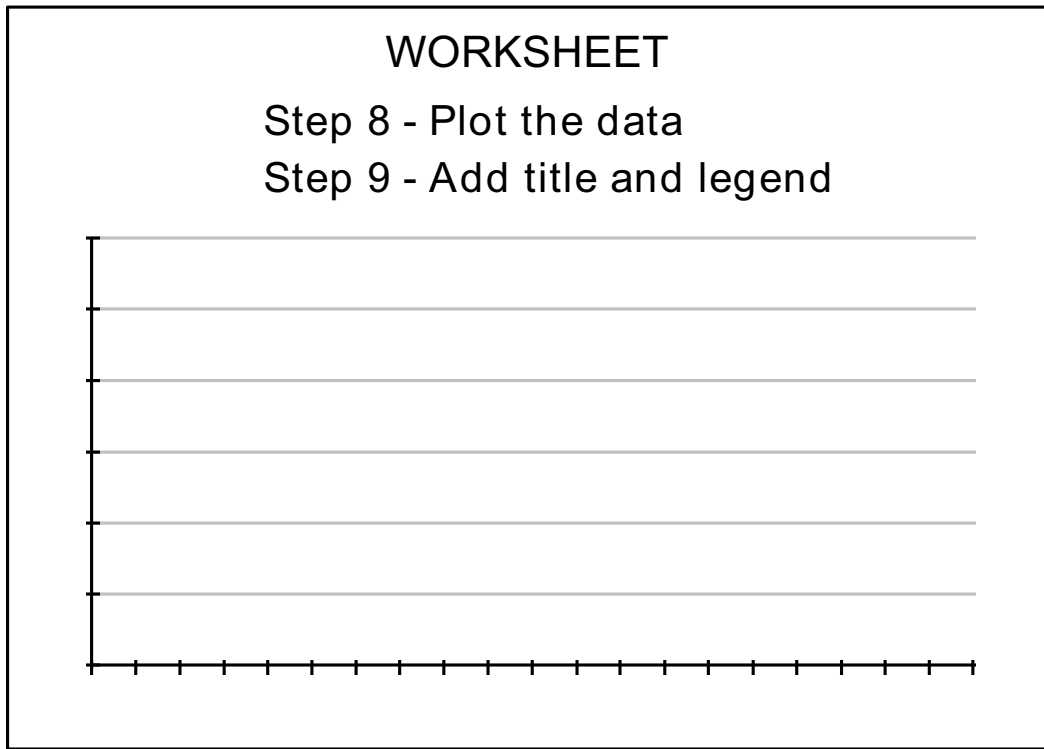
Step 6 - Determine the starting point of each interval

Step 7 - Count the number of points in each interval

INTERVAL NUMBER	STARTING VALUE	INTERVAL WIDTH	ENDING VALUE	NUMBER OF COUNTS
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

HISTOGRAM

VIEWGRAPH 22



HISTOGRAM

VIEWGRAPH 23

EXERCISE 1 ANSWER KEY

Step 1 - Count the number of data points

11	22	15	7	13	20	25	12	16	19
4	14	11	16	18	32	10	16	17	10
8	11	23	14	16	10	5	21	26	10
23	12	10	16	17	24	11	20	9	13
24	10	16	18	22	15	13	19	15	24
11	20	15	13	9	18	22	16	18	9
14	20	11	19	10	17	15	12	17	11
17	11	15	11	15	16	12	28	14	13

TOTAL = 80

HISTOGRAM

VIEWGRAPH 24

EXERCISE 1 ANSWER KEY

Step 2 - Summarize the data on a tally sheet

<u>%</u>	<u>NO. OF PERS</u>	<u>%</u>	<u>NO. OF PERS</u>	<u>%</u>	<u>NO. OF PERS</u>
FAT		FAT		FAT	
0	0	11	9	22	3
1	0	12	4	23	2
2	0	13	5	24	3
3	0	14	4	25	1
4	1	15	7	26	1
5	1	16	8	27	0
6	0	17	5	28	1
7	1	18	4	29	0
8	1	19	3	30	0
9	3	20	4	31	0
10	7	21	1	32	1

