

THE MANGA GUIDE TO

# STATISTICS

SHIN TAKAHASHI  
TREND-PRO, CO., LTD.



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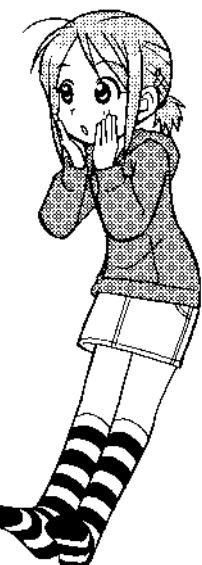
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THE MANGA GUIDE TO STATISTICS



THE MANGA GUIDE™ TO  
**STATISTICS**

SHIN TAKAHASHI  
TREND-PRO CO., LTD.



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# PREFACE

This is an introductory book on statistics. The intended readers are:

- Those who need to conduct data analysis for research or business
- Those who do not necessarily need to conduct data analysis now but are interested in getting an idea of what the world of statistics is like
- Those who have already acquired general knowledge of statistics and want to learn more

Statistics is one of the areas of mathematics most closely related to everyday life and business. Familiarizing yourself with statistics may come in handy in situations like:

- Estimating how many servings of fried noodles you can sell at a food stand you are planning to set up during a school festival
- Estimating whether you will be able to pass a certification exam
- Comparing the probability that a sick person will get better between a case in which medicine  $X$  is used and a case in which it is not used

This book consists of seven chapters. Basically, each chapter is organized in the following sections:

- Cartoon
- Text explanation to supplement the cartoon
- Exercise and answer
- Summary

You can learn a lot by just reading the cartoon section, but deeper understanding and knowledge will be acquired if you read the other sections as well.

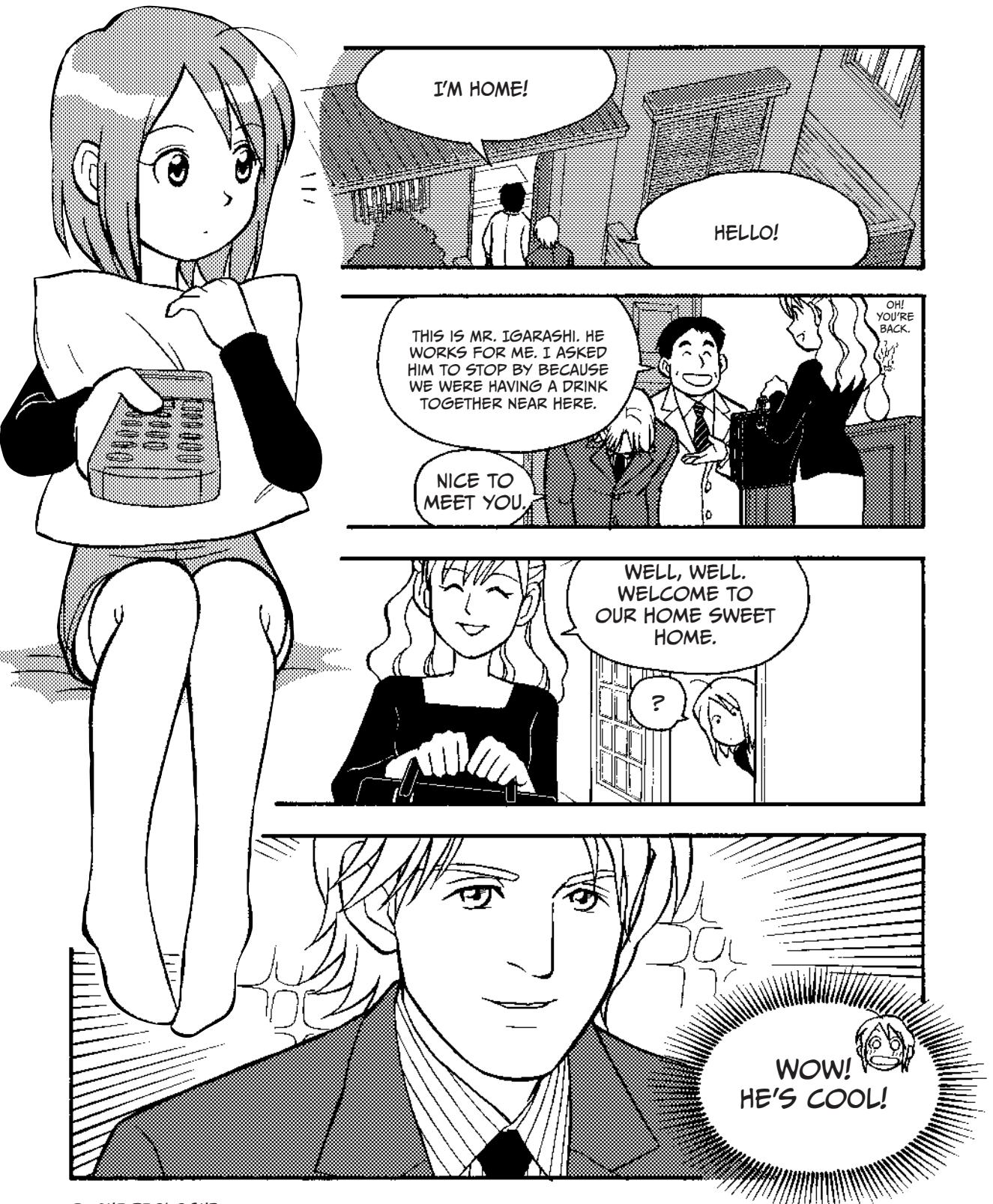
I would be very pleased if you start feeling that statistics is fun and useful after reading this book.

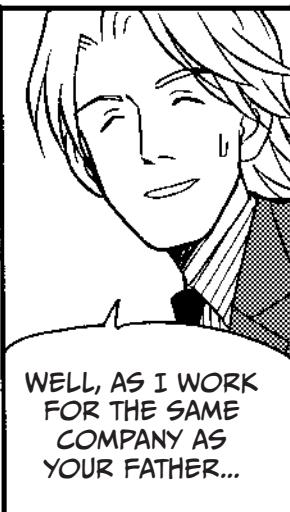
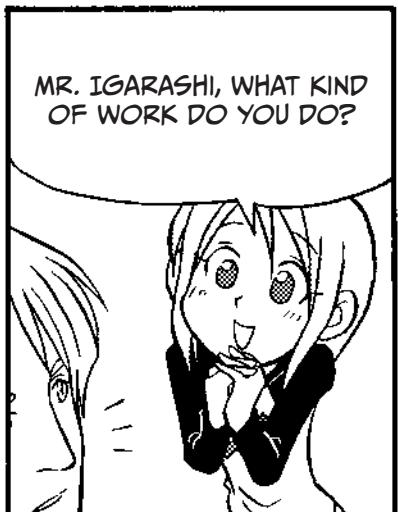
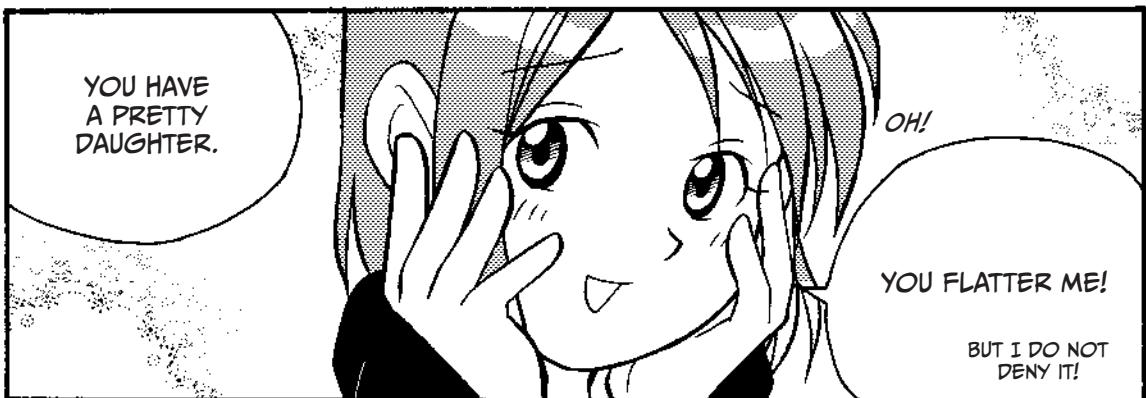
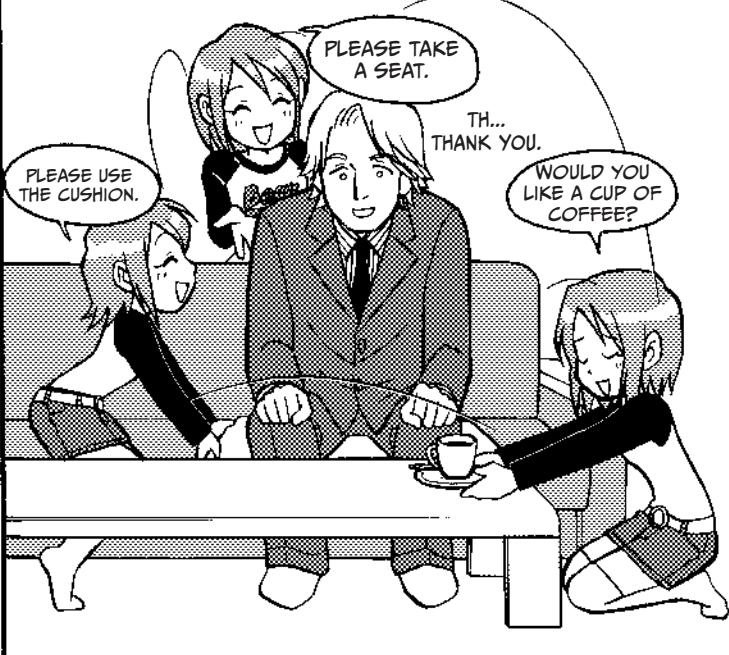
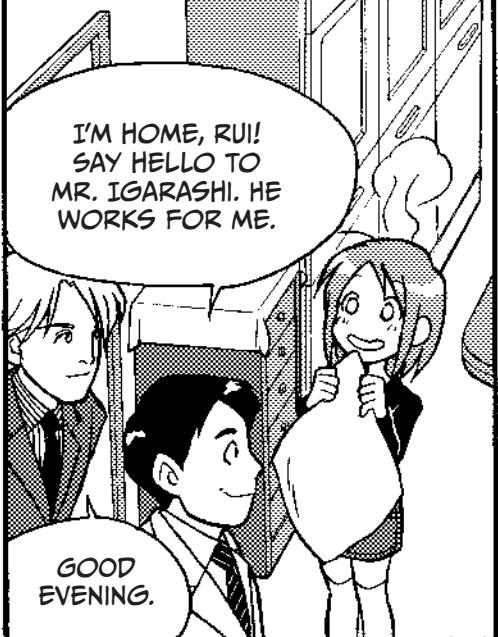
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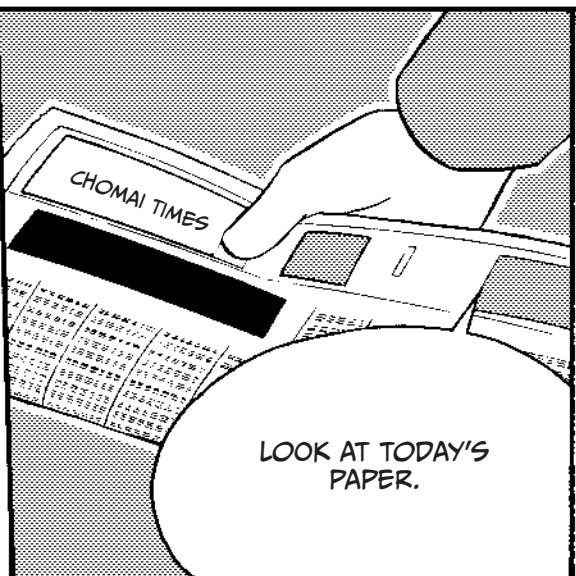
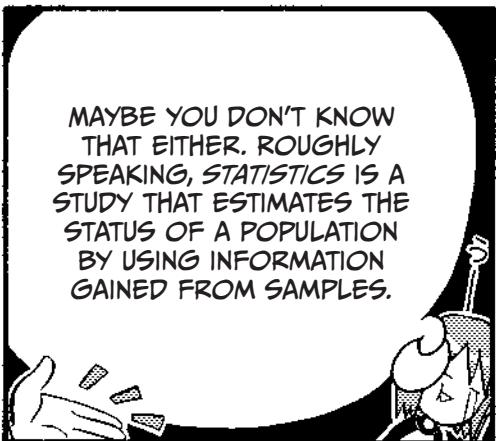
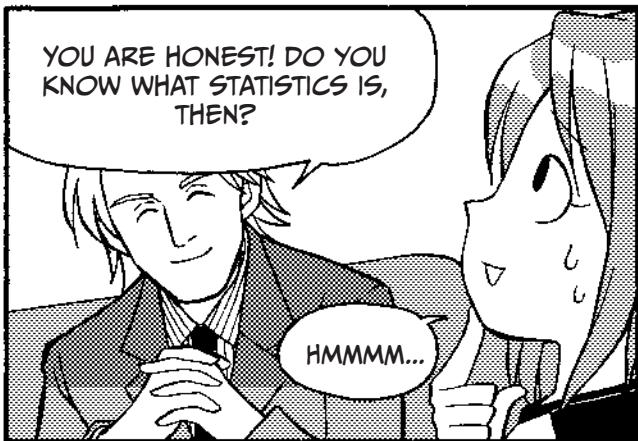
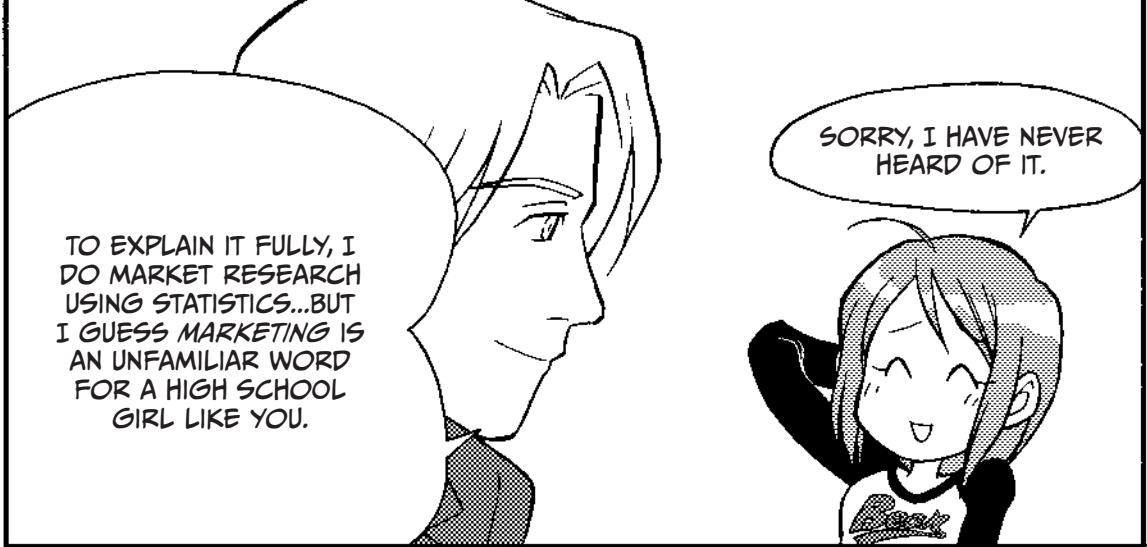
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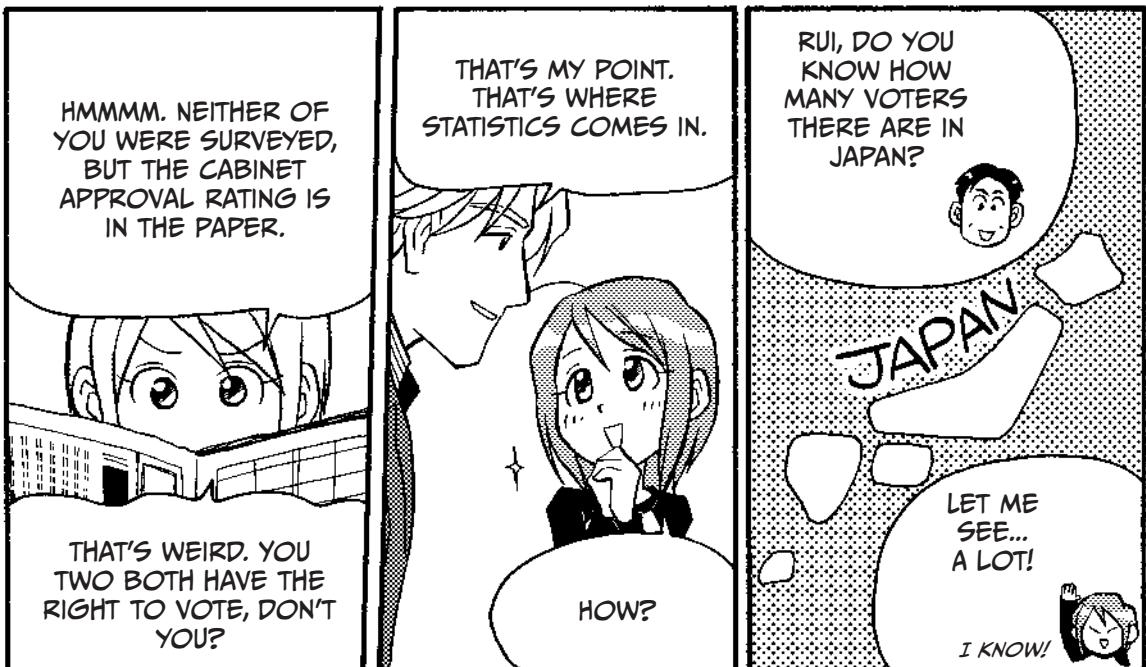
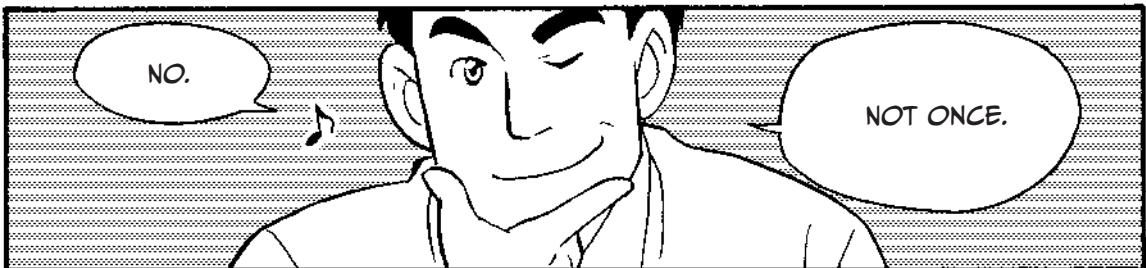
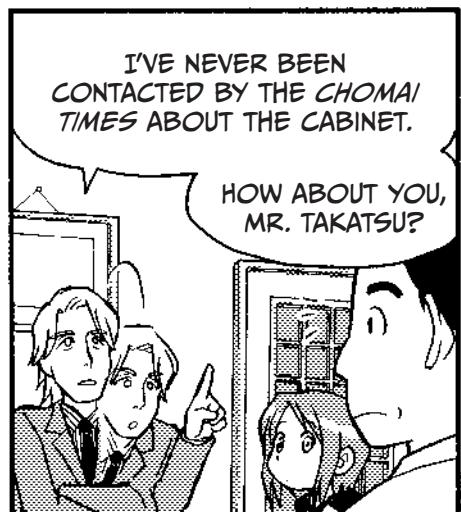
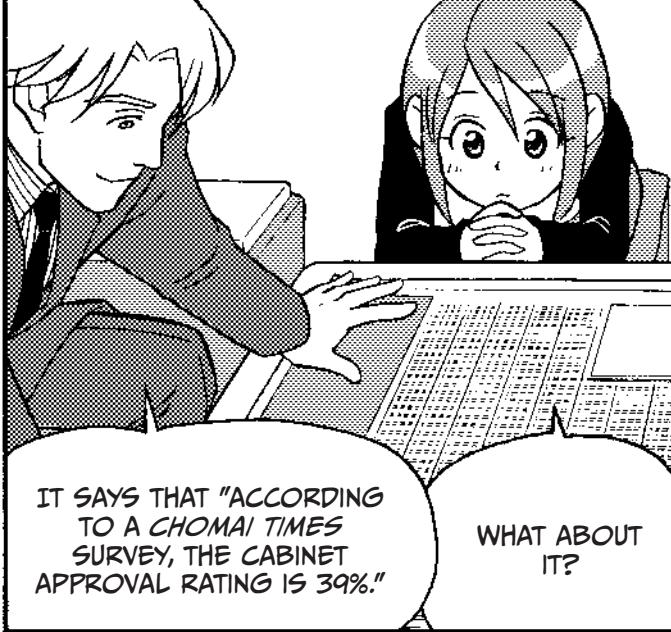


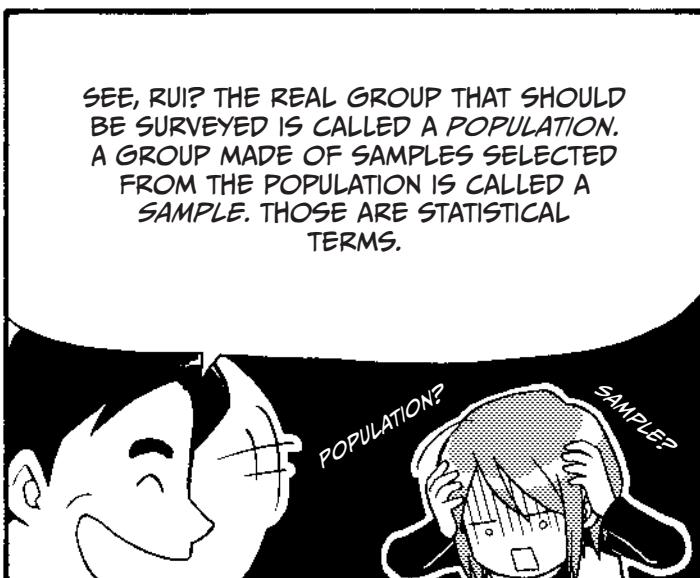
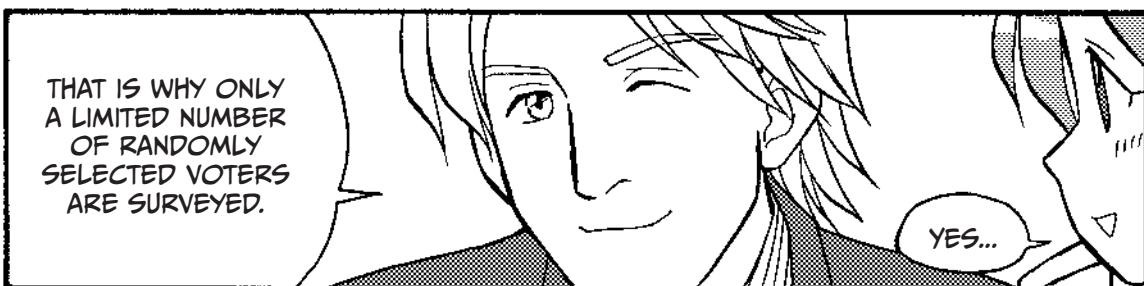
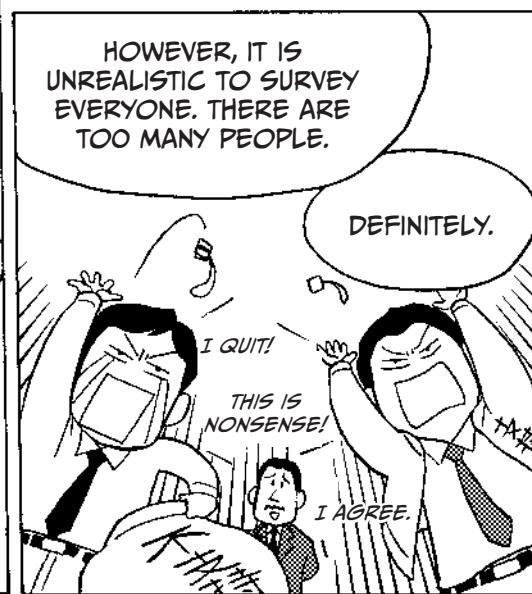
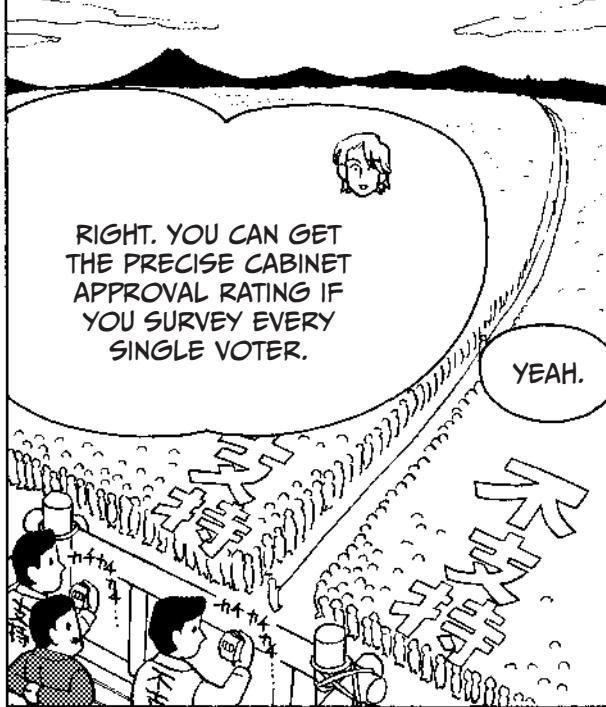
OUR PROLOGUE:  
STATISTICS WITH  
♥ HEART-POUNDING EXCITEMENT ♥





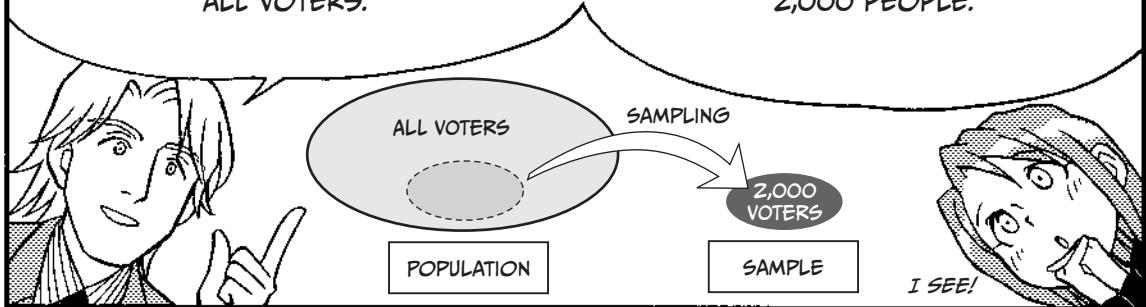






WHAT HE IS SAYING IS...IN THE CASE OF THE APPROVAL RATING OF THE CABINET, THE POPULATION IS ALL VOTERS.

IT SAYS THAT THE SURVEY WAS CONDUCTED WITH 2,000 PEOPLE, SO IN THIS CASE, THE SAMPLE IS THOSE 2,000 PEOPLE.



IF POSSIBLE, I WANT TO EXAMINE THE POPULATION...

BUT THAT IS TECHNICALLY IMPOSSIBLE. WHAT AM I GOING TO DO?

HOW CAN I GET AN IDEA OF THE POPULATION'S STATUS? IT DOES NOT HAVE TO BE STRICTLY PRECISE, BUT IT HAD BETTER BE AS ACCURATE AS POSSIBLE.

100M<sup>2</sup>

WHICH PLANT IS MOST ABUNDANT IN THIS LAND?

100M<sup>2</sup>

THAT IS TOO DIFFICULT!

I DON'T WANT TO DO IT!

100M<sup>2</sup>

HMMMM...

I'LL EXAMINE ONLY 1 SQUARE METER.

THAT'S WHERE STATISTICS COMES IN HANDY.

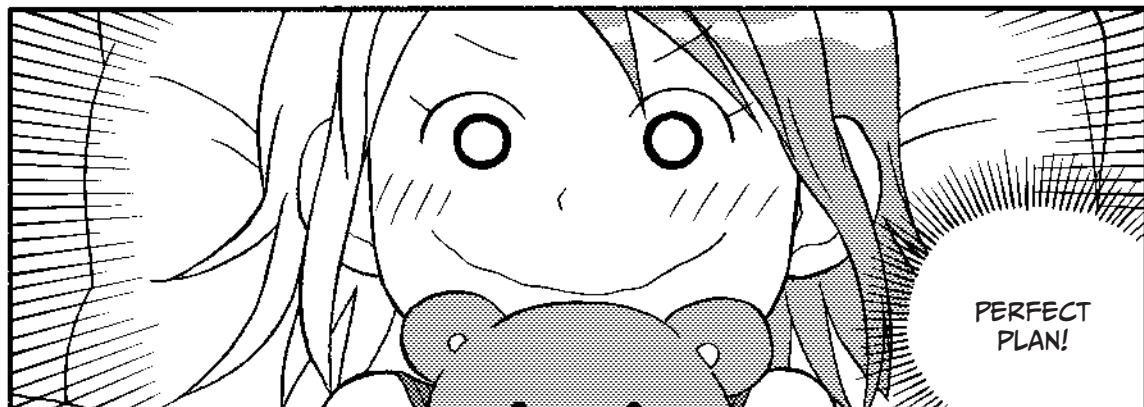
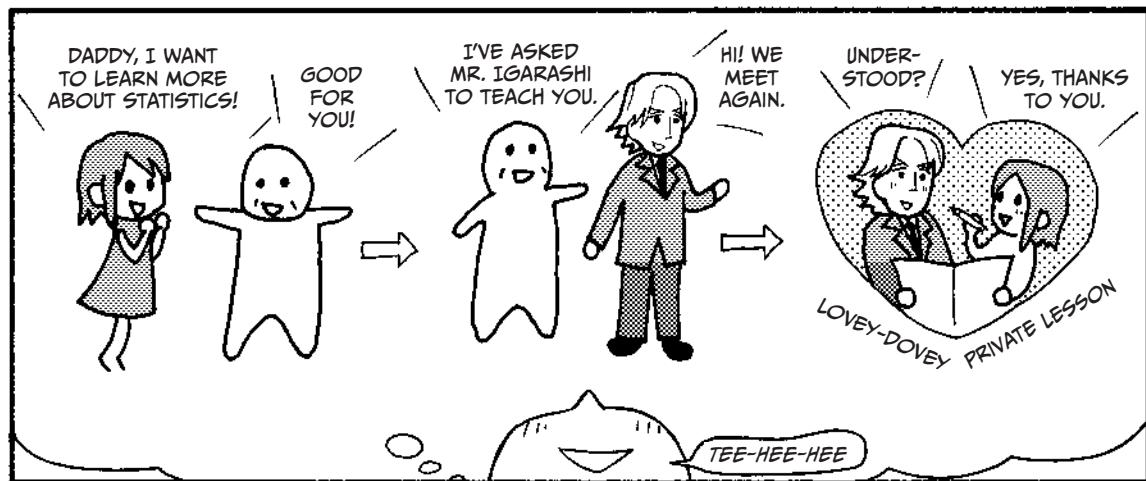
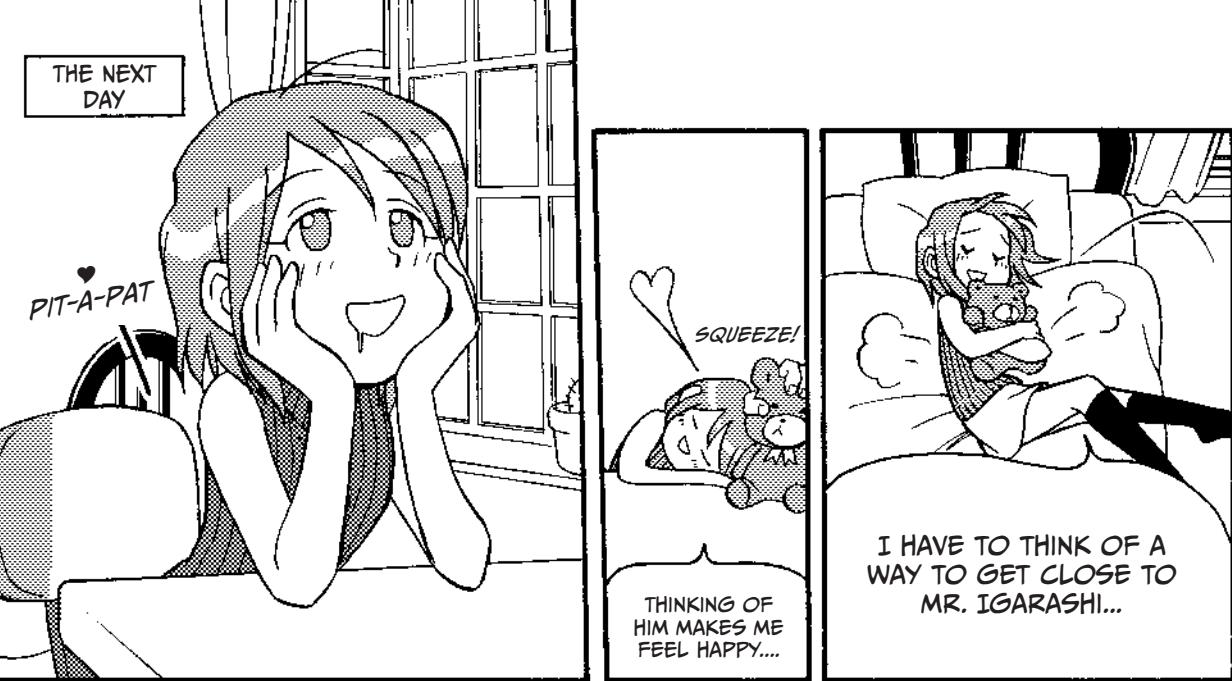
WELL, MAYBE NEXT TIME.

