**Question 1**

**1A**

Research Question: Does the amount (volume) of crème in crème-filled cookies vary by type of cookie?

Factors: type of cookie (3 levels)

Treatments: type of cookie (3 treatments)

**1B**

A well-designed experiment includes replication, randomization, and blocking. Although 15 of each type of cookie is measured in the experiment, each cookie type is measured by the same person, which results in pseudoreplication of the measurements. A better strategy here would be to randomly assign cookies of all three types. to each person. We do see one implementation of randomization, by randomly assigning cookie type to each person, however, randomization should also be used in obtaining the 15 cookies out of the bag (they were all taken from the top of the bag). A blocking strategy could also be employed here to account for experimental error and improve precision. Finally, there is no mention of cookie diameter and because this experiment is interested in volume of crème, diameter (or radius) of each cookie must be measured or accounted for in some way.

**1C**

Suggestion 2 is the best choice here and improves the pseudoreplication problem mentioned above. The process of distributing the second and third rounds of cookies to measure isn’t described in detail, but this should be randomized for best results.

Suggestion 1 has the same weaknesses as mentioned above in 1B, except it does include averaging the measurements. Suggestion 3 removes all randomization from the experiment.

**Question 2**

**2A**

The cell means model for the trout hemoglobin study is:

*yij =* μ*i + eij*

where:

*i* = level *i* of factor 1; type of antibacterial is the only factor in this experiment and it has 4 levels

*j* = numbered experimental unit; each antibacterial is applied to ten different trout fish, which are the experimental units

*yij* = observed response for the *jth* experimental unit assigned to the *ith* treatment; hemoglobin measured in each trout

μ*i* = mean response for the *ith* treatment; mean hemoglobin concentration for trout receiving each of the four antibacterial treatements

*eij* = error for *jth* experimental unit assigned to *ith* treatment and we assume *eij* ~N(0,σ2), independent (errors are normally distributed, have mean zero, constant variance, and independent); difference between measured hemoglobin in single trout from the mean hemoglobin for all trout receiving same treatment

**2B**

This experiment aims to test the hypothesis that on average, type of antibacterial affects hemoglobin in trout. To test this hypothesis, we assume a null hypothesis of H0: μ1=μ2=μ3=μ4, and an alternative hypothesis HA: μj≠μk for some j and k, and a significance level of a=0.05. If the overall F value is beyond the critical value, and the associated P value is at or below the significance level, we will reject the null hypothesis. Otherwise, we will fail to reject the null hypothesis.

The ANOVA for this experiment (R output) shows a model F value of 471.66 and an associated P value of 2.2e-16. This is well below our significance level of 0.05, and we reject the null hypothesis. We are 95% confident that at least one of the mean responses of antibacterial treatments is significantly different than the other antibacterial mean responses.

**2C**

Contrast 1 is testing for a difference in mean hemoglobin response from antibacterial 1 versus antibacterial 2. The R output shows a t value of -3.803 and a P value of 0.000534, which is well below our significance level of 0.05. Therefore, we conclude that there is a significant difference in mean hemoglobin response between antibacterial 1 and 2 with means of 7.20 and 9.33, respectively.

Contrast 2 is testing for a difference in mean hemoglobin response from antibacterial 2 versus antibacterial 3. The R output shows a t value of -0.536 and a P value of 0.596, which is well above our significance level of 0.05. Therefore, we conclude that there is no significant difference in mean hemoglobin response between antibacterial 2 and 3 with means of 9.33 and 9.03, respectively.

**BONUS**

**3A**

The cell means model for the fabric study is:

*yijk =* μ*ij + eijk*

where:

*i* = level *i* of factor 1; there are two factors for this experiment, brand of battery and temperature, each having 2 levels; assume factor 1 is brand with 2 levels, Store=1 and Name=2

*j* = level *j* of factor 2; there are two factors for this experiment, brand of battery and temperature, each having 2 levels; assume factor 2 is temperature with 2 levels, Chilled=1 and Room=2

*k* = numbered experimental units; there are four treatments (2x2 levels), three replicates for each treatment, and 12 experimental units (single batteries)

μ*ij* = mean battery life of units treated with level *i* of factor 1, level *j* of factor 2

*yijk* = observed battery life for the *kth* experimental unit treated with level *i* of factor 1 and level *j* of factor 2

*eijk* = error for the *kth* experimental unit treated with level *i* of factor 1 and level *j* of factor 2 (*yijk* – μ*ij*)

**3B**

This experiment is testing the hypothesis that the brand of battery and/or working temperature significantly affect the life of the battery. The null hypothesis states that brand and temperature do not affect battery life. The alternative hypothesis stats that brand and/or temperature do affect battery life. A significance level of a=0.05 is used in this experiment. If the overall F value is beyond the critical value, and the associated P value is at or below the significance level, we will reject the null hypothesis. Otherwise, we will fail to reject the null hypothesis.

The ANOVA for this experiment (R output) shows that brand has an F value of 220.0082 and a P value of 4.203e-07, and temperature has an F value of 59.1002 and a P value of 5.810e-05. Both P values are well below the significance level of 0.05 and we reject the null hypothesis and conclude that both brand and temperature significantly affect battery life.

**3C**

Battery life of Store brand (1) versus Name brand (2) has estimated means (and 95% confidence intervals) of 87.7 (81.7-93.7) minutes and 142.3 (136.3-148.3) minutes, respectively. The contrast testing this comparison of battery brand on battery life shows a t value of -14.833 and a P value of <0.0001, which is well below the significance level of 0.05. We can conclude that there is a significant difference in battery life due to battery brand, and that the Name brand batteries have the longest life on average.

**3D**

Mean battery life as a response of temperature is 101 (94.8-107) and 129 (123.2-135) for chilled versus room temperature, respectively. The contrast testing this comparison of temperature versus battery life shows a t value of -7.688 and a P value of 0.0001, which is well below the significance level of 0.05. We can conclude that there is a significant difference in battery life due to temperature, and that Room temperature batteries have the longest life on average. In 3C we concluded that there is a significant difference in battery life due to battery brand, and that the Name brand batteries have the longest life on average. These affects are significant and meaningful.