



# MATH 308 Assignment 15: Exercises 5.10

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**5**

**a)**

Suppose that cookie orders are represented such that, for example, an order of 1 sugar, 2 chocolate chips, 0 oatmeal, 0 peanut butter, and 2 ginger snaps is given by  $|c|cc|cc|$ . Then, two of the bars are fixed, giving the string  $|??????|$ , where the nine ? symbols are to be replaced by five  $c$ 's and two  $|$ 's. If we choose 5 distinct positions in which to place the  $c$ 's, the positions of the remaining  $|$ 's is fixed. Thus, the number of possible cookie orders is  $\binom{9}{5}$ .

**b)**

More generally, we can use 'cookie types' to represent occurrences of particular elements in the chosen sets. Then, fixing the position of two  $|$ 's leaves  $n + 1 - 2 = n - 1$   $|$ 's and  $n$   $c$ 's, for a total of  $2n - 1$  symbols. Picking element members requires  $n$  position choices, giving the total number of set choices as  $\binom{2n-1}{n}$ .

**c)**

For a sample  $S$  of size  $n$ , each bootstrap sample represents the choice of  $n$  elements from  $S$  with replacement. Thus, the number of bootstrap samples is as above  $\binom{2n-1}{n}$ .

**6**

**a)**

The number of bootstrap samples with  $k_1$   $a_1$ 's,  $k_2$   $a_2$ 's  $\dots k_n$   $a_n$ 's is the same as the number of permutations of the string

$$\underbrace{\overbrace{a_1 a_1 \dots a_1}^{k_1 \text{ times}} \overbrace{a_2 a_2 \dots a_2}^{k_2 \text{ times}} \dots \overbrace{a_n a_n \dots a_n}^{k_n \text{ times}}}_{n \text{ symbols}}$$

Using the formula for string permutations with repeated characters, this yields

$$\frac{n!}{k_1! k_2! \dots k_n!}$$

which, by definition, equals

$$\binom{n}{k_1, k_2 \dots k_n} \quad \square$$

**b)**

A bootstrap sample with  $k_i$   $a_i$ 's requires choosing  $k_i$  of  $n$  positions, after which the remaining  $n - k_i$  positions can be filled by any of the remaining  $n - 1$  elements. Thus, the number of such samples is:

$$(n - 1)^{n - k_i} \binom{n}{k_i}$$

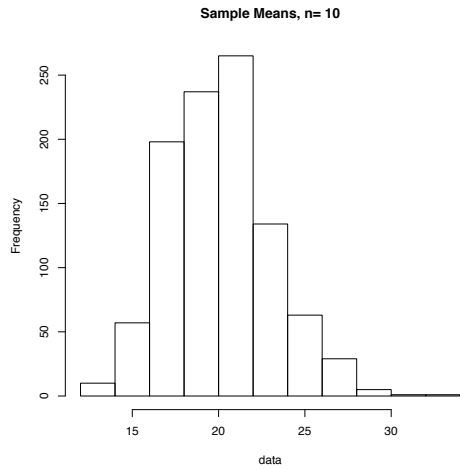
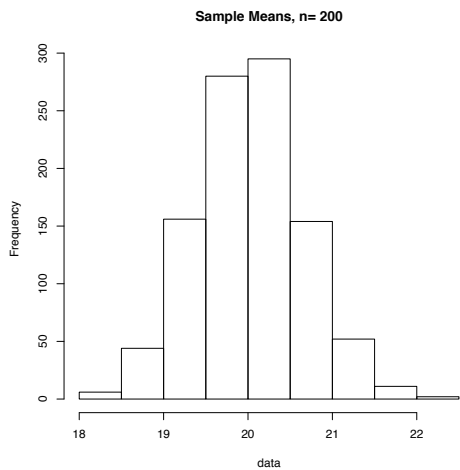
The total number of bootstrap samples is simply  $n^n$ . Thus, the required probability is

$$\frac{(n - 1)^{n - k_i}}{n^n} \binom{n}{k_i}$$

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a)

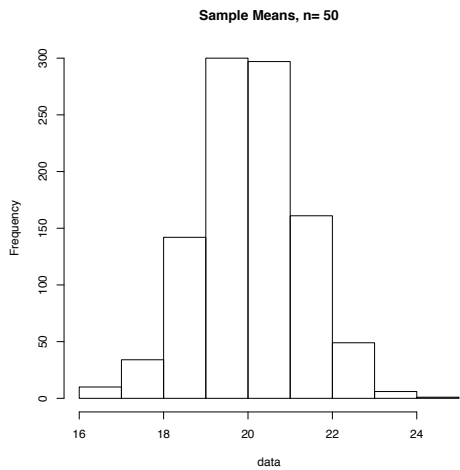
Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
16.19	19.26	20.03	20.03	20.87	24.43



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
18.21	19.58	20.02	20.02	20.44	22.49

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
12.56	17.87	19.99	20.05	21.89	33.20

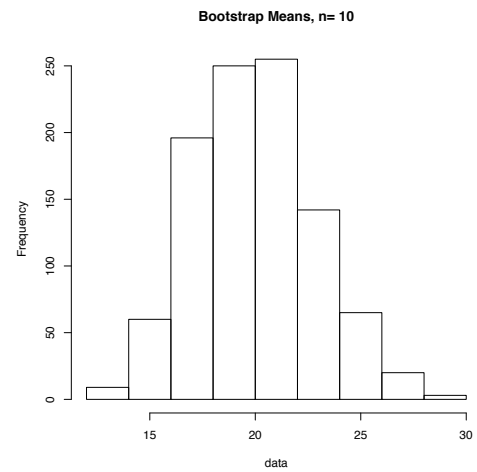
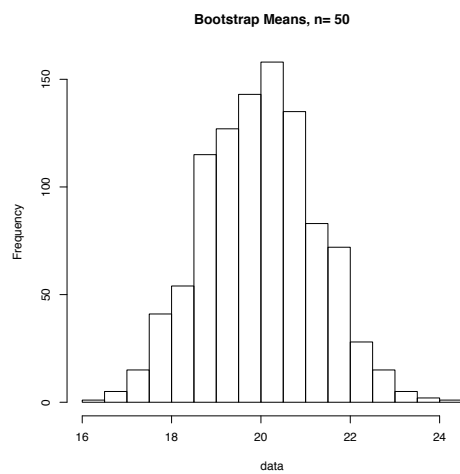
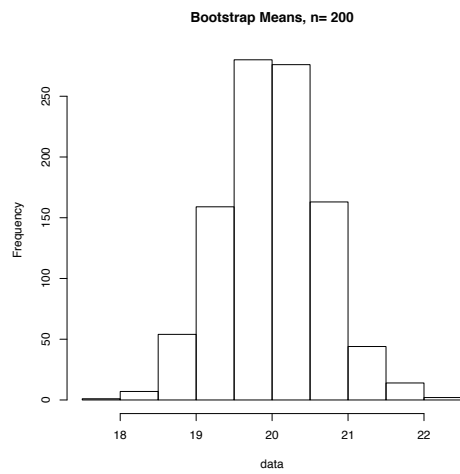
b)



n	Mean	SD
200	20.00	8.94
50	19.98	8.98
10	19.98	9.00

c)

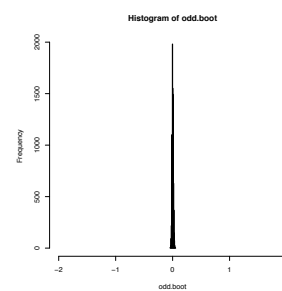
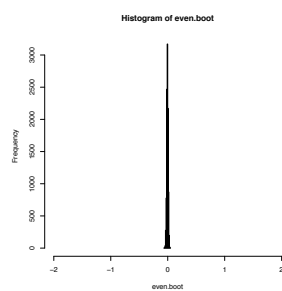
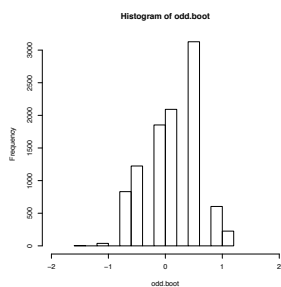
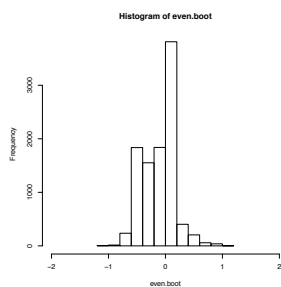
n	Mean	SE
200	20.00	0.65
50	19.98	1.25
10	19.98	2.82



e)

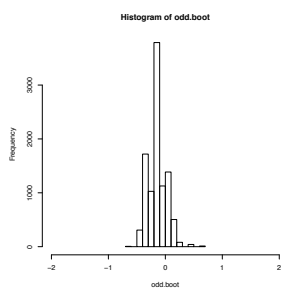
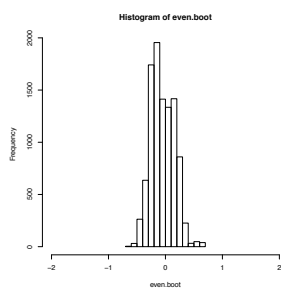
Increasing sample size reduces the bootstrap standard error.

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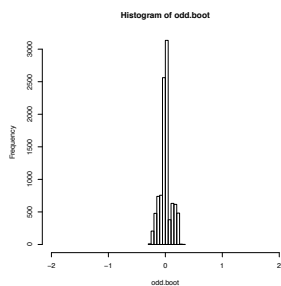
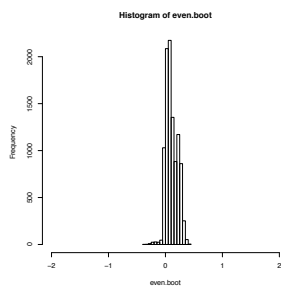
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The evenness of  $N$  does not seem to affect the histograms, but increasing  $N$  reduces the spread.