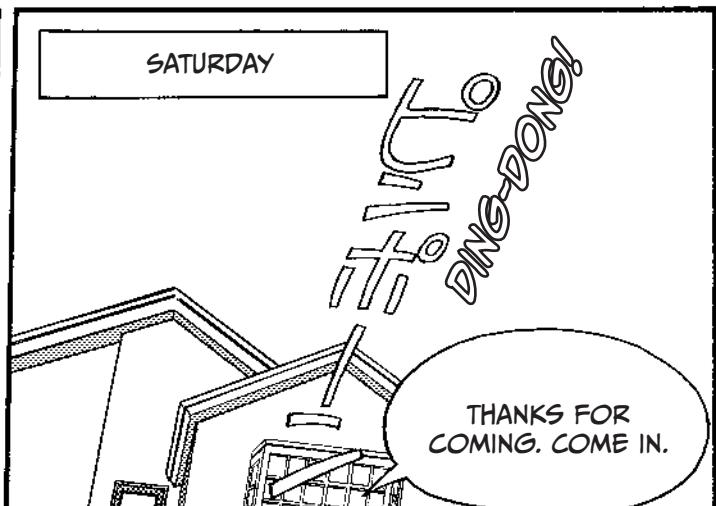
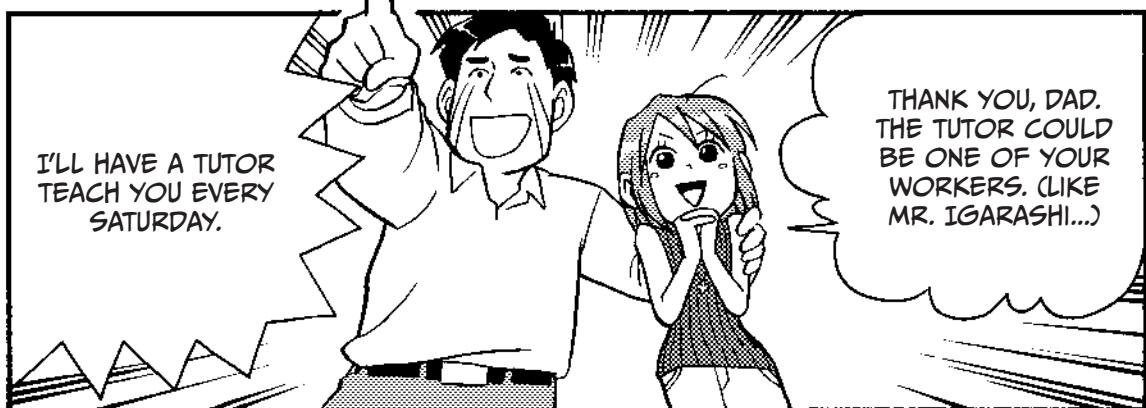
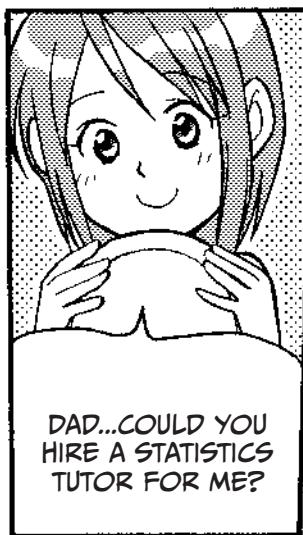
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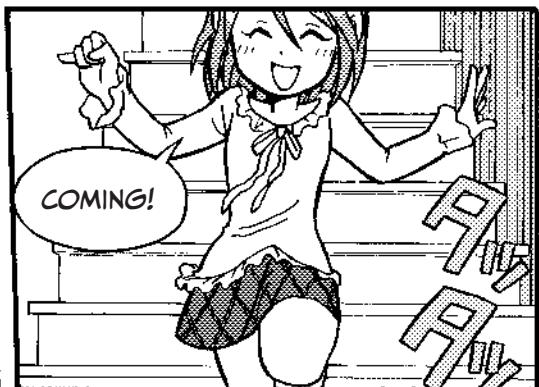
PLEASE! PLEASE TELL ME MORE.

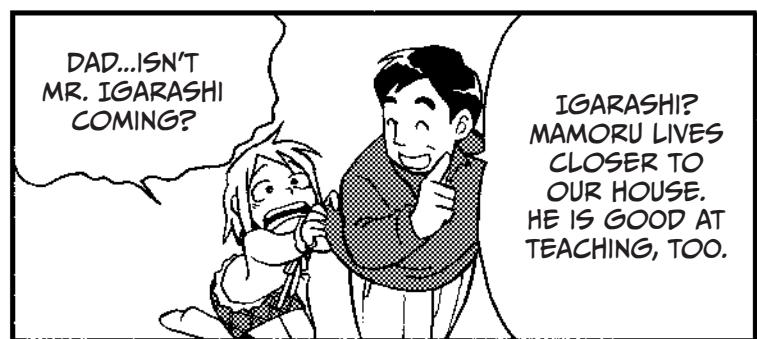
HE IS SOOOO GOOD LOOKING!

THE NEXT DAY

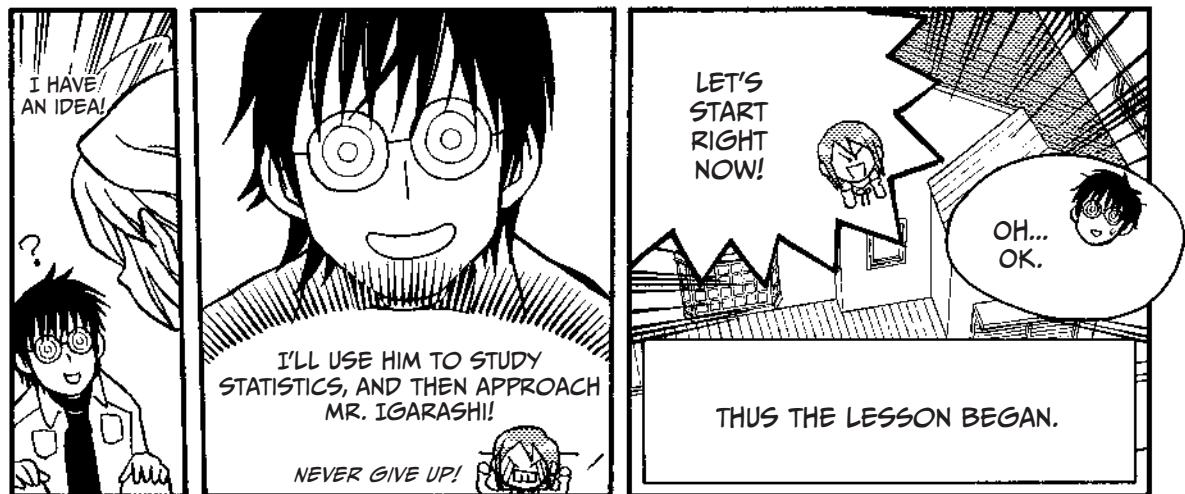
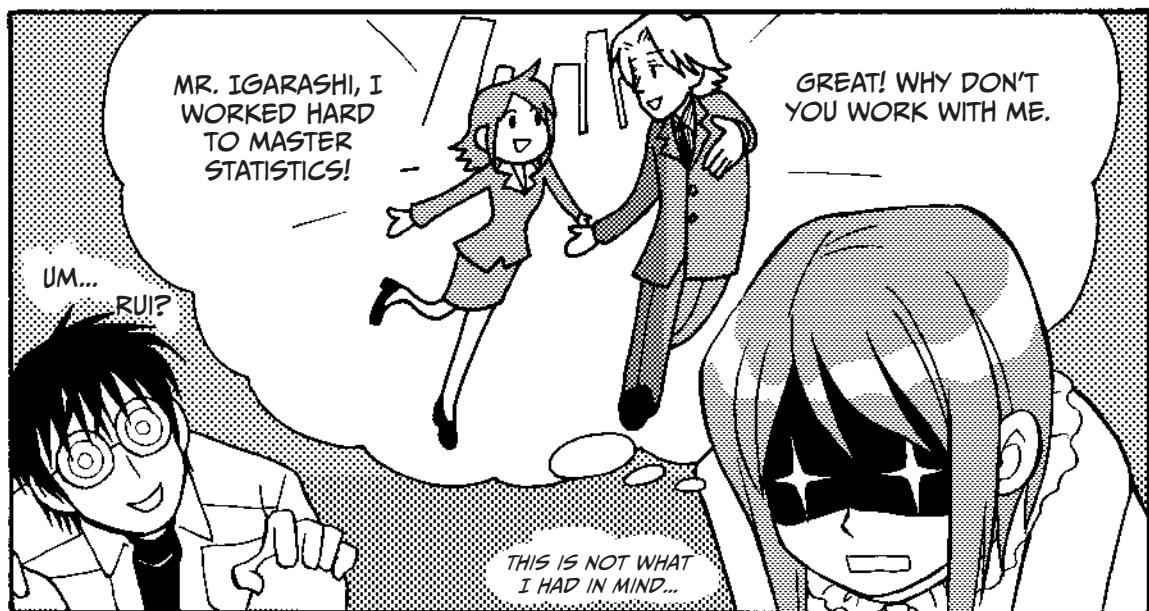
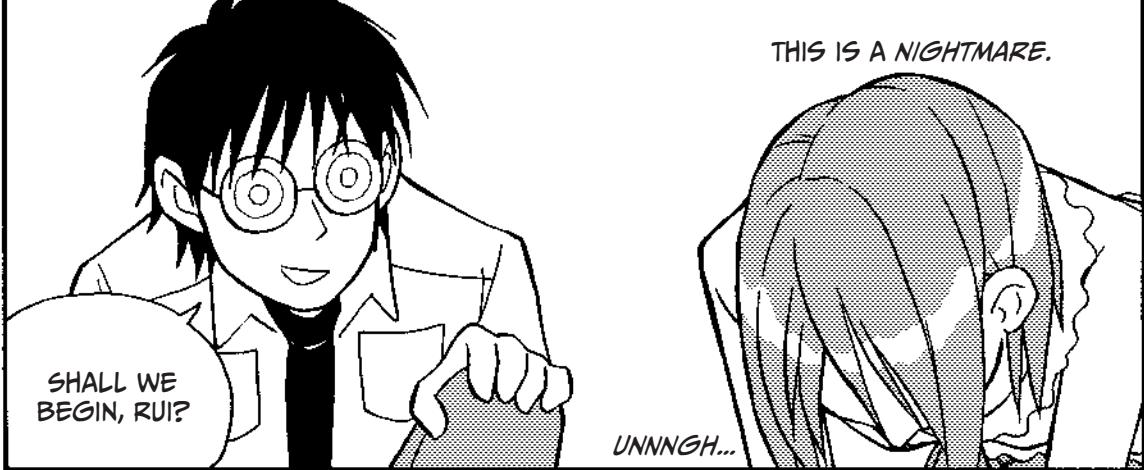








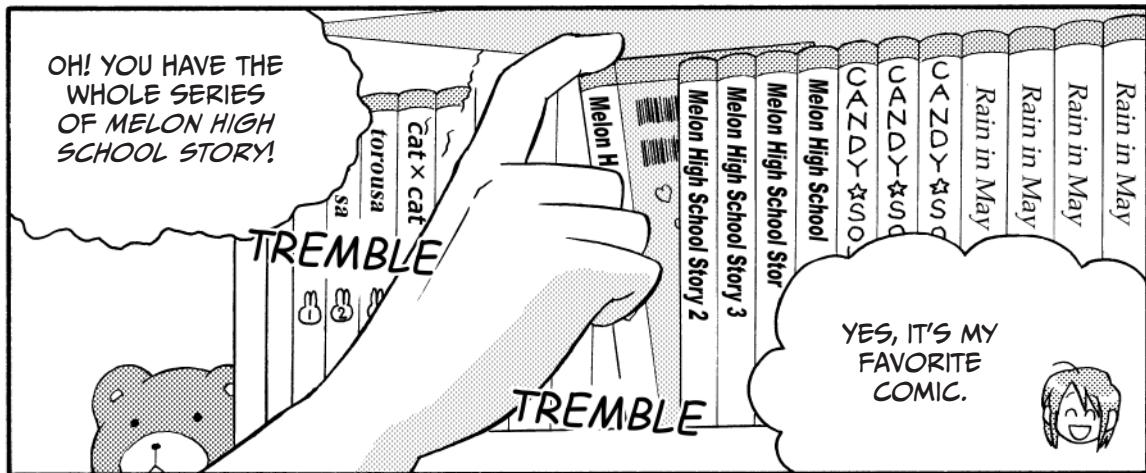
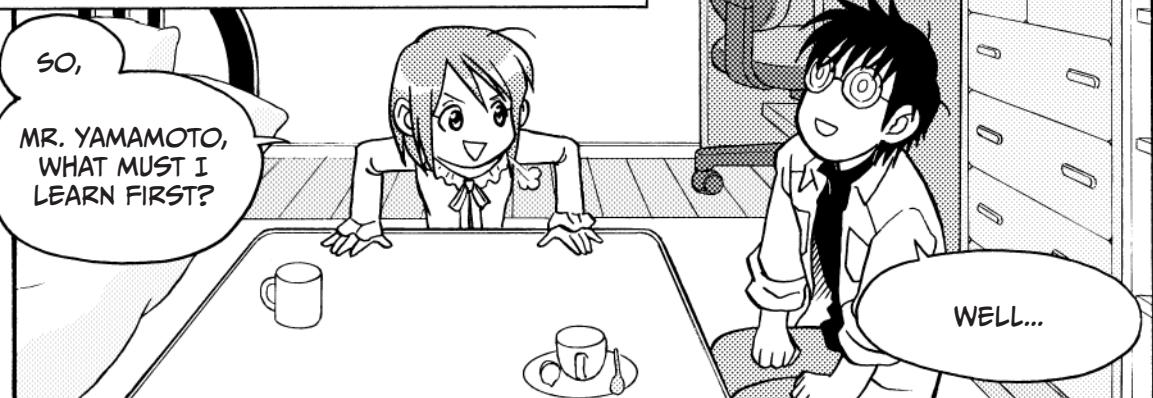
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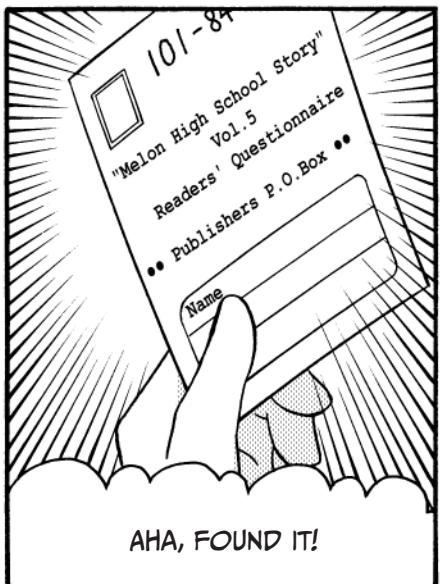


1

## DETERMINING DATA TYPES

## 1. CATEGORICAL DATA AND NUMERICAL DATA





## Melon High School Story Vol. 5 Reader Questionnaire

Q1. What is your impression of *Melon High School Story Vol. 5*?

1. Very fun
2. Rather fun
3. Average
4. Rather boring
5. Very boring

Q2. Sex

1. Female
2. Male

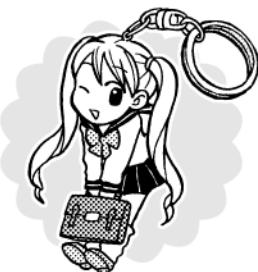
Q3. Age

\_\_\_\_\_ years old

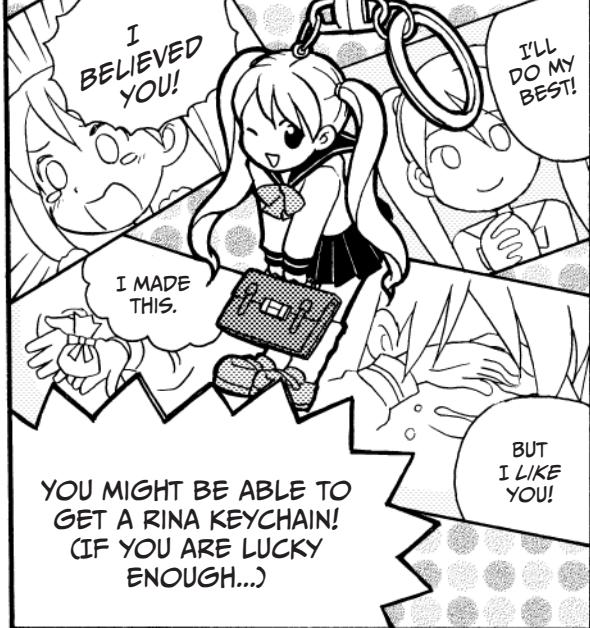
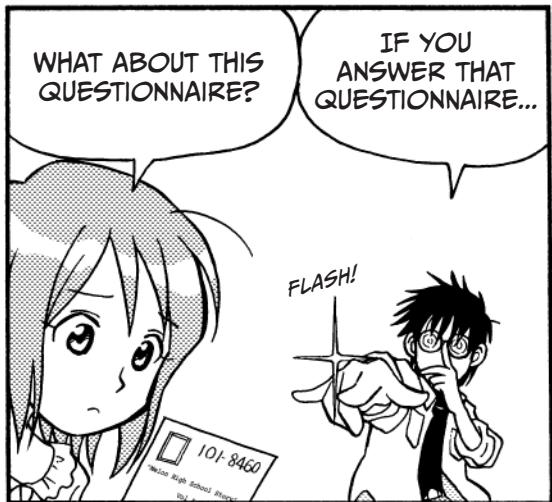
Q4. How many comics do you purchase per month?

\_\_\_\_\_ titles

A Rina keychain will be given away to 30 lucky winners among those who send back this questionnaire!

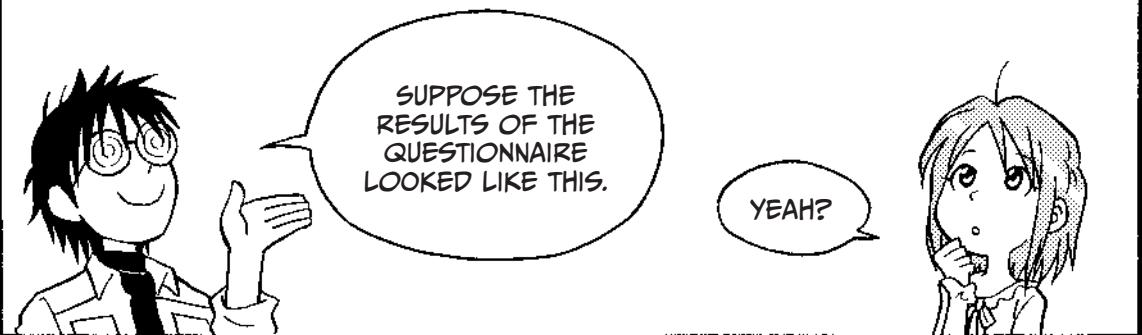


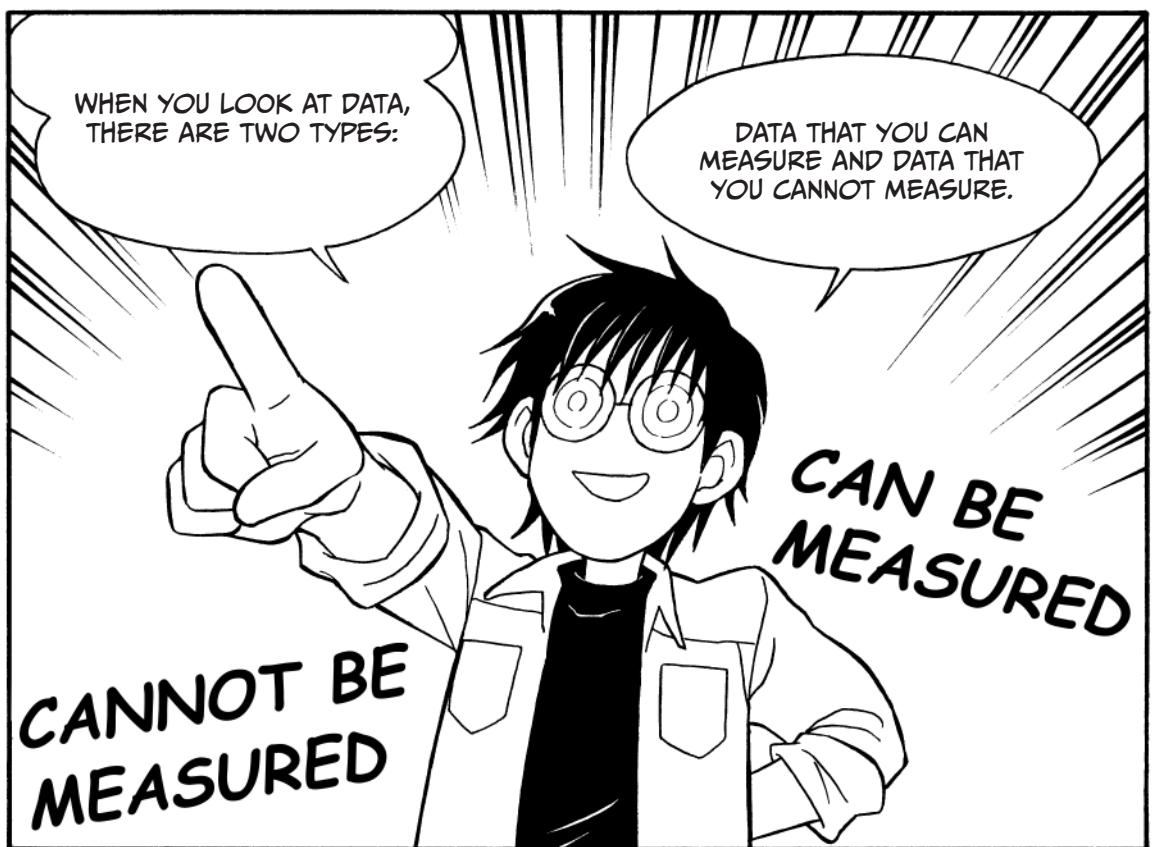
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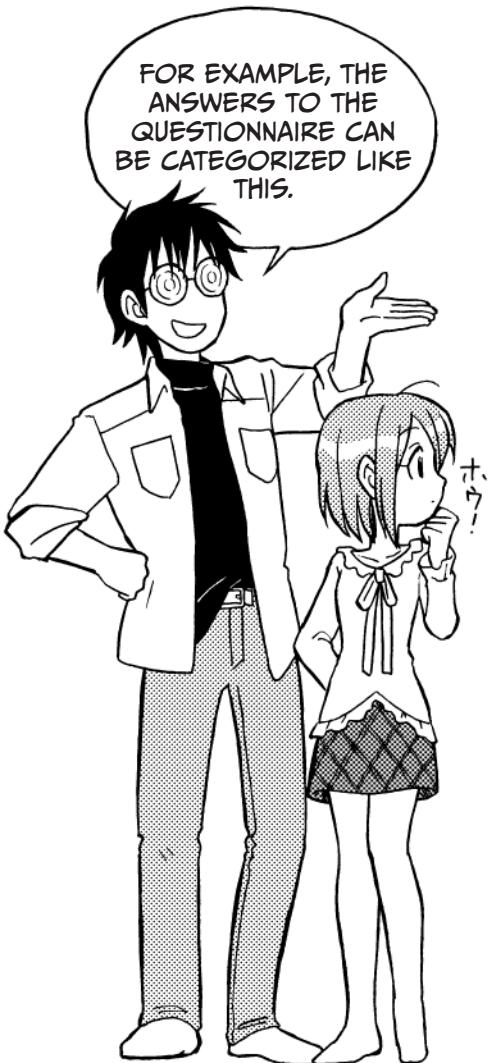


## QUESTIONNAIRE RESULTS

RESPONDENT	Q1 YOUR IMPRESSION OF MELON HIGH SCHOOL STORY	Q2 SEX	Q3 AGE	Q4 COMIC BOOK PURCHASES PER MONTH
RUI	VERY FUN	FEMALE	17	2
A	RATHER FUN	FEMALE	17	1
B	AVERAGE	MALE	18	5
C	RATHER BORING	MALE	22	7
D	RATHER FUN	FEMALE	25	4
E	VERY BORING	MALE	20	3
F	VERY FUN	FEMALE	16	1
G	RATHER FUN	FEMALE	17	2
H	AVERAGE	MALE	18	0
I	AVERAGE	FEMALE	21	3
...	...	...	...	...







## Melon High School Story Vol. 5 Reader Questionnaire

Q1. What is your impression of  
*Melon High School Story Vol. 5?*

- 1. Very fun
- 2. Rather fun
- 3. Average
- 4. Rather boring
- 5. Very boring

**CANNOT BE  
MEASURED**

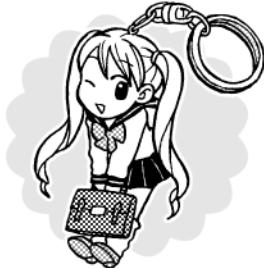
Q2. Sex

- 1. Female
- 2. Male

Q3. Age 17 years old

Q4. How many titles purchase per month? CAN BE MEASURED titles

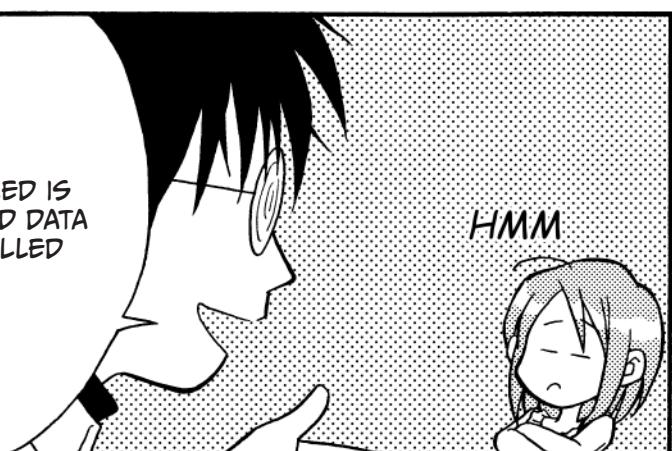
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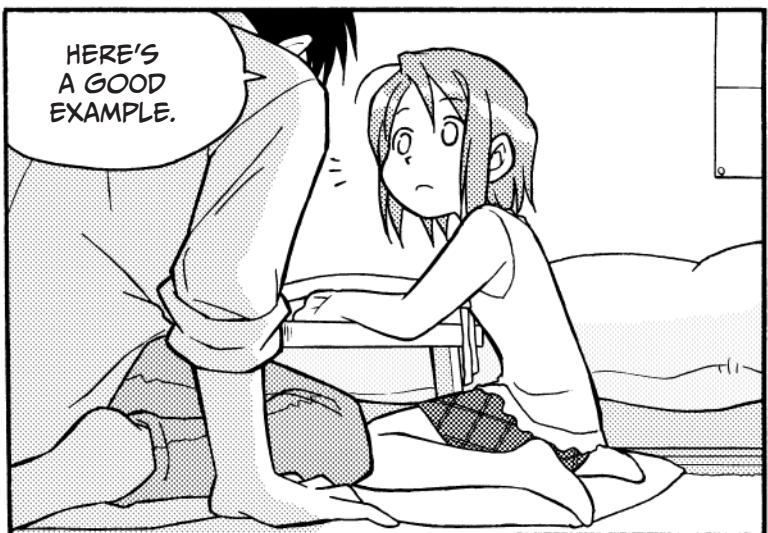
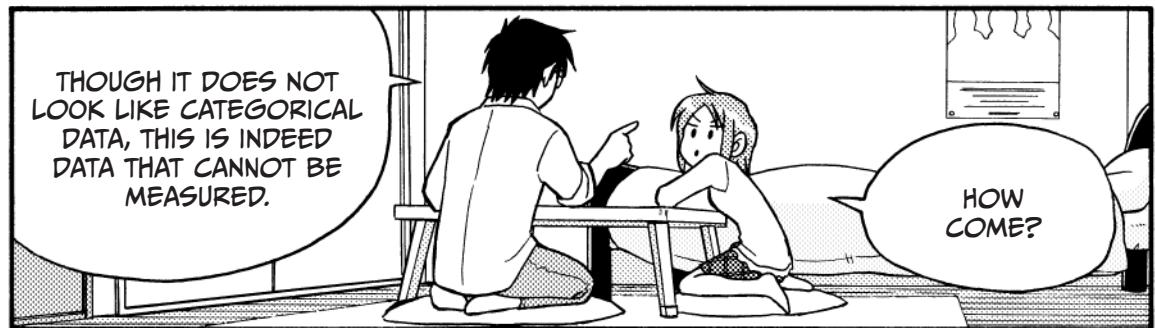
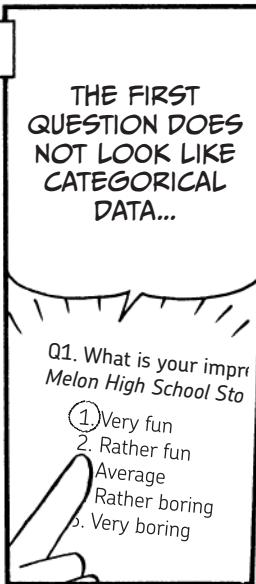
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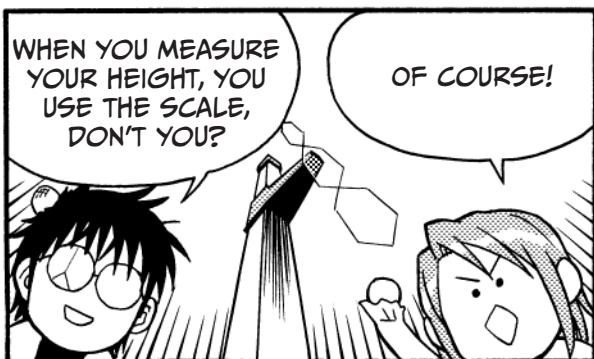
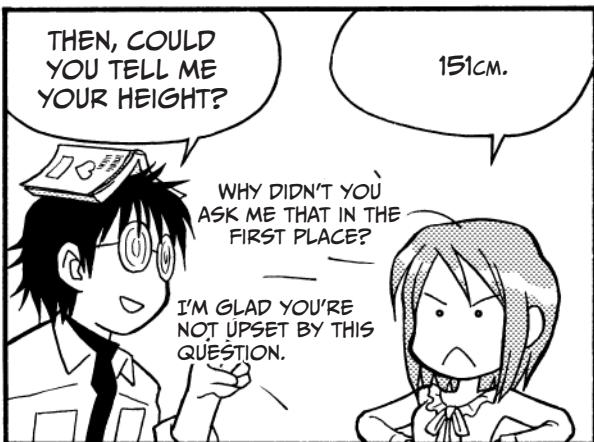
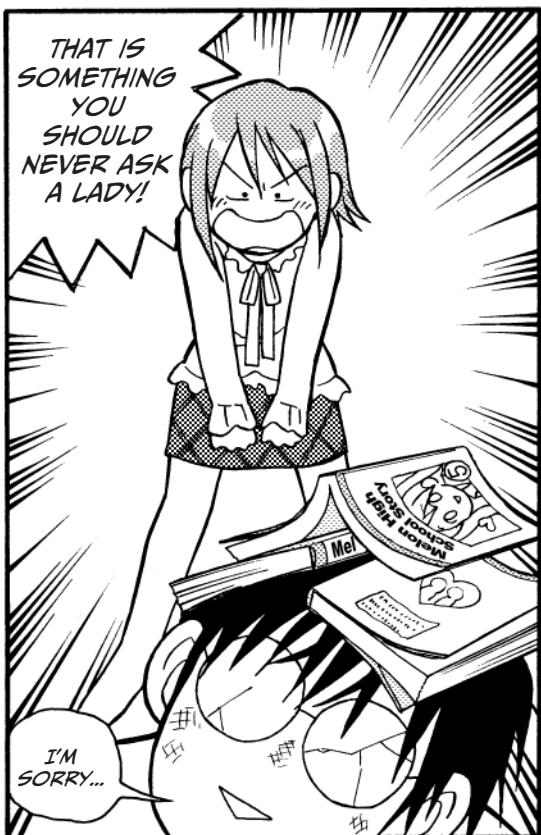
DATA THAT CANNOT BE MEASURED IS CALLED CATEGORICAL DATA, AND DATA THAT CAN BE MEASURED IS CALLED NUMERICAL DATA.\*

\* CATEGORICAL DATA IS ALSO SOMETIMES CALLED QUALITATIVE, AND NUMERICAL DATA IS SOMETIMES CALLED QUANTITATIVE.



## 2. AN EXAMPLE OF TRICKY CATEGORICAL DATA





# POM!

151CM EXACTLY.

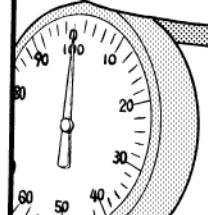
IT'S DIVIDED INTO SINGLE CENTIMETERS.

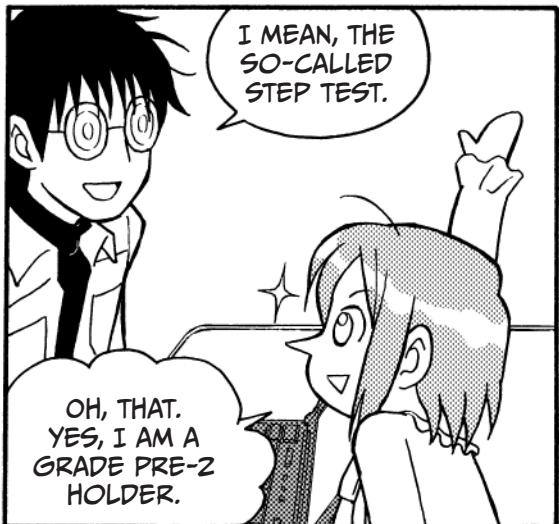
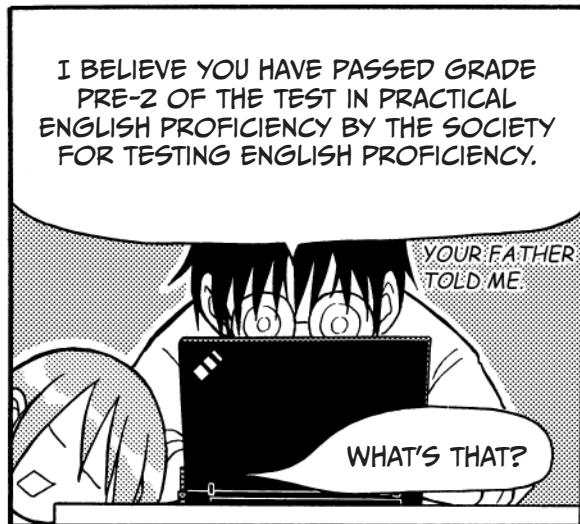
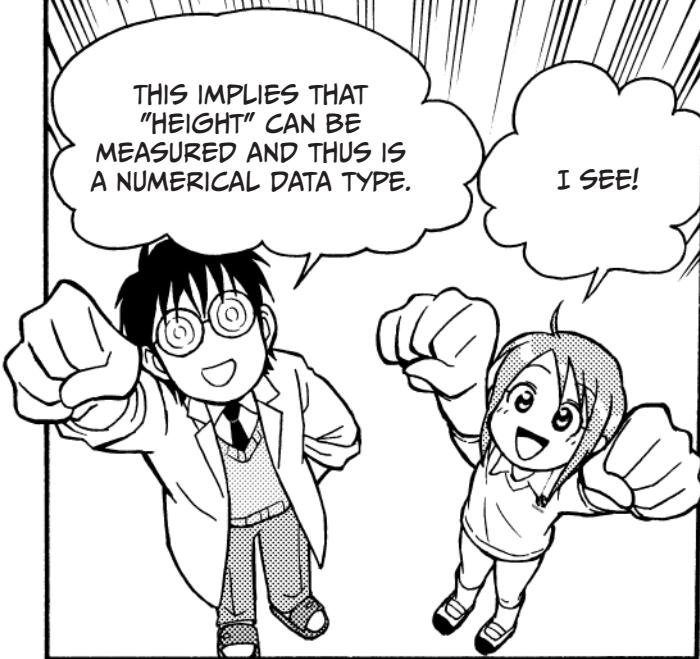
SO THE GRADUATION ABOVE 151CM IS 152, AND IT PROCEEDS TO 153, 154, AND SO ON, IN EQUAL INTERVALS.