HISTOGRAM

VIEWGRAPH 25

EXERCISE 1 ANSWER KEY

Step 3 - Compute the range for the data set

Largest value = 32 Percent body fat

Smallest value = 4 Percent body fat

Range of values = 28 Percent body fat

HISTOGRAM

VIEWGRAPH 26

EXERCISE 1 ANSWER KEY

Step 4 - Determine the number of intervals

IF YOU HAVE THIS
MANY DATA POINTS

USE THIS NUMBER
OF INTERVALS:

Less than 50

5 to 7 intervals

50 to 99

6 to 10 intervals

100 to 250

7 to 12 intervals

More than 250

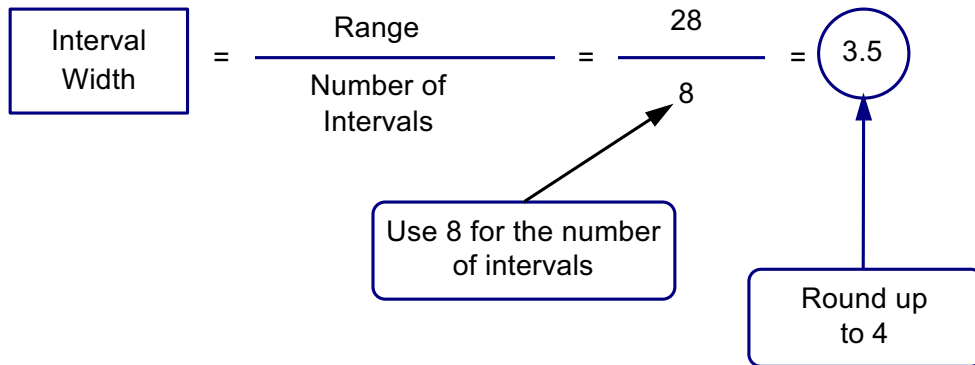
10 to 20 intervals

HISTOGRAM

VIEWGRAPH 27

EXERCISE 1 ANSWER KEY

Step 5 - Compute the interval width



HISTOGRAM

VIEWGRAPH 28

EXERCISE 1 ANSWER KEY

Step 6 - Determine the starting point of each interval

Step 7 - Count the number of points in each interval

INTERVAL NUMBER	STARTING VALUE	INTERVAL WIDTH	ENDING VALUE	NUMBER OF COUNTS
1	4	+ 4	8	3
2	8	+ 4	12	20
3	12	+ 4	16	20
4	16	+ 4	20	20
5	20	+ 4	24	10
6	24	+ 4	28	5
7	28	+ 4	32	1
8	32	+ 4	36	1

