In [2]:

```
import matplotlib   # library for plotting
import matplotlib.pyplot as plt #  later you will type plt.$COMMAND
import numpy as np   # basic math library  you will type np.$STUFF  e.g., np.cos(1)
import pandas as pd  # library for data analysis for text files (everything but net
cdf files)
import scipy.stats as stats # imports stats functions https://docs.scipy.org/doc/sc
ipy/reference/stats.html
from netCDF4 import Dataset
```

Question 1a:

In [3]:

```
# Define variables
negrate = 0.9 # Background negative rate
posrate = 0.1 # Background positive rate
accrate = 0.8 # Percentage of covid tests that are correct
failrate = 0.2 # Percentage of covid tests that are incorrect
test_result = 'negative'
def Bayes(negrate,posrate,accrate,failrate):
    Pr_true_result = (negrate*accrate)/(negrate*accrate + posrate*failrate)
    return Pr_true_result*100
answer = Bayes(negrate,posrate,accrate,failrate)
print("The probability that the friend was actually negative is " + str(np.round(an
swer,2)) + "%")
```

```
The probability that the friend was actually negative is 97.3%
```

Reasoning: Covid tests are accurate 80% of the time, but the background rate must also be considered. 90% of people do not have covid, so it is even more likely that the friend does not have covid when they tested negative. Bayes theorem factors in this information and tells us that the chance of the friend being negative is 97.3%.

Question 1b:

5 steps:

1. State the significance level (alpha): .05, .01
2. State the null hypothesis H0 and the alternative H1: H0: The sample mean is not significantly different from 0. H1: The sample mean is significantly different from 0.
3. State the statistic to be used and the assumptions required to use it: z statistic, assume normal distribution
4. State the critical region: $-1.96 < z < 1.96$, $-2.58 < z < 2.58$
5. Evaluate the statistic and state the conclusion:

In [5]:

```
N = 15
values = np.random.randn(N)
sigma = 1
mean = 0
sample_mean = np.mean(values)
def z_statistic(mean,sample_mean,sigma,N):
    z = (sample_mean - mean)/(sigma/(np.sqrt(N)))
    return z
z = z_statistic(mean,sample_mean,sigma,N)
if -1.96 < z < 1.96:
    print("95% confidence, N = 15: We cannot reject the null hypothesis")
else:
    print("95% confidence, N = 15: We can reject the null hypothesis")
if -2.58 < z < 2.58:
    print("99% confidence, N = 15: We cannot reject the null hypothesis")
else:
    print("99% confidence, N = 15: We can reject the null hypothesis")
N = 1000
z = z_statistic(mean,sample_mean,sigma,N)
if -1.96 < z < 1.96:
    print("95% confidence, N = 1000: We cannot reject the null hypothesis")
else:
    print("95% confidence, N = 1000: We can reject the null hypothesis")
if -2.58 < z < 2.58:
    print("99% confidence, N = 1000: We cannot reject the null hypothesis")
else:
    print("99% confidence, N = 1000: We can reject the null hypothesis")
```

```
95% confidence, N = 15: We cannot reject the null hypothesis
99% confidence, N = 15: We cannot reject the null hypothesis
95% confidence, N = 1000: We can reject the null hypothesis
99% confidence, N = 1000: We can reject the null hypothesis
```

Question 1c: I will be taking precipitation data spatially averaged over a domain in the North Pacific from the HadAM4 historical climate simulation that uses radiative forcing from 2006. I will find the ensemble member with the highest mean precipitation and perform a z test to see if that ensemble member mean precipitation is significantly higher than mean precipitation from the ensemble member with the lowest mean precipitation. I realize that Libby's notes explicitly say that rain rate is not a good variable to run a t-test/z-test on. However, I am averaging over a large spatial domain and comparing across 4 months and many ensemble members. Given the amount of data, I am still assuming a normal distribution for precipitation rate.

5 steps:

alpha = .05

H0: the sample mean with the maximum mean precipitation is not significantly higher than the sample mean with the lowest mean precipitation.

H1: the sample mean with the maximum mean precipitation is significantly higher than the sample mean with the lowest mean precipitation.

z statistic, assume normal distribution of daily mean precipitation

critical region: z < 1.65

Evaluation below

In [7]:

```
# Step 1: Load in data and locate ensemble member with highest mean IWV
filename = 'hadPrecip.nc'
precip = Dataset(filename).variables['PRECT'][:] # Precipitation rate (m/s)
i = 0
ensemblemeans = np.zeros(precip.shape[0])
while i < precip.shape[0]: # number of ensemble members
    ensemblemeans[i] = np.mean(precip[i,:])
    i+=1
maxensemble = np.where(ensemblemeans == np.max(ensemblemeans))
minensemble = np.where(ensemblemeans == np.min(ensemblemeans))
print(maxensemble)
print(minensemble)
```

```
(array([80]),)
(array([111]),)
```

We find that the 81st ensemble member has the highest mean precipitation rate and the 112th ensemble member has the lowest mean precipitation rate.

In [11]:

```
# Step 2: Calculate variables required in z test and run z test
def z_statistic_sample(sample_mean1,sample_mean2,sigma1,sigma2,N1,N2):
    z = (sample_mean1 - sample_mean2)/np.sqrt(((sigma1*sigma1)/N1)+(sigma2*sigma2)/
N2)
    return z
dailymean1 = np.zeros(120)
dailymean2 = np.zeros(120)
i = 0
while i < 120:
    dailymean1[i] = np.mean(precip[80,i*4:(i*4 + 4)]) # 6 hourly temporal resolutio
n
    dailymean2[i] = np.mean(precip[111,i*4:(i*4 + 4)])
    i+=1
sample_mean1 = np.mean(dailymean1)
sample_mean2 = np.mean(dailymean2)
sigma1 = np.std(dailymean1)
sigma2 = np.std(dailymean2)
N1 = len(dailymean1)
N2 = len(dailymean2)
z = z_statistic_sample(sample_mean1,sample_mean2,sigma1,sigma2,N1,N2)
if z < 1.65:
    print("95% confidence: We cannot reject the null hypothesis")
else:
    print("95% confidence: We can reject the null hypothesis")
```

```
95% confidence: We can reject the null hypothesis
```

Question 1d:

5 steps:

alpha = .05

H0: the sample with the maximum mean precipitation rate is not significantly higher than the ensemble mean precipitation rate.

H1: the sample mean with the maximum mean precipitation rate is significantly higher than the ensemble mean precipitation rate.

z statistic, assume normal distribution of mean precipitation rate across ensemble members, days

critical region: z < 1.65

Evaluation below

In [23]:

```
dailymean = np.zeros(int(np.size(precip[:,:])/4))
reshaped_precip = np.reshape(precip,[np.size(dailymean)*4])
i = 0
while i < len(dailymean):
    dailymean[i] = np.mean(reshaped_precip[i*4:(i*4 + 4)])
    i+=1

mean = np.mean(dailymean[:])
sigma = np.std(dailymean[:])
z = z_statistic(mean,sample_mean1,sigma,N1)
if z < 1.65:
    print("95% confidence: We cannot reject the null hypothesis")
else:
    print("95% confidence: We can reject the null hypothesis")
```

```
95% confidence: We can reject the null hypothesis
```

Question 1e: I will compare standard deviations between mean precipitation rate in November-December of the first 51 ensemble members and mean precipitation rate in January-February of the next 51 ensemble members

H0: The ensemble variability is not different between November-December and January-February.

H1: The ensemble variability is different between November-December and January-February

In [25]:

```
precipnovdec = np.mean(precip[0:61,0:240],axis=1)
precipjanfeb = np.mean(precip[61:122,240:480],axis=1)
sigma1 = np.std(precipnovdec,axis=0)
sigma2 = np.std(precipjanfeb,axis=0)

DF1 = 61 - 1
DF2 = 61 - 1
F = (sigma1*sigma1)/(sigma2*sigma2)
if F < 1.5343:
    print("95% confidence: We cannot reject the null hypothesis")
else:
    print("95% confidence: We can reject the null hypothesis")
print("NOTE: I was confused about this. I was not sure which sample should be in the numerator and which sample should be in the denominator")
```

```
95% confidence: We cannot reject the null hypothesis
NOTE: I was confused about this. I was not sure which sample should be
in the numerator and which sample should be in the denominator
```

Question 2a:

In [149]:

```
### Read in the data
filename='homework1_data.csv'
data=pd.read_csv(filename,sep=',')
R = data["R_inches"]
P = data["P_hPa"]
average_pressure = np.mean(P)
print("The average pressure in Fort Collins in 2014 was "+str(np.round(average_pres
sure,2))+" hPa")
Rainyindex = np.where(R>0.01)
Rainydaypressureavg = np.round(np.mean(P[Rainyindex[0][:]]),2)
print("The average pressure in Fort Collins in 2014 on rainy days was "+str(Rainyda
ypressureavg)+" hPa")
```

```
The average pressure in Fort Collins in 2014 was 846.33 hPa
The average pressure in Fort Collins in 2014 on rainy days was 846.82 h
Pa
```

Question 2b:

H0: The pressure is not different when raining

H1: The pressure is different when raining

In [158]:

```
sigma = np.std(P)
mean = np.mean(P)
sample_mean = Rainydaypressureavg
N = len(Rainyindex[0][:])
z = z_statistic(mean,sample_mean,sigma,N)
if -1.96 < z < 1.96:
    print("z statistic: We cannot reject the null hypothesis")
else:
    print("z statistic: We can reject the null hypothesis")
sample_sigma = np.std(P[Rainyindex[0][:]])
def t_test(mean,sample_mean,sample_sigma,N):
    t = (sample_mean - mean)/(sample_sigma/(np.sqrt(N-1)))
    return t
t = t_test(mean,sample_mean,sample_sigma,N)
if -1.98 < t < 1.98:
    print("t statistic: We cannot reject the null hypothesis")
else:
    print("t statistic: We can reject the null hypothesis")
```

```
z statistic: We cannot reject the null hypothesis
t statistic: We cannot reject the null hypothesis
```

The z statistic is appropriate because N > 30

Question 2c:

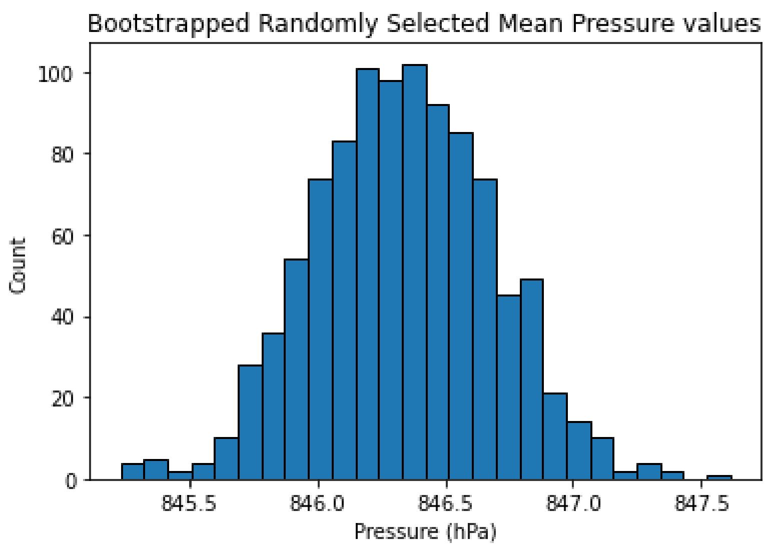
In [173]:

```
Nbs = 1000
P_Bootstrap=np.empty((Nbs,len(P[Rainyindex[0][:]])))
for ii in range(Nbs):
    P_Bootstrap[ii,:]=np.random.choice(P,len(P[Rainyindex[0][:]]))
P_Bootstrap_mean=np.mean(P_Bootstrap,axis=1)
binsize = 0.1
min4hist=np.round(np.min(P_Bootstrap_mean),1)-binsize
max4hist=np.round(np.max(P_Bootstrap_mean),1)+binsize
nbins=int((max4hist-min4hist)/binsize)

plt.hist(P_Bootstrap_mean,nbins,edgecolor='black')
plt.xlabel('Pressure (hPa)');
plt.ylabel('Count');
plt.title('Bootstrapped Randomly Selected Mean Pressure values');

print("Minimum: " + str(np.round(np.min(P_Bootstrap_mean),2)))
print("Maximum: " + str(np.round(np.max(P_Bootstrap_mean),2)))
print("Mean: " + str(np.round(np.mean(P_Bootstrap_mean),2)))
print("Standard Deviation: " + str(np.round(np.std(P_Bootstrap_mean),2)))
```

```
Minimum: 845.23
Maximum: 847.61
Mean: 846.33
Standard Deviation: 0.35
```



In [178]:

```
mean = np.mean(P_Bootstrap_mean)
sigma=np.std(P_Bootstrap_mean)
N = 1
z = z_statistic(mean,sample_mean,sigma,N)
if -1.96 < z < 1.96:
    print("z statistic: We cannot reject the null hypothesis")
else:
    print("z statistic: We can reject the null hypothesis")
prob=(1-stats.norm.cdf(np.abs(z)))*2*100
print("Probability of the mean value occuring by chance: " + str(np.round(prob,2))
+ "%")
```

```
z statistic: We cannot reject the null hypothesis
Probability of the mean value occuring by chance: 16.53%
```

In [ ]:

```
```