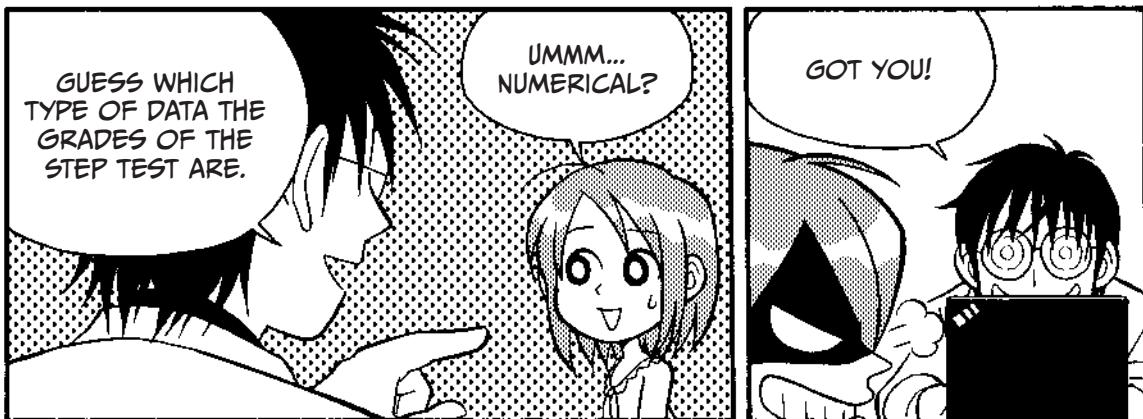
LOOK AT THIS SCALE.

YEAH.

IF THE INTERVALS BETWEEN EACH GRADUATION ARE EQUAL...



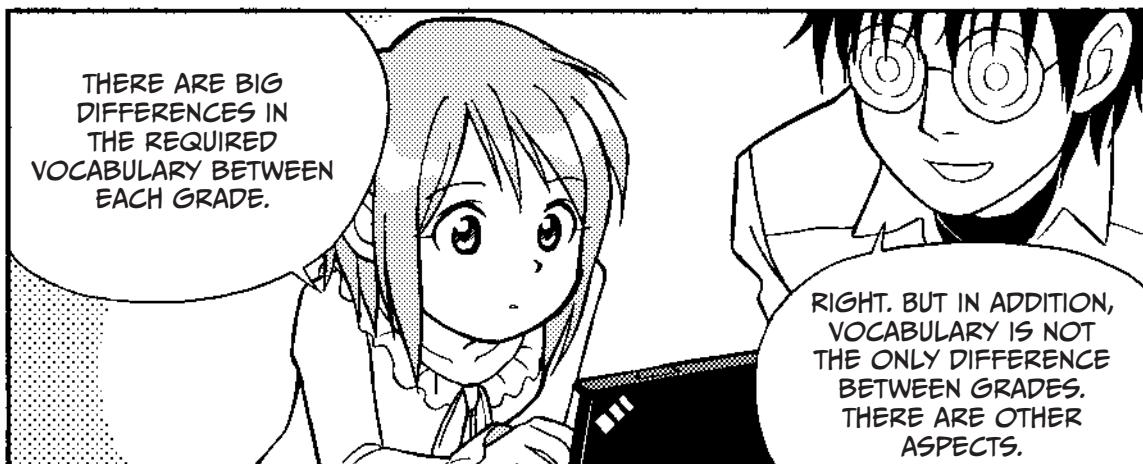
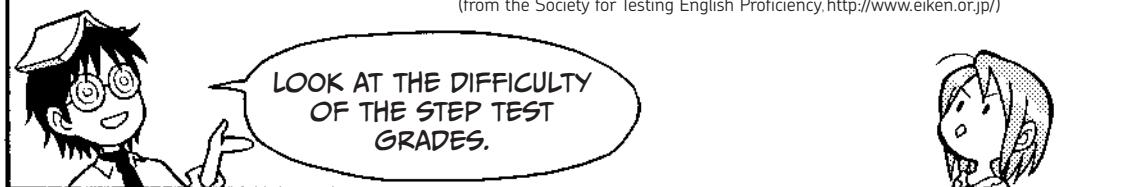


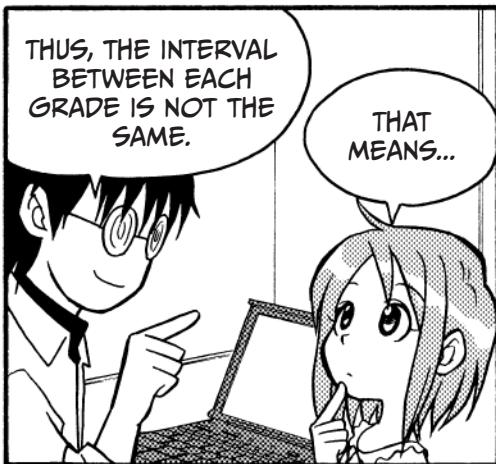


### THE STEP TEST GRADES

Grade	Requirements
Grade 1	Advanced university graduate level, vocabulary 10,000–15,000 words
Grade 2	High school graduate level, vocabulary 5,100 words
Grade 3	Junior high school graduate level, vocabulary 2,100 words
Grade 4	Intermediate junior high school level, vocabulary 1,300 words
Grade 5	Beginner junior high school level, vocabulary 600 words

(from the Society for Testing English Proficiency, <http://www.eiken.or.jp/>)





NOW, YOU SHOULD BE ABLE TO ANSWER THIS QUESTION.

### Melon High School Story Vol. 5 Reader Questionnaire

Q1. What is your impression of Melon High School Story Vol. 5?

- 1. Very fun
- 2. Rather fun
- 3. Average
- 4. Rather boring
- 5. Very boring

Q2. Sex

- 1. Female
- 2. Male

Q3. Age

Q4. How many comics do you purchase per month?

17 years old

2 titles

DO THE ANSWERS TO Q1 HAVE EQUAL INTERVALS?

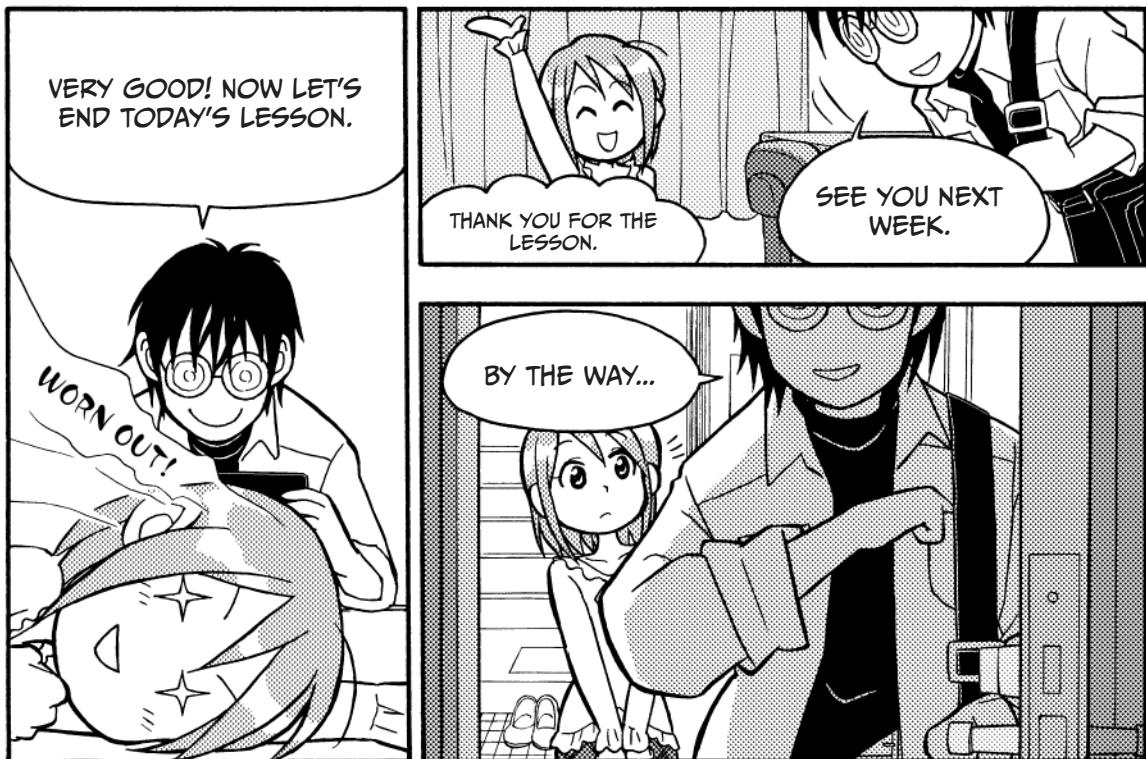
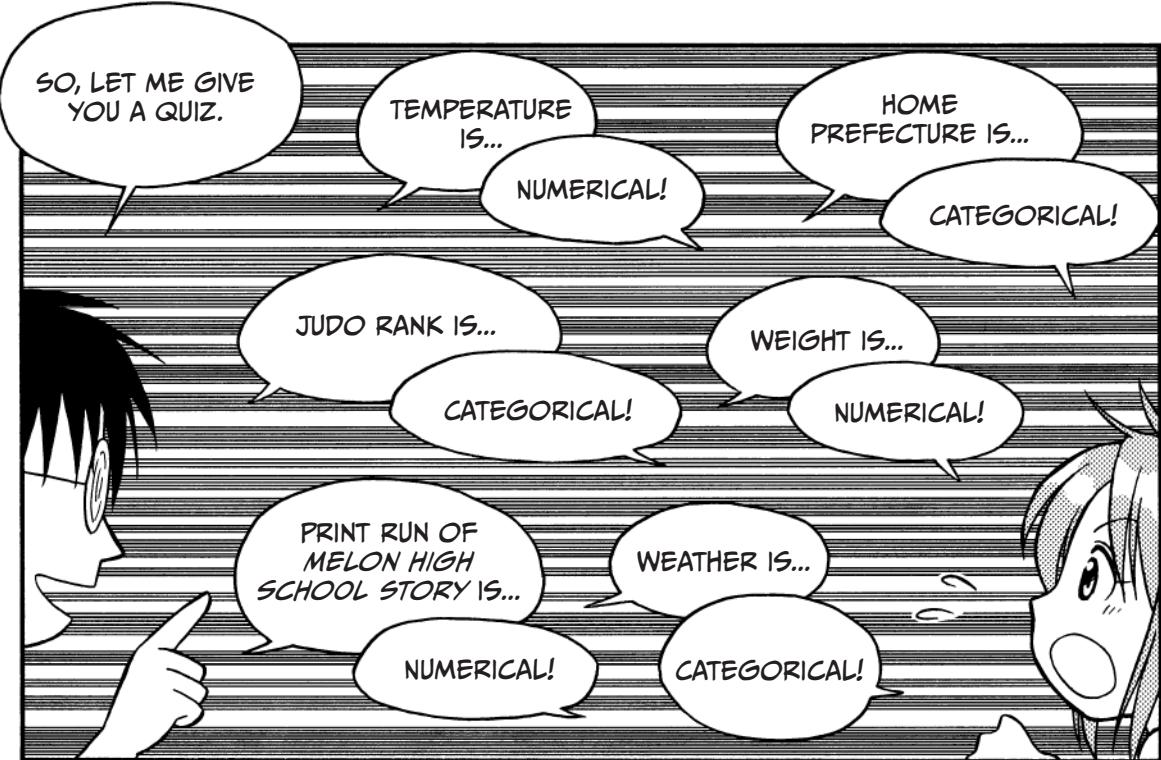
NO!  
THEY DO NOT.

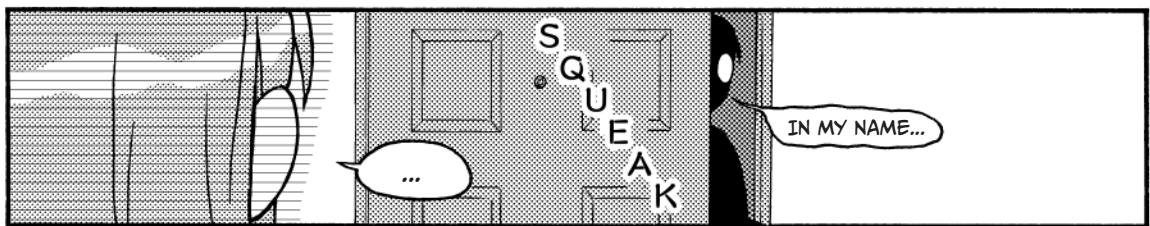
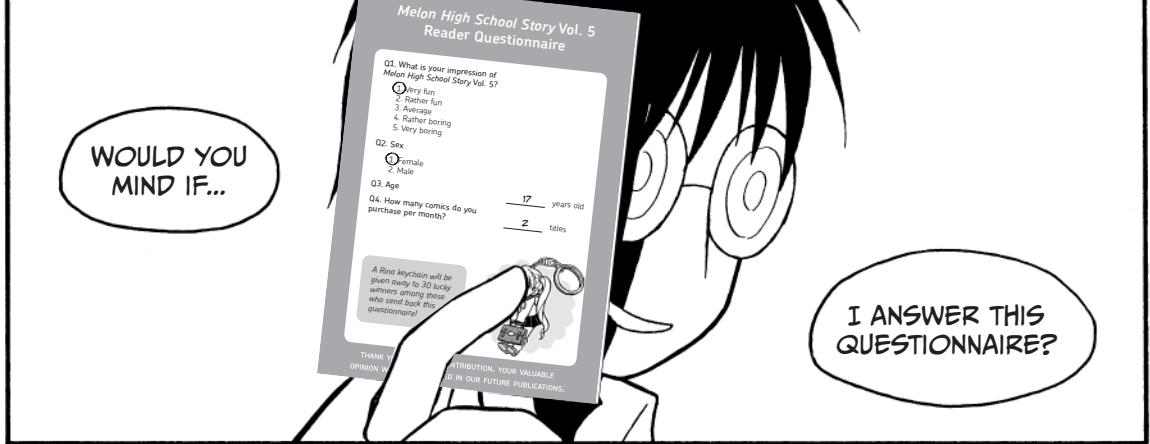
THAT DEPENDS ON EACH PERSON'S TASTE...

THEY ARE CATEGORICAL DATA.

CORRECT!

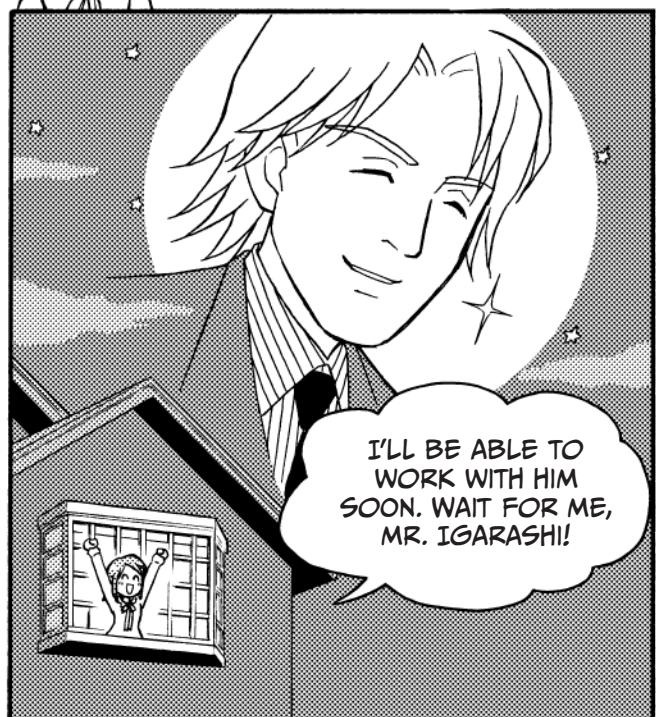
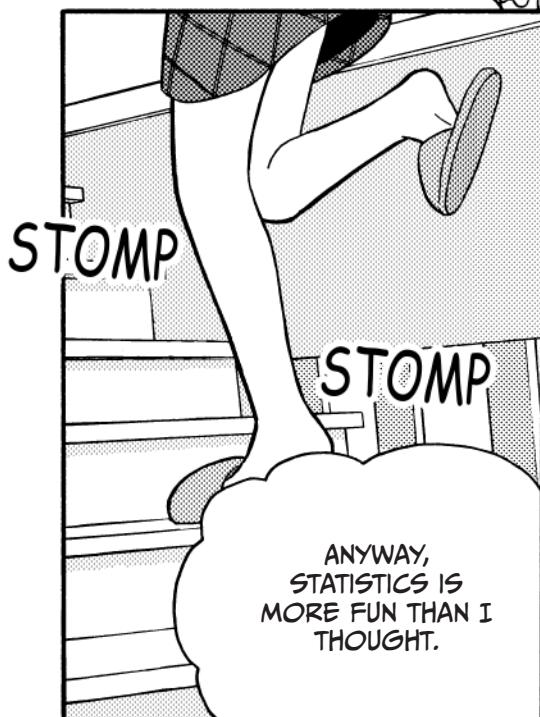






HE SURE IS A WEIRDO!

BANG



### 3. HOW MULTIPLE-CHOICE ANSWERS ARE HANDLED IN PRACTICE



As mentioned on page 25, the multiple-choice answers for the first question of the readers' questionnaire are categorical data. However, in practice, it is possible to handle such data as numerical data when processing consumer questionnaires and so on. Some examples are below.

Very fun	⇒	5 points
Rather fun	⇒	4 points
Average	⇒	3 points
Rather boring	⇒	2 points
Very boring	⇒	1 point

Very fun	⇒	2 points
Rather fun	⇒	1 point
Average	⇒	0 points
Rather boring	⇒	-1 points
Very boring	⇒	-2 points

The same data is handled differently in theory and in practice. Keep in mind that data may be categorized differently in different situations.

## EXERCISE AND ANSWER

### EXERCISE

Determine whether the data in the following table is categorical data or numerical data.

Respondent	Blood type	Opinion on sports drink X	Comfortable air conditioning temperature (°C)	100m track race record (seconds)
Mr./Ms. A	B	Not good	25	14.1
Mr./Ms. B	A	Good	24	12.2
Mr./Ms. C	AB	Good	25	17.0
Mr./Ms. D	O	Average	27	15.6
Mr./Ms. E	A	Not good	24	18.4
...	...	...	...	...

### ANSWER

Blood type and opinion on sports drink X are examples of categorical data. Comfortable air conditioning temperature and 100m track race record are examples of numerical data.

## SUMMARY

- Data is classified as categorical data or numerical data.
- Some data, such as “very fun” or “very boring,” is theoretically categorical data. However, in practice, it is possible to treat it as numerical data.

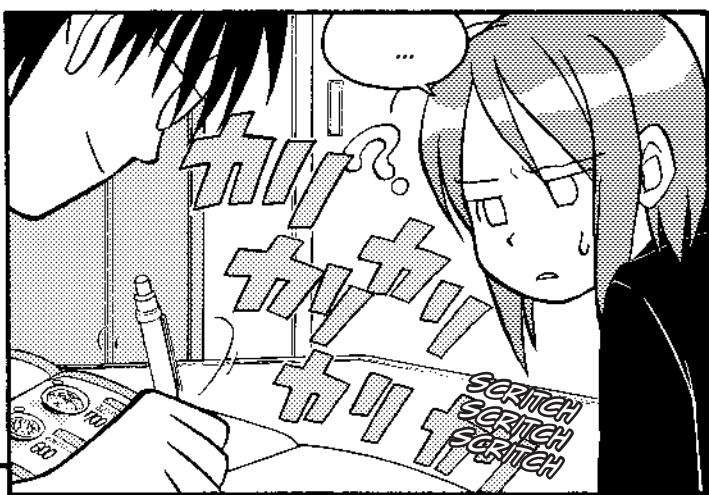


# Z

GETTING THE BIG PICTURE:  
UNDERSTANDING NUMERICAL DATA

# 1. FREQUENCY DISTRIBUTION TABLES AND HISTOGRAMS





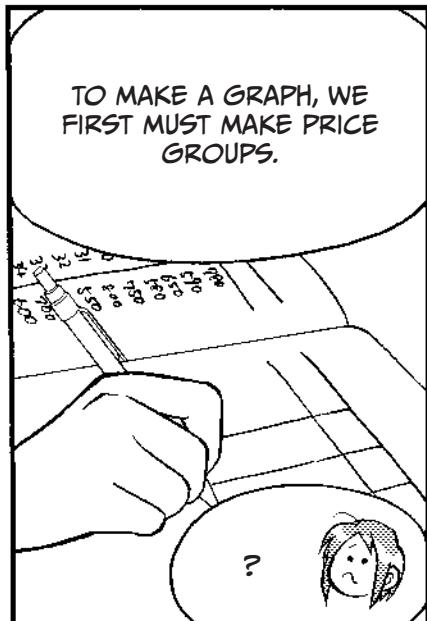
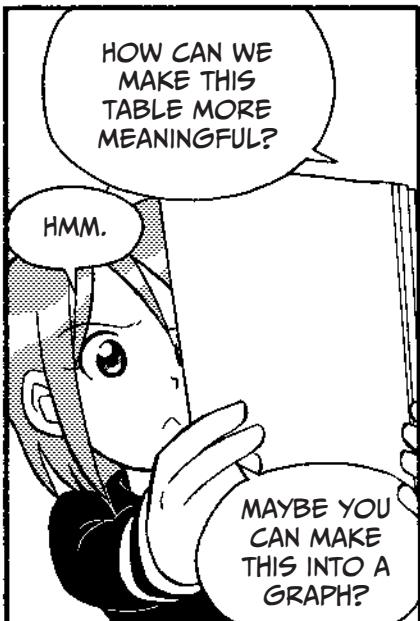
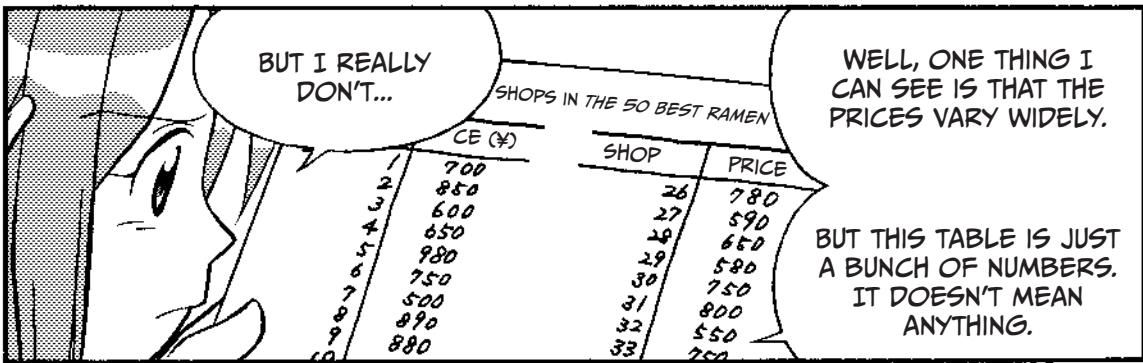
PRICES AT RAMEN SHOPS IN THE 50 BEST RAMEN SHOPS

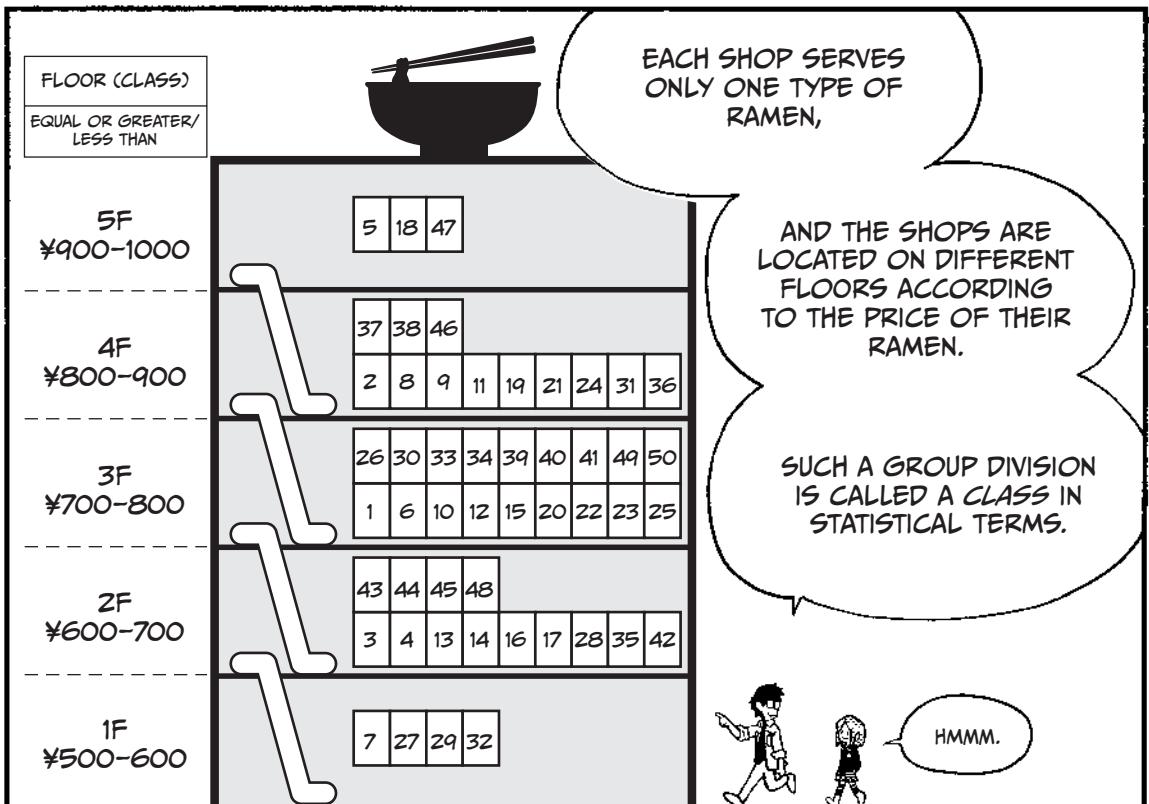
SHOP	PRICE (¥)	SHOP	PRICE (¥)
1	700	26	780
2	850	27	590
3	600	28	650
4	650	29	580
5	980	30	750
6	750	31	800
7	500	32	550
8	890	33	750
9	880	34	700
10	700	35	600
11	890	36	800
12	720	37	800
13	680	38	880
14	650	39	790
15	790	40	790
16	670	41	780
17	680	42	600
18	900	43	670
19	880	44	680
20	720	45	650
21	850	46	890
22	700	47	930
23	780	48	650
24	850	49	777
25	750	50	700

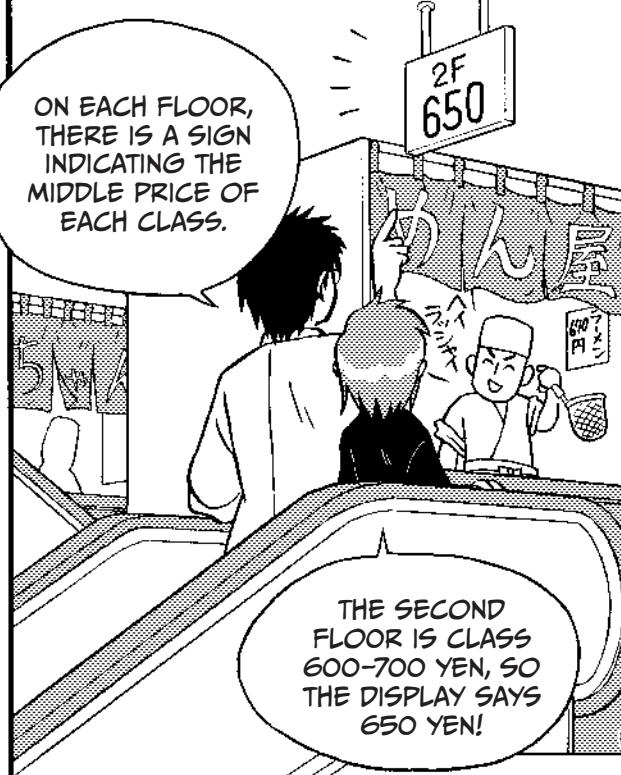
I MADE A PRICE CHART.

YOU START THE LESSON SO SUDDENLY.

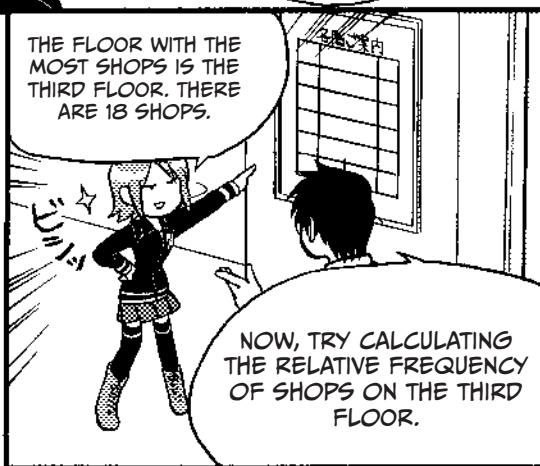
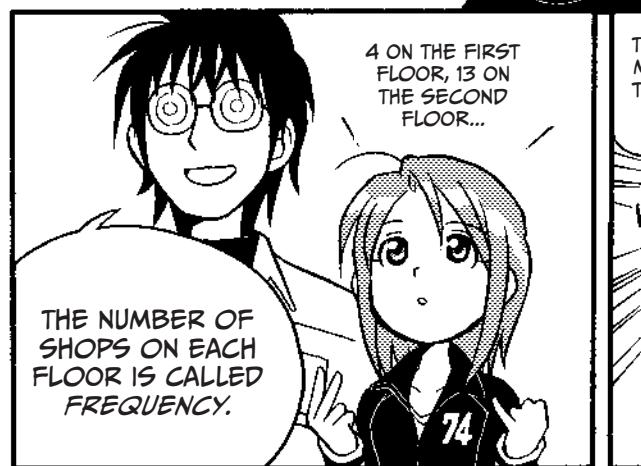
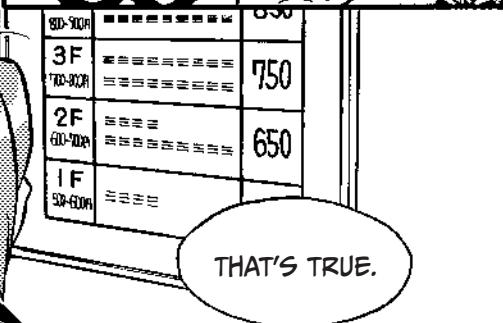
WEIRD!