Equal to or greater than the STARTING VALUE

But less than the ENDING VALUE

HISTOGRAM

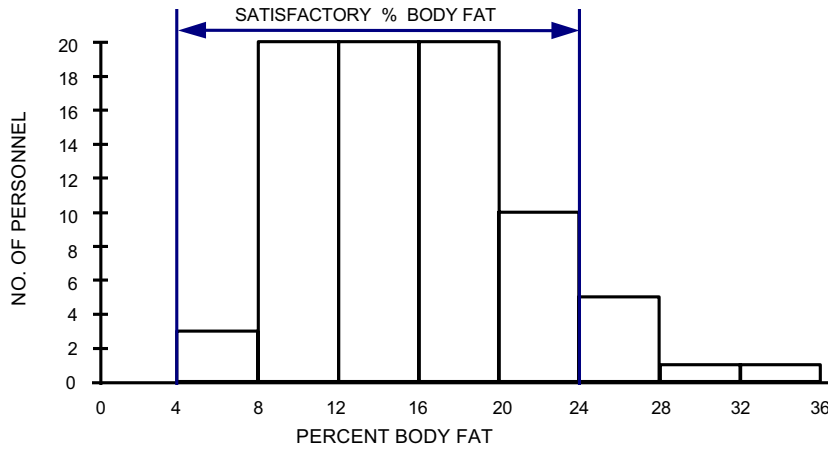
VIEWGRAPH 29

EXERCISE 1 ANSWER KEY

Step 8 - Plot the data

Step 9 - Add title and legend

JUNE 94 PRT PERCENT BODY FAT



LEGEND: USS LEADER (MSO-490), 25 JUNE 94, ALL 80 PERSONNEL SAMPLED

HISTOGRAM

VIEWGRAPH 30

EXERCISE 2: The source of data for the second exercise is the following scenario. A listing of the data collected follows this description. Use the blank worksheets in Viewgraphs 17 through 23 to do this exercise. You will find answer keys in Viewgraphs 31 through 37.

A Marine Corps small arms instructor was performing an analysis of 9 mm pistol marksmanship scores to improve training methods. For every class of 25, the instructor recorded the scores for each student who occupied the first four firing positions at the small arms range. The instructor then averaged the scores for each class, maintaining a database on 105 classes. These are the data collected:

AVERAGE SMALL ARMS SCORES

160	190	155	300	280	185	250	285	200	165
175	190	210	225	275	240	170	185	215	220
270	265	255	235	170	175	185	195	200	260
180	245	270	200	200	220	265	270	250	230
255	180	260	240	245	170	205	260	215	185
255	245	210	225	225	235	230	230	195	225
230	255	235	195	220	210	235	240	200	220
195	235	230	215	225	235	225	200	245	230
220	215	225	250	220	245	195	235	225	230
210	240	215	230	220	225	200	235	215	240
220	230	225	215	225					

EXERCISE 2 ANSWER KEY

Step 1 - Count the number of data points

160	190	155	300	280	185	250	285	200	165
175	190	210	225	275	240	170	185	215	220
270	265	255	235	170	175	185	195	200	260
180	245	270	200	200	220	265	270	250	230
255	180	260	240	245	170	205	260	215	185
255	245	210	225	225	235	230	230	195	225
230	255	235	195	220	210	235	240	200	220
195	235	230	215	225	235	225	200	245	230
220	215	225	250	220	245	195	235	225	230
210	240	215	230	220	225	200	235	215	240
220	230	225	215	225					

TOTAL = 105

HISTOGRAM

VIEWGRAPH 31

EXERCISE 2 ANSWER KEY

Step 2 - Summarize the data on a tally sheet

<u>SCORE</u>	<u>TALLY</u>	<u>SCORE</u>	<u>TALLY</u>	<u>SCORE</u>	<u>TALLY</u>
155	1	205	1	255	4
160	1	210	4	260	3
165	1	215	7	265	2
170	3	220	8	270	3
175	2	225	11	275	1
180	2	230	9	280	1
185	4	235	8	285	1
190	2	240	5	290	0
195	5	245	5	295	0
200	7	250	3	300	1

HISTOGRAM

VIEWGRAPH 32

EXERCISE 2 ANSWER KEY

Step 3 - Compute the range for the data set

Largest value = 300 Points

Smallest value = 155 Points

Range of values = 145 Points

HISTOGRAM

VIEWGRAPH 33

EXERCISE 2 ANSWER KEY

Step 4 - Determine the number of intervals

IF YOU HAVE THIS
MANY DATA POINTS

USE THIS NUMBER
OF INTERVALS:

Less than 50

5 to 7 intervals

50 to 99

6 to 10 intervals

100 to 250

7 to 12 intervals

More than 250

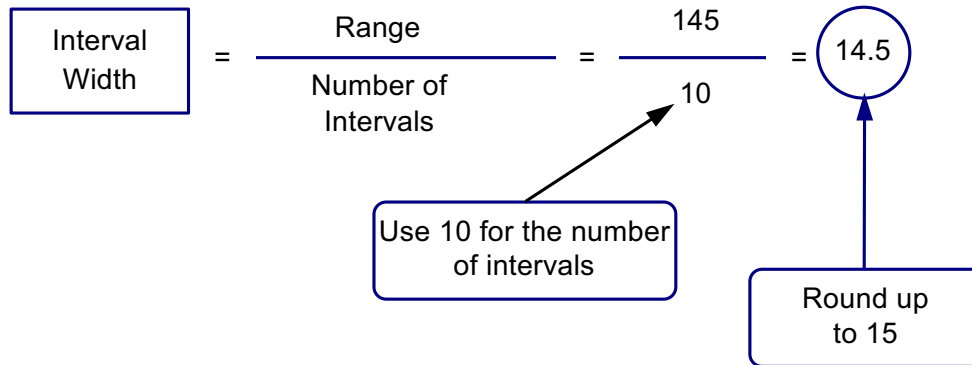
10 to 20 intervals

HISTOGRAM

VIEWGRAPH 34

EXERCISE 2 ANSWER KEY

Step 5 - Compute the interval width



HISTOGRAM

VIEWGRAPH 35

EXERCISE 2 ANSWER KEY

Step 6 - Determine the starting point of each interval

Step 7 - Count the number of points in each interval

INTERVAL NUMBER	STARTING VALUE	INTERVAL WIDTH	ENDING VALUE	NUMBER OF COUNTS
1	155	+ 15	170	3
2	170	+ 15	185	7
3	185	+ 15	200	11
4	200	+ 15	215	12
5	215	+ 15	230	26
6	230	+ 15	245	22
7	245	+ 15	260	12
8	260	+ 15	275	8
9	275	+ 15	290	3
10	290	+ 15	300	1

Equal to or greater than the STARTING VALUE

But less than the ENDING VALUE

HISTOGRAM

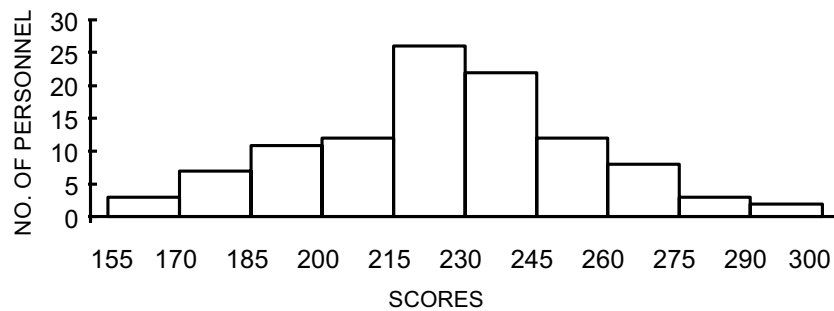
VIEWGRAPH 36

EXERCISE 2 ANSWER KEY

Step 8 - Plot the data

Step 9 - Add title and legend

MARKSMANSHIP SCORES FOR 9mm PISTOL



LEGEND: MCBH KANEOHE BAY, HI; AVERAGE OF 4 SCORES PER CLASS, 105 CLASSES, 1 JUNE 94 - 15 JULY 94

HISTOGRAM

VIEWGRAPH 37

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2. Department of the Navy (November 1992), Fundamentals of Total Quality Leadership (Instructor Guide), pp. 6-44 - 6-47. San Diego, CA: Navy Personnel Research and Development Center.
3. Department of the Navy (September 1993). Systems Approach to Process Improvement (Instructor Guide), pp. 10-17 - 10-38. San Diego, CA: OUSN Total Quality Leadership Office and Navy Personnel Research and Development Center.
4. Naval Medical Quality Institute (Undated). Total Quality Leader's Course (Student Guide), pp. U-26 - U-28. Bethesda, MD.