

# Lecture 38 Simple Linear Regression - The Model

BIO210 Biostatistics

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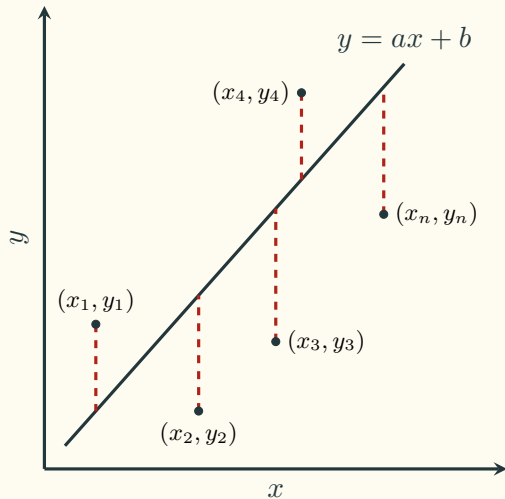
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# Simple Linear Regression



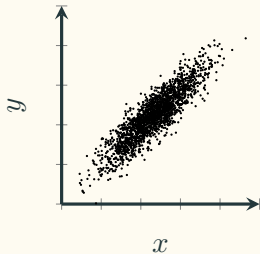
Using OLS regression:

$$SE_{line} = \sum_{i=1}^n [y_i - (ax_i + b)]^2$$

$\Downarrow$  minimise

$$\begin{cases} a = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x})^2} \\ b = \bar{y} - a \cdot \bar{x} \end{cases}$$

# Simple Linear Regression - the model



**Simple Linear Regression** is a statistical method that allows us to summarize and study relationships between two continuous (quantitative) variables.

$X$ :	independent variable	explanatory variable	predictor variable
$Y$ :	dependent variable	outcome variable	response variable

The Simple Linear Regression Model using OLS:

population regression line

For the entire population:  $\mathbf{Y = \beta_0 + \beta_1 X + \epsilon}$

For each observation:  $y_i = \beta_0 + \beta_1 x_i + \epsilon_i$

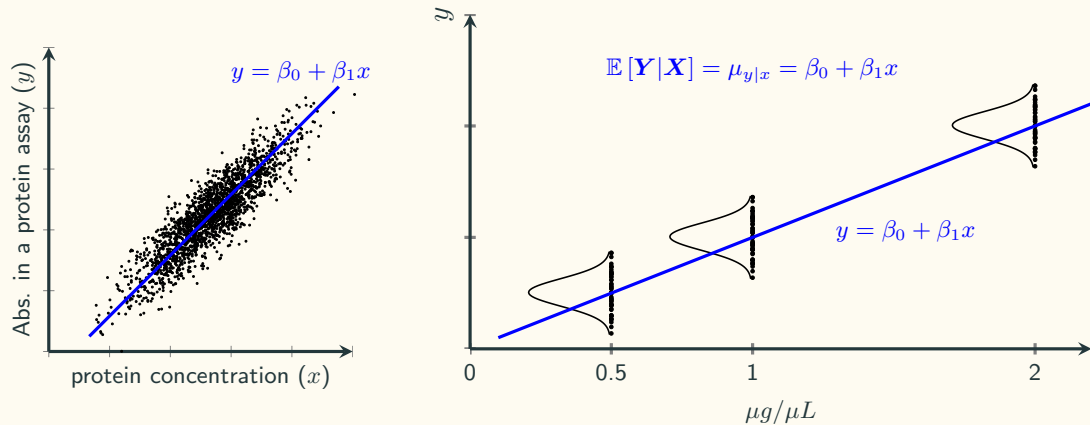
where:

$\beta_0$  is the population intercept

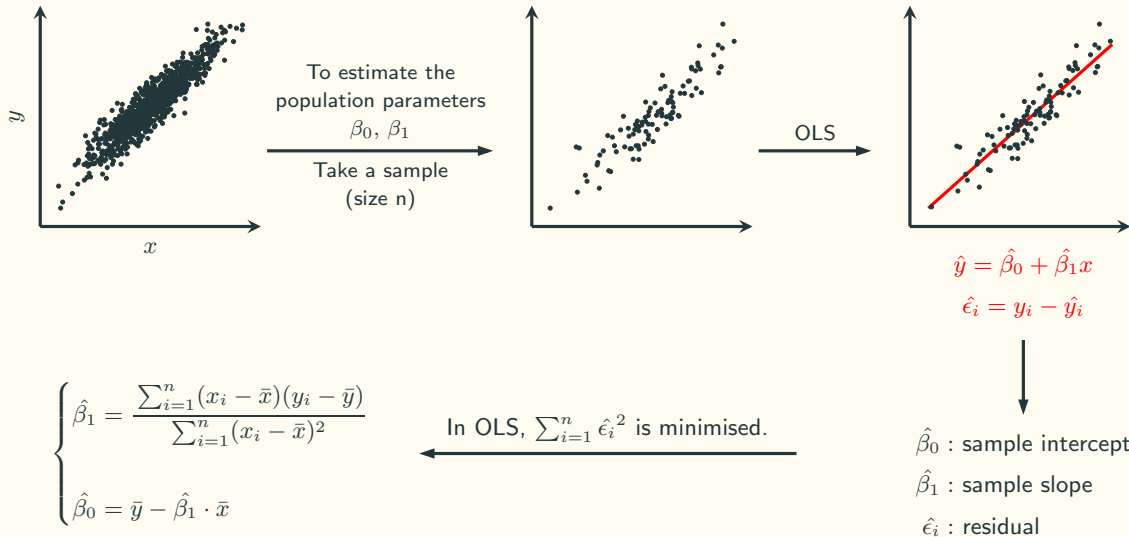
$\beta_1$  is the population slope

$\epsilon_i$  is the error from  $y_i$  to the line  $\beta_0 + \beta_1 x_i$

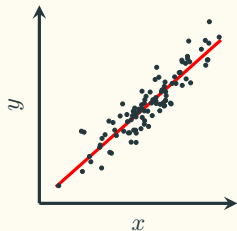
# Simple Linear Regression - the model



# Best Fit Line



# Evaluation of the model: Coefficient of Determination $r^2$



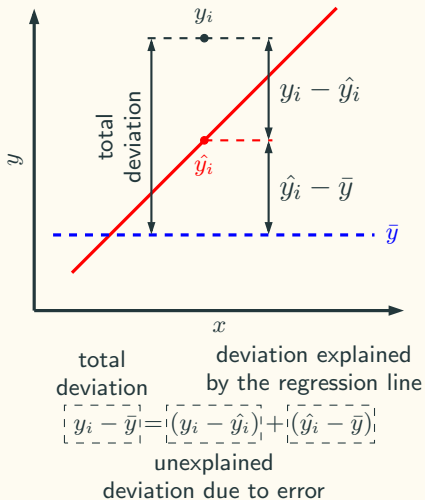
$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x$$

$$\hat{\epsilon}_i = y_i - \hat{y}_i$$

$$\text{minimise } \sum_{i=1}^n \hat{\epsilon}_i^2$$

$$\begin{cases} \hat{\beta}_1 = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x})^2} \\ \hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \cdot \bar{x} \end{cases}$$

How useful is the model?



Sum of squares total:

$$SST = \sum_{i=1}^n (y_i - \bar{y})^2$$

Sum of squares regression:

$$SSR = \sum_{i=1}^n (\hat{y}_i - \bar{y})^2$$

Sum of squares error/residual:

$$SSE = \sum_{i=1}^n (y_i - \hat{y}_i)^2$$

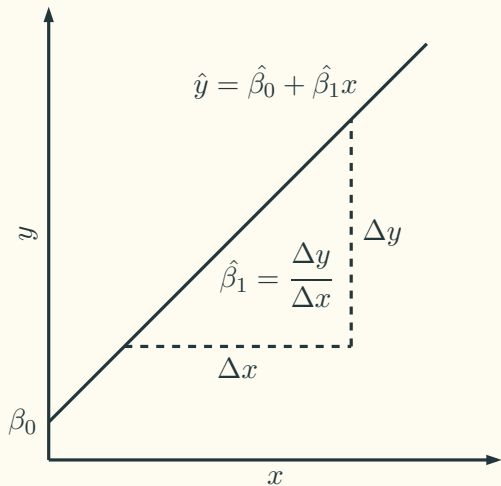
$$SST = SSR + SSE$$

$$\begin{aligned} r^2 &= \frac{\text{explained}}{\text{total}} \\ &= \frac{SSR}{SST} = 1 - \frac{SSE}{SST} \end{aligned}$$

## The ANOVA Table For OLS

Source of Variation	SS	d.f.	MS
Regression	$SSR = \sum_{i=1}^n (\hat{y}_i - \bar{y})^2$	1	$MSR = \frac{SSR}{1} = SSR$
Error/Residual	$SSE = \sum_{i=1}^n (y_i - \hat{y}_i)^2$	$n - 2$	$MSE = \frac{SSE}{n - 2}$
Total	$SST = \sum_{i=1}^n (y_i - \bar{y})^2 = SSR + SSE$	$n - 1$	

# Interpretation of The Regression Parameters



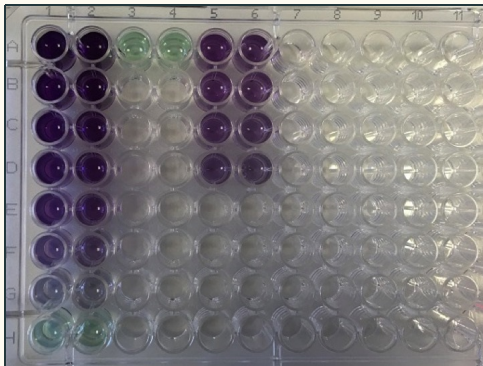
$\hat{\beta}_1$ : the predicted change of the dependent variable  $y$  when the independent variable  $x$  changes one unit

$\hat{\beta}_0$ : the predicted value of the dependent variable  $y$  when the independent variable  $x$  takes the value of 0. It may not have actual meaning.

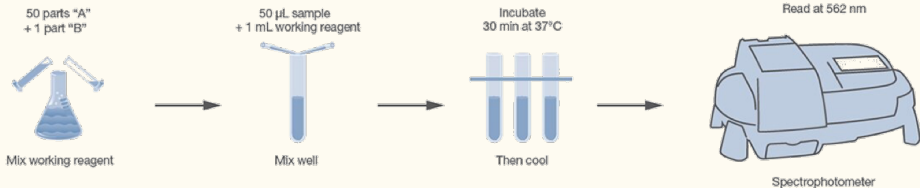
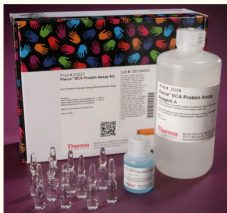


## BCA To Measure Protein Concentration

The BCA Protein Assay combines the well-known reduction of  $Cu^{2+}$  to  $Cu^{1+}$  by protein in an alkaline medium with the highly sensitive and selective colorimetric detection of the cuprous cation ( $Cu^{1+}$ ) by bicinchoninic acid (BCA).

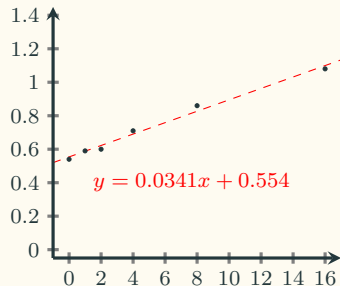


# BCA To Measure Protein Concentration



BSA (mg/mL)	Absorb.
0	0.54
1	0.59
2	0.60
4	0.71
8	0.86
16	1.08
$\bar{x} = 5.17$	$\bar{y} = 0.73$

$x_i - \bar{x}$	$y_i - \bar{y}$	$(x_i - \bar{x})^2$	prod.
-5.17	-0.19	26.73	0.98
-4.17	-0.14	17.39	0.57
-3.17	-0.13	10.049	0.42
-1.17	-0.02	1.37	0.03
2.83	0.131	8.00	0.37
10.83	0.351	117.29	3.80



# Assumptions For Simple Linear Regression

The “LINE” assumptions must be met when performing a simple linear regression:

- The mean of the dependent variable ( $\mathbb{E}[Y|X], \mu_{y|x}$ ) is a **L**inear function of  $X$
- The errors/residuals  $\epsilon_i|X = x_i$  are **I**ndependent
- The errors/residuals  $\epsilon_i|X = x_i$  are **N**ormally distributed
- The errors/residuals  $\epsilon_i|X = x_i$  have **E**qual variance for all  $x_i$  values  
(homoscedasticity)

$$\epsilon \sim \mathcal{N}(0, \sigma_\epsilon^2)$$

# Seaborn Tips Datasets

Food servers' tips in restaurants may be influenced by many factors, including the nature of the restaurant, size of the party, and table locations in the restaurant. Restaurant managers need to know which factors matter when they assign tables to food servers. For the sake of staff morale, they usually want to avoid either the substance or the appearance of unfair treatment of the servers, for whom tips (at least in restaurants in the United States) are a major component of pay. In one restaurant, a food server recorded the following data on all customers they served during an interval of two and a half months in early 1990. The restaurant, located in a suburban shopping mall, was part of a national chain and served a varied menu. In observance of local law, the restaurant offered to seat in a non-smoking section to patrons who requested it. Each record includes a day and time, and taken together, they show the server's work schedule.