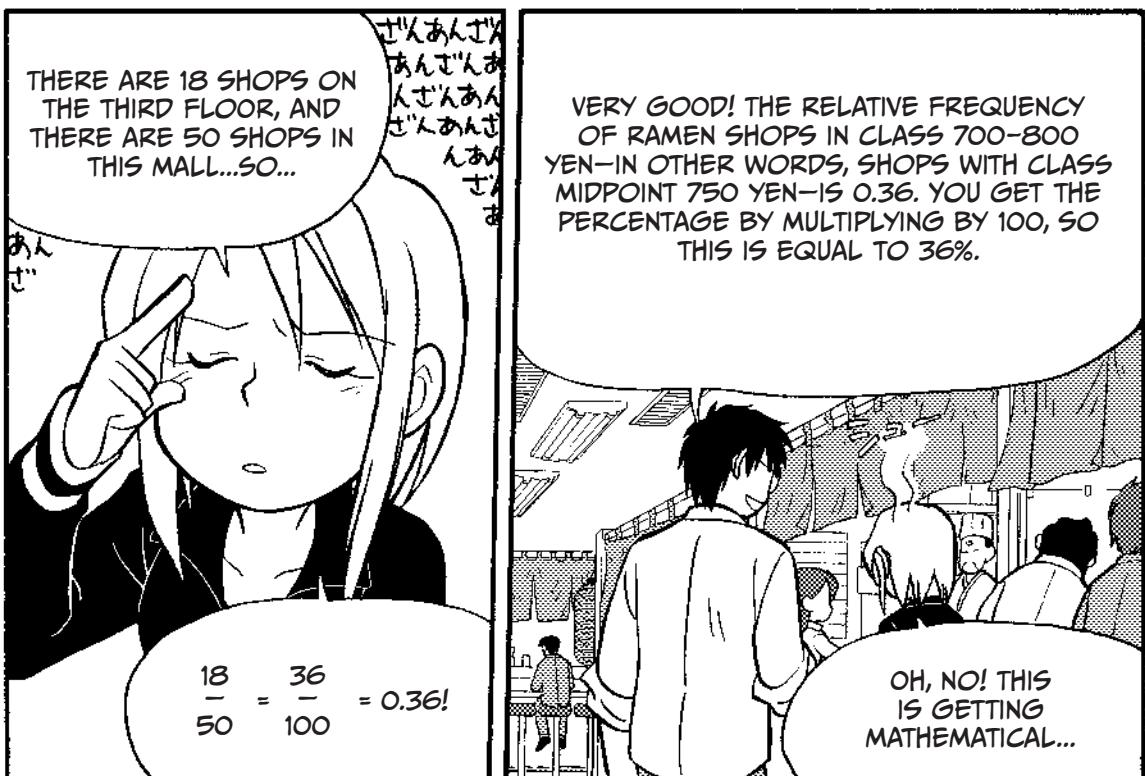
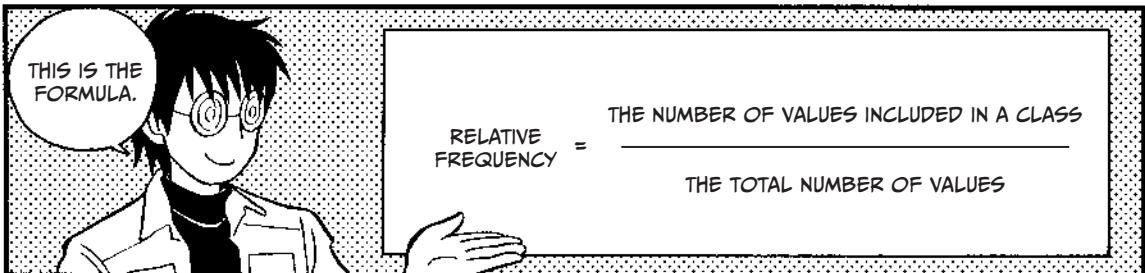
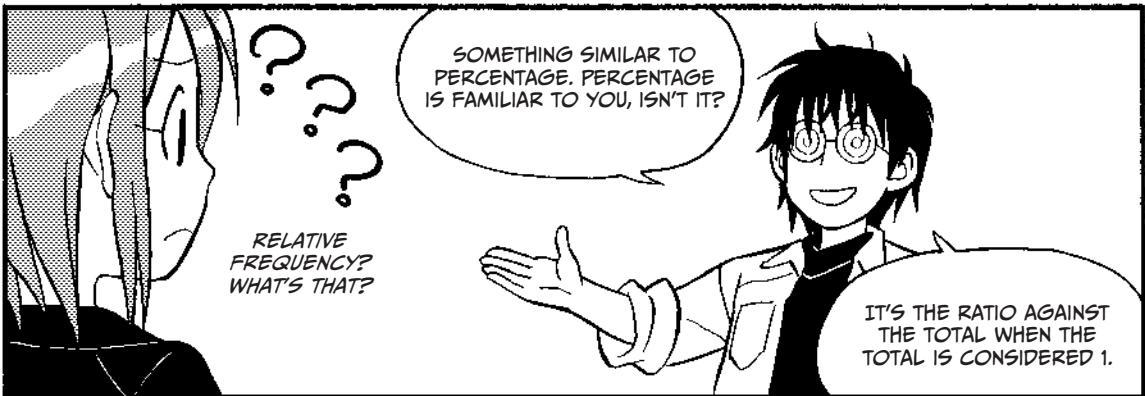






FLOOR GUIDE		
FLOOR	SHOP NAME	CLASS MIDPOINT
2F	¥900-1000	950
4F	¥800-900	850
3F	¥700-800	750
2F	¥600-700	650
1F	¥500-600	550

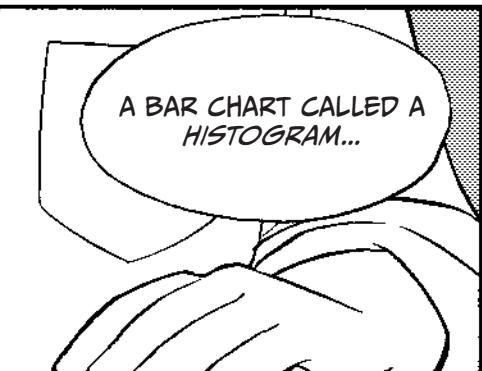
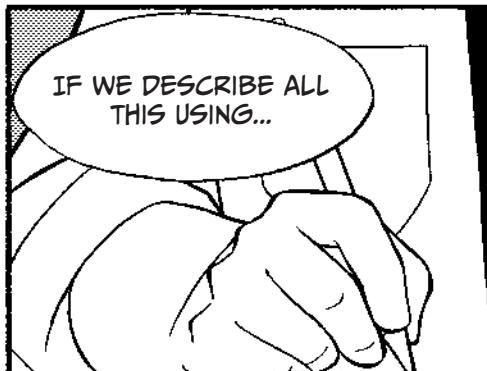






50 BEST RAMEN SHOPS FREQUENCY TABLE

CLASS (EQUAL OR GREATER/ LESS THAN)	CLASS MIDPOINT	FRE-QUENCY	RELATIVE FREQUENCY
500-600	550	4	0.08
600-700	650	13	0.26
700-800	750	18	0.36
800-900	850	12	0.24
900-1000	950	3	0.06
SUM		50	1.00



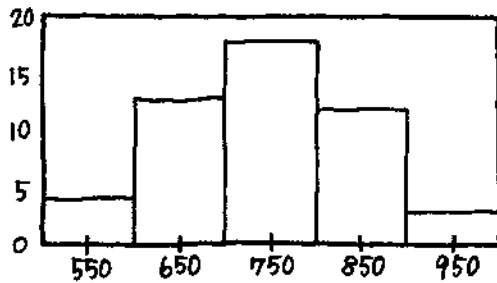
OUR HORIZONTAL AXIS SHOWS THE VARIABLES— IN THIS CASE, THE PRICE OF RAMEN.

THE WIDTH OF EACH BAR IS THE RANGE OF THE CLASS.

THE CENTER OF EACH BAR IS THE CLASS MIDPOINT.

HISTOGRAMS BASED ON 50 BEST RAMEN SHOPS FREQUENCY TABLE

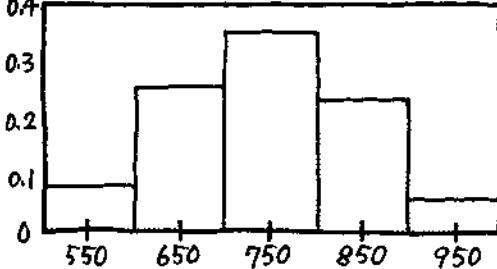
HISTOGRAM (VERTICAL AXIS IS FREQUENCY)



THE VERTICAL AXIS SHOWS THE FREQUENCY IN THE FIRST HISTOGRAM

AND THE RELATIVE FREQUENCY IN THE SECOND HISTOGRAM.

HISTOGRAM  
(VERTICAL AXIS IS RELATIVE FREQUENCY)



IS THIS EASIER TO UNDERSTAND?

WELL...

I FEEL LIKE I AM SORT OF BEGINNING TO...

GRASP THE OVERALL IMAGE OF RAMEN PRICES.

TO "FEEL LIKE" GRASPING IS IMPORTANT. THE FREQUENCY TABLE AND HISTOGRAM EXIST TO GIVE YOU A BETTER SENSE OF ALL THE DATA.

IS THAT SO?

2. MEAN (AVERAGE)

THE OTHER DAY, I WENT BOWLING WITH ALL THE GIRLS IN MY HOMEROOM CLASS.

DID YOU KNOCK OVER ANY PINS?

WHAT?! I'LL KNOCK YOU OVER, YOU PINHEAD!

I'M GOOD AT BOWLING!

74

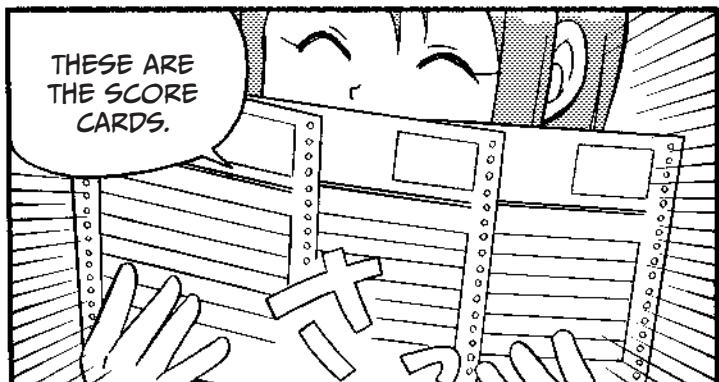
JUST KIDDING!

ALL THE GIRLS IN YOUR HOMEROOM CLASS...THAT MUST BE A LOT.



WELL, THERE WERE 18 OF US, SO WE FORMED 3 TEAMS OF 6, AND PLAYED 1 GAME.

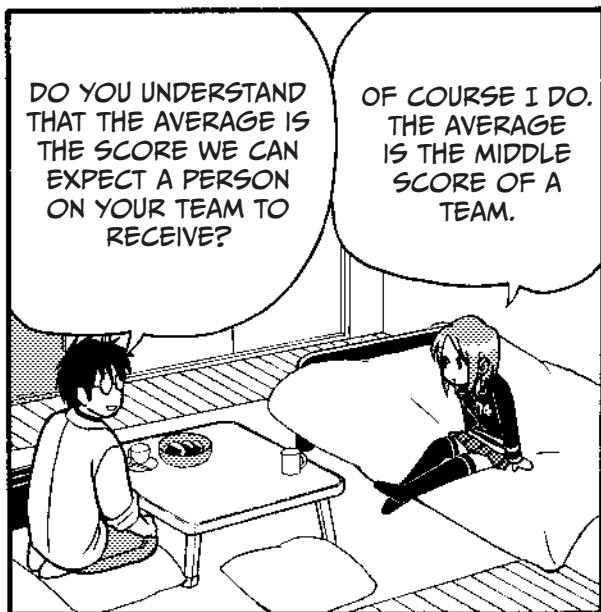
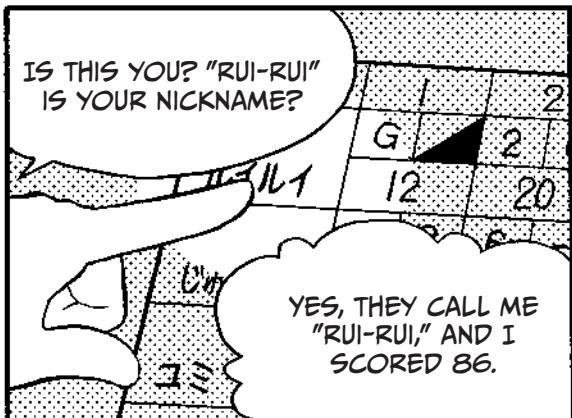
THESE ARE THE SCORE CARDS.



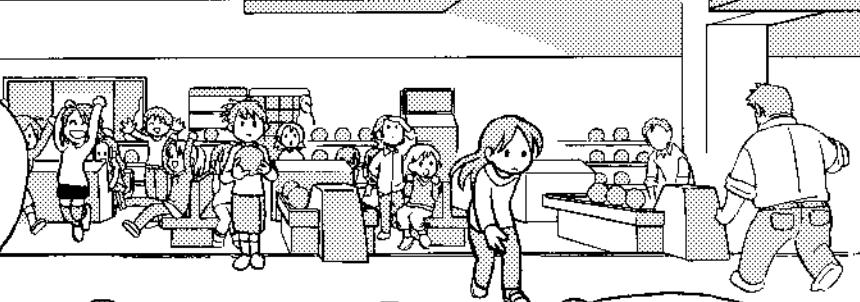


### RESULTS OF BOWLING TOURNAMENT

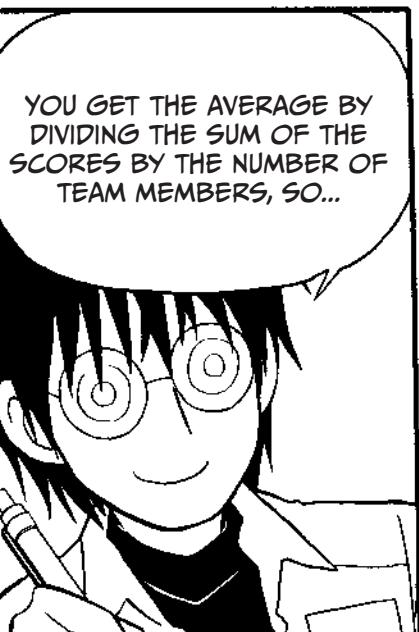
TEAM A		TEAM B		TEAM C	
PLAYER	SCORE	PLAYER	SCORE	PLAYER	SCORE
RUI-RUI	86	KIMIKO	84	SHINOBU	229
JUN	73	MEGUMI	71	YUKA	77
YUMI	124	YOSHIMI	103	SAKURA	59
SHIZUKA	111	MEI	85	KANAKO	95
TOUKO	90	KAORI	90	KUMIKO	70
KAEDE	38	YUKIKO	89	HIRONO	88



SINCE THE GAME WAS PLAYED BETWEEN TEAMS, I GUESS YOU COMPARED THE SUM OF THE SCORES OF EACH TEAM.



EXACTLY.



YOU GET THE AVERAGE BY DIVIDING THE SUM OF THE SCORES BY THE NUMBER OF TEAM MEMBERS, SO...

TEAM A

$$\frac{86+73+124+111+90+38}{6} = \frac{522}{6} = 87$$

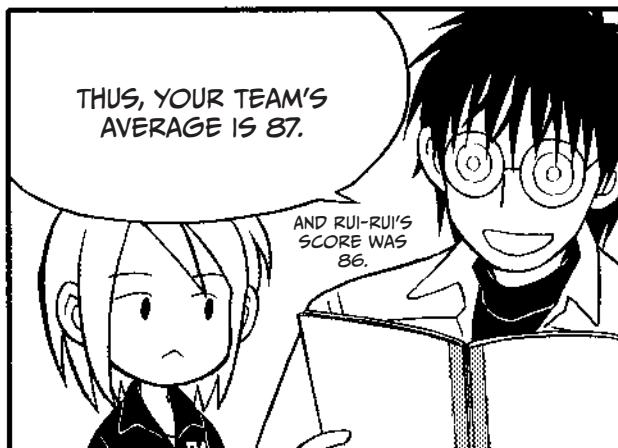
TEAM B

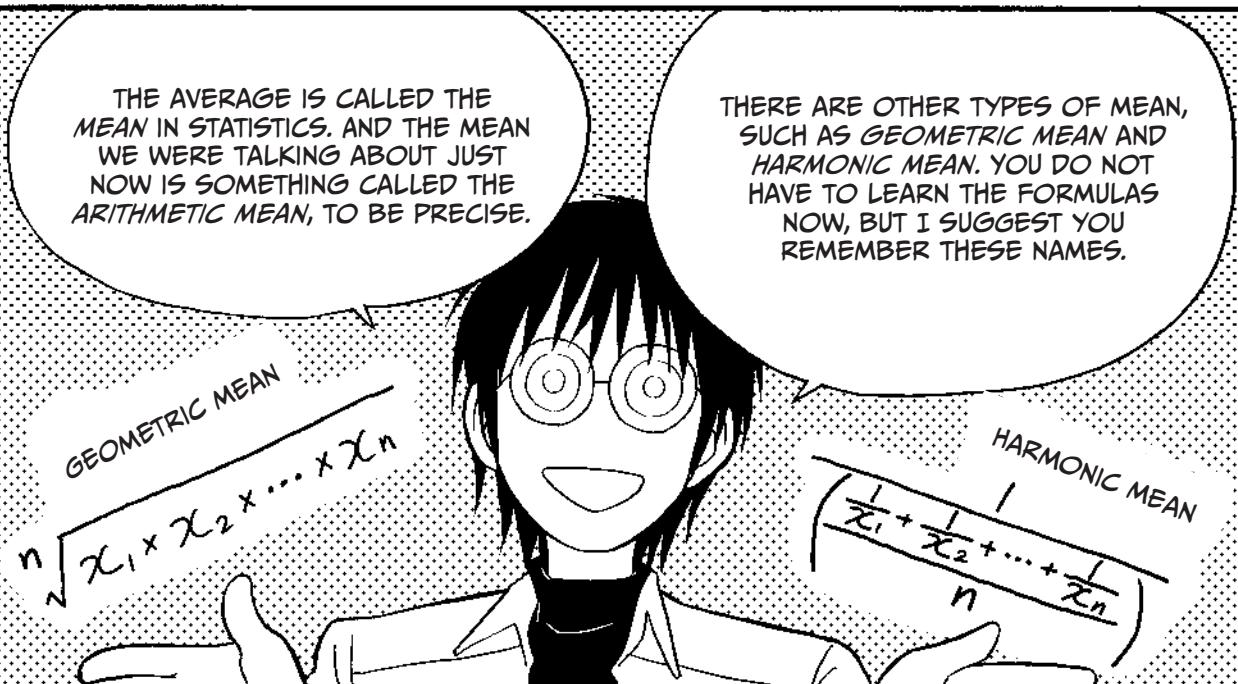
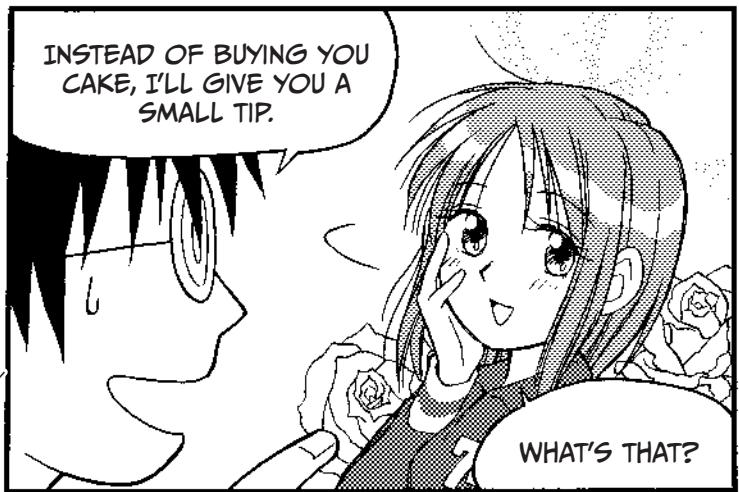
$$\frac{84+71+103+85+90+89}{6} = \frac{522}{6} = 87$$

TEAM C

$$\frac{229+77+59+95+70+88}{6} = \frac{618}{6} = 103$$

TEAM C IS SO STRONG.





3. MEDIAN

NOW, BACK TO THE SCORE CARD.

WHAT IS IT THIS TIME?

LET'S IGNORE TEAMS A AND B FOR NOW, AND LOOK AT TEAM C...

RESULTS OF BOWLING TOURNAMENT

TEAM A

PLAYER	SCORE
RUI-RUI	86
JUN	73
YUMI	124
SHIZUKA	111
TOUKO	90
KAEDA	38

TEAM B

PLAYER	SCORE
KIMIKO	84
MEGUMI	71
YOSHIMI	103
MEI	85
KAORI	90
YUKIKO	89

TEAM C

PLAYER	SCORE
SHINOBU	229
YUKA	77
SAKURA	59
KANAKO	95
KUMIKO	70
HIRONO	88

HERE, I DON'T THINK YOU CAN REALLY SAY THAT THE AVERAGE IS "ROUGHLY THE SCORE OF EACH PERSON."

I AGREE. THE AVERAGE IS ABOVE 100...BUT 5 PEOPLE SCORED BELOW 100.

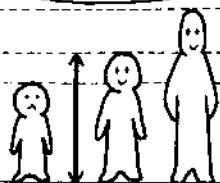
SHINOBU WAS VERY GOOD.

IN CASES LIKE THIS, WHEN THERE IS A VALUE THAT IS EXTREMELY LARGE OR SMALL,

IT IS MORE APPROPRIATE TO USE THE MEDIAN INSTEAD OF THE MEAN.

MEDIAN?

THE MEDIAN IS THE VALUE THAT COMES IN THE MIDDLE WHEN YOU PUT THE VALUES IN ORDER FROM SMALLEST TO LARGEST.



TEAM A

38	73	86	90	111	124
----	----	----	----	-----	-----

TEAM B

71	84	85	89	90	103
----	----	----	----	----	-----

TEAM C

59	70	77	88	95	229
----	----	----	----	----	-----

NUMBER OF VALUES = ODD

-1041.6	-39.0	-5.7	60.4	77.3
---------	-------	------	------	------

↑  
MEDIAN

NUMBER OF VALUES = EVEN

-0.4	35.2	37.8	42.2	46.1	910.3
------	------	------	------	------	-------

↑  
MEDIAN IS THE AVERAGE  
OF THESE TWO

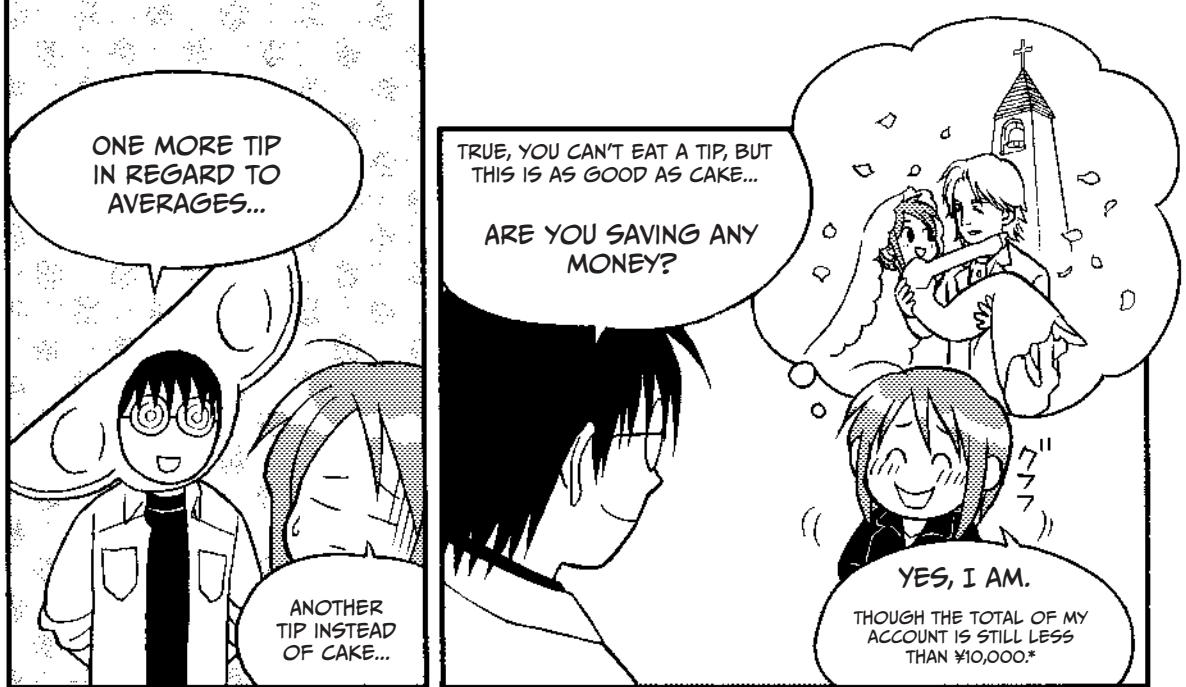
IF THE NUMBER OF VALUES IS ODD, THE SCORE THAT IS IN THE MIDDLE IS THE MEDIAN.

IF THE NUMBER OF VALUES IS EVEN, AS IN THE CASE OF THIS BOWLING GAME, THE AVERAGE OF THE TWO VALUES IN THE MIDDLE IS THE MEDIAN.

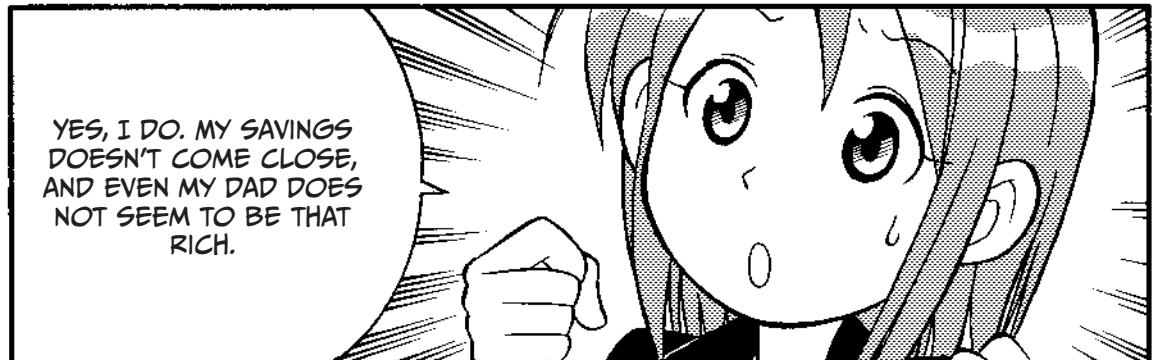
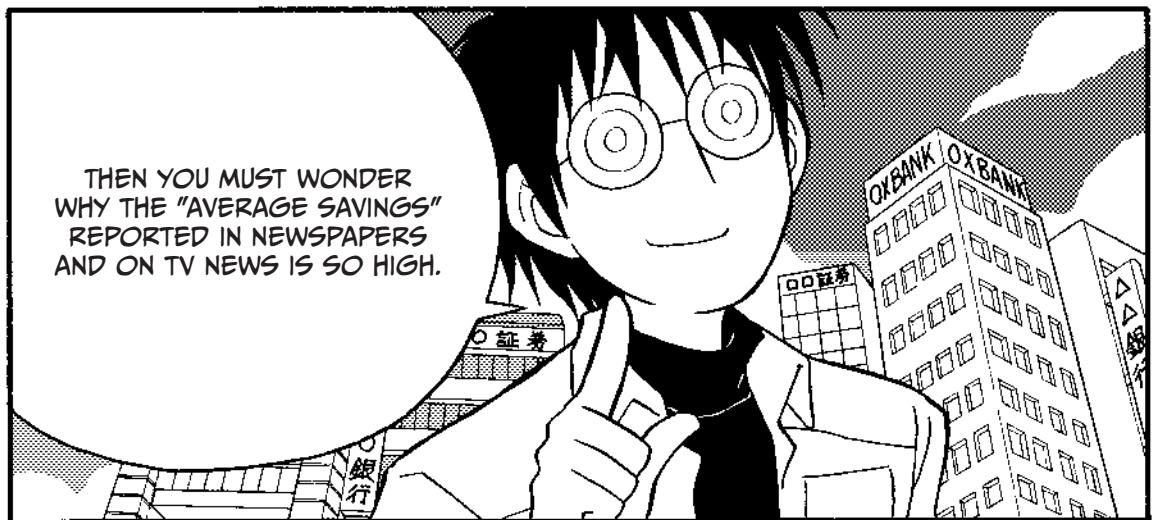
CAN YOU CALCULATE THE MEDIAN OF TEAM C?

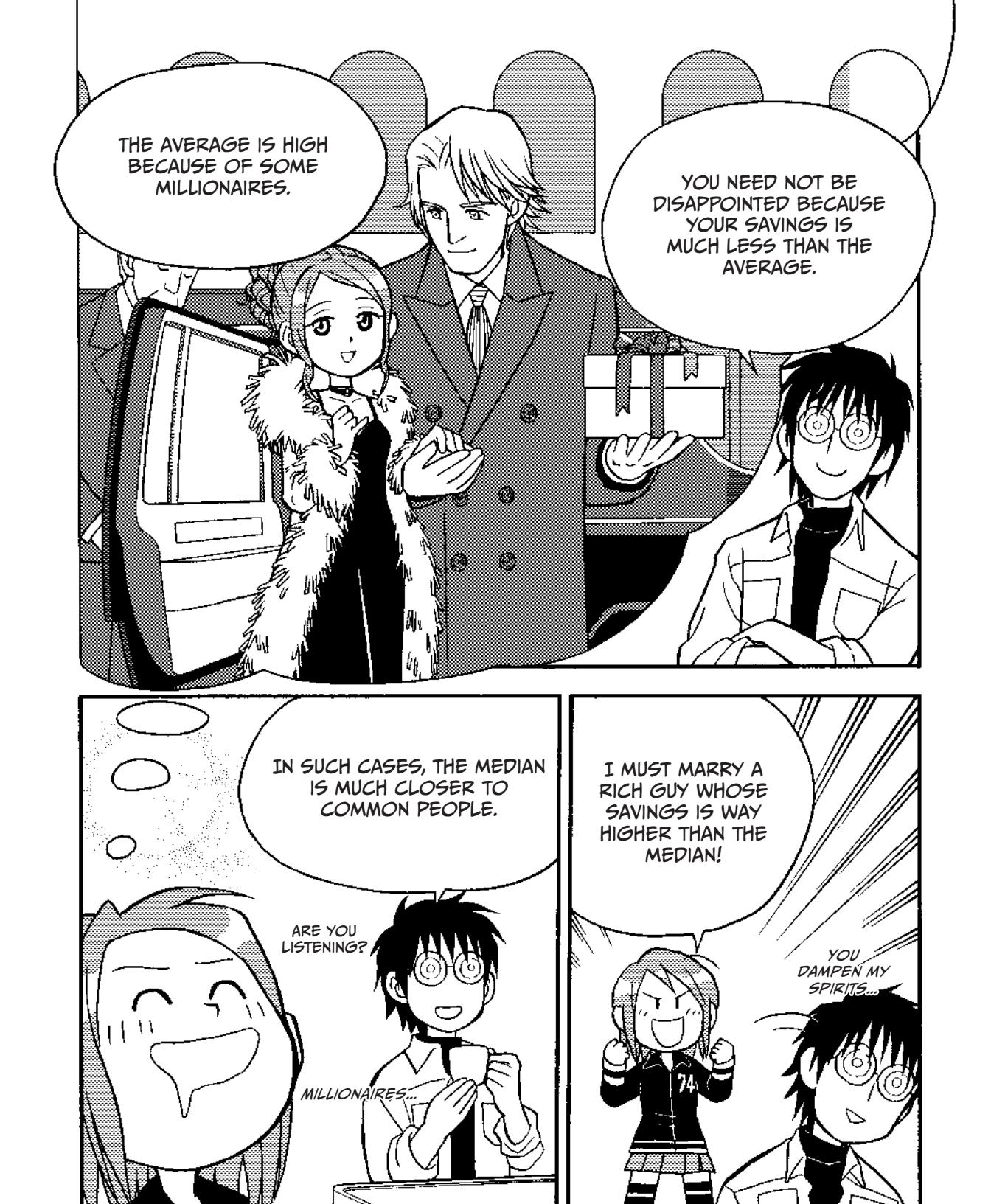
IT'S  
 $(77 + 88) \div 2 = 82.5$ .

CORRECT!



\*LESS THAN \$100





THE AVERAGE IS HIGH  
BECAUSE OF SOME  
MILLIONAIRES.

YOU NEED NOT BE  
DISAPPOINTED BECAUSE  
YOUR SAVINGS IS  
MUCH LESS THAN THE  
AVERAGE.

IN SUCH CASES, THE MEDIAN  
IS MUCH CLOSER TO  
COMMON PEOPLE.

ARE YOU  
LISTENING?

MILLIONAIRES...

I MUST MARRY A  
RICH GUY WHOSE  
SAVINGS IS WAY  
HIGHER THAN THE  
MEDIAN!

YOU  
DAMPEN MY  
SPIRITS...

#### 4. STANDARD DEVIATION

THIS TIME, LOOK AT  
THE SCORES OF

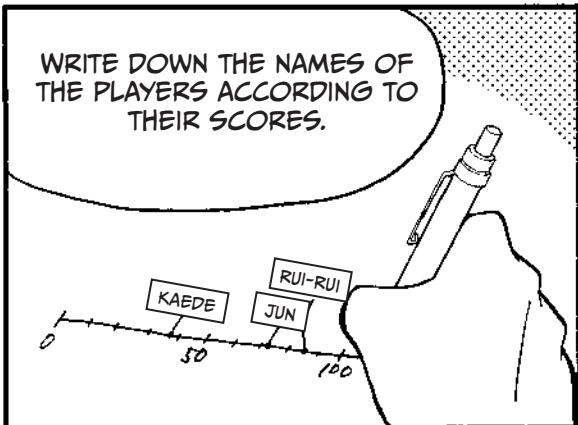
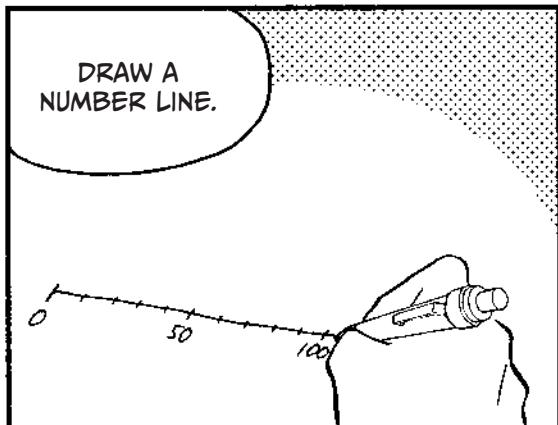
TEAM A AND  
TEAM B.

OKAY...



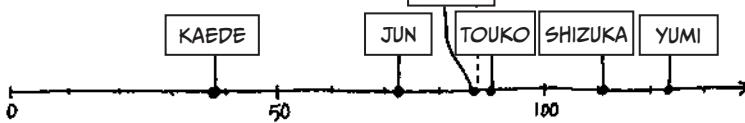
DRAW A  
NUMBER LINE.

WRITE DOWN THE NAMES OF  
THE PLAYERS ACCORDING TO  
THEIR SCORES.



TEAM A

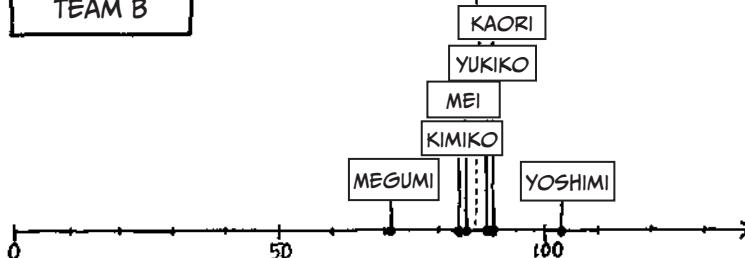
AVERAGE



EVEN THOUGH THE  
AVERAGE SCORE  
OF EACH TEAM  
WAS 87...

TEAM B

AVERAGE



THE TRENDS  
DESCRIBED BY THE  
NUMBER LINES ARE  
QUITE DIFFERENT.

THEY SURE ARE.  
TEAM A'S SCORES  
VARY FROM LOW TO  
HIGH, BUT TEAM B'S  
SCORES ARE MORE  
SIMILAR.

STANDARD DEVIATION  
IS USED TO DESCRIBE  
SUCH SCATTERING OF  
DATA.

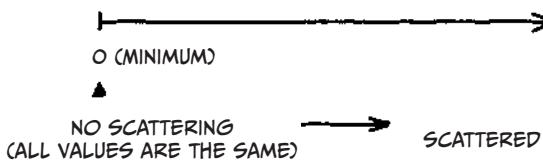
ANOTHER  
NEW TERM?!

