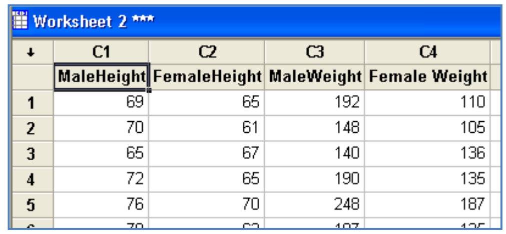
Measurements of height and weight of 22 Truman students were taken, resulting in the following data:

Male	Height (in)	*69*	*70*	*65*	*72*	*76*	*70*	*70*	*66*	*68*	*73*		
	Weight (lb)	192	148	140	190	248	197	170	137	160	185		

Female	Height (in)	*65*	*61*	*67*	*65*	*70*	*62*	*63*	*60*	*66*	*66*	*65*	*64*
	Weight (lb)	110	105	136	135	187	125	147	118	128	175	147	120

When you enter it in Minitab, it should look like this:



Say we want to determine if the average height for females at Truman is 63 inches. When running a t-test, the two-sided hypothesis would be:

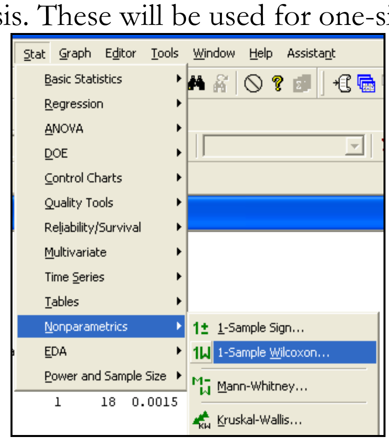
$$H_o : \mu_F = 63 \text{ inches} \quad \& \quad H_A : \mu_F \neq 63 \text{ inches}$$

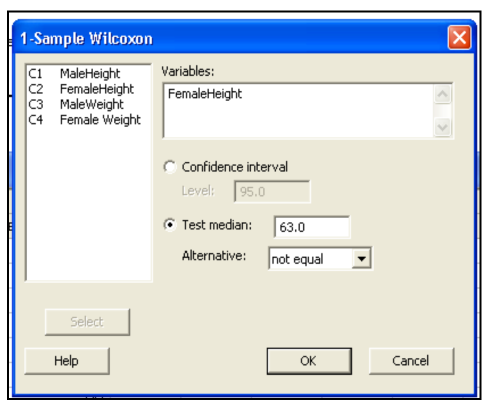
Since the non-parametric tests look at median, we need to rewrite these as:

$$H_o : \theta_F = 63 \text{ inches} \quad \& \quad H_A : \theta_F \neq 63 \text{ inches}$$

Wilcoxon Signed-Rank Test (One-Sample):

To test the height of females according to our hypothesis go to **Stat: Nonparametric: 1-Sample Wilcoxon**. We enter 'FemaleHeight' as our variable and choose the 'test median' option. Enter 63 in the 'test median:' box. In this case we have a two-sided hypothesis, so we choose 'not equal,' but notice the 'less than' and 'greater than' options in the drop down menu for the alternative hypothesis. These will be used for one-sided hypotheses.





The output looks like this:

```
Results for: Worksheet 2

Wilcoxon Signed Rank Test: FemaleHeight

Test of median = 63.00 versus median not = 63.00

                  N for  Wilcoxon          Estimated
              N   Test   Statistic     P      Median
FemaleHeight 12     11        52.0  0.100      64.50
```

The hypothesis is given, so make sure it matched what you had intended to test.

Our p-value is 0.100, so at the 95% level, we fail to reject the null hypothesis and conclude that it is possible that the median height of women could be 63 inches.

Sign Test (One-Sample):

The sign test is very similar and we will use the same hypothesis. This time go to **Stat: Nonparametric: 1-Sample Sign**.

Our output looks like this:

Sign Test for Median: Height

```
Sign test of median =  63.00 versus not = 63.00

         N  Below  Equal  Above       P  Median
Height  12      3      1      8  0.2266   65.00
```

The p-value this time is 0.2266, so once again we fail to reject the null hypothesis.

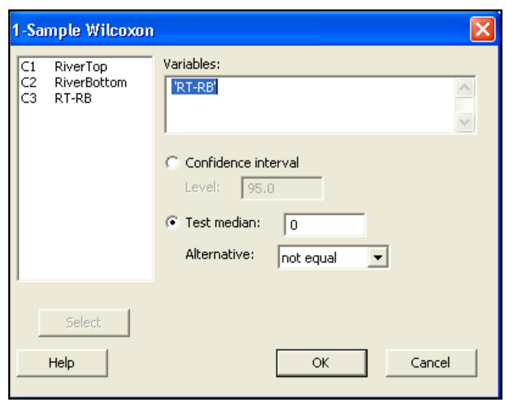
Sign and Wilcoxon Tests (Matched Pairs):

We can also run the Wilcoxon and Sign Tests for matched-ordinal data. The process is very similar to what we just did, except this time we must calculate the difference of our two samples.Then we set the 'test median' to 0. Notice how this will affect our hypothesis. If there is no difference in our pairs, then the differences should be equal to 0, but if a difference is found then the median difference will not be equal to 0.

H_0: RT-RB = 0 H_A: RT-RB $\neq$ 0

Worksheet 4 ***

↓	C1	C2	C3
	RiverTop	RiverBottom	RT-RB
1	0.415	0.430	-0.015
2	0.238	0.266	-0.028
3	0.390	0.567	-0.177
4	0.410	0.531	-0.121
5	0.605	0.707	-0.102
6	0.609	0.716	-0.107
7			



Wilcoxon Signed Rank Test: RT-RB

```
Test of median = 0.000000 versus median not = 0.000000

          N for  Wilcoxon             Estimated
      N    Test  Statistic       P       Median
RT-RB  6      6        0.0   0.036      -0.1020
```

The p-value for the Wilcoxon test is 0.036, so we reject the null hypothesis and conclude that the difference is not equal to 0. This means that we have evidence to conclude that the two samples are different.

The same process is used for the sign test. The p-value is 0.0313, so again we reject the null hypothesis.

Sign Test for Median: RT-RB

```
Sign test of median =  0.00000 versus not = 0.00000

        N  Below  Equal  Above       P   Median
RT-RB   6      6      0      0  0.0313  -0.1045
```

Mann-Whitney Test (Two Independent Samples):

This test can be used to compare two samples that are independent of each other, such as height of males verse females. Our hypothesis is:

$$H_0 : \theta_F = \theta_M \quad \& \quad H_A : \theta_F \neq \theta_M$$

This time we go to **Stat: Nonparametric: Mann-Whitney.** Enter 'MaleHeight' as the first sample, and 'FemaleHeight' as the second sample. The output looks like this:

```
Mann-Whitney Test and CI: MaleHeight, FemaleHeight

               N  Median
MaleHeight    10  70.000
FemaleHeight  12  65.000


Point estimate for ETA1-ETA2 is 5.000
95.6 Percent CI for ETA1-ETA2 is (2.999,8.002)
W = 163.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0017
The test is significant at 0.0016 (adjusted for ties)
```

We see that the p-value is 0.0017, and so we reject the null hypothesis and conclude that we have statistically significant evidence that the heights of males verse females are different.

Kruskal-Wallis Test(3+ Samples):

Next we will look at a test that will allow us to compare more than two samples. The following example with essentially look at four samples, and will compare year in school to the number of credit hours that students are taking. Consider the following data set:

3	2	3	4	1	2	2	1	3	2	1	2	4	3	1	3	4	1	2	1	1	4	3	2	1	4
15	14	12	15	15	15	17	15	12	15	17	18	9	15	12	12	15	18	15	15	15	9	12	14	13	15

Our null hypothesis would be that year in school has no effect on credit hours taken. The alternate hypothesis is that there is a difference between the four groups. After entering the data, we go to **Stat: Nonparametric: Kruskal-Wallis.** We enter year in school as the 'factor' and credit hours as the 'response.' Here is the output:

```
Kruskal-Wallis Test on Credits

Year       N  Median  Ave Rank      Z
1          8   15.00      16.0   1.11
2          7   15.00      16.8   1.33
3          6   12.00       8.8  -1.70
4          5   15.00      10.5  -0.98
Overall   26              13.5

H = 5.15  DF = 3  P = 0.161
H = 5.76  DF = 3  P = 0.124  (adjusted for ties)
```

We see that the p-value is 0.161, so we cannot reject the null hypothesis. We have found no difference in number of credit hours taken based on year in school.

Friedman Test:

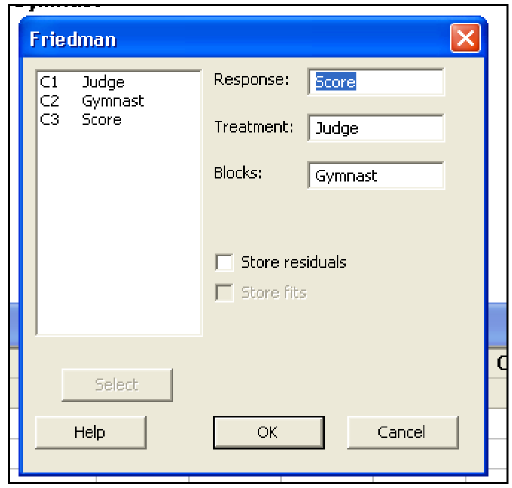
For this test we will look at scores of gymnasts from three different judges based on what gym the attend. Here is the data set:

Judge	Gymnast	Score
1	1	9
2	1	8

3	1	9
1	2	7
2	2	9
3	2	6
1	3	8
2	3	7
3	3	8
1	4	8
2	4	7
3	4	9
1	5	6
2	5	7
3	5	4
1	6	8
2	6	9
3	6	9
1	7	9
2	7	6
3	7	10
1	8	7
2	8	9
3	8	7
1	9	7
2	9	8
3	9	10

We want to determine if scoring of any one judge differs from the other judges. Our null hypothesis is that there is no difference. Our alternate hypothesis is that one judge scores differently than the others.

We go to **Stat: Nonparametric: Friedman.**



Since score is what is being measured, this is the response variable. The treatment is the judge, and the gymnast is the block variable. Here is our output:

```
Friedman Test: Score versus Judge blocked by Gymnast

S = 0.72  DF = 2  P = 0.697
S = 0.81  DF = 2  P = 0.666 (adjusted for ties)

                            Sum of
Judge  N  Est Median   Ranks
1      9      7.6667    16.5
2      9      8.0000    17.5
3      9      8.3333    20.0

Grand median = 8.0000
```

Since the p-value is 0.697, we fail to reject the null hypothesis, and conclude that no one judge scores differently than all of the other judges.