We use the iron retention data in chapter 11 to show two-way ANOVA. Below are the data

<table>
<thead>
<tr>
<th></th>
<th>Fe2+</th>
<th></th>
<th>Fe3+</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>high</td>
<td>medium</td>
<td>low</td>
<td>high</td>
<td>medium</td>
<td>low</td>
</tr>
<tr>
<td>0.71</td>
<td>2.20</td>
<td>2.25</td>
<td>2.20</td>
<td>4.04</td>
<td>2.71</td>
<td></td>
</tr>
<tr>
<td>1.66</td>
<td>2.30</td>
<td>3.93</td>
<td>2.69</td>
<td>4.16</td>
<td>5.43</td>
<td></td>
</tr>
<tr>
<td>2.01</td>
<td>3.08</td>
<td>5.08</td>
<td>3.54</td>
<td>4.42</td>
<td>6.38</td>
<td></td>
</tr>
<tr>
<td>2.16</td>
<td>3.49</td>
<td>5.82</td>
<td>3.75</td>
<td>4.93</td>
<td>6.38</td>
<td></td>
</tr>
<tr>
<td>2.42</td>
<td>4.11</td>
<td>5.84</td>
<td>3.83</td>
<td>5.49</td>
<td>8.32</td>
<td></td>
</tr>
<tr>
<td>2.42</td>
<td>4.95</td>
<td>6.89</td>
<td>4.08</td>
<td>5.77</td>
<td>9.04</td>
<td></td>
</tr>
<tr>
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<td>5.16</td>
<td>8.50</td>
<td>4.27</td>
<td>5.86</td>
<td>9.56</td>
<td></td>
</tr>
<tr>
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<td>5.54</td>
<td>8.56</td>
<td>4.53</td>
<td>6.28</td>
<td>10.01</td>
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</tr>
<tr>
<td>3.31</td>
<td>5.68</td>
<td>9.44</td>
<td>5.32</td>
<td>6.97</td>
<td>10.08</td>
<td></td>
</tr>
<tr>
<td>3.64</td>
<td>6.25</td>
<td>10.52</td>
<td>6.18</td>
<td>7.06</td>
<td>10.62</td>
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</tr>
<tr>
<td>3.74</td>
<td>7.25</td>
<td>13.46</td>
<td>6.22</td>
<td>7.78</td>
<td>13.80</td>
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</tr>
<tr>
<td>3.74</td>
<td>7.90</td>
<td>13.57</td>
<td>6.33</td>
<td>9.23</td>
<td>15.99</td>
<td></td>
</tr>
<tr>
<td>4.39</td>
<td>8.85</td>
<td>14.76</td>
<td>6.97</td>
<td>9.34</td>
<td>17.90</td>
<td></td>
</tr>
<tr>
<td>4.50</td>
<td>11.96</td>
<td>16.41</td>
<td>6.97</td>
<td>9.91</td>
<td>18.25</td>
<td></td>
</tr>
<tr>
<td>5.07</td>
<td>15.54</td>
<td>16.96</td>
<td>7.52</td>
<td>13.46</td>
<td>19.32</td>
<td></td>
</tr>
<tr>
<td>5.26</td>
<td>15.89</td>
<td>17.56</td>
<td>8.36</td>
<td>18.40</td>
<td>19.87</td>
<td></td>
</tr>
<tr>
<td>8.15</td>
<td>18.30</td>
<td>22.82</td>
<td>11.65</td>
<td>23.89</td>
<td>21.60</td>
<td></td>
</tr>
</tbody>
</table>
As discussed in Chapter 11, the data are skewed and a log transformation was applied to
the data. The boxplot after the log transformation:

And the plot of the means of the six combinations (two iron forms and three dosage levels)

Here is the code for drawing boxplots and conducting two-way ANOVA.

```r
> ####### read data ###########
> #the data in the link are log-transformed data
> iron=read.table("http://www.ics.uci.edu/~zhaoxia/teaching/stat120c/Data/iron.txt",
```
hand= T)
> names(iron) # the iron data has three columns
[1] "concentration" "Fe" "dosage"
>
> ############ draw a boxplot ############
> boxplot(concentration ~ Fe + dosage, data=iron,
+ names = c(
+ "high
 Fe2+",
+ "high
 Fe3+",
+ "low
 Fe2+",
+ "low
 Fe3+",
+ "medium
 Fe2+",
+ "medium
 Fe3+"),
+ ylab = "iron retention (log)"
>
>
> ############ plot cell means ############
> # calculate cell means
> Fe2.means = c(
+ mean(iron$concentration[iron$Fe==2 & iron$dosage=="h"]),
+ mean(iron$concentration[iron$Fe==2 & iron$dosage=="m"]),
+ mean(iron$concentration[iron$Fe==2 & iron$dosage=="l"]))
>
> Fe3.means = c(
+ mean(iron$concentration[iron$Fe==3 & iron$dosage=="h"]),
+ mean(iron$concentration[iron$Fe==3 & iron$dosage=="m"]),
+ mean(iron$concentration[iron$Fe==3 & iron$dosage=="l"]))
>
> # Another way to calculate cell means
> means = sapply(split(iron$concentration, data.frame(Fe=iron$Fe,dosage=iron$dosage)),
+ mean)
> names(means)
[1] "2.h" "3.h" "2.1" "3.1" "2.m" "3.m"
> Fe2.means = means[c(1,5,3)] # from high to low
> Fe3.means = means[c(2,6,4)] # from high to low
>
> # plot the cell means
> dosage = c(10.2, 1.2, 0.3)
> plot(dosage,Fe2.means, type="l", lty=2, ylim=c(1.0,2.5),
+ xlab="dosage", ylab="mean retention (log)"
> lines(dosage, Fe3.means)
> legend(4,2.5,legend=c("Fe2+", "Fe3+"), lty=c(2,1))
Handout 3: Example of Two-Way ANOVA

```r
my.obj = aov(concentration ~ factor(Fe) + factor(dosage) + factor(Fe)*factor(dosage), data = iron)
#you can often do it in this way
summary(my.obj)
```

```
Df  Sum Sq Mean Sq F value Pr(>F)
factor(Fe)   1  2.074  2.074   5.993  0.01607 *
factor(dosage) 2 15.588  7.794  22.524 7.91e-09 ***
factor(Fe):factor(dosage) 2   0.810  0.405   1.171 0.31426
Residuals    102 35.296  0.346                
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Interpretations of the results can be found in the text (Section 12.3 Example A).

The R source code can be found here R source code