IN SHORT, STANDARD  
DEVIATION IS AN  
INDICATOR TO SHOW  
THE DIFFERENCE  
FROM THE MEAN OF  
EACH VALUE IN THAT  
SET.

INDICATOR TO SHOW  
THE DIFFERENCE...?

THE MINIMUM STANDARD DEVIATION IS  
ZERO, AND AS THE "SCATTERING OF DATA"  
INCREASES, SO DOES THE STANDARD  
DEVIATION.

GUESS WHICH STANDARD  
DEVIATION IS LARGER, TEAM A'S  
OR TEAM B'S?



HMM...  
MAYBE TEAM A'S?

RIGHT. THE FORMULA  
IS AS FOLLOWS.

IT IS SUDDENLY  
STARTING TO  
SOUND LIKE  
MATHEMATICS.

SUM OF (EACH VALUE - MEAN)<sup>2</sup>

NUMBER OF VALUES

IT'S EASY. YOU JUST  
PUT SOME NUMBERS  
INTO THE FORMULA.

LET'S TRY IT  
TOGETHER.

OKAY, I'LL  
GIVE IT A  
TRY.

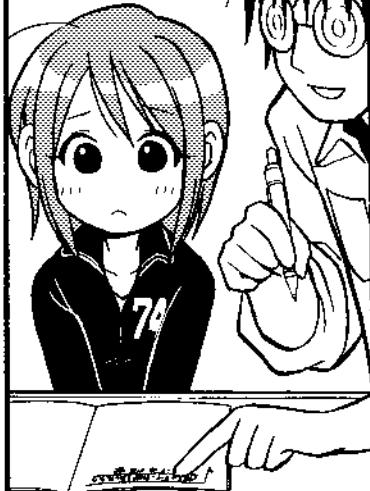
FIRST, TEAM A.

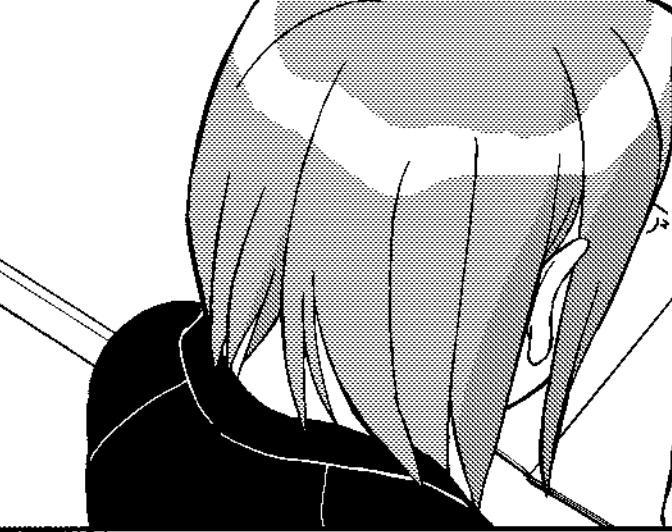
TEAM A

$$\begin{aligned} & \sqrt{\frac{(86-87)^2 + (73-87)^2 + (124-87)^2 + (111-87)^2 + (90-87)^2 + (38-87)^2}{6}} \\ &= \sqrt{\frac{(-1)^2 + (-14)^2 + 37^2 + 24^2 + 3^2 + (-49)^2}{6}} \\ &= \sqrt{\frac{1 + 196 + 1369 + 576 + 9 + 2401}{6}} \\ &= \sqrt{\frac{4552}{6}} \\ &= \sqrt{758.6\dots} \\ &\approx 27.5 \end{aligned}$$

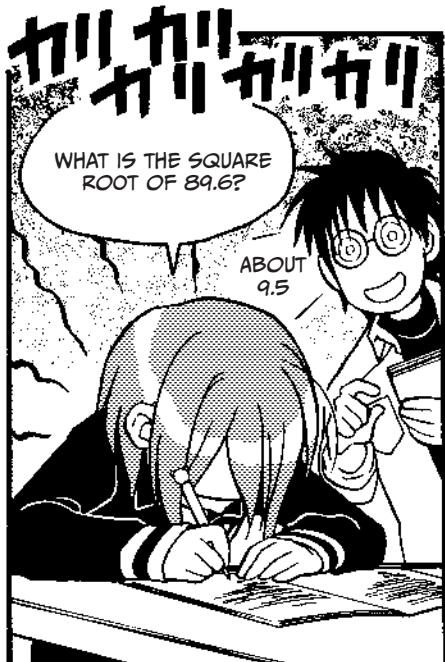
IT'S EASIER  
THAN I  
THOUGHT. I  
THINK I CAN  
DO THIS.

THEN TRY FIGURING  
OUT THE STANDARD  
DEVIATION OF TEAM B  
BY YOURSELF.





I PUT THIS NUMBER HERE, AND...



FINISHED! TEAM B

$$\begin{aligned} & \sqrt{\frac{(84-87)^2 + (71-87)^2 + (103-87)^2 + (85-87)^2 + (90-87)^2 + (89-87)^2}{6}} \\ &= \sqrt{\frac{(-3)^2 + (-16)^2 + 16^2 + (-2)^2 + 3^2 + 2^2}{6}} \\ &= \sqrt{\frac{9 + 256 + 256 + 4 + 9 + 4}{6}} \\ &= \sqrt{\frac{538}{6}} \\ &= \sqrt{89.6\dots} \\ &\approx 9.5 \end{aligned}$$

CORRECT!  
SEE? YOU CAN  
DO IT!



STANDARD DEVIATION

TEAM A = 27.5      TEAM B = 9.5

MEMBERS OF TEAM B  
HAD SCORES SIMILAR TO  
EACH OTHER. THUS THE  
STANDARD DEVIATION IS  
SMALLER THAN TEAM A'S.

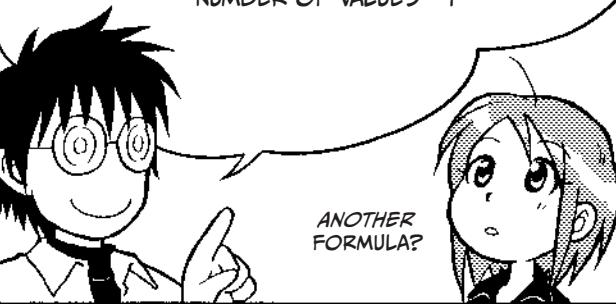


I TOLD YOU THAT THE FORMULA FOR STANDARD DEVIATION IS:

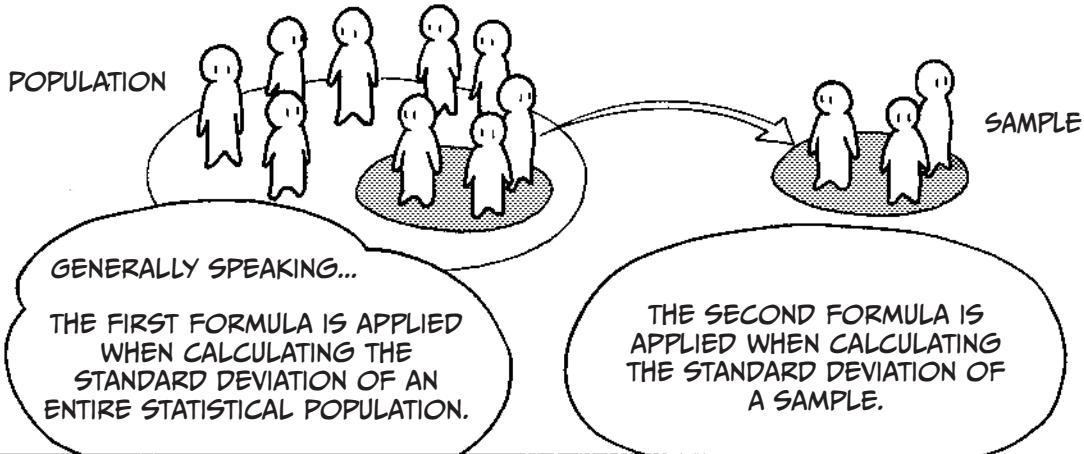
$$\sqrt{\frac{\text{SUM OF (EACH VALUE - MEAN)}^2}{\text{NUMBER OF VALUES}}}$$

THERE'S ALSO A DIFFERENT FORMULA, WHICH IS:

$$\sqrt{\frac{\text{SUM OF (EACH VALUE - MEAN)}^2}{\text{NUMBER OF VALUES} - 1}}$$

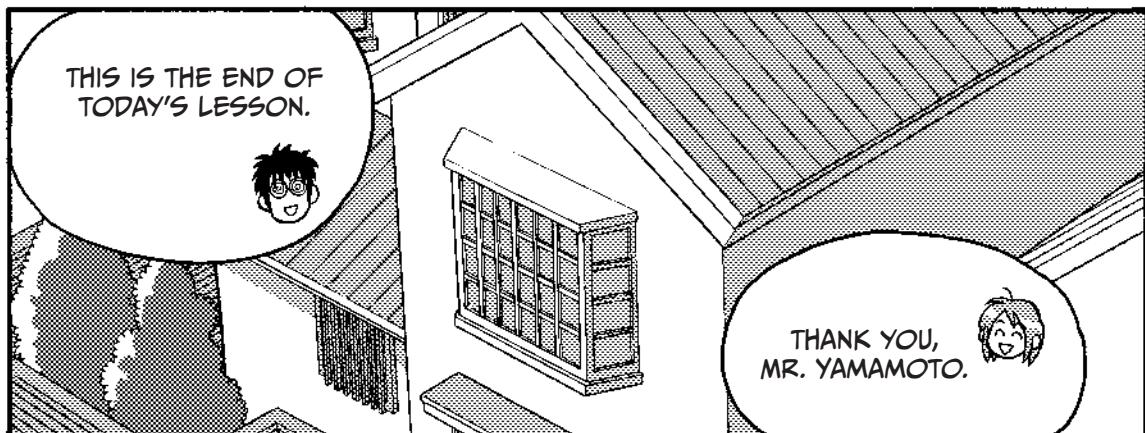
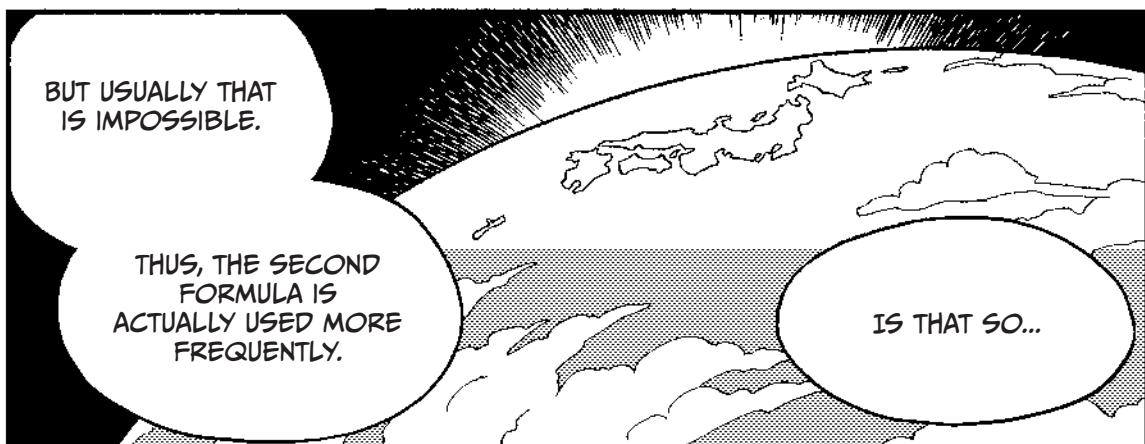
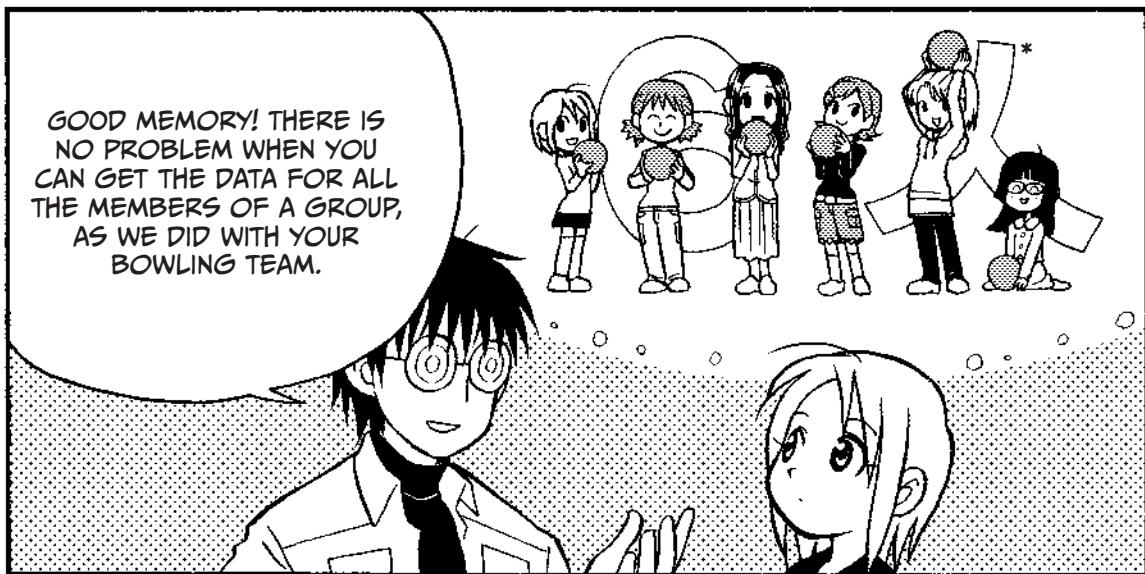


YOU SUBTRACT 1 FROM THE TOTAL NUMBER OF VALUES?



SO, A POPULATION IS THE REAL GROUP YOU ACTUALLY WANT TO EXAMINE.

AND A SAMPLE IS A GROUP OF PEOPLE SELECTED FROM THE POPULATION.



## 5. THE RANGE OF CLASS OF A FREQUENCY TABLE



If you felt that something was unclear in “Frequency Distribution Tables and Histograms” on page 32, take another look here at the table introduced on page 38.

TABLE 2-1: 50 BEST RAMEN SHOPS FREQUENCY TABLE

Class (equal or greater/less than)	Class midpoint	Frequency	Relative frequency
500-600	550	4	0.08
600-700	650	13	0.26
700-800	750	18	0.36
800-900	850	12	0.24
900-1000	950	3	0.06
<b>Sum</b>		50	1.00

As you can see, the range of class in this table is 100. The range was not determined according to any kind of mathematical standard—I set the range subjectively. Determining the range of class is up to the person who is analyzing the data.

But shouldn’t there be a way to set the range of class mathematically? A frequency table may seem invalid if its range is determined subjectively.

There is a way to figure out the range of class mathematically. This is explained on the following pages. You’ll also find a sample calculation using the data in Table 2-1.

**Step 1**

Calculate the number of classes using the Sturges' Rule below:

$$1 + \frac{\log_{10}(\text{number of values})}{\log_{10}2}$$

$$1 + \frac{\log_{10}50}{\log_{10}2} = 1 + 5.6438\dots = 6.6438\dots \approx 7$$

**Step 2**

Calculate the range of class using the formula below:

$$\frac{(\text{the maximum value}) - (\text{the minimum value})}{\text{the number of classes calculated from the Sturges' Rule}}$$

$$\frac{980 - 500}{7} = \frac{480}{7} = 68.5714\dots \approx 69$$

Below is a frequency chart organized according to the range of class as calculated by the formula in step 2.

TABLE 2-2: 50 BEST RAMEN SHOPS FREQUENCY TABLE  
(RANGE OF CLASS DETERMINED MATHEMATICALLY)

Class (equal or greater/less than)	Class midpoint	Frequency	Relative frequency
500-569	534.5	2	0.04
569-638	603.5	5	0.10
638-707	672.5	15	0.30
707-776	741.5	6	0.12
776-845	810.5	10	0.20
845-914	879.5	10	0.20
914-983	948.5	2	0.04
<b>Sum</b>		50	1.00

What do you think of this? Does this table seem even less convincing compared to Table 2-1? And why is the interval 69 yen?

If you try to explain to people that “this was calculated by a formula called the Sturges’ Rule,” they will only get mad and say, “Who cares about Stur . . . whatever! Why did you set the interval to a weird amount like 69 yen?”

To summarize, some people may hesitate to set the range of class subjectively. However, as the table above indicates, determining the range of class with the Sturges’ Rule does not necessarily provide a convincing table. A frequency table is, after all, a tool to help you visualize data. The analyst should set the range of class to any amount he or she thinks is appropriate.

## 6. ESTIMATION THEORY AND DESCRIPTIVE STATISTICS

In the prologue, we explain that statistics can make an estimate about the situation of the population based on information collected from samples. To tell the truth, this explanation is not necessarily correct.

Statistics can be roughly classified into two categories: estimation theory and descriptive statistics. The one introduced in the prologue is the former. What, then, is descriptive statistics? It is a kind of a statistics that aims to describe the status of a group simply and clearly by organizing data. Descriptive statistics regards the group as the population.

Perhaps this explanation of descriptive statistics is abstract and difficult to understand. Here is an example to help clarify things. Remember when I figured out the mean and standard deviation of Rui's bowling team? This was not because I was trying to estimate the status of a population from the information collected from Rui's team. I calculated the mean and standard deviation purely because I wanted to describe the status of Rui's team simply. That kind of statistics is descriptive statistics.

### EXERCISE AND ANSWER



#### EXERCISE

The table below is a record of a high school girls' 100m track race.

Runner	100m track race (seconds)
Ms. A	16.3
Ms. B	22.4
Ms. C	18.5
Ms. D	18.7
Ms. E	20.1

1. What is the average?
2. What is the median?
3. What is the standard deviation?

## ANSWER

1. The arithmetic mean is  $\frac{16.3 + 22.4 + 18.5 + 18.7 + 20.1}{5} = \frac{96}{5} = 19.2$

2. The median is 18.7.    16.3    18.5    **18.7**    20.1    22.4

3. The standard deviation is

$$\begin{aligned}& \sqrt{\frac{(16.3 - 19.2)^2 + (22.4 - 19.2)^2 + (18.5 - 19.2)^2 + (18.7 - 19.2)^2 + (20.1 - 19.2)^2}{5}} \\&= \sqrt{\frac{(-2.9)^2 + 3.2^2 + (-0.7)^2 + (-0.5)^2 + 0.9^2}{5}} \\&= \sqrt{\frac{8.41 + 10.24 + 0.49 + 0.25 + 0.81}{5}} \\&= \sqrt{\frac{20.2}{5}} \\&= \sqrt{4.04} \\&\approx 2.01\end{aligned}$$

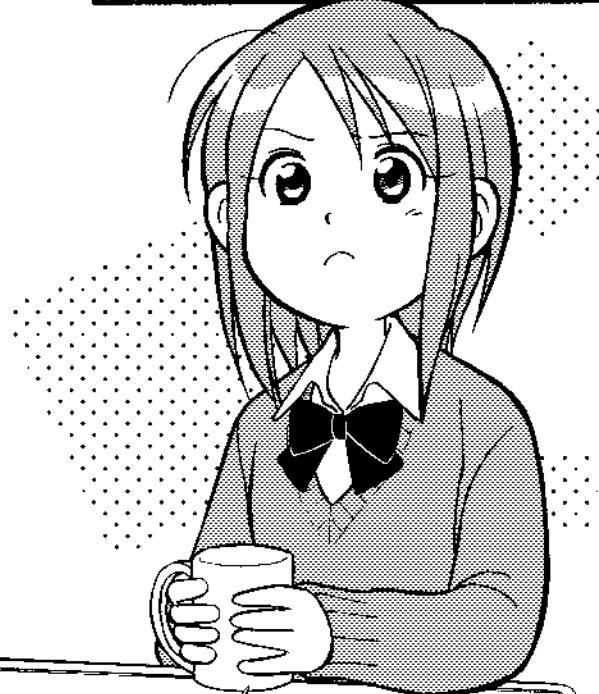
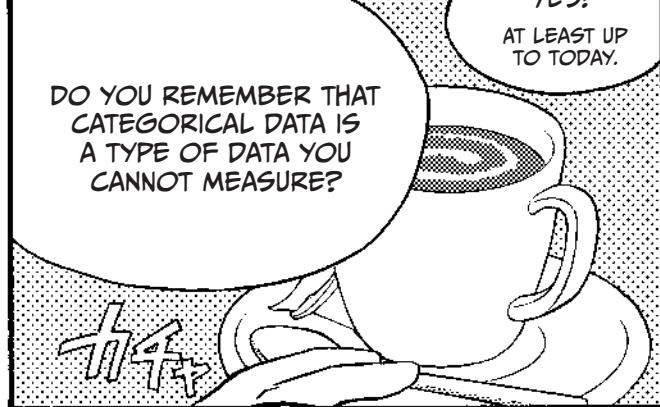
## SUMMARY

- To visualize the big picture of the data intuitively, create a frequency table or draw a histogram.
- When making a frequency table, the range of class may be determined by the Sturges' Rule.
- To visualize the data mathematically, calculate the arithmetic mean, median, and standard deviation.
- When there is an extremely large or small value in the data set, it is more appropriate to use the median than the arithmetic mean.
- *Standard deviation* is an index to describe “the size of scattering” of the data.

# 3

## GETTING THE BIG PICTURE: UNDERSTANDING CATEGORICAL DATA

## 1. CROSS TABULATIONS





LOOK, THIS IS OUR NEW UNIFORM.

A PLAID SAILOR OUTFIT? THAT'S RATHER UNUSUAL.

WE CONDUCTED A SURVEY ON THE UNIFORM DESIGN IN OUR CLASS.

DO YOU LIKE OR DISLIKE THE NEW UNIFORM DESIGN?

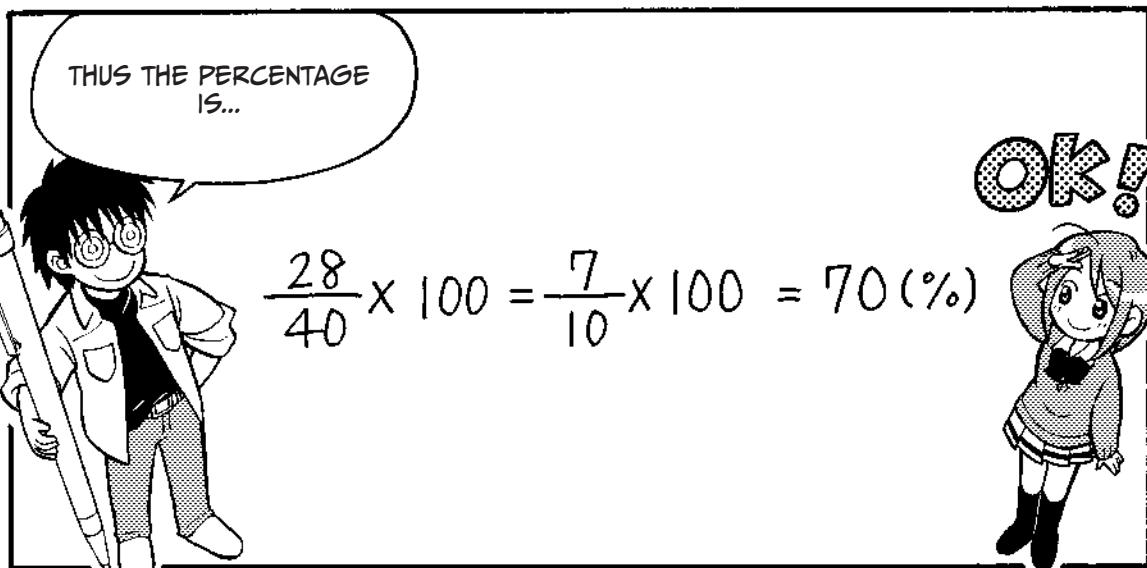
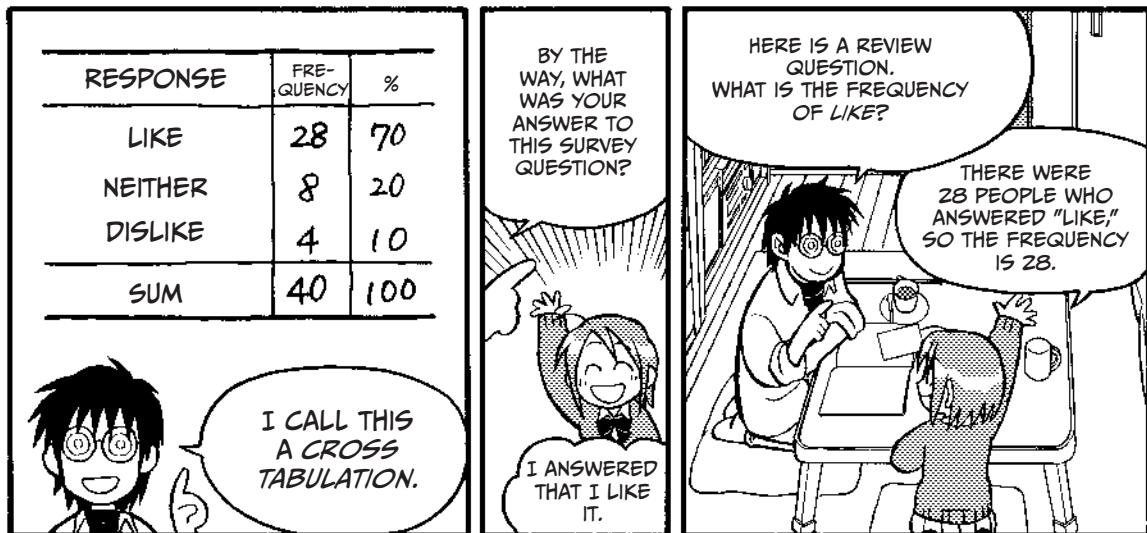
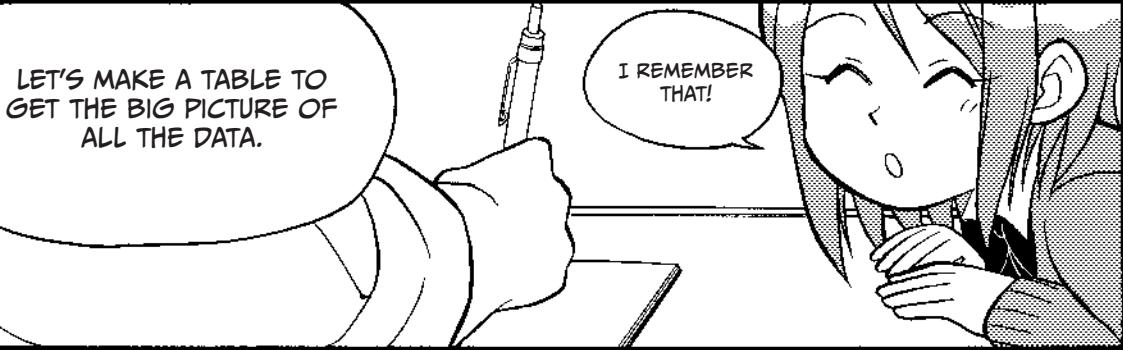
RESPONSE	RESPONSE	RESPONSE
1 LIKE	16 NEITHER	31 NEITHER
2 NEITHER	17 LIKE	32 NEITHER
3 LIKE	18 LIKE	33 LIKE
4 NEITHER	19 LIKE	34 DISLIKE
5 DISLIKE	20 LIKE	35 LIKE
6 LIKE	21 LIKE	36 LIKE
7 LIKE	22 LIKE	37 LIKE
8 LIKE	23 DISLIKE	38 LIKE
9 LIKE	24 NEITHER	39 NEITHER
10 LIKE	25 LIKE	40 LIKE
11 LIKE	26 LIKE	
12 LIKE	27 DISLIKE	
13 NEITHER	28 LIKE	
14 LIKE	29 LIKE	
15 LIKE	30 LIKE	

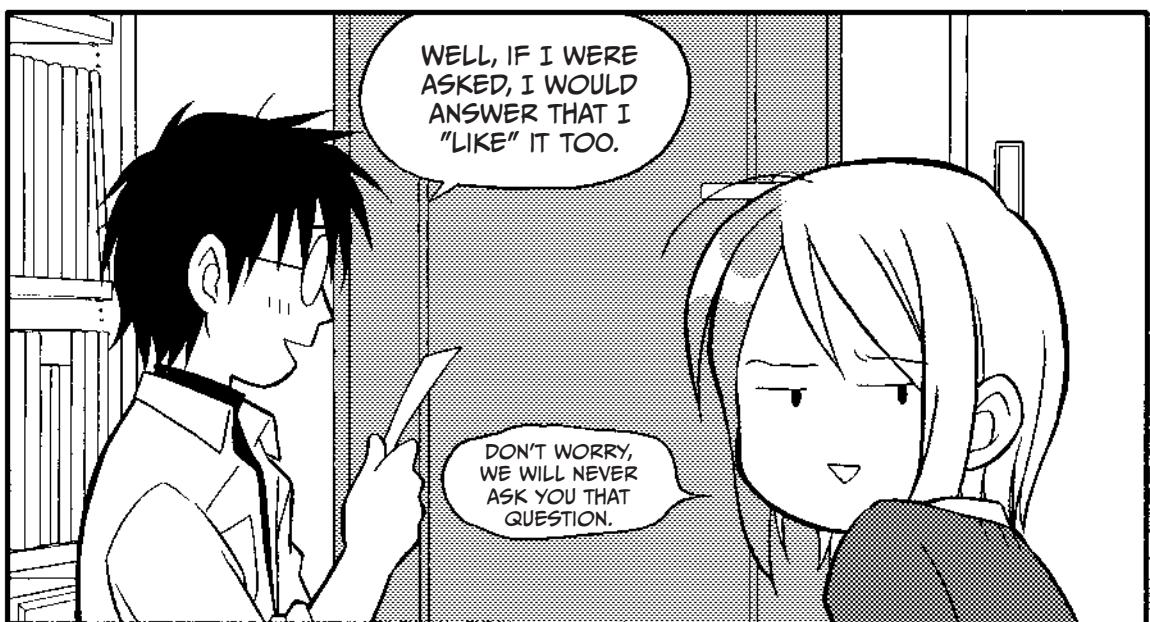
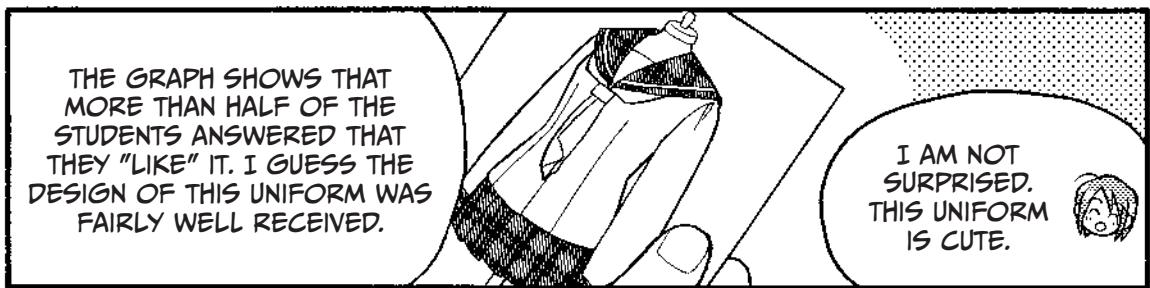
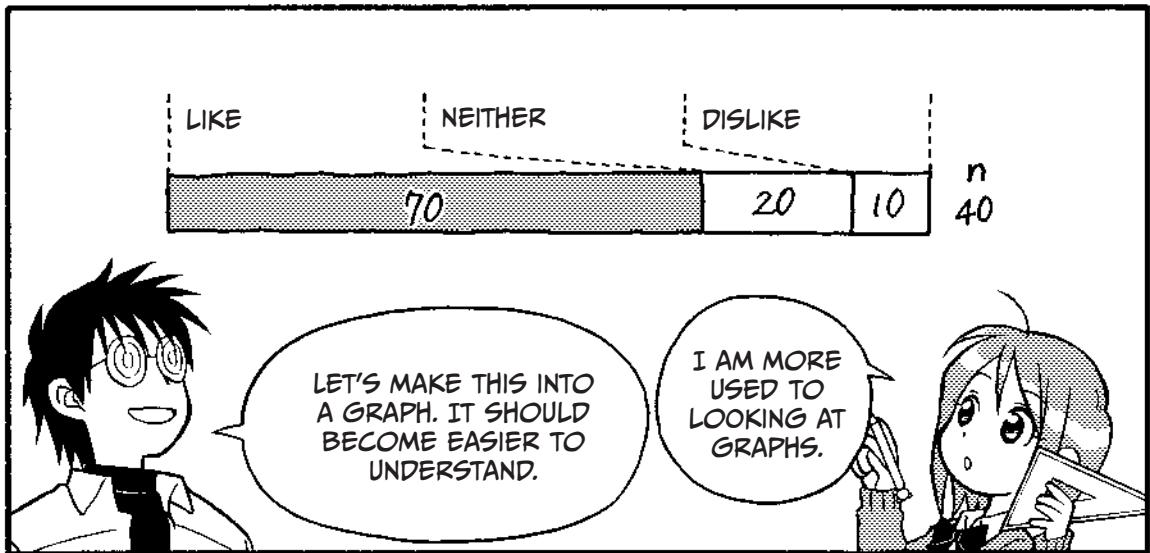
HERE ARE THE RESULTS.



WOW! THE RESULTS OF THIS SURVEY ARE CATEGORICAL DATA.

YOU CAN'T "MEASURE" LIKES AND DISLIKES, RIGHT?





## EXERCISE AND ANSWER



### EXERCISE

A newspaper took a survey on political party A, which hopes to win the next election. The results are below.

Respondent	Do you expect party A to win or lose against party B?
1	Lose
2	Lose
3	Lose
4	I don't know
5	Win
6	Lose
7	Win
8	I don't know
9	Lose
10	Lose

Make a cross tabulation from these survey results.

### ANSWER

Below is the cross tabulation.