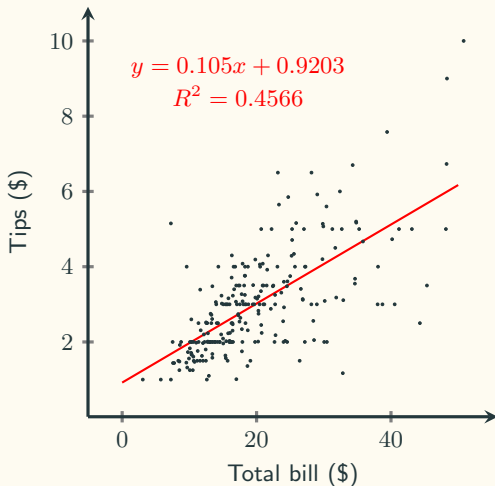
<https://www.kaggle.com/ranjeetjain3/seaborn-tips-dataset>

# Tips

Restaurant Address	
1 Burger	£13.99
1 French fries	£5.99
2 Fish & chips	£11.99
1 Lamb kebab	£10.99
5 Coke	£3.99
AMOUNT: £74.90	
TIP: _____	
TOTAL: _____	

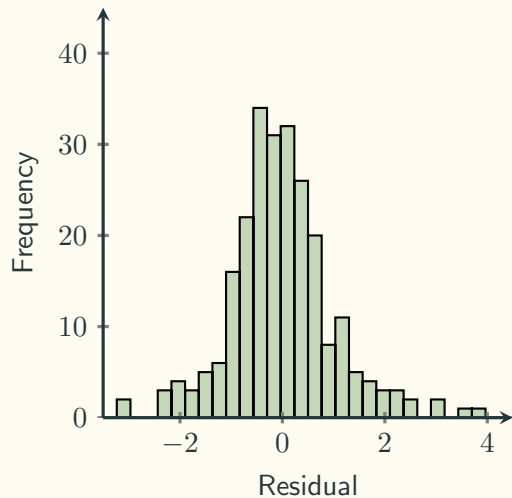


Total bill	Tips
16.99	1.01
10.34	1.66
21.01	3.5
23.68	3.31
24.59	3.61
25.29	4.71
8.77	2
26.88	3.12
15.04	1.96
14.78	3.23
10.27	1.71
⋮	⋮

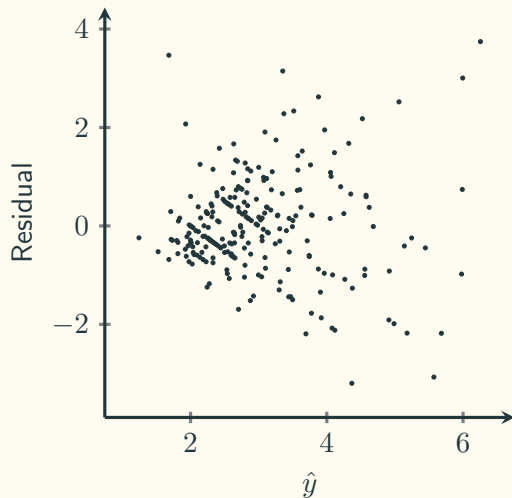


# The Residual Plot

Distribution of Residual

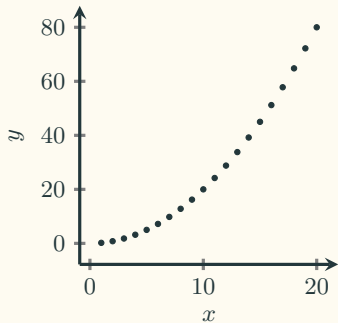


The Residual Plot

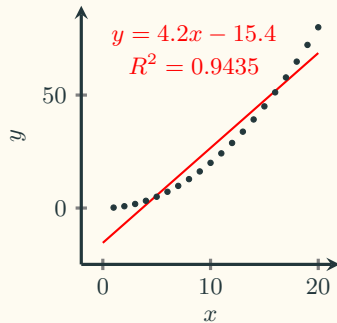


# The Residual Plot

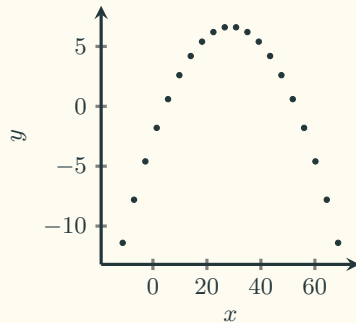
Original data



Best Fit Line



The Residual Plot



# Linear Regression

- The Simple Linear Regression Model

- $Y = \beta_0 + \beta_1 X + \epsilon$

- The Multiple Linear Regression Model

- $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_q X_q + \epsilon$

- The Logistic Regression Model ( $Y$  is categorical)

- $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_q X_q + \epsilon$