SDS/MTH 220: Badge Challenge 1

Name: ____

Instructions

- This badge challenge must be your own work entirely.
- This is an open mind, closed stats notebook, closed textbook, and closed fellow statistician badge challenge.
- All questions will be graded under the badge level grading system. On badge challenges, formatting and presentation guidelines are suspended, but you must show ***all*** work for computational answers and justify all claims for expository questions.
- Keep your explanations contextually meaningful and concise!
- You do not have to perform any long computations. For example, if the answer is 18.5, you will receive full credit for writing $2.5 * (4 + 3.5) - (1/2)^2$.
- Use the provided blank sheets of paper to write your answers. You may also use these pages for your scratch work.
- Please write on ***one side*** *of the blank pages* and staple any pages you want graded to the badge challenge. Your *answers should appear in **question order***.
- Put your name on the top right corner of each page that you submit and do not write where the staple will go.
- This is the first of four opportunities to demonstrate your current understanding of the first five badges for the course. You may complete as many badges as you would like. Questions left unattempted will not receive a badge level.

Name: ______________________________

Question	**Badge 1**	**Badge 2**	**Badge 3**	**Badge 4**	**Badge 5**
1					
2					
3					
4					
5					
Recorded Score by Badge					

Badge 1: Understand the grammar of graphics: construct graphics based on a dataset, deconstruct graphics into a data set

Question X Short Answer

(a) In terms of the “Grammar of Graphics” what is a statistical graphic?

(b) What is the chief difference between a barplot and a histogram?

(c) What is ***overplotting***? Name the two ways seen in class to deal with it.

Question X

(a) For which of the following pairs of variables would you visualize with a scatterplot? Circle which pairs.

- Pair 1: “Distance from school in miles” and “mode of transportation to school (bike, walking, bus)”
- Pair 2: “Number of years at a job” and “Salary”
- Pair 3: “Years experience playing an instrument” and “number of mistakes made playing a song”
- Pair 4: “Number of years since a person retired” and “favorite sport”

(b) Recall Table 2.4 you saw in ModernDive summarizing the ”Five Named Graphs”. It is presented here with 10 text segments labeled “A” though “J” blanked out.

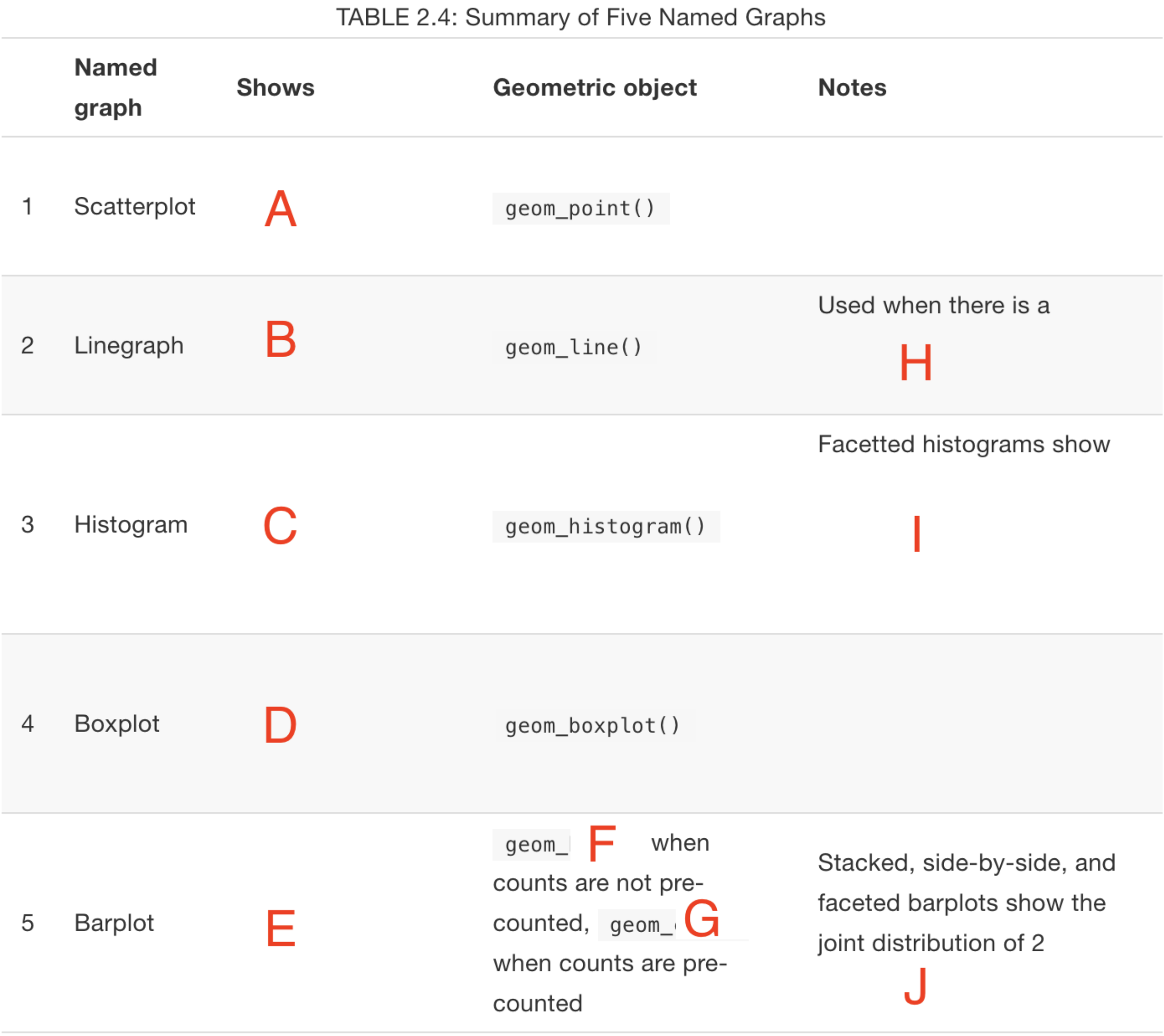


TABLE 2.4: Summary of Five Named Graphs

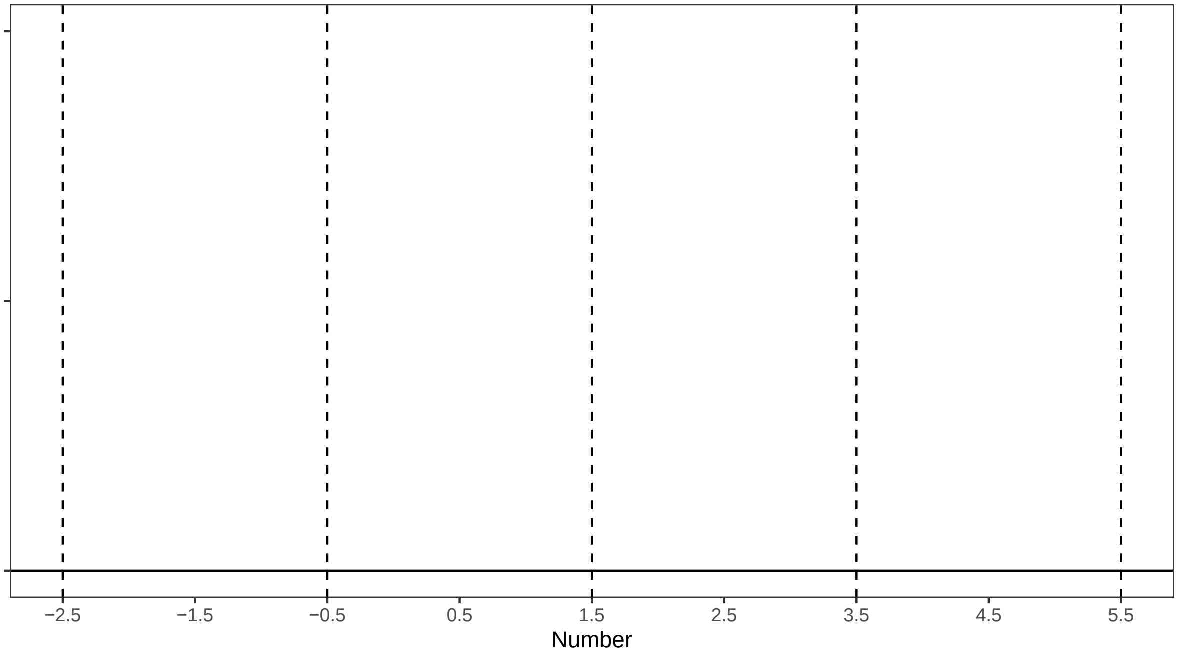
	Named graph	Shows	Geometric object	Notes
1	Scatterplot	A	`geom_point()`	
2	Linegraph	B	`geom_line()`	Used when there is a H
3	Histogram	C	`geom_histogram()`	Facetted histograms show I
4	Boxplot	D	`geom_boxplot()`	
5	Barplot	E	`geom_` F when counts are not pre-counted, `geom_` G when counts are pre-counted	Stacked, side-by-side, and faceted barplots show the joint distribution of 2 J

Write down in bullet point form what these 10 missing text segments labeled “A” though “J’ should read.

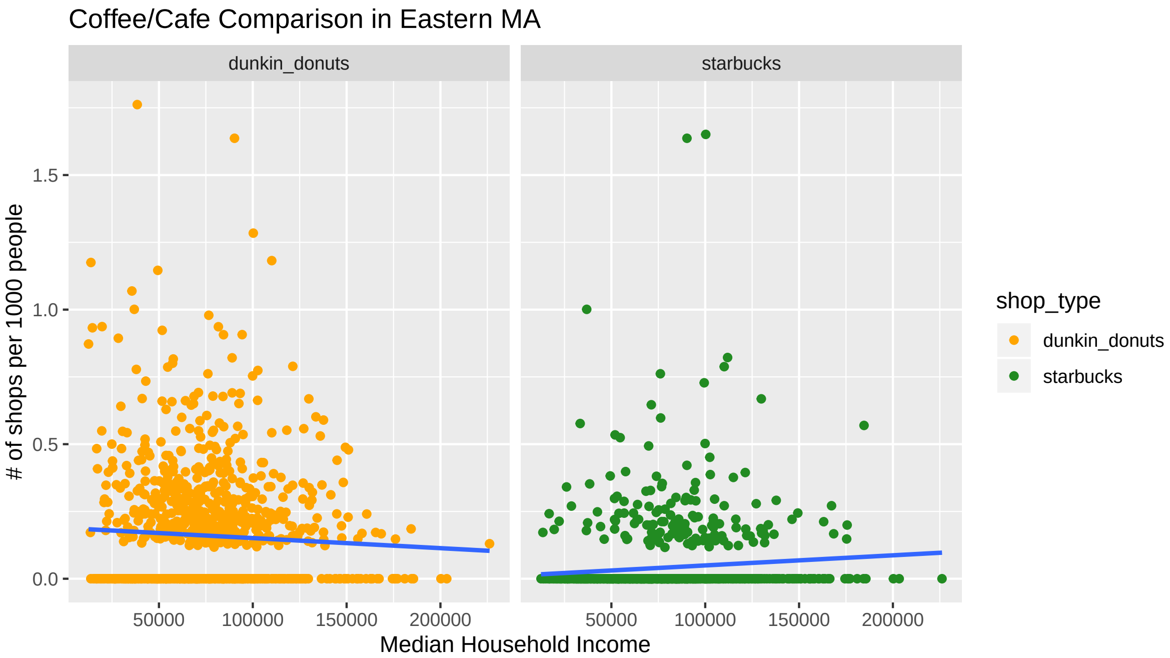
(c) Say you have a data frame named `example` that has 4 variables and 4 rows of data:

type	fruit	city	number
D	apple	Toronto	3
B	apple	Montreal	4
A	orange	Toronto	2
C	orange	Montreal	1

Draw the histogram for the variable `number` using the bins indicated with the dashed vertical lines. Be sure to write down appropriate y-axis information.



(d) A researcher from eastern Massachusetts is a big Starbucks fan. She has a suspicion that Starbucks tend to locate in richer neighborhoods, while this is not the case for Dunkin Donuts. She writes code to pull data from the internet about all 1024 census tracts (areas where decennial census data are collected) in Eastern Massachusetts. She summarizes her results in the following graphic:



(a) Write out the elements of the "Grammar of Graphics" that need to be specified to create this graphic. You do not need to specify the axes labels, the plot title, nor the regression lines

(b) Assuming there are no missing data, how many rows are in the data frame that we input into the `ggplot()` function?

(c) Does the presented visualization support or contradict the researcher's suspicion? Why?

(e) The asking prices for a sample of 15 textbooks currently being sold are listed below. For convenience, the data have been ordered:

-11	12	15	20	20	30	30	30	30	40	40	40	40	41	51

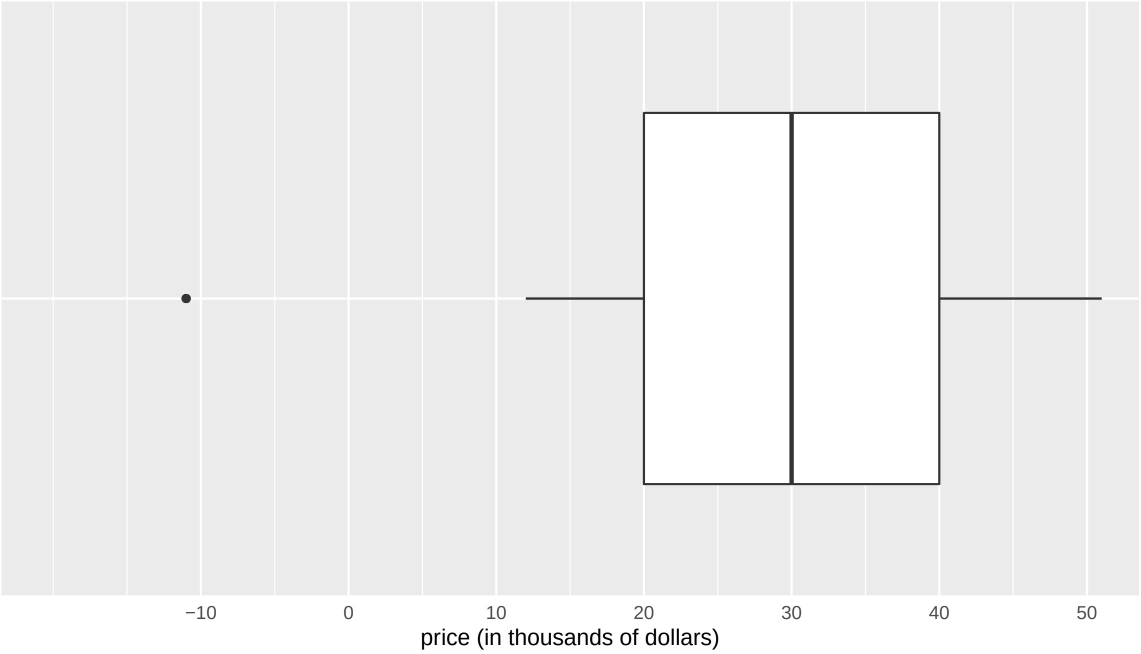
Furthermore, the following three *summary statistics* have been computed:

1st quartile	Average	3rd quartile
20	28.53333	40

a) What is the interquartile range (IQR) for this data?

b) Is the IQR a measure of center or a measure of spread of a numerical variable? Circle your response.

c) Draw the boxplot for this dataset. Be sure to mark all relevant numerical values:



(f) NPR recently posted an article titled “How Much (Or Little) The Middle Class Makes, In 30 U.S. Cities.” It included the image on the following page.

a) This image most closely resembles what statistical visualization we’ve seen?

b) Which city has the third highest mean family income?

c) Which four cities have the highest income disparity in the US?

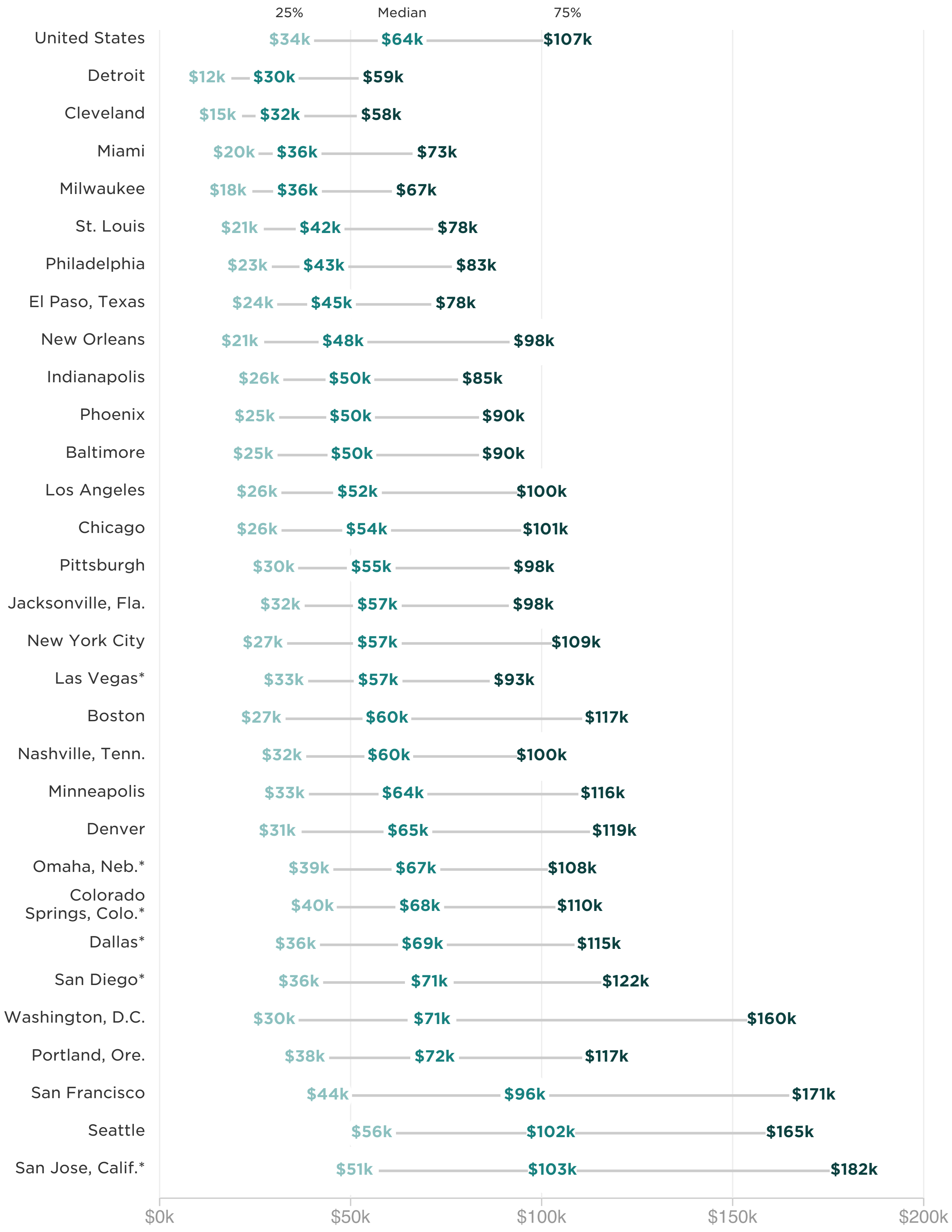
d) Quantify this income disparity for only one of the four chosen cities in part c) using a summary statistic of your choice.

e) What proportion of Nashville families had a family income of $100K or more?

f) What proportion of Nashville families had a family income of $80K or more?

What Is Middle Class?

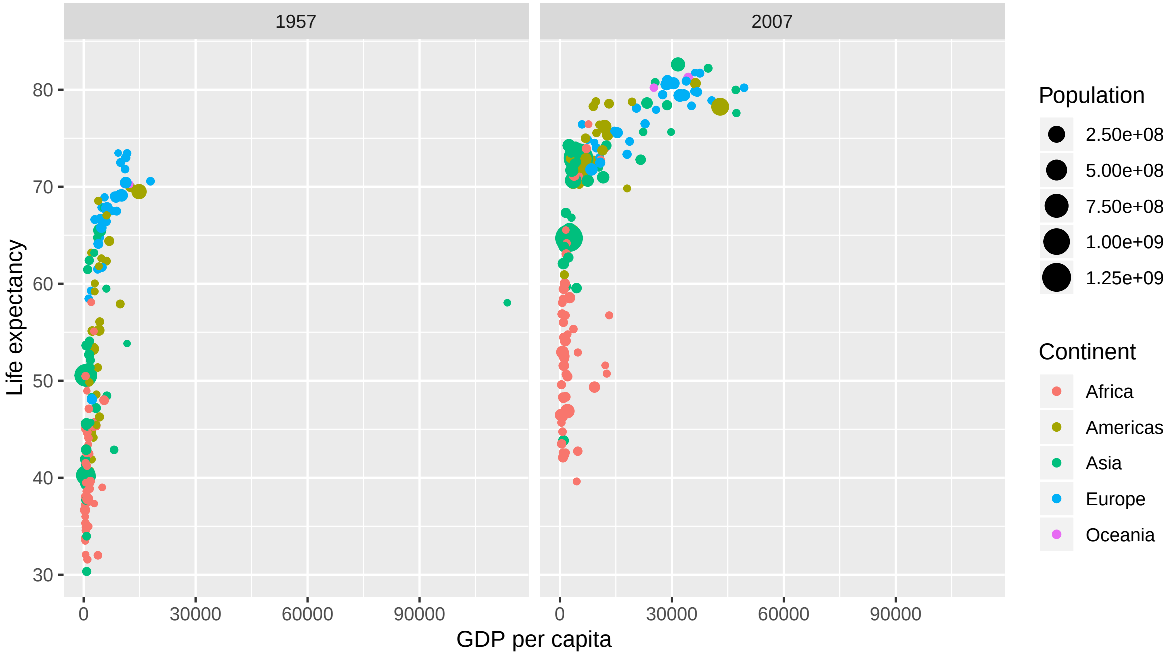
Family income by city, 2013



(g) Consider a subset of the **gapminder** dataset we've seen numerous times in class:

```
## # A tibble: 284 x 6
##    country     continent  year lifeExp      pop gdpPercap
##    <fct>       <fct>     <int>   <dbl>    <int>     <dbl>
##  1 Afghanistan Asia       1957    30.3  9240934      821.
##  2 Afghanistan Asia       2007    43.8 31889923      975.
##  3 Albania     Europe     1957    59.3  1476505     1942.
##  4 Albania     Europe     2007    76.4  3600523     5937.
##  5 Algeria     Africa     1957    45.7 10270856     3014.
##  6 Algeria     Africa     2007    72.3 33333216     6223.
##  7 Angola      Africa     1957    32.0  4561361     3828.
##  8 Angola      Africa     2007    42.7 12420476     4797.
##  9 Argentina   Americas   1957    64.4 19610538     6857.
## 10 Argentina   Americas   2007    75.3 40301927    12779.
## # ... with 274 more rows
```

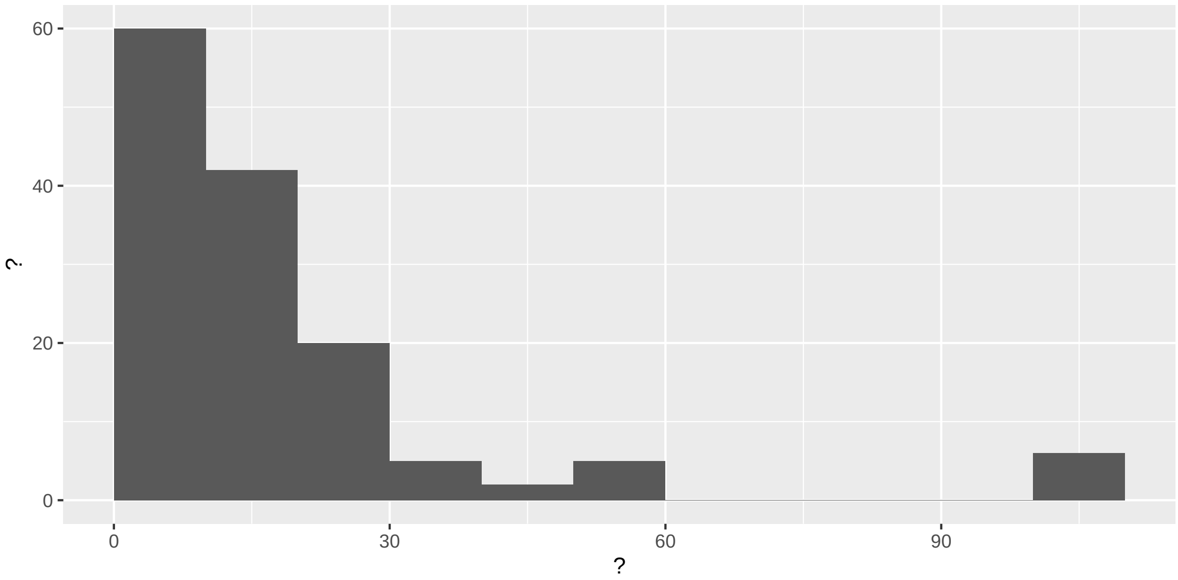
Using this data, we can create the following plot:



Write out **in bullet point form** all the elements of the "Grammar of Graphics" that need to be specified in a `ggplot()` function call to create this graphic. Note

- You don't need to write code, you only need to specify all components of the graphic.
- There is no need to specify the x and y axes labels.

(h) In a statistics class with 140 students, the professor records how much money (in dollars) each student has in their possession during the first class of the semester. The histogram shown below represents the data they collected:



a) What is the variable on the horizontal (x) axis?

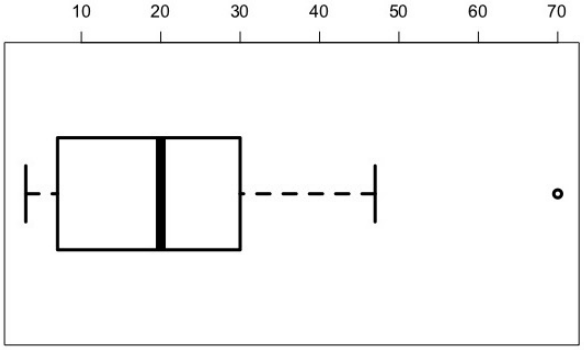
b) What is the quantity on the vertical (y) axis?

c) The height of the second bar is 42. What does that tell us? Say precisely in **one sentence**.

d) Fill in the blanks: The median amount of money possessed is between \$ ________ and \$ ________. Show work or briefly explain your reasoning.

Question X

For this question consider the below box plot.



(a) For each of the below statements, state whether it is true or false and briefly ***explain*** your answer.

- The range of extremes is [3,47].
- According to the boxplot, the number of data points used to construct the box plot is 17.
- The 50% coverage interval is [7,30].
- The data is skew-left.
- According to the boxplot, the mean is 20.

(b) If you would like to know the above 5 summary statistics (i.e. range of extremes, skewness, mean, coverage intervals, and number of data points), is a box plot the best visual representation for your data? If not, what visualization would be better? Justify your answer.

Badge 2: Write pseudocode for basic data wrangling and exploratory data analysis

Question X Short Answer

(a)

Question X

(a) Recall the `babynames` dataset that contains all babynames used more than 5 times for any given year, split by sex, for the years 1880 through 2015. Here is a preview of the first 10 rows:

year	sex	name	n	prop
1880	F	Mary	7065	0.0723836
1880	F	Anna	2604	0.0266790
1880	F	Emma	2003	0.0205215
1880	F	Elizabeth	1939	0.0198658
1880	F	Minnie	1746	0.0178884
1880	F	Margaret	1578	0.0161672
1880	F	Ida	1472	0.0150812
1880	F	Alice	1414	0.0144870
1880	F	Bertha	1320	0.0135239
1880	F	Sarah	1288	0.0131960

START WRITING YOUR RESPONSES WHERE INDICATED BELOW.

a) Write the pseudocode that is going to compute the total number of babies born between 1950 and 2000 that are named “Riley.”

b) You want to compare the degree to which the names “Casey” and “Riley” have been “unisex” names for all years between 1950 to 2000, in other words the focus is on the degree to which the names have been used by both sexes

- Write the pseudocode for the data wrangling.
- Specify all the elements of the grammar of graphics that is going to generate an appropriate visualization.

(b) **a)** The `weather` data set in the `nycflights13` package contains hourly meterological data for the three NYC airports (EWR, JFK, and LGA) for every day in 2013. We present a snapshot of the data below, but only for the first 6 rows in the data set. What variables are needed to uniquely identify each observation?

origin	year	month	day	hour	temp	humid	wind_speed	precip	pressure	visib
EWR	2013	1	1	1	39.02	59.37	10.35702	0	1012.0	10
EWR	2013	1	1	2	39.02	61.63	8.05546	0	1012.3	10
EWR	2013	1	1	3	39.02	64.43	11.50780	0	1012.5	10
EWR	2013	1	1	4	39.92	62.21	12.65858	0	1012.2	10
EWR	2013	1	1	5	39.02	64.43	12.65858	0	1011.9	10
EWR	2013	1	1	6	37.94	67.21	11.50780	0	1012.4	10

b) Write down the arithmetic operation you would enter into a calculator to compute the number rows that the `weather` data set has (not including the header row). An example of an arithmetic operation is $10 \times 7 + 6$.

(c) You are presented with data on the Titanic disaster of 1912 in a data frame `Titanic`, which cross-classifies survival vs death by class, sex, and age. Write down the *pseudocode* of the commands that will output a table comparing survival vs death counts for the following three scenarios:

a) by sex

b) by sex and class and age

c) to answer the question if the "women and children"-first policy of the White Star Line Company (the company that ran the Titanic) held true or not.

Note: you don't need to calculate the output table, just write the pseudocode that would produce it where the more concise the pseudocode the better. Here is what the `Titanic` data looks like:

Class	Sex	Age	Survived	n
1st	Male	Child	No	0
2nd	Male	Child	No	0
3rd	Male	Child	No	35
Crew	Male	Child	No	0
1st	Female	Child	No	0
2nd	Female	Child	No	0
3rd	Female	Child	No	17
Crew	Female	Child	No	0
1st	Male	Adult	No	118
2nd	Male	Adult	No	154
3rd	Male	Adult	No	387
Crew	Male	Adult	No	670
1st	Female	Adult	No	4
2nd	Female	Adult	No	13
3rd	Female	Adult	No	89
Crew	Female	Adult	No	3
1st	Male	Child	Yes	5
2nd	Male	Child	Yes	11
3rd	Male	Child	Yes	13
Crew	Male	Child	Yes	0
1st	Female	Child	Yes	1
2nd	Female	Child	Yes	13
3rd	Female	Child	Yes	14
Crew	Female	Child	Yes	0
1st	Male	Adult	Yes	57
2nd	Male	Adult	Yes	14
3rd	Male	Adult	Yes	75
Crew	Male	Adult	Yes	192
1st	Female	Adult	Yes	140
2nd	Female	Adult	Yes	80
3rd	Female	Adult	Yes	76
Crew	Female	Adult	Yes	20

Badge 3: Compute and interpret summary statistics: measures of centrality and spread

Question X Short Answer

(a) Say a class of 30 introductory statistics students took a test where the median score was 17 and the interquartile range was 0. What are the 25th and 75th percentiles of test scores? Hint: A picture may help.

Question X

You are investigating if countries get a 'bump' in their gold medal count when they host the Winter Olympics. Recalling that the 2010 Winter Olympics were in Vancouver Canada, you decide to use Canada as a first test case. You found the following Canadian gold medal tallies for the past 9 Winter Olympics:

Year	1984	1988	1992	1994	1998	2002	2006	2010	2014
Canada's Gold Medals	2	0	2	3	6	7	7	26	10

(a) What is the median number of gold medals that Team Canada have won over the past 9 Winter Olympics? Show all work.

(b) Find the 50% coverage interval. Show all work.

(c) Based on the above table and results, do you think that Canada got a 'bump' for being the host country? Justify your answer.

(d) You double check the table's data and notice that for the 2010 games, the listed number of medals is the total number and not the just the gold medals. The correct number of gold medals is actually 13 gold medals. Does the median number of gold medals that Team Canada has won over the past 9 Winter Olympics change? Does the mean change? Justify ***both*** your answers ***without*** doing any ***additional*** computations.

Alternative

You have been asked to consult on a small study. Due to privacy concerns, all you have is a collection of values for one variable: Mystery $= \{8, 6, 12, 7, 6, 5, 12, 6, 10, 6, 12, 10, 7\}$. You do not know what the data is about.

a) Compute the *median* and the *mode* of Mystery. Show all work.

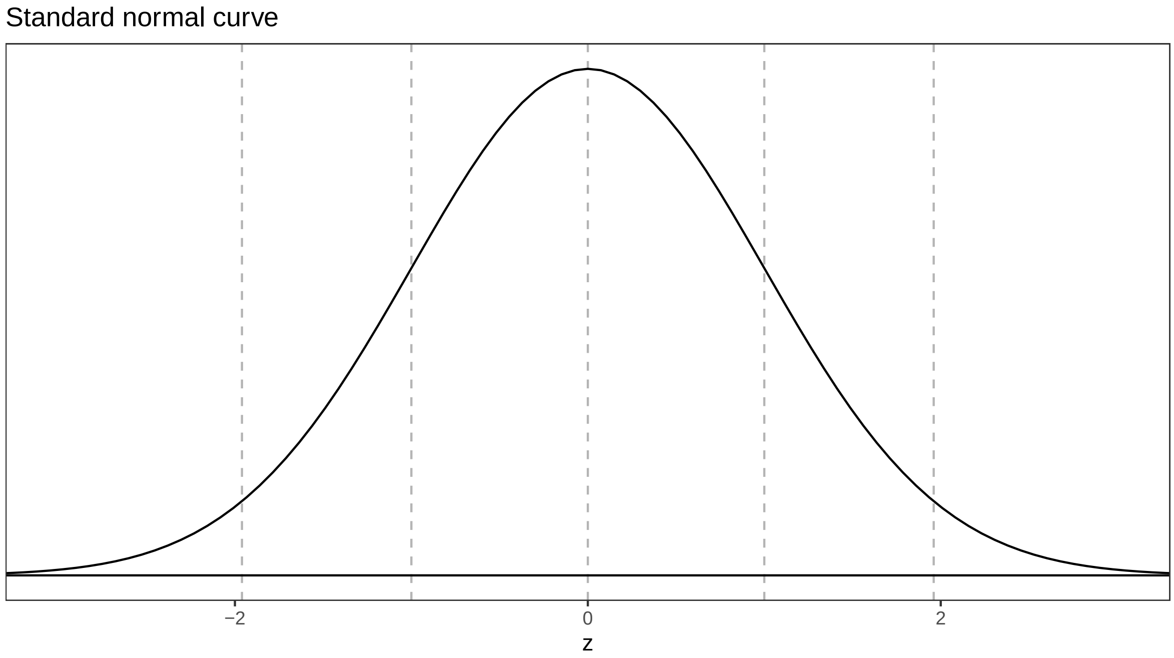
b) The head researcher found that the mean and the standard deviation of Mystery are 8.2. and 2.6, respectively. He says that 68% of the data falls between 5.6 and 10.8. Can he make such a claim about this data? Why or why not?

c) A postdoc on the study realizes that the data notebook for Mystery was incorrectly transcribed and that the true data is Mystery $= \{8, 6, 12, 7, 6, 5, 12, 6, 10, 0, 12, 10, 7\}$. In other words, the number recorded as a 6 is actually a 0. Does this discovery change the value of the standard deviation? Justify your answer ***without*** computing the new standard deviation.

d) Does the above discovery change the value of the 25th percentile? Again, justify your answer ***without*** computing the new 25th percentile.

Question X

(a) Below we have a standard Normal Z-curve along with 5 vertical dashed lines at $z =$ -1.96, -1, 0, 1, and 1.96 cutting the x-axis into 6 segments. In the plot below, write down the 6 proportion of values under the Z-curve in each of the 6 segments. Hint: Your 6 proportions should sum to 100%.



Badge 4: Fit and understand regression models with numerical explanatory variables

Question X Short Answer

(a)

Question X

(a) An analysis of Middlebury faculty salaries shows that on average women get paid significantly less than men. However, an astute statistician observes that

- Younger faculty tend to get paid less than older faculty due to seniority.
- Amongst the younger faculty, there is better representation of women because of shifts in the labor pool and hiring practices.

In this example, age is an example of what?

(b) Consider the following hypothetical study. Say you collect two variables of information from a population of interest: $y =$ life expectancy and $x =$ annual income out of college measured in units of thousands of dollars. You find that

(a) the correlation coefficient is 0.25

(b) the fitted regression line $\widehat{y} = 45 + 0.5x$

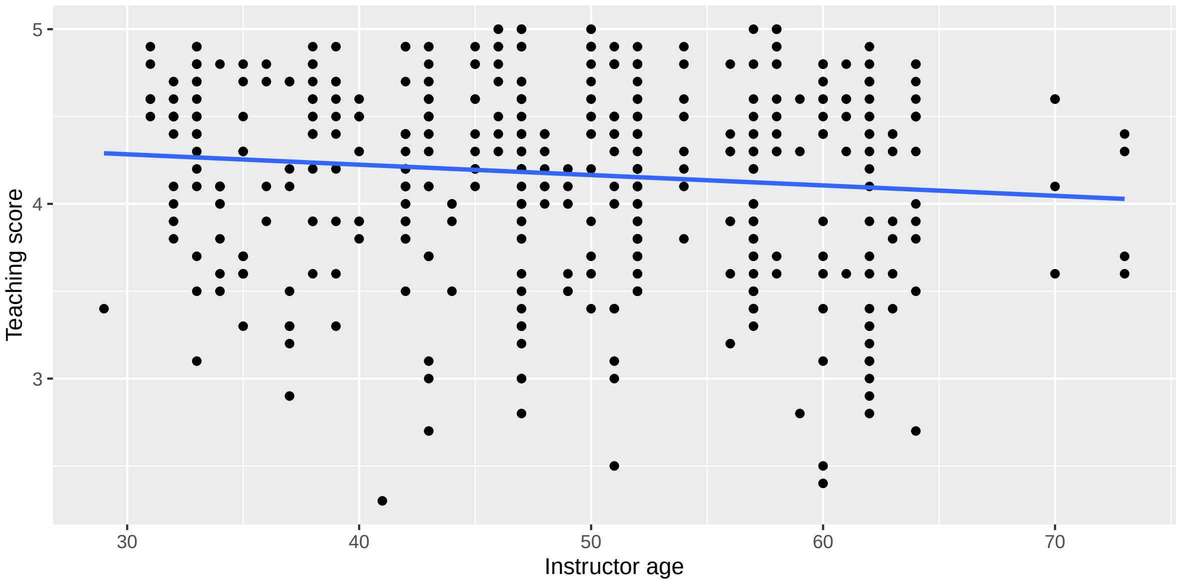
Write down what the following two quantities would be if x was not measured in units of thousands of dollars, but measured in units of dollars:

(a) the correlation coefficient

(b) the fitted slope b_1 of the regression line $\widehat{y} = b_0 + b_1 x$

(c) Recall our teaching evaluation dataset seen in class. We're interested in fitting a model of teaching score (evaluated by students) as a function of instructor age.

```r
ggplot(data = evals, mapping = aes(x = age, y = score)) +
  geom_point() +
  geom_smooth(method = "lm", se = FALSE) +
  labs(x = "Instructor age", y = "Teaching score")
```



```
model_score <- lm(score ~ age, data = evals)
get_regression_table(model_score)

## # A tibble: 2 x 7
##   term      estimate std_error statistic p_value lower_ci upper_ci
##   <chr>        <dbl>     <dbl>     <dbl>   <dbl>    <dbl>    <dbl>
## 1 intercept    4.46      0.127     35.2    0         4.21     4.71
## 2 age         -0.006     0.003     -2.31   0.021   -0.011   -0.001
```

a) Interpret the `intercept` term in the `estimate` column of the regression table.

b) Give the precise interpretation of the slope for `age` in the `estimate` column of the regression table.

c) The regression line visualized in the above figure is considered the "best fitting line" through these points. By what criteria do we mean "best"?

d) What is the correlation coefficient of `age` and `score`? Is it positive or negative?

e) Consider the first row of the following output. Write down the equation that computes the first value of `score_hat`: `4.25`.

```
model_points <- get_regression_points(model_score)
model_points

## # A tibble: 463 x 5
##       ID score   age score_hat residual
##    <int> <dbl> <int>     <dbl>    <dbl>
##  1     1   4.7    36      4.25    0.452
##  2     2   4.1    36      4.25   -0.148
##  3     3   3.9    36      4.25   -0.348
##  4     4   4.8    36      4.25    0.552
##  5     5   4.6    59      4.11    0.488
##  6     6   4.3    59      4.11    0.188
##  7     7   2.8    59      4.11   -1.31
##  8     8   4.1    51      4.16   -0.059
##  9     9   3.4    51      4.16   -0.759
## 10    10   4.5    40      4.22    0.276
## # ... with 453 more rows
```

f) Write down the equation that computes the first value of `residual`: `0.452`.

g) Write down the data wrangling pseudocode to apply to `model_points` to compute the value of the criteria described in part c).

Badge 5: Fit and understand regression models with categorical explanatory variables

Question X Short Answer

(a)

Question X

Australian researchers explored the association between depression and factors such as employment status, marital status, and satisfaction with their level of social interaction. You worked with a sociology researcher to build a model using the following variables:

`BDI`	Beck depression index (high `BDI` = high depression)
`employment`	`employed, govt assistance, other,` or `parental support`
`psisat`	satisfaction with positive social interaction (high `psisat` = high satisfaction)

Unfortunately, the original code got deleted! The below is all you have:

```
                           Estimate Std. Error
(Intercept)                 32.2064     4.7728
employmentgovt assistance    4.4003     2.5579
employmentother             -3.9285     2.4804
employmentparental support  -2.0387     2.2902
psisat                      -1.7314     0.3727
```

a) Write out the model formula associated to the above output.

b) Interpret the intercept term in a contextually meaningful way.

c) What is the reference level for `employment`? Justify your answer.

d) Does this model assume that the relationship between `employment` and `BDI` depends on `psisat`? Justify your answer.

Question X

Consider the Galton data, which contains the following variables among others:

`heights` - The child's height as an adult (inches)
`mother` - The child's mother's height as an adult (inches)
`sex` - The sex of the child (M or F)

Consider the following model:

```
heights = 43.15546 + 0.32655*mother + 1.96331*sexM + 0.05014*mother*sexM
```

(a) What is the reference level for this model? Justify your answer.

(b) Use the above model to construct a model formula between one's height and mother's height for females. Show or justify all work.

(c) Interpret the final coefficient in a contextually meaningful manner.

(d) Based on what you know about the above model, would you choose to keep the model as is or build a different trivariate model? Note that if you were to change the model, you must still use all of the three given variables and no others. Justify your choice.

Question X

(a) Note: for this question, you do not need to do the arithmetic (adding, subtracting, multiplying, dividing), but rather write down what you would enter into a calculator if you had one. Let's consider the `gapminder` development data, but only for the year 2007. Let's look at a random sample of 5 out of the 142 rows of this dataset:

country	continent	lifeExp
Togo	Africa	58.420
Sao Tome and Principe	Africa	65.528
Congo, Dem. Rep.	Africa	46.462
Lesotho	Africa	42.592
Bulgaria	Europe	73.005

We are interested in modeling the relationship between the outcome variable y = life expectancy in years and the categorical explanatory variable x = continent. You fit a following regression and obtain the following regression table rounded to the nearest integer:

```
## # A tibble: 5 x 7
##   term              estimate std_error statistic p_value lower_ci upper_ci
##   <chr>                <dbl>     <dbl>     <dbl>   <dbl>    <dbl>    <dbl>
## 1 intercept             54.8      1.02     53.4        0     52.8     56.8
## 2 continentAmericas     18.8      1.8      10.4        0     15.2     22.4
## 3 continentAsia         15.9      1.65      9.68       0     12.7     19.2
## 4 continentEurope       22.8      1.70     13.5        0     19.5     26.2
## 5 continentOceania      25.9      5.33      4.86       0     15.4     36.4
```

a) What is the fitted value $\widehat{y}$ of life expectancy in years for any given country in:

(a) Africa

(b) Asia

(c) Europe

b) What is the residual for the following three countries?

(a) Nambia

(b) Iran

(c) Italy

c) What is the mean life expectancy for countries in the following continents:

(a) Africa

(b) Asia

(c) Europe