Response	Frequency	%
Win	2	20
I don't know	2	20
Lose	6	60
<b>Sum</b>	<b>10</b>	<b>100</b>

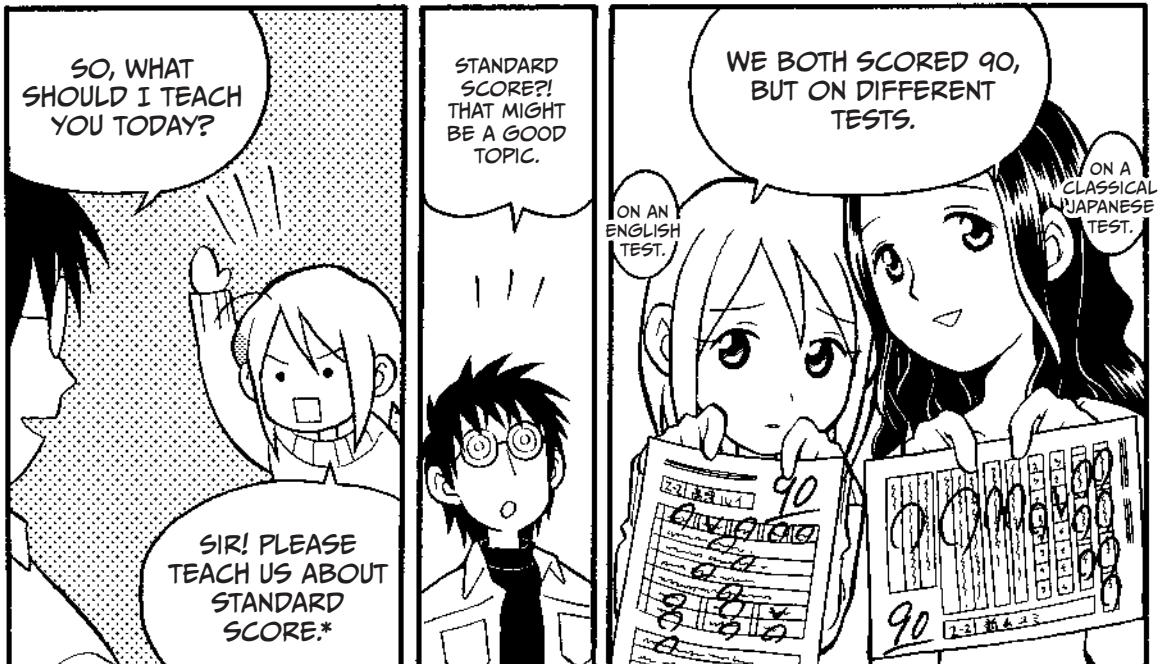
## SUMMARY

- One way to see the big picture of all the data is to make a cross tabulation.

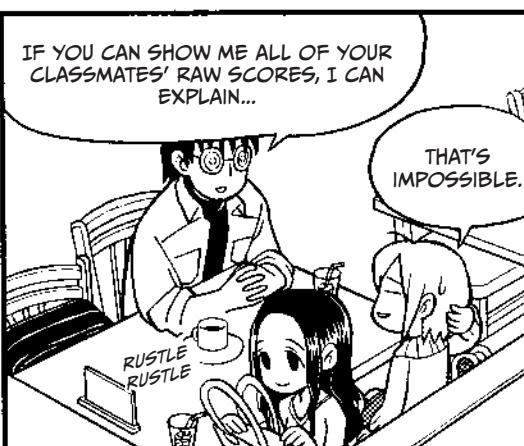
# 4

## STANDARD SCORE AND DEVIATION SCORE

## 1. NORMALIZATION AND STANDARD SCORE



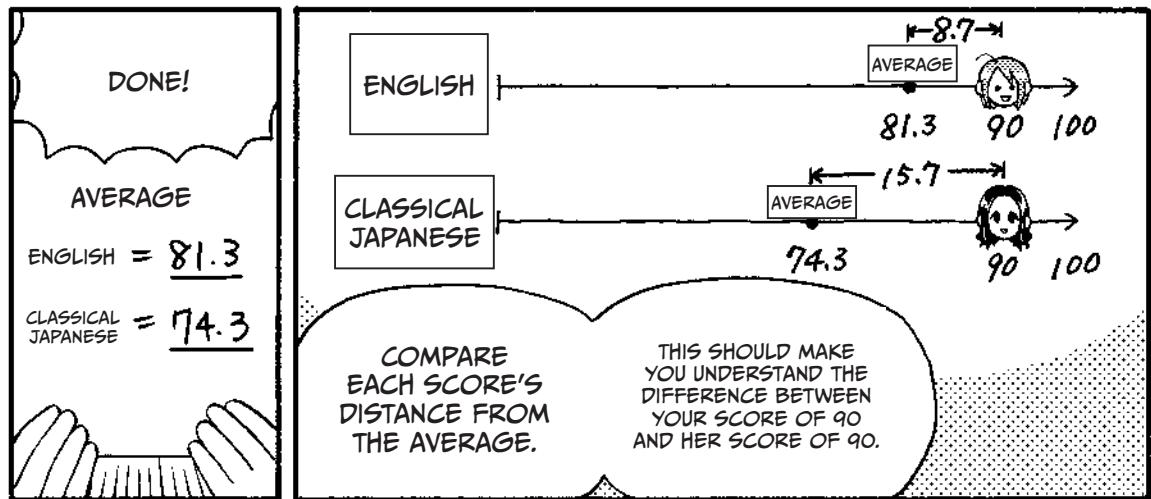
\* ADJUSTING TEST RESULTS BASED ON STANDARD SCORE IS COMMONLY KNOWN AS GRADING ON A CURVE.

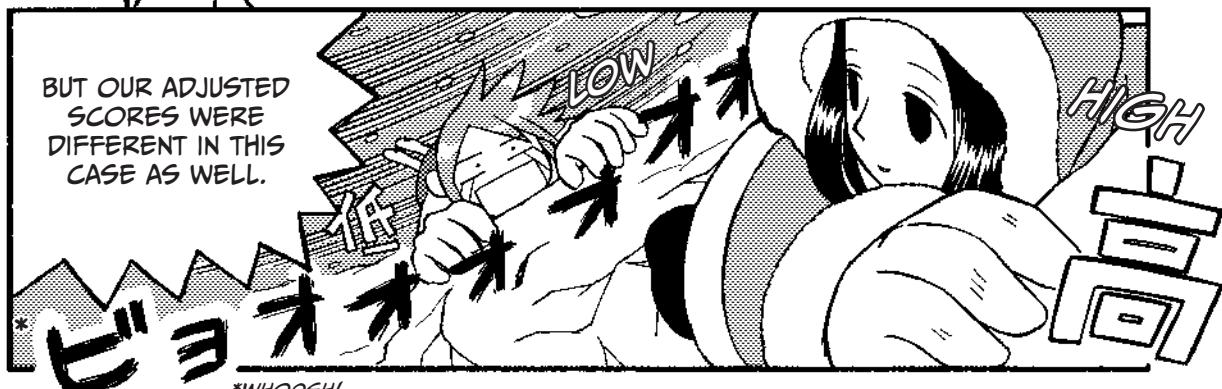
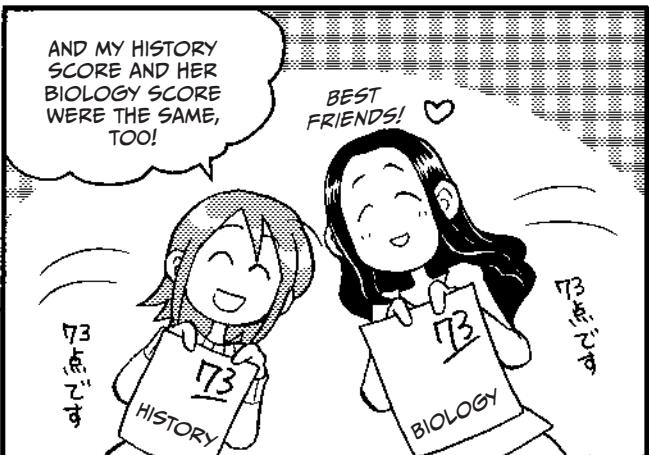
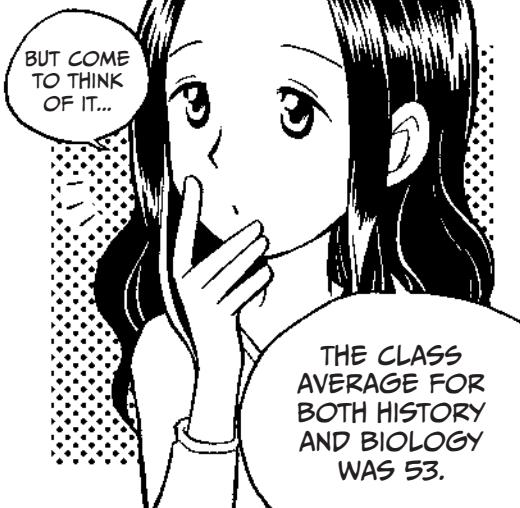


**RAW TEST SCORES (OUT OF 100)**

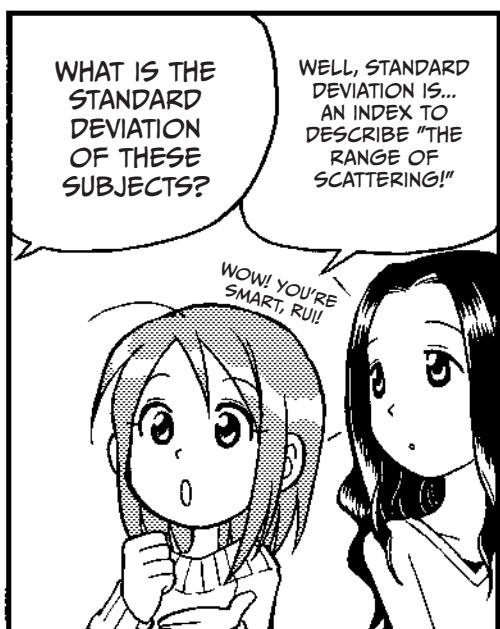
STUDENT	ENGLISH	CLASSICAL JAPANESE	STUDENT	ENGLISH	CLASSICAL JAPANESE
RUI	90	71	H	67	85
YUMI	81	90	I	87	93
A	73	79	J	78	89
B	97	70	K	85	78
C	85	67	L	96	74
D	60	66	M	77	65
E	74	60	N	100	78
F	64	83	O	92	53
G	72	57	P	86	80

I SEE...





STUDENT	HISTORY	BIOLOGY	STUDENT	HISTORY	BIOLOGY
RUI	73	59	H	7	50
YUMI	61	73	I	53	41
A	14	47	J	100	62
B	41	38	K	57	44
C	49	63	L	45	26
D	87	56	M	56	91
E	69	15	N	34	35
F	65	53	O	37	53
G	36	80	P	70	68
AVERAGE		53	53		



$\checkmark$  SUM OF (EACH VALUE - MEAN)<sup>2</sup>

NUMBER OF VALUES

ITS FORMULA  
IS...

STANDARD DEVIATION

$$\text{HISTORY} = 22.7$$

$$\text{BIOLOGY} = 18.3$$

THERE!

THE SMALLER THE STANDARD DEVIATION IS, THE SMALLER THE "RANGE OF SCATTERING" OF THE DATA...

SO, YOUR CLASSMATES HAD MORE SIMILAR SCORES IN BIOLOGY THAN IN HISTORY.



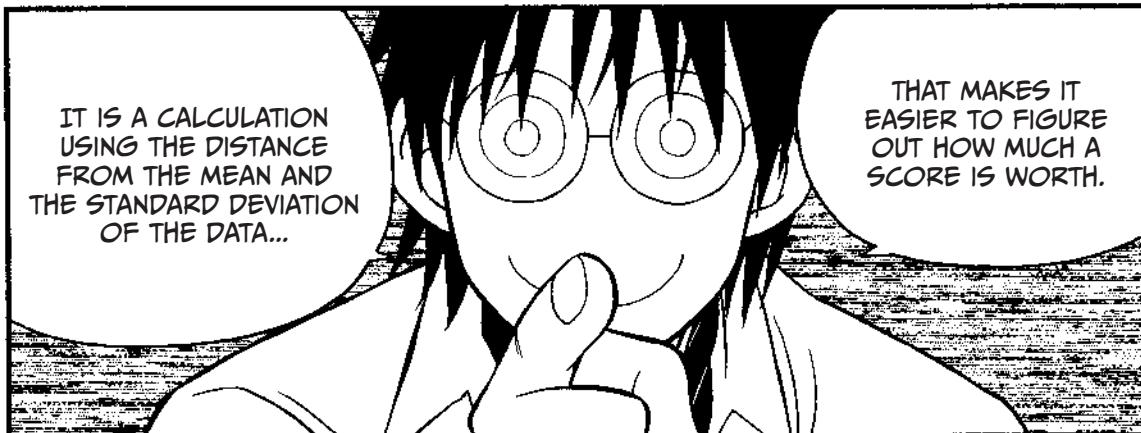
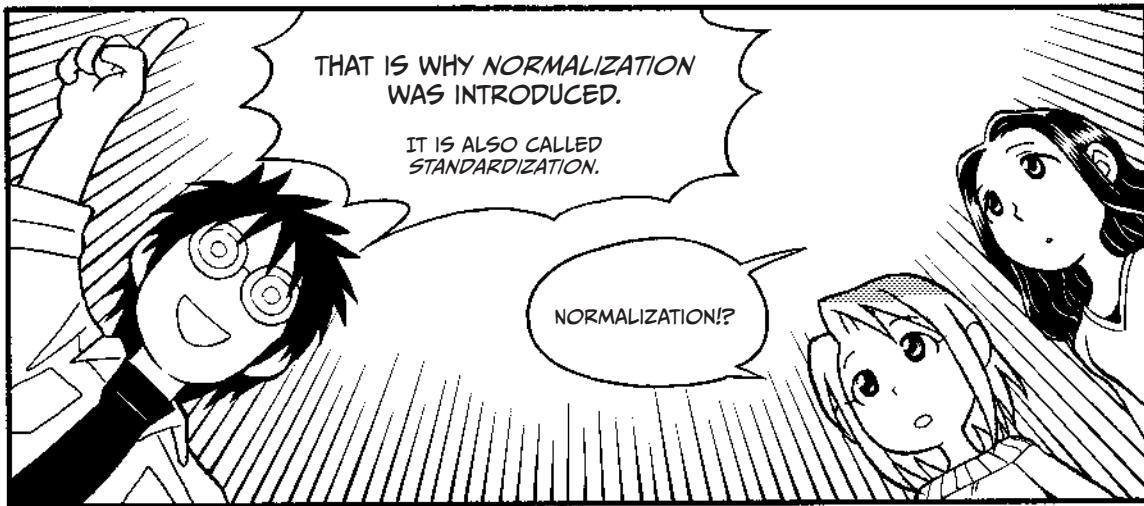
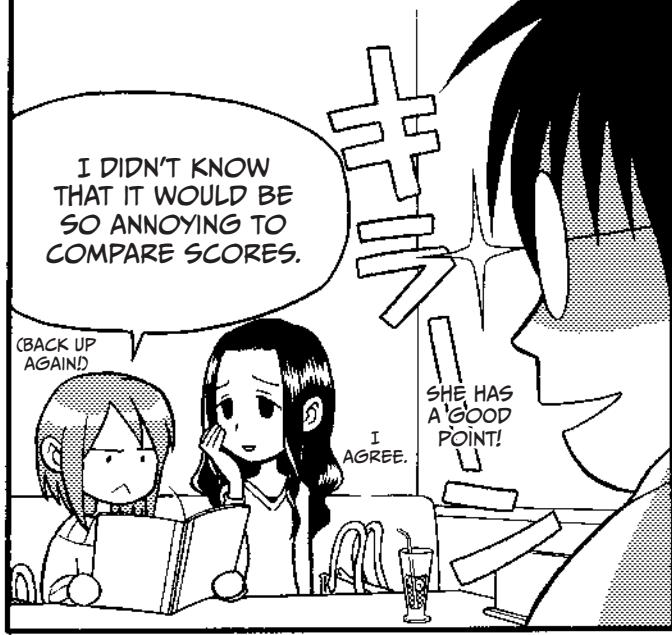
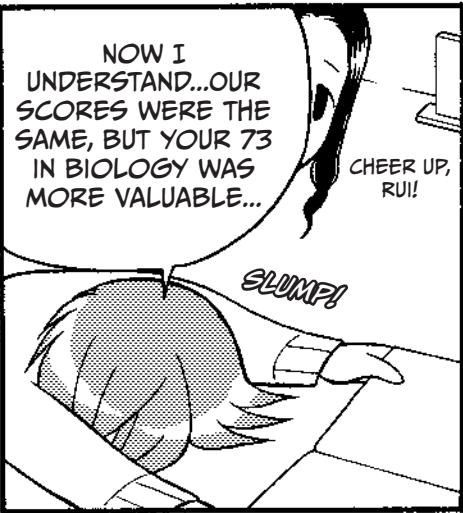
WHAT DO YOU MEAN?

IF I WERE A HIGH SCHOOL JUNIOR APPLYING FOR COLLEGE, I'D STUDY HARD FOR BIOLOGY.

ONE OR TWO POINTS MAY AFFECT YOUR RANK GREATLY.

A HIGH SCHOOL UNIFORM SUITS HIM SO WELL!

TEE-HEE!



THIS IS HOW YOU CALCULATE STANDARDIZATION. THE STANDARDIZED DATA IS CALLED THE STANDARD SCORE.\*

(EACH VALUE) - (MEAN)

STANDARD DEVIATION

= STANDARD SCORE

WOW!



YOU CAN THINK OF THE STANDARD SCORE AS THE NUMBER OF STANDARD DEVIATIONS A VALUE IS ABOVE OR BELOW THE MEAN. FOR EXAMPLE, A STANDARD SCORE OF 1 MEANS THAT THE TEST RESULTS ARE 1 STANDARD DEVIATION (IN THIS CASE, 22.7 POINTS) ABOVE THE CLASS AVERAGE...

\* STANDARD SCORE IS ALSO CALLED Z-SCORE.



...AND A STANDARD SCORE OF -1 MEANS THE RESULTS ARE 1 STANDARD DEVIATION BELOW THE CLASS AVERAGE. LET'S APPLY THIS TO THE TEST SCORES WE WERE TALKING ABOUT.

ROGER!



#### RESULTS AND STANDARD SCORES OF HISTORY AND BIOLOGY TESTS

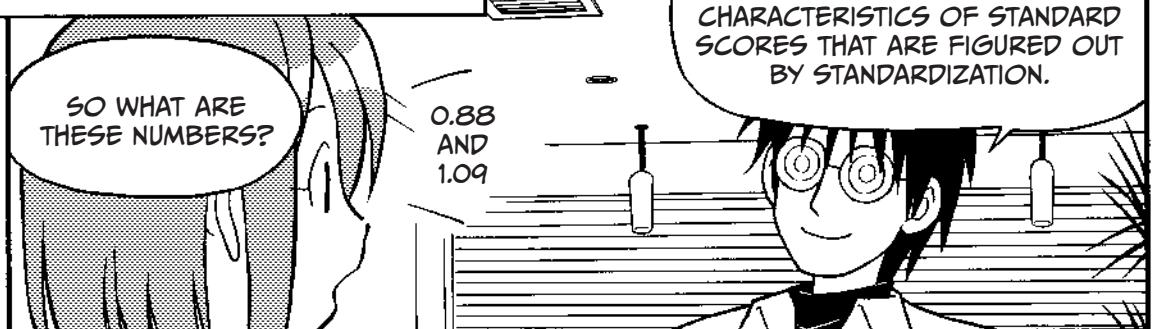
STUDENT	HISTORY	BIOLOGY	STANDARD SCORE OF HISTORY	STANDARD SCORE OF BIOLOGY
RUI	73	59	0.88	0.33
YUMI	61	73	0.35	1.09
A	14	47	-1.71	-0.33
B	41	38	-0.53	-0.82
C	49	63	-0.18	0.55
D	87	56	1.49	0.16
E	69	15	0.70	-2.08
F	65	53	0.53	0
G	36	80	-0.75	1.48
H	7	50	-2.02	-0.16
I	53	41	0	-0.66
J	100	62	2.07	0.49
K	57	44	0.18	-0.49
L	45	26	-0.35	-1.48
M	56	91	0.13	2.08
N	34	35	-0.84	-0.98
O	37	53	-0.70	0
P	70	68	0.75	0.82
AVERAGE	53	53	0	0
STANDARD DEVIATION	22.7	18.3	1	1

SO THESE ARE THE VALUES.

$$\text{STANDARD SCORE OF RUI'S HISTORY TEST} = \frac{73 - 53}{22.7} = \frac{20}{22.7} = 0.88$$

$$\text{STANDARD SCORE OF YUMI'S BIOLOGY TEST} = \frac{73 - 53}{18.3} = \frac{20}{18.3} = 1.09$$

## 2. CHARACTERISTICS OF STANDARD SCORE



(1) No matter what the maximum value of your variable is, the arithmetic mean of the standard score is always 0, and the standard deviation is always 1.

YOU CAN COMPARE THE SCORES OF TWO TESTS WHOSE MAXIMUM VALUES ARE 100 AND 200.

(2) Whatever the unit of the variable in question is, the arithmetic mean of the standard score is always 0, and the standard deviation is always 1.

YOU CAN COMPARE VALUES WITH DIFFERENT UNITS, SUCH AS BATTING AVERAGE AND NUMBER OF HOME RUNS.

BY GETTING THE STANDARD SCORES OF 0.88 (HISTORY) AND 1.09 (BIOLOGY), IT IS OBVIOUS WHICH SCORE HAD A GREATER VALUE RELATIVE TO THE OTHER SCORES ON THE SAME TEST.

NOW I HAVE NO DOUBT I'M THE LOSER.

### 3. DEVIATION SCORE

LET'S MOVE ON TO DEVIATION SCORE. THIS IS SIMPLY A TRANSFORMED VERSION OF STANDARD SCORE: IT'S CENTERED AT 50 INSTEAD OF 0 AND HAS A STANDARD DEVIATION OF 10 INSTEAD OF 1.

OH!

THIS IS THE FORMULA.

$$\text{DEVIATION SCORE} = \text{STANDARD SCORE} \times 10 + 50$$

WHAT YOU SAID  
WAS TRUE.  
THE FORMULA  
DOES INCLUDE  
STANDARD SCORE.

THESE ARE  
YOUR DEVIATION  
SCORES.

RUI  
(HISTORY)

YUMI  
(BIOLOGY)

$$0.88 \times 10 + 50 = 8.8 + 50 = 58.8$$

$$1.09 \times 10 + 50 = 10.9 + 50 = 60.9$$

THESE ANSWERS ARE EXACTLY  
WHAT WE WERE INFORMED WERE  
OUR DEVIATION SCORES!

LET ME  
EXPLAIN THESE  
CHARACTERISTICS.

STANDARD  
SCORE

(1) No matter what the maximum value of your variable is, the arithmetic mean of the standard score is always 0, and the standard deviation is always 1.

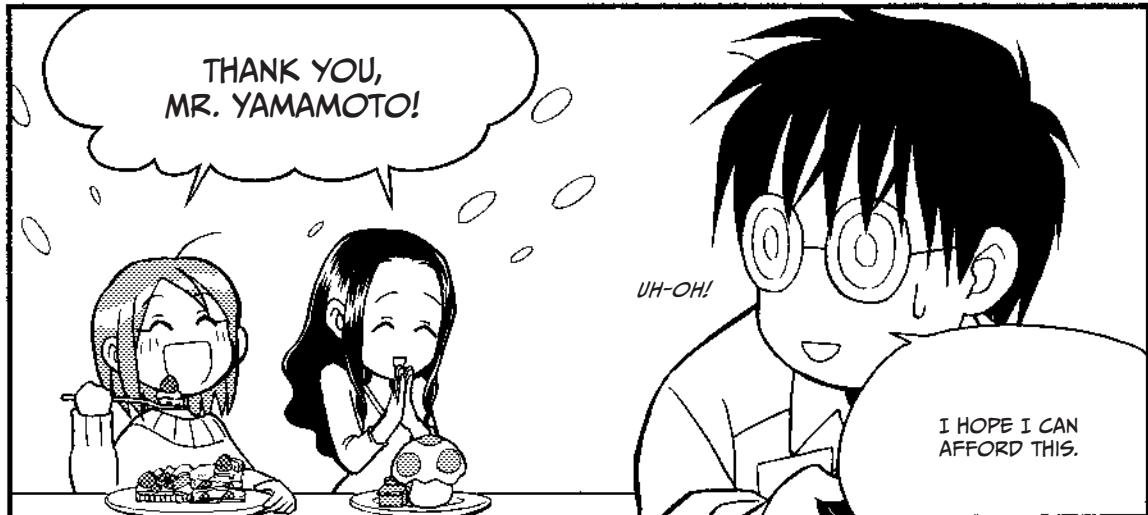
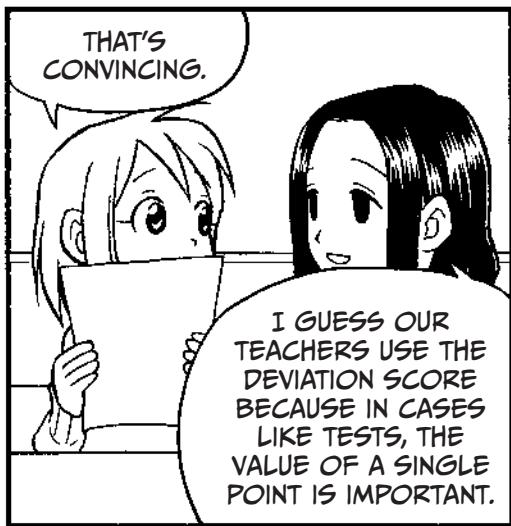
(2) Whatever the unit of the variable in question is, the arithmetic mean of the standard score is always 0, and the standard deviation is always 1.



DEVIATION  
SCORE

(1) No matter what the maximum value of your variable is, the arithmetic mean of the deviation score is always 50, and its standard deviation is always 10.

(2) No matter what units of measurement your variable uses, the arithmetic mean of the deviation score is always 50, and its standard deviation is always 10.



## 4. INTERPRETATION OF DEVIATION SCORE



Special caution is necessary when interpreting deviation scores. As explained on page 74, the definition of deviation score is:

$$\text{deviation score} = \text{standard score} \times 10 + 50 = \frac{(\text{each value} - \text{mean})}{\text{standard deviation}} \times 10 + 50$$

As mentioned on page 62, Rui's class has a total of 40 students, and as mentioned on page 40, there are 18 girls in the class. The example of deviation score on page 69 is not for the whole class, but is for the girls only. If the story were about the whole class, the mean and standard deviation would have been different from those for the girls only. Naturally, the deviation scores for Rui and Yumi would have been different as well. In fact, when everybody in the class is taken into consideration, Rui has the higher deviation score. Table 4-1 shows the test results for the whole class. Try calculating the deviation score.

To tell you the answer in advance, the deviation score for Rui's history test is 59.1, and that of Yumi's biology test is 56.7.

Suppose the same test is given to students in classes 1 and 2. The mean and standard deviation of class 1 are calculated individually, and deviation scores are obtained according to those amounts. Similarly, mean, standard deviation, and deviation scores for class 2 are obtained. Student A in class 1 has a deviation score of 57. Student B in class 2 has the same deviation score of 57. Outwardly, students A and B seem to have the same ability. However, the mean and standard deviation used to calculate these two deviation scores differ, because they come from two different classes. Unless the mean and standard deviation of the two classes are equal, you cannot compare the deviation scores of the two students.

Here is another example. Suppose student A takes an entrance exam at a prep school in April and gets a deviation score of 54. After studying hard at a special summer course, student A takes an entrance exam at a different prep school in September. The deviation score is 62. It may seem that student A's proficiency has increased. However, the exam and the students taking it in April are different from the exam and the students taking it in September. Therefore, you cannot compare the deviation scores for these two exams, because the data used to calculate the mean and standard deviation of the April and September exams is different. In exam situations, you can only compare deviation scores for a group of students who all take the same exam. Keep these facts in mind when you interpret deviation scores.

TABLE 4-1: TEST RESULTS OF HISTORY AND BIOLOGY (ALL MEMBERS OF RUI'S CLASS)

Girls	History	Biology	Boys	History	Biology
Rui	73	59	a	54	2
Yumi	61	73	b	93	7
A	14	47	c	91	98
B	41	38	d	37	85
C	49	63	e	44	100
D	87	56	f	16	29
E	69	15	g	12	57
F	65	53	h	44	37
G	36	80	i	4	95
H	7	50	j	17	39
I	53	41	k	66	70
J	100	62	l	53	14
K	57	44	m	14	97
L	45	26	n	73	39
M	56	91	o	6	75
N	34	35	p	22	80
O	37	53	q	69	77
P	70	68	r	95	14
			s	16	24
			t	37	91
			u	14	36
			v	88	76
<b>Average of the whole class</b>				48.0	54.9
<b>Standard deviation of the whole class</b>				27.5	26.9

## EXERCISE AND ANSWER



### EXERCISE

Below are the results of a high school girls' 100m track race.

<b>Runner</b>	<b>100m track race (seconds)</b>
Ms. A	16.3
Ms. B	22.4
Ms. C	18.5
Ms. D	18.7
Ms. E	20.1
<b>Mean</b>	19.2
<b>Standard deviation</b>	2.01

1. Demonstrate that the mean of the standard scores of the 100m track race is 0.
2. Demonstrate that the standard deviation of the standard score of the 100m track race is 1.

## ANSWER

1. Mean of the standard score of the 100m track race

$$\begin{aligned}
 &= \frac{\left(\frac{16.3 - 19.2}{2.01}\right) + \left(\frac{22.4 - 19.2}{2.01}\right) + \left(\frac{18.5 - 19.2}{2.01}\right) + \left(\frac{18.7 - 19.2}{2.01}\right) + \left(\frac{20.1 - 19.2}{2.01}\right)}{5} \\
 &= \frac{\left\{ (16.3 - 19.2) + (22.4 - 19.2) + (18.5 - 19.2) + (18.7 - 19.2) + (20.1 - 19.2) \right\}}{\frac{2.01}{5}} \\
 &= \frac{\left\{ 16.3 + 22.4 + 18.5 + 18.7 + 20.1 - 19.2 - 19.2 - 19.2 - 19.2 - 19.2 \right\}}{\frac{2.01}{5}} \\
 &= \frac{\left\{ \frac{96 - 19.2 \times 5}{2.01} \right\}}{5} \\
 &= \frac{\left\{ \frac{96 - 96}{2.01} \right\}}{5} \\
 &= \frac{0}{5} \\
 &= 0
 \end{aligned}$$

The numerator has been clarified.

The numerator has been reorganized so that each value and (-19.2) are separate.

2. Standard deviation of the standard score of the 100m track race

$$\begin{aligned}
 &= \sqrt{\frac{\left(\frac{16.3 - 19.2}{2.01} - 0\right)^2 + \left(\frac{22.4 - 19.2}{2.01} - 0\right)^2 + \left(\frac{18.5 - 19.2}{2.01} - 0\right)^2 + \left(\frac{18.7 - 19.2}{2.01} - 0\right)^2 + \left(\frac{20.1 - 19.2}{2.01} - 0\right)^2}{5}} \\
 &= \sqrt{\frac{\left(\frac{16.3 - 19.2}{2.01}\right)^2 + \left(\frac{22.4 - 19.2}{2.01}\right)^2 + \left(\frac{18.5 - 19.2}{2.01}\right)^2 + \left(\frac{18.7 - 19.2}{2.01}\right)^2 + \left(\frac{20.1 - 19.2}{2.01}\right)^2}{5}} \\
 &= \sqrt{\frac{\left\{ (16.3 - 19.2)^2 + (22.4 - 19.2)^2 + (18.5 - 19.2)^2 + (18.7 - 19.2)^2 + (20.1 - 19.2)^2 \right\}}{2.01^2}} \\
 &= \sqrt{\frac{1}{2.01^2} \times \frac{(16.3 - 19.2)^2 + (22.4 - 19.2)^2 + (18.5 - 19.2)^2 + (18.7 - 19.2)^2 + (20.1 - 19.2)^2}{5}} \\
 &= \frac{1}{2.01} \times \sqrt{\frac{(16.3 - 19.2)^2 + (22.4 - 19.2)^2 + (18.5 - 19.2)^2 + (18.7 - 19.2)^2 + (20.1 - 19.2)^2}{5}} \\
 &= \frac{1}{\text{standard deviation of the 100m track race}} \times \text{standard deviation of the 100m track race}
 \end{aligned}$$

The numerator has been clarified.

The numerator has been clarified.

Carefully look at the table on page 78.

---

## SUMMARY

---

- *Standardization* helps you examine the value of a data point relative to the rest of your data by using its distance from the mean and “the size of scattering” of the data.
- Use standardization to:
  - Compare variables with different ranges
  - Compare variables that use different units of measurements
- A data point that has been standardized is called the *standard score* for that observation. Deviation score is an application of standard score.

5

LET'S OBTAIN THE PROBABILITY

## 1. PROBABILITY DENSITY FUNCTION

IN STATISTICS, WE OFTEN USE THE TERM PROBABILITY.

WE SAY, "THE PROBABILITY OF BLAH BLAH IS SMALLER THAN 0.05."

TODAY, I WILL TEACH YOU WHAT YOU NEED TO KNOW TO OBTAIN THAT "PROBABILITY OF BLAH BLAH."

STARE...

"MR. YAMAMOTO'S KIND OF CUTE!"

HE IS NOT CUTE AT ALL. MY PRINCE CHARMING IS MR. IGARASHI...

RUI?

SORRY! IS THE PROBABILITY YOU ARE TALKING ABOUT THE SAME AS THE PROBABILITY I OFTEN HEAR IN WEATHER FORECASTS?

TODAY'S TOPIC IS A LITTLE ABSTRACT.

BUT STUDY HARD. WHAT YOU ARE GOING TO LEARN TODAY IS USED IN MANY AREAS OF STATISTICS.

EXACTLY.

ABSTRACT?! OH, NO!

RUI

I'LL TRY.

ENGLISH TEST RESULTS OF ALL HIGH SCHOOL JUNIORS IN PREFECTURE A

STUDENT	SCORE
1	42
2	91
...	...
10,421	50
MEAN	53
STANDARD DEVIATION	10

SUPPOSE

ALL HIGH SCHOOL JUNIORS IN PREFECTURE A...

TAKE AN ENGLISH TEST.

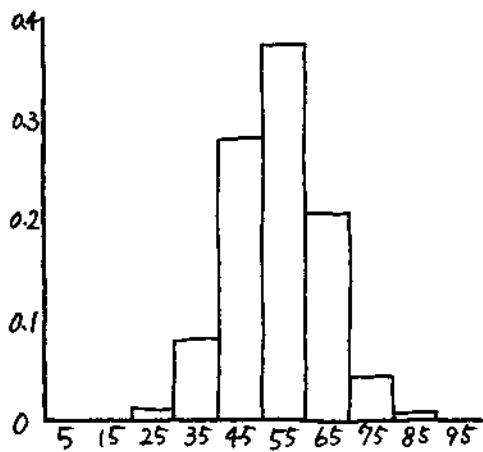
WOW, YOU ARE WELL PREPARED TODAY.

HA-HA-HA!  
WE'RE JUST  
GETTING  
STARTED.

フフフフフフ...

THIS IS A HISTOGRAM OF THAT TABLE...THE Y-AXIS SHOWS THE PERCENTAGE OF THE STUDENTS IN A CLASS WHO RECEIVE THAT SCORE.

HISTOGRAM OF "ENGLISH TEST RESULTS"  
(RANGE OF CLASS = 10)



IT IS SO MUCH EASIER TO UNDERSTAND WHEN TABLES ARE REDRAWN INTO HISTOGRAMS.

IT'S MORE VISUAL, YOU KNOW.

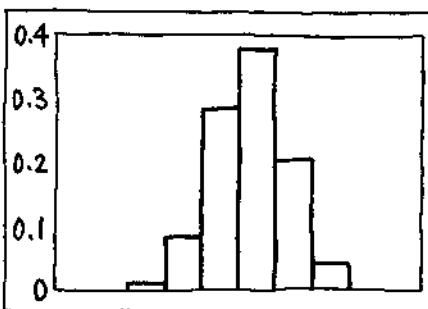
GUESS WHAT HAPPENS WHEN THE RANGE OF CLASS IN THIS HISTOGRAM IS MADE SMALLER.

WHAT?

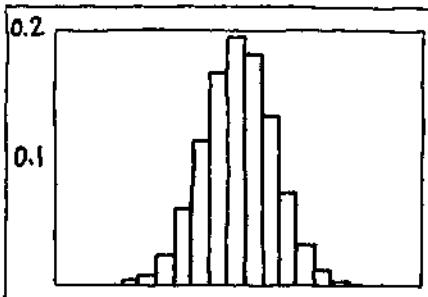
LIKE THIS...

RANGE OF CLASS AND HISTOGRAM OF  
"ENGLISH TEST RESULTS"

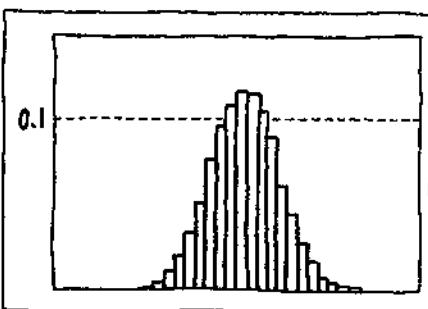
RANGE OF CLASS = 10



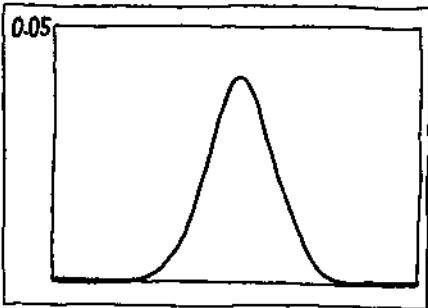
RANGE OF CLASS = 5



RANGE OF CLASS = 3



CURVE



WOW! IT EVENTUALLY BECOMES A CURVED LINE!

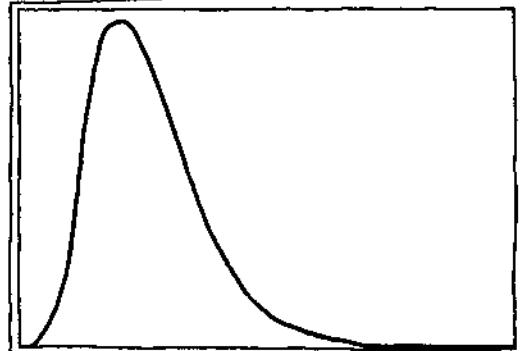
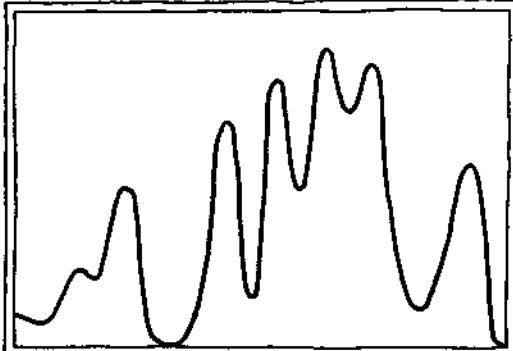


WHEN THE RANGE OF CLASS IN A HISTOGRAM IS DECREASED TO THE LIMIT AT ZERO,

WE CALL THE FORMULA OF THAT LINE THE PROBABILITY DENSITY FUNCTION.

# PROBABILITY DENSITY FUNCTION

PUSH



THEORETICALLY,

THERE ARE MANY TYPES OF PROBABILITY DENSITY FUNCTION GRAPHS.

TODAY I WILL INTRODUCE YOU TO SOME OF THE MOST IMPORTANT ONES.

PLEASE GO AHEAD.

## 2. NORMAL DISTRIBUTION

$$f(x) = \frac{1}{(\text{standard deviation of } x)\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x - \text{mean of } x}{\text{standard deviation of } x}\right)^2}$$

LOOK AT THIS.

WHAT IS THIS STUFF?!

THIS IS A  
POPULAR  
PROBABILITY  
DENSITY  
FUNCTION IN  
STATISTICS.

WHAT IS THIS  
ITALIC e?!

THE NAME OF THIS  
ITALIC e IS EULER'S  
NUMBER, AND ITS VALUE  
IS 2.71828...\*

\* e IS ALSO KNOWN AS NAPIER'S CONSTANT.

HA!  
HA!  
HA!

JUST THINK  
OF IT AS  
SOMETHING  
LIKE PI.

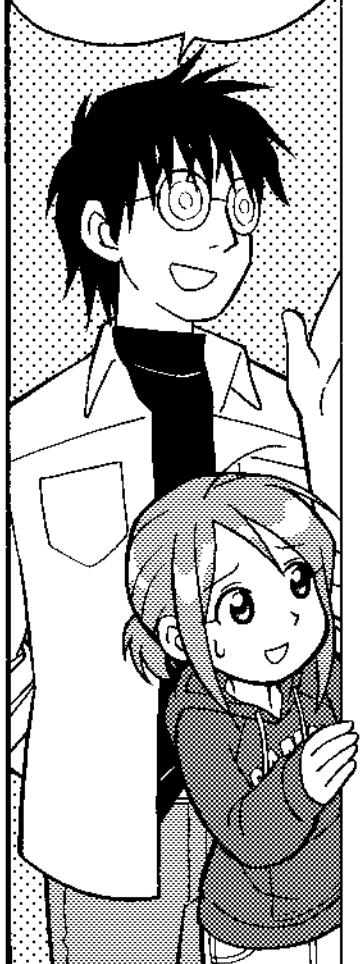
THAT I CAN MANAGE TO  
UNDERSTAND...

OH,  
WELL...

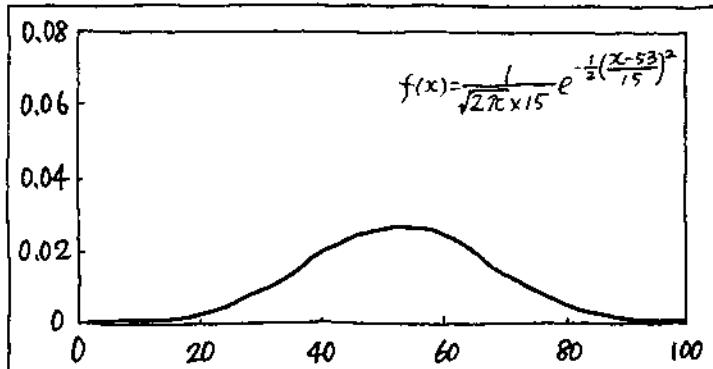
THE GRAPH OF THE  
NORMAL DISTRIBUTION  
HAS TWO  
CHARACTERISTICS.

IT IS SYMMETRICAL,  
WITH THE MEAN IN THE  
CENTER.

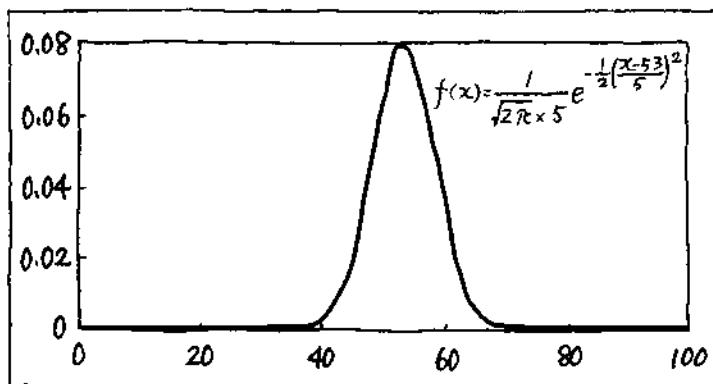
IT IS AFFECTED  
BY THE MEAN AND  
STANDARD DEVIATION.



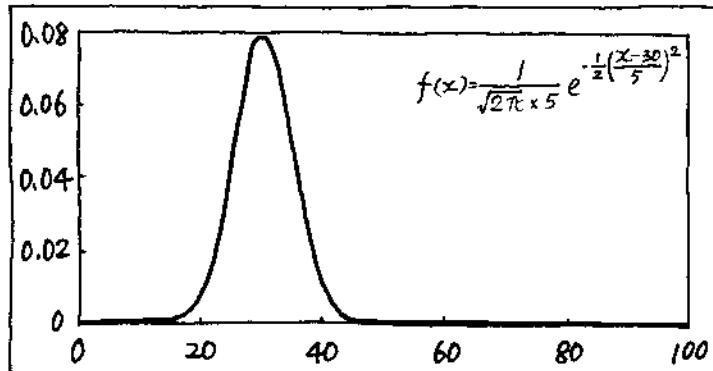
MEAN IS 53, STANDARD DEVIATION IS 15



MEAN IS 53, STANDARD DEVIATION IS 5



MEAN IS 30, STANDARD DEVIATION IS 5



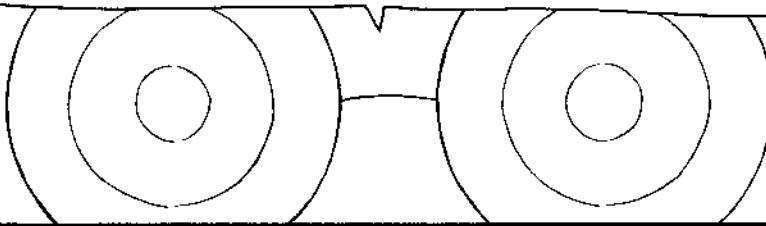
THERE IS A CERTAIN WAY TO DESCRIBE THIS IN STATISTICS. REMEMBER...



WHEN THE FORMULA FOR PROBABILITY DENSITY FUNCTION OF  $X$  IS

$$f(x) = \frac{1}{(\text{standard deviation of } x)\sqrt{2\pi}} e^{-\frac{1}{2} \left( \frac{x - \text{mean of } x}{\text{standard deviation of } x} \right)^2}$$

YOU SAY THAT " $X$  FOLLOWS A NORMAL DISTRIBUTION WITH MEAN  $\mu$  AND STANDARD DEVIATION  $\sigma$ ."

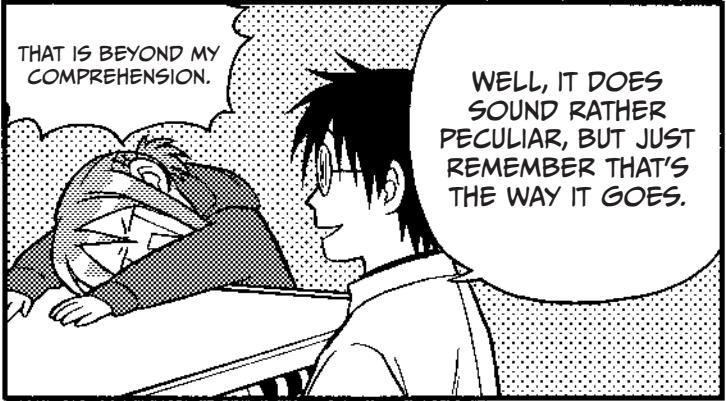


THE PHRASE SEEMS SO COMPLICATED.



" $X$  FOLLOWS WHAT WITH WHAT AND WHAT"...?!"

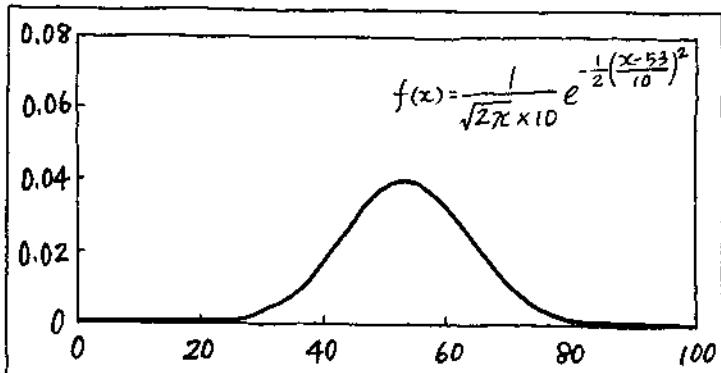
THAT IS BEYOND MY COMPREHENSION.



LET'S RETURN TO THE STORY ABOUT THE TEST.

IF THE PROBABILITY DENSITY FUNCTION OF "ENGLISH TEST RESULTS" IS LIKE THIS...

NORMAL DISTRIBUTION WITH MEAN 53 AND STANDARD DEVIATION 10



YOU CAN SAY THE RESULTS OF THE ENGLISH TEST FOLLOW A NORMAL DISTRIBUTION WITH MEAN 53 AND STANDARD DEVIATION 10.

I THINK I AM STARTING TO GET IT!

### 3. STANDARD NORMAL DISTRIBUTION

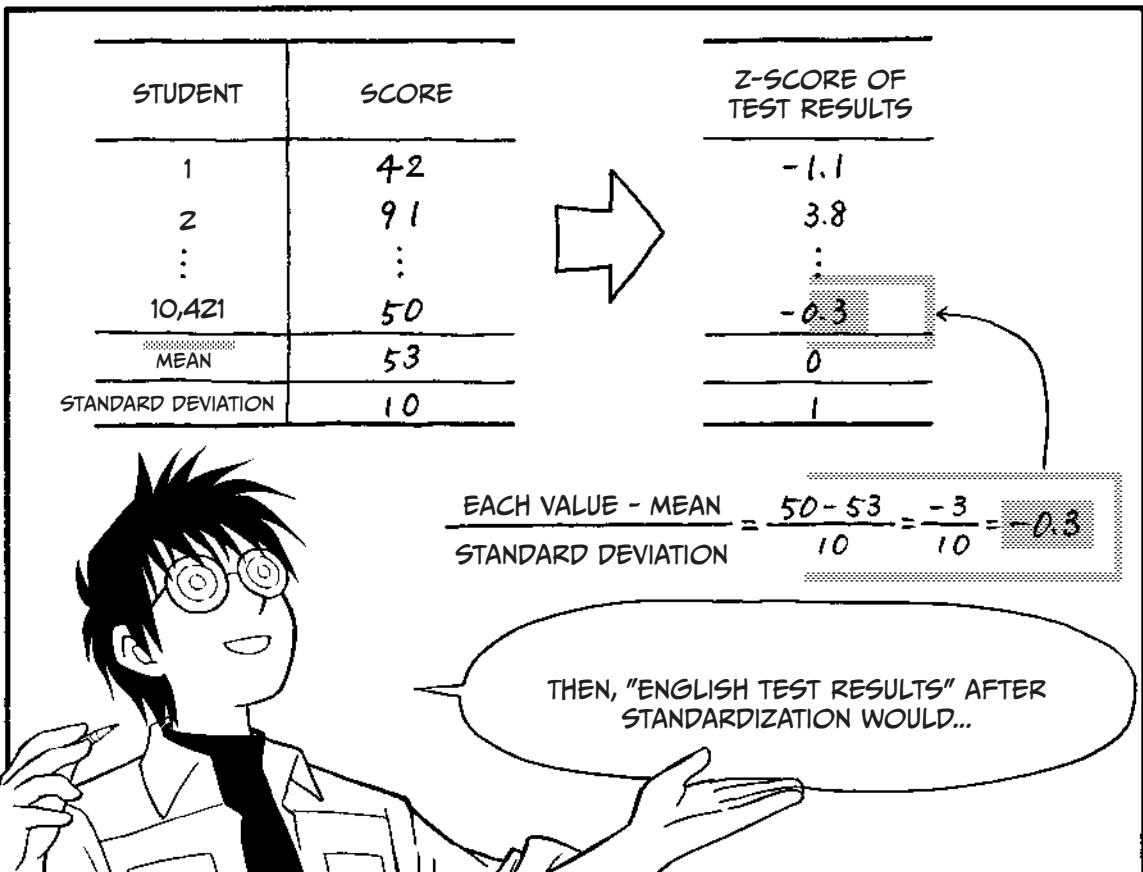
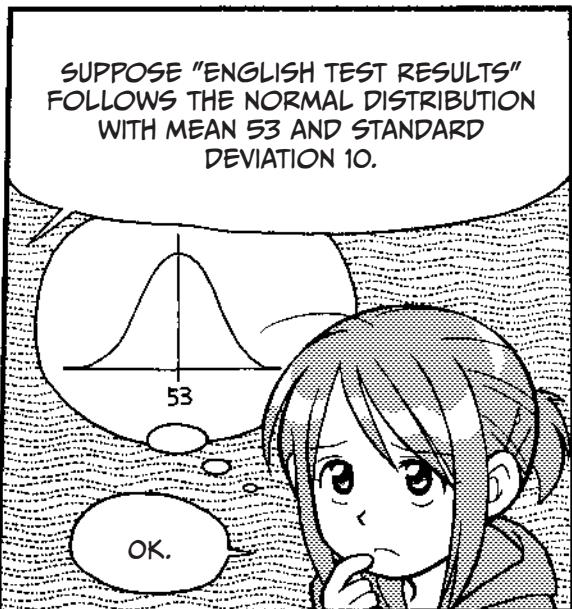
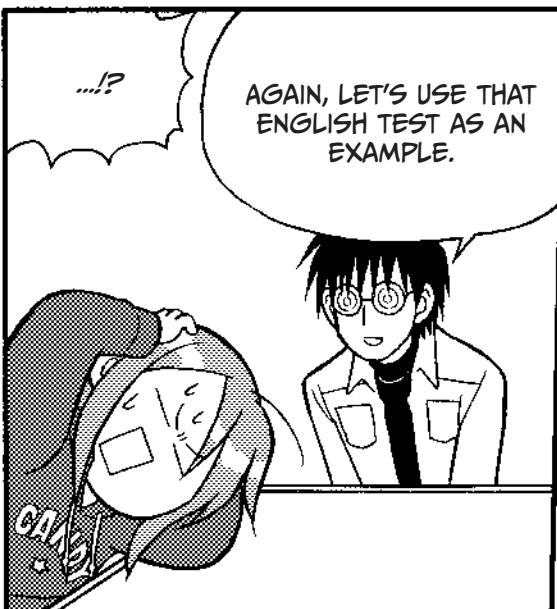
NOW, FOR THE NEXT TOPIC.

YES, SIR.

WHEN THE FORMULA FOR PROBABILITY DENSITY FUNCTION OF X IS

$$f(x) = \frac{1}{(\text{standard deviation of } x)\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x - \text{mean of } x}{\text{standard deviation of } x}\right)^2}$$
$$= \frac{1}{1 \times \sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x - 0}{1}\right)^2} = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}x^2}$$

YOU DON'T SAY, "X FOLLOWS A NORMAL DISTRIBUTION WITH MEAN 0 AND STANDARD DEVIATION 1." IN STATISTICS, WE DESCRIBE THIS AS A STANDARD NORMAL DISTRIBUTION.



## STANDARD NORMAL DISTRIBUTION

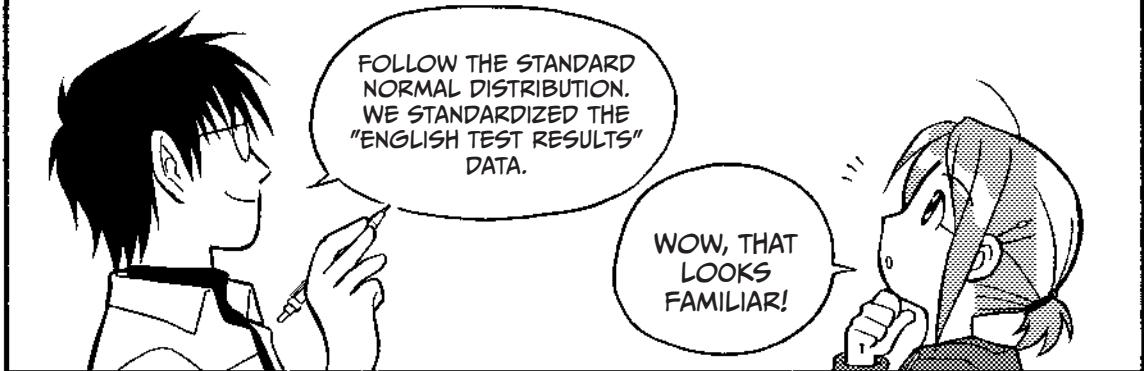
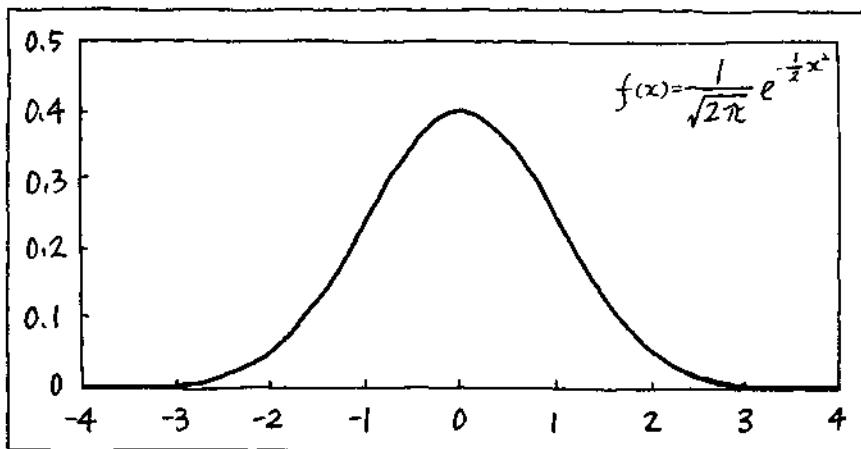
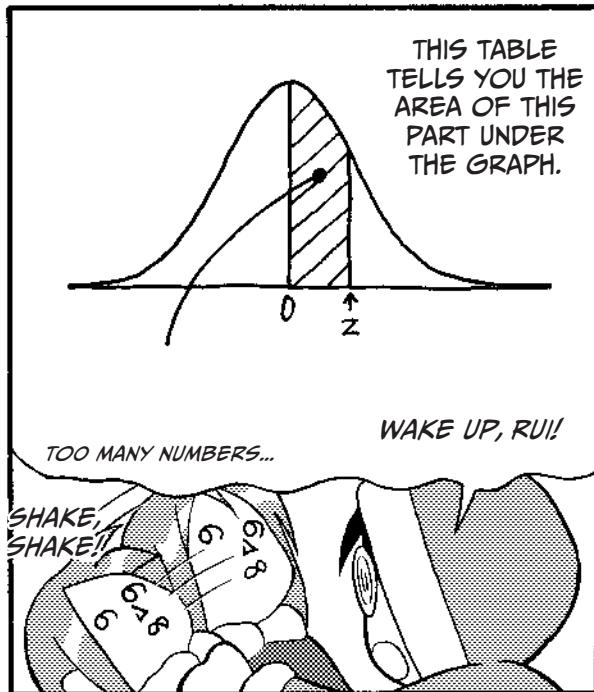
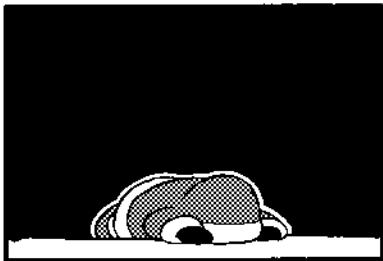
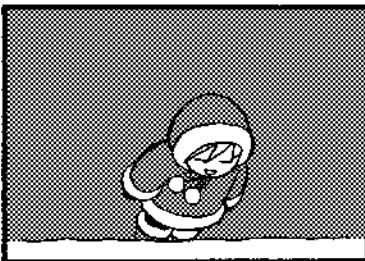
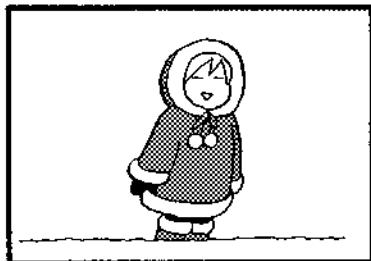
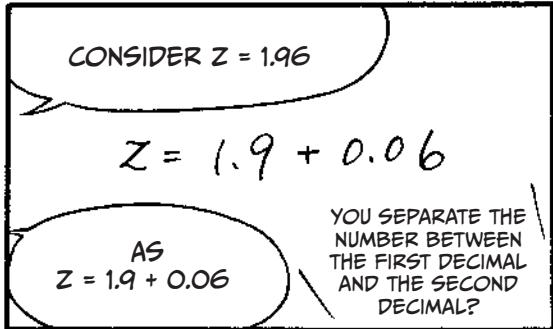
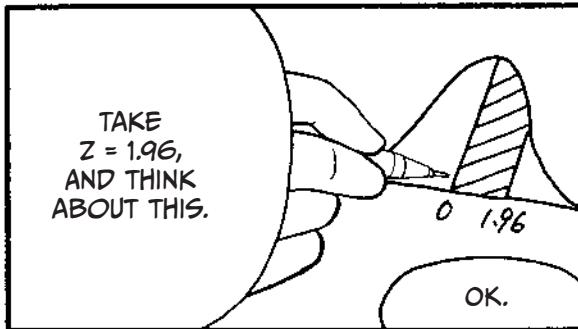


TABLE OF STANDARD NORMAL DISTRIBUTION

Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
	...	...	...	...	...	...	...	...	...	...
	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
	...	...	...	...	...	...	...	...	...	...



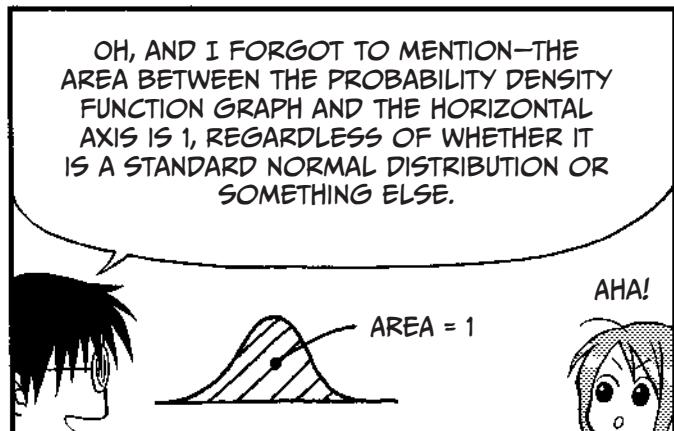
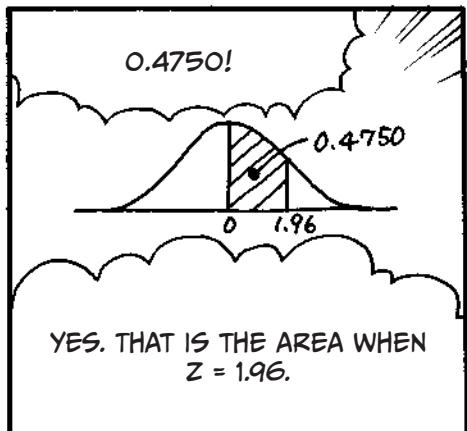


THEN GO BACK TO  
THE TABLE.

Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1102
...	...	...	...	...	...	...	...	...	...
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761
...	...	...	...	...	...	...	...	...	...

A hand points to the intersection of the row for Z=1.9 and the column for 0.06 in the table, which is shaded in gray.

THE LINE AND ROW FOR 1.9  
AND 0.06, RESPECTIVELY,  
CROSS EACH OTHER  
AT...0.4750!



NOW, PAY ATTENTION, BECAUSE  
WHAT I AM GOING TO EXPLAIN  
NEXT IS TODAY'S MAIN DISH.

I CAN'T WAIT  
TO HAVE IT.

THE AREA BOUNDED BY THE STANDARD  
NORMAL DISTRIBUTION AND THE HORIZONTAL  
AXIS IS THE SAME AS THE PROBABILITY!

WHA...?

I AM NOW GOING SHOW YOU TWO EXAMPLES. TRY  
TO FOLLOW ALONG.

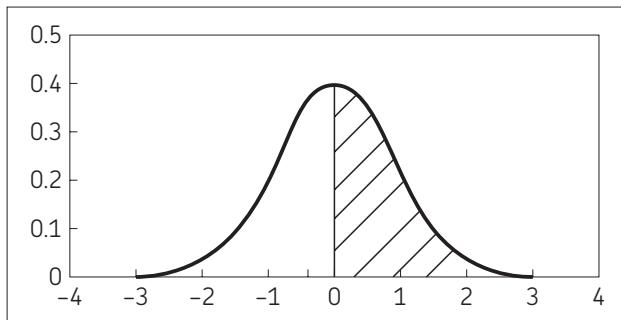


## EXAMPLE I

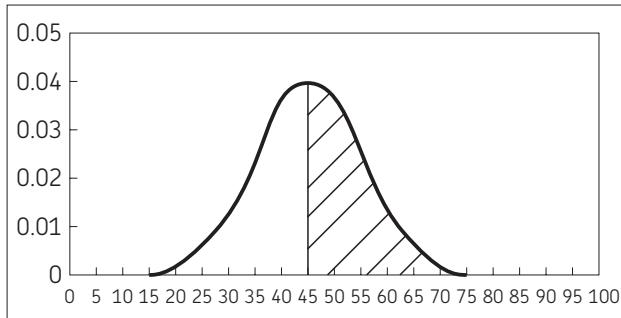


All high school freshmen in prefecture B took a math test. After the tests were marked, the test results turned out to follow a normal distribution with a mean of 45 and a standard deviation of 10. Now, think carefully. The five sentences below all have the same meaning.

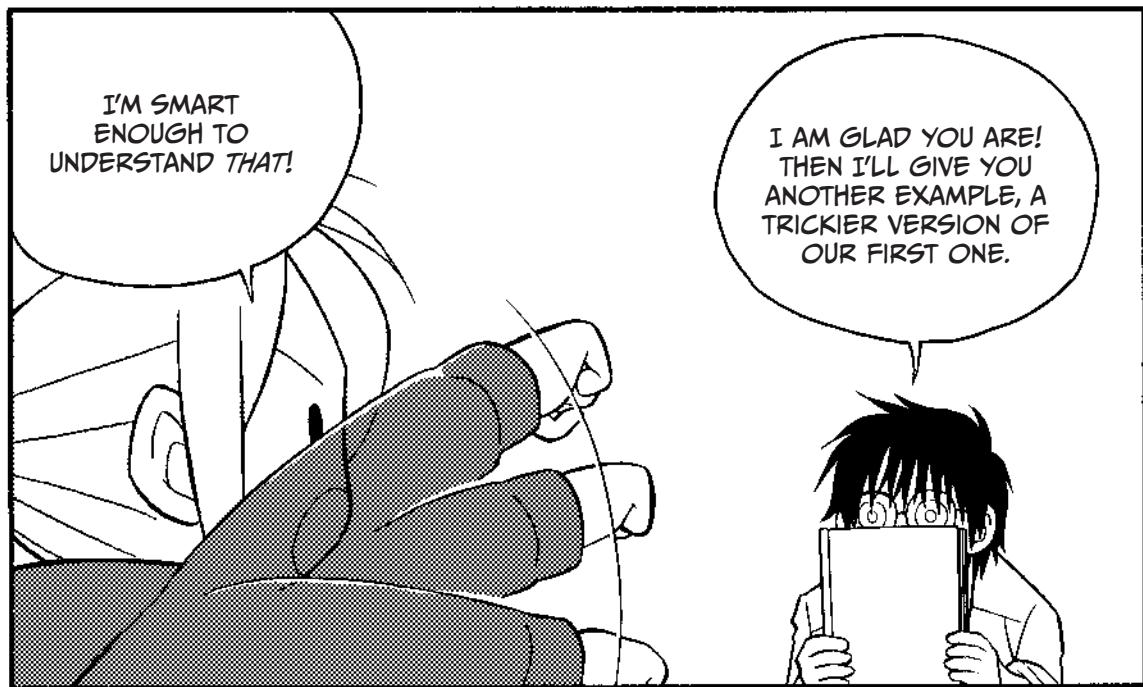
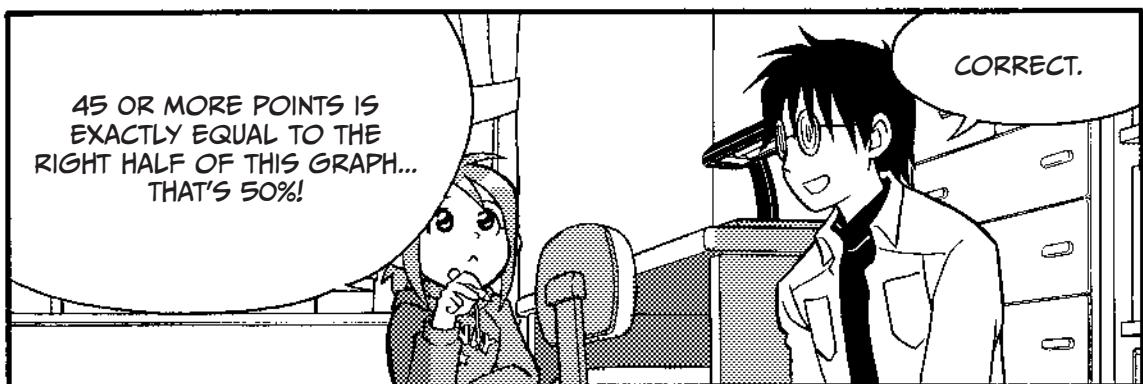
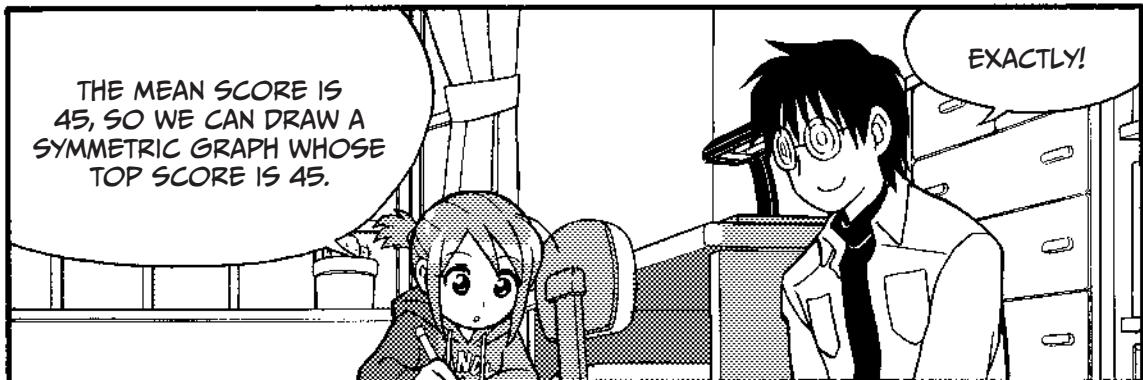
1. In a normal distribution with an average of 45 and a standard deviation of 10, the shaded area in the chart below is 0.5.



2. The ratio of students who scored 45 points or more is 0.5 (50% of all students tested).
3. When one student is randomly chosen from all students tested, the probability that the student's score is 45 or more is 0.5 (50%).
4. In a normal distribution of standardized "math test results," the ratio of students with a standard score of 0 or more is 0.5 (50% of all students tested).



5. When one student's results are randomly chosen from all of those tested in a normal distribution of standardized "math test results," the probability that the selected student's standard score is 0 or more is 0.5 (50%).

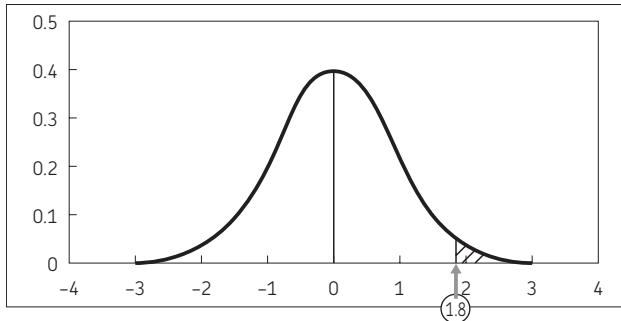


## EXAMPLE II

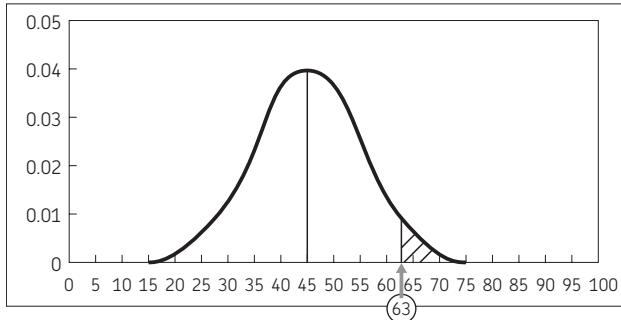
All high school freshmen in prefecture B took a math test. Now, think carefully. The five sentences below all have the same meaning.



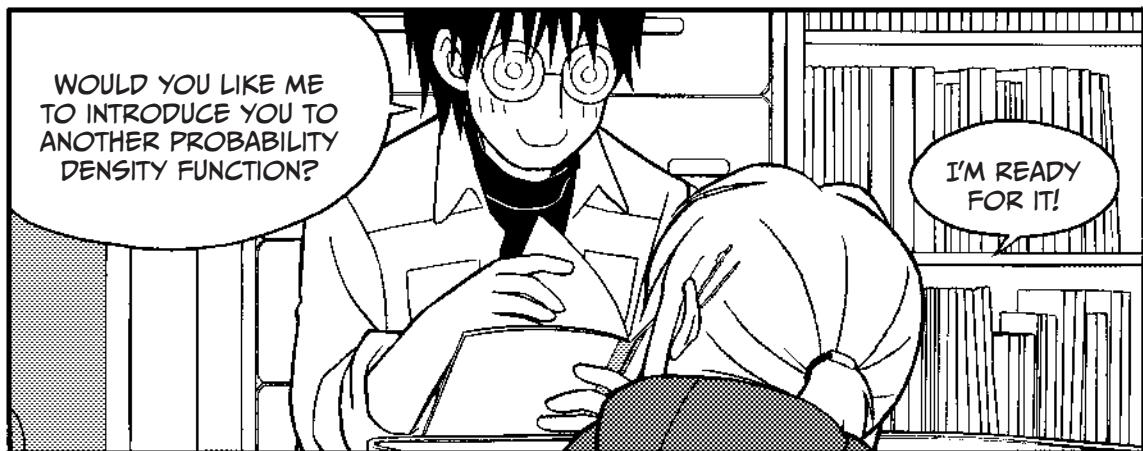
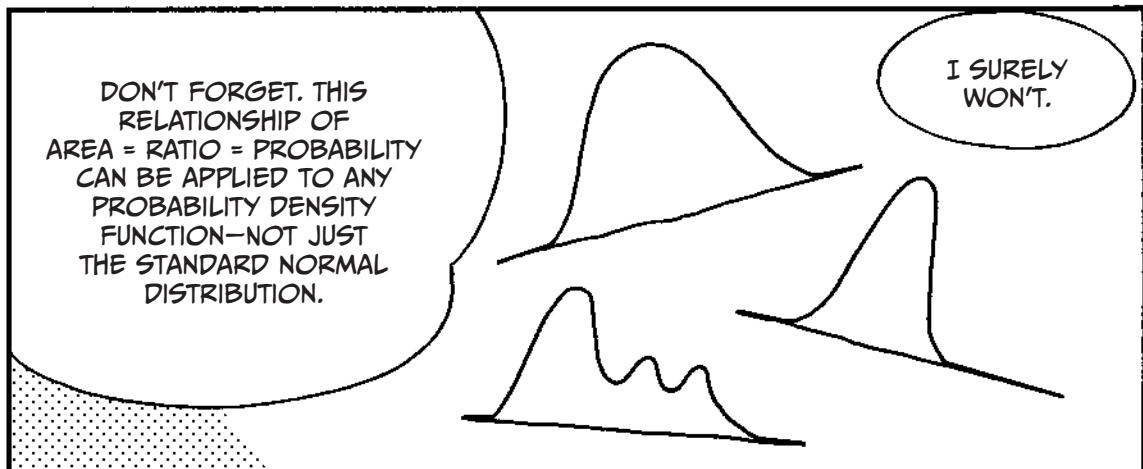
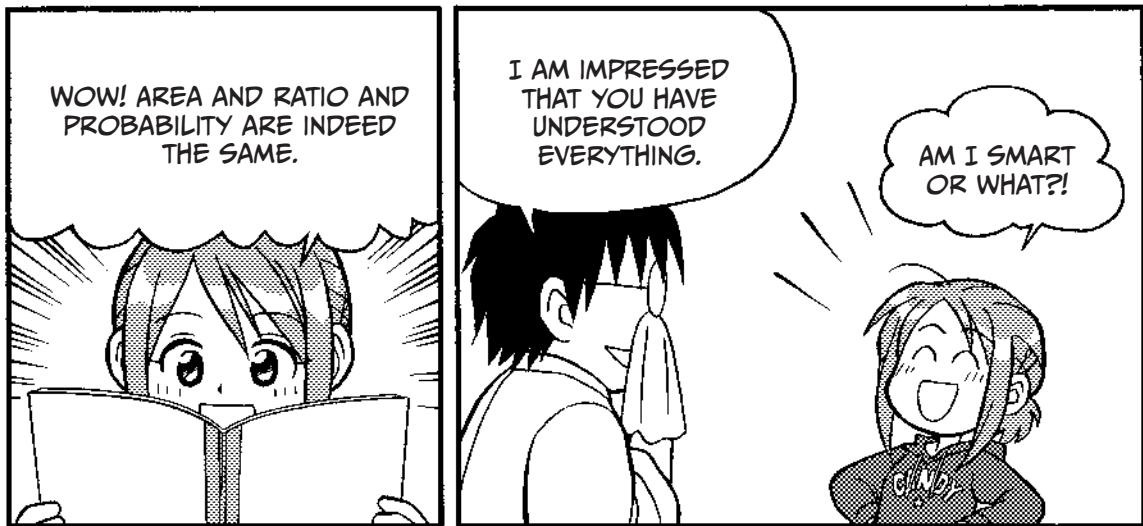
1. In a normal distribution with a mean of 45 and a standard deviation of 10, the shaded area in the chart below is  $0.5 - 0.4641 = 0.0359$ .



2. The ratio of students who scored 63 points or more is  $0.5 - 0.4641 = 0.0359$  (3.59% of all students tested).
3. When one student is randomly chosen from all those tested, the probability that the student's score is 63 or more is  $0.5 - 0.4641 = 0.0359$  (3.59%).
4. In a normal distribution of standardized test results, the ratio of students with standard scores (or z-scores) of 1.8 or more [(each value – average) ÷ standard deviation =  $(63 - 45) \div 10 = 18 \div 10 = 1.8$ ] is 3.59% ( $0.5 - 0.4641 = 0.0359$ ). You can also obtain this value from a table of standard normal distribution.



5. When one student is randomly chosen from all those tested in a normal distribution of standardized "math test results," the probability that the student's standard score is 1.8 or more is  $0.5 - 0.4641 = 0.0359$  (3.59%).



#### 4. CHI-SQUARE DISTRIBUTION

THERE IS A KIND OF DISTRIBUTION CALLED THE CHI-SQUARE DISTRIBUTION.

"CHI?" IS THAT LIKE A SQUARE KAYAK?

NO, IT WASN'T SO BAD!

\*BAD JOKE...

WHEN THE PROBABILITY DENSITY FUNCTION IS...

WHEN  
 $x > 0 \dots$

$$f(x) = \frac{1}{2^{\frac{df}{2}} \times \int_0^{\infty} x^{\frac{df}{2}-1} e^{-x} dx} \times x^{\frac{df}{2}-1} \times e^{-\frac{x}{2}}$$

WHEN  
 $x \leq 0 \dots$

$$f(x) = 0$$

WE SAY, "X FOLLOWS A CHI-SQUARE DISTRIBUTION WITH N DEGREES OF FREEDOM (DF)" IN STATISTICS.

IT'S GETTING EVEN MORE DIFFICULT!

DON'T WORRY. YOU'LL NEVER HAVE TO LEARN THIS FORMULA ITSELF UNLESS YOU BECOME A MATHEMATICIAN.

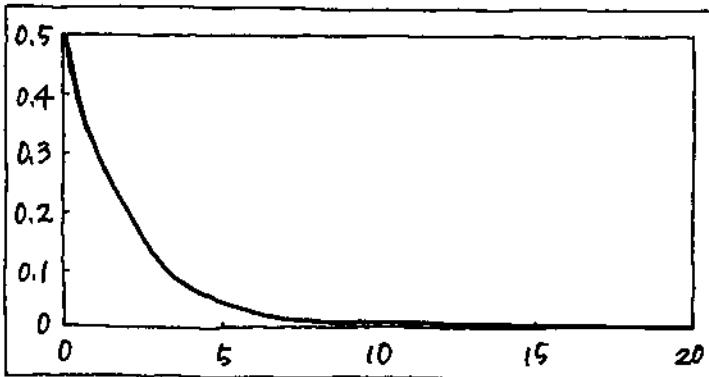
I JUST SHOWED IT TO YOU TO SCARE YOU.

TO BEGIN WITH, LET ME SHOW YOU GRAPHS WITH 2, 10, AND 20 DEGREES OF FREEDOM.

WHAT A COMPLICATED FORMULA...

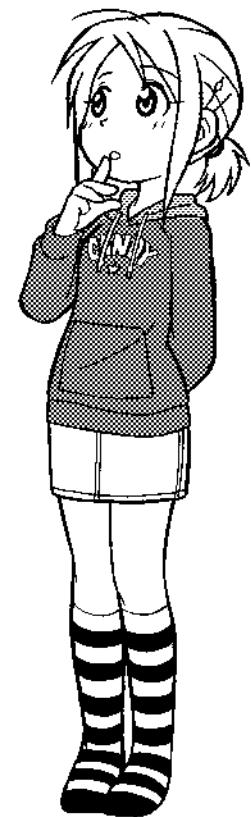
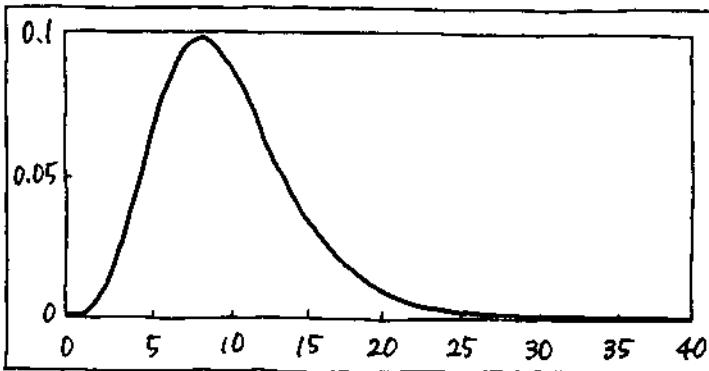


2 DEGREES OF FREEDOM

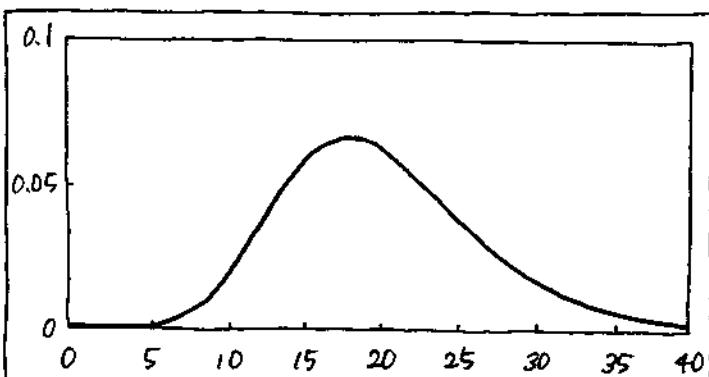


THE SHAPE OF  
THE GRAPH VARIES  
ACCORDING TO THE  
NUMBER OF DEGREES  
OF FREEDOM.

10 DEGREES OF FREEDOM



20 DEGREES OF FREEDOM



BY THE WAY, I HAVE NO IDEA WHAT "DEGREES OF FREEDOM" ARE.

OH, EXCUSE ME FOR FAILING TO EXPLAIN THAT.

BANG!

WHAT WAS THE NAME FOR A IN THE SIMPLE FUNCTION  $f(x) = Ax + B$ ?

$$f(x) = ax + b$$

HMM...WAS IT THE SLOPE?

VERY GOOD! IF THE VALUE OF A CHANGES, THE SLOPE OF THE GRAPH WILL CHANGE. WE CAN TAKE THAT FOR GRANTED, CAN'T WE?

YES.

DEGREES OF FREEDOM ARE JUST LIKE THE SLOPE. THE VALUE AFFECTS THE SHAPE OF A PROBABILITY DISTRIBUTION FUNCTION.

IS THAT ALL "DEGREES OF FREEDOM" MEANS?

IT'S ALSO RELATED TO SAMPLE SIZE. THE BIGGER THE SAMPLE, THE MORE DEGREES OF FREEDOM.

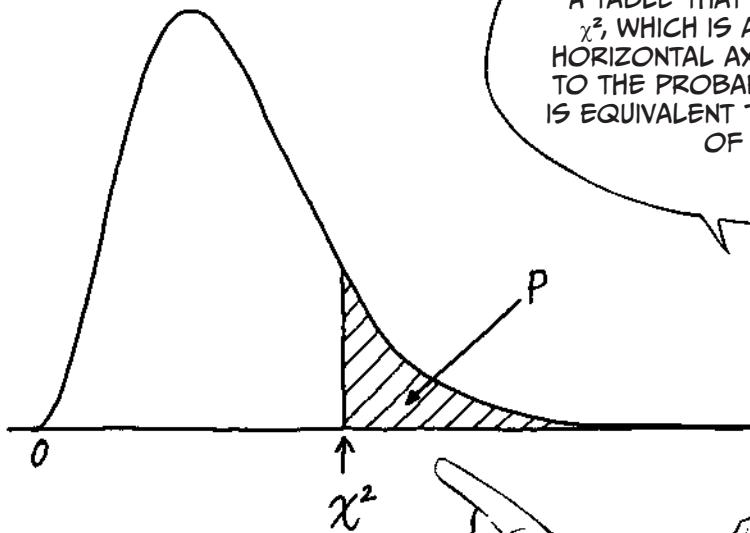
IN OTHER WORDS, WHEN THE VALUE OF DEGREES OF FREEDOM CHANGES, THE SHAPE OF THE GRAPH CHANGES AS WELL.

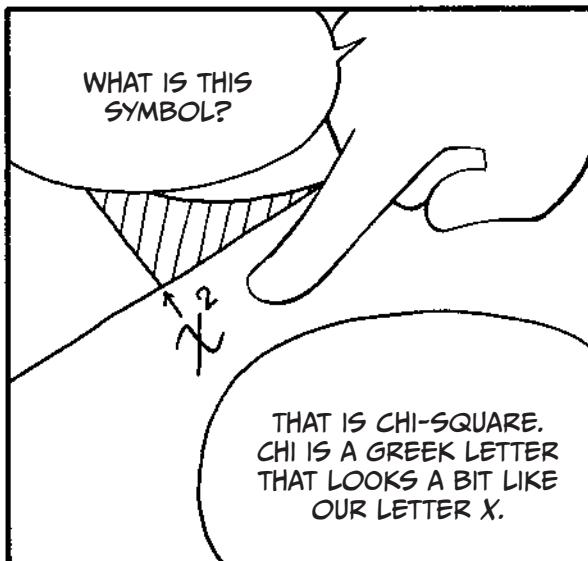
JUST LIKE THERE IS A TABLE OF PROBABILITIES FOR THE STANDARD NORMAL DISTRIBUTION,

THERE IS A TABLE OF PROBABILITIES FOR THE CHI-SQUARE DISTRIBUTION.

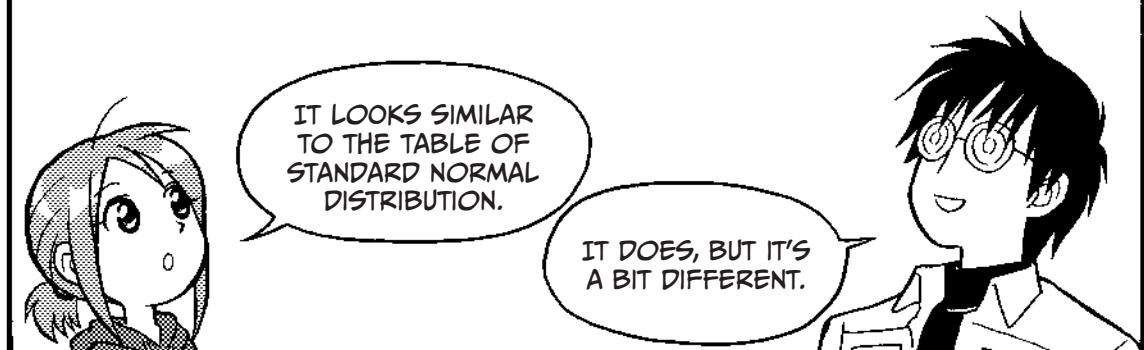
THE TABLE OF CHI-SQUARE DISTRIBUTION IS...

A TABLE THAT SHOWS THE VALUE OF  $\chi^2$ , WHICH IS A GRADUATION ON THE HORIZONTAL AXIS THAT CORRESPONDS TO THE PROBABILITY (WHICH WE KNOW IS EQUIVALENT TO THE AREA AND RATIO) OF THIS PART P.





P DEGREES OF FREEDOM	0.995	0.99	0.975	0.95	0.05	0.025	0.01	0.005
1	0.000039	0.0002	0.0010	0.0039	3.8415	5.0239	6.6349	7.8794
2	0.0100	0.0201	0.0506	0.1026	5.9915	7.3778	9.2104	10.5965
3	0.0717	0.1148	0.2158	0.3518	7.8147	9.3484	11.3449	12.8381
4	0.2070	0.2971	0.4844	0.7107	9.4877	11.1433	13.2767	14.8602
5	0.4118	0.5543	0.8312	1.1455	11.0705	12.8325	15.0863	16.7496
6	0.6757	0.8721	1.2373	1.6354	12.5916	14.4494	16.8119	18.5475
7	0.9893	1.2390	1.6899	2.1673	14.0671	16.0128	18.4753	20.2777
8	1.3444	1.6465	2.1797	2.7326	15.5073	17.5345	20.0902	21.9549
9	1.7349	2.0879	2.7004	3.3251	16.9190	19.0228	21.6660	23.5893
10	2.1558	2.5582	3.2470	3.9403	18.3070	20.4832	23.2093	25.1881
...	...	...	...	...	...	...	...	...



WITH THE TABLE OF STANDARD NORMAL DISTRIBUTION, YOU PROVIDE THE X-COORDINATE, AND IT TELLS YOU THE ASSOCIATED PROBABILITY.

IT PROVIDED THE PROBABILITY (= AREA = RATIO)

WITH THE TABLE OF CHI-SQUARE DISTRIBUTION, YOU PROVIDE THE PROBABILITY, AND IT TELLS YOU THE ASSOCIATED X-COORDINATE.

THIS VALUE!

I AM GETTING CONFUSED....!

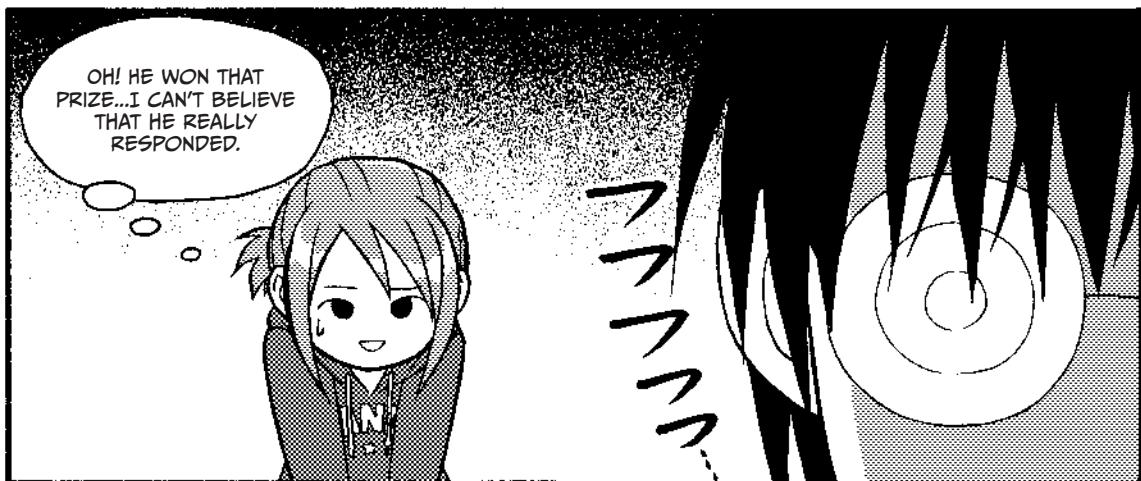
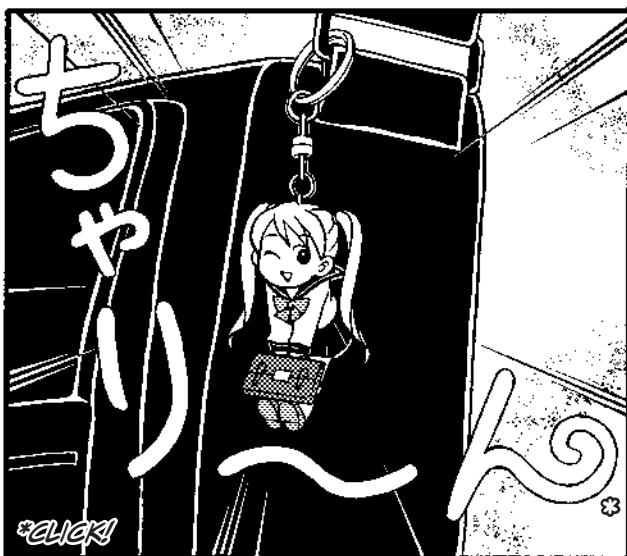
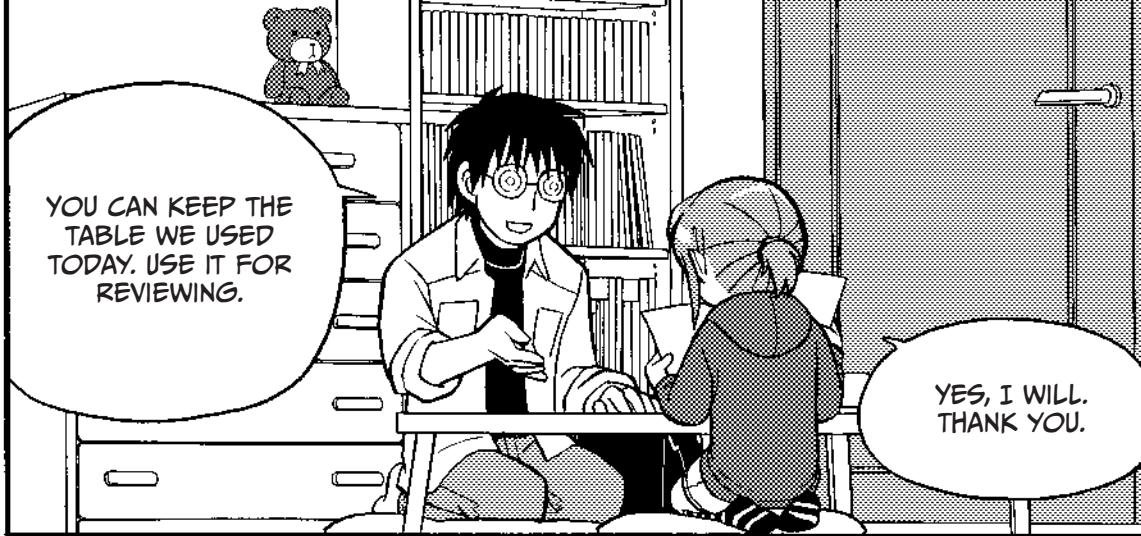
CALM DOWN!

LET'S FIND OUT WHAT THE VALUE OF  $\chi^2$  IS IN A CASE IN WHICH THE DEGREE OF FREEDOM IS 1 AND P IS 0.05.

\* TABLE OF CHI-SQUARE DISTRIBUTION

THE LINE FOR 1 AND THE ROW FOR 0.05 CROSS AT...

3.8415.



## 5. T DISTRIBUTION

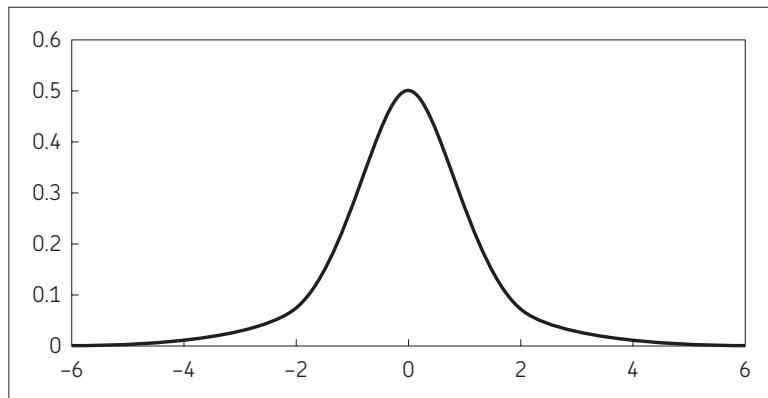


The probability density function below is a popular topic in statistics.

$$f(x) = \frac{\int_0^{\infty} x^{\frac{df+1}{2}-1} e^{-x} dx}{\sqrt{df \times \pi} \times \int_0^{\infty} x^{\frac{df}{2}-1} e^{-x} dx} \times \left(1 + \frac{x^2}{df}\right)^{-\frac{df+1}{2}}$$

When the probability density function for  $x$  looks like this, we say, “ $x$  follows a t distribution with  $n$  degrees of freedom.”

Here is a case with 5 degrees of freedom:



## 6. F DISTRIBUTION

The probability density function below is a popular topic in statistics.

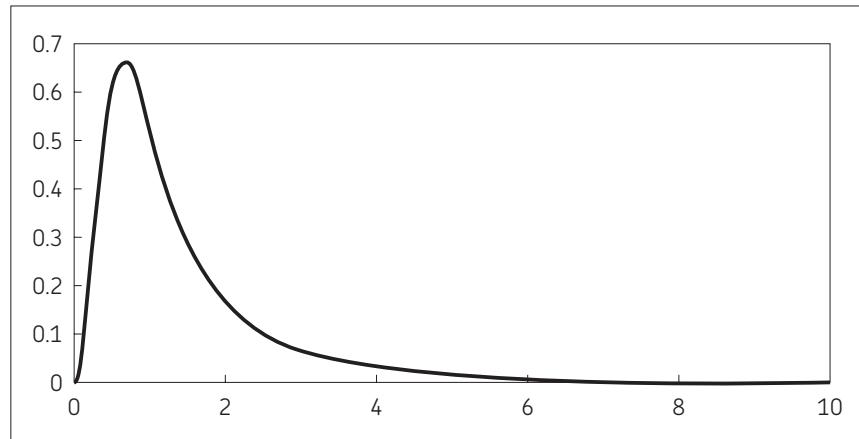
when  $x > 0$ :

$$f(x) = \frac{\left(\int_0^{\infty} x^{\frac{\text{first df}+1}{2}-1} e^{-x} dx\right) \times \left(\text{first df}\right)^{\frac{\text{first df}}{2}} \times \left(\text{second df}\right)^{\frac{\text{second df}}{2}}}{\left(\int_0^{\infty} x^{\frac{\text{first df}}{2}-1} e^{-x} dx\right) \times \left(\int_0^{\infty} x^{\frac{\text{second df}}{2}-1} e^{-x} dx\right)} \times \frac{x^{\frac{\text{first df}-1}{2}}}{\left(\text{first df} \times x + \text{second df}\right)^{\frac{(\text{first df}+\text{second df})}{2}}}$$

when  $x \leq 0$ :  $f(x) = 0$

When the probability density function for  $x$  looks like this, we say, “ $x$  follows an F distribution with the first degree of freedom  $m$  and the second degree of freedom  $n$ .”

Here is a case in which the first degree of freedom is 10 and the second degree of freedom is 5:



## 7. DISTRIBUTIONS AND EXCEL

Until the rise of personal computers (roughly speaking, around the beginning of the 1990s), it was difficult for an individual to calculate the probability without tables of standard normal distribution or chi-square distribution. However, these tables of distribution are not used much anymore—you can use Excel functions to find the same values as the ones provided by the tables. This enables individuals to calculate even more types of values than the ones found in the tables of distribution. Table 5-1 summarizes Excel functions related to various distributions. (Refer to the appendix on page 191 for more information on making calculations with Excel.)

TABLE 5-1: EXCEL FUNCTIONS RELATED TO VARIOUS DISTRIBUTIONS

Distribution	Functions	Feature of the function
normal*	NORMDIST	Calculates the probability that corresponds to a point on the horizontal axis.
normal	NORMINV	Calculates a point on the horizontal axis that corresponds to the probability.
standard normal	NORMSDIST	Calculates the probability that corresponds to a point on the horizontal axis.
standard normal	NORMSINV	Calculates a point on the horizontal axis that corresponds to the probability.
chi-square	CHIDIST	Calculates the probability that corresponds to a point on the horizontal axis.
chi-square	CHIINV	Calculates a point on the horizontal axis that corresponds to the probability.
t	TDIST	Calculates the probability that corresponds to a point on the horizontal axis.
t	TINV	Calculates a point on the horizontal axis that corresponds to the probability.
F	FDIST	Calculates the probability that corresponds to a point on the horizontal axis.
F	FINV	Calculates a point on the horizontal axis that corresponds to the probability.

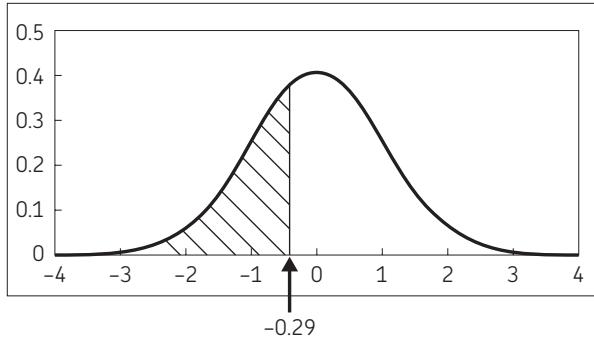
\* The probability density function for normal distribution is affected by the mean and standard deviation. Thus, it is impossible to make a “table of normal distribution,” and no such thing exists in this world. However, by using Excel, you can conveniently calculate the values and make a table relevant to the normal distribution.

## EXERCISE AND ANSWER



### EXERCISE

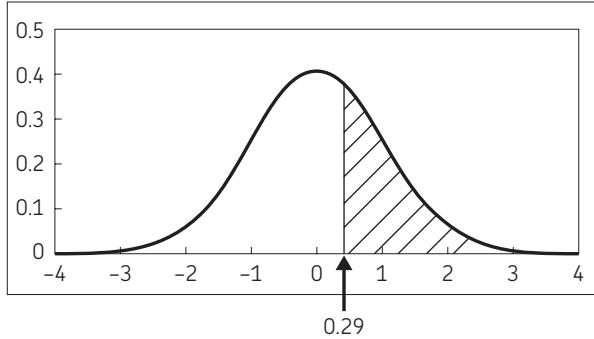
- Calculate the probability (the shaded area in the graph below) using the table of standard normal distribution on page 93.



- Calculate the value of  $\chi^2$  when there are 2 degrees of freedom and P is 0.05 using the table of chi-square distribution on page 103.

### ANSWER

- Because the standard normal distribution is symmetrical, the probability in question is equal to the probability shown in the graph below.



The probability when  $z = 0.29 = 0.2 + 0.09$  is 0.1141 according to the table of standard normal distribution. Therefore, the probability to be obtained is  $0.5 - 0.1141 = 0.3859$ .

- The value of  $\chi^2$  to be obtained is 5.9915 according to the table of chi-square distribution.

---

## SUMMARY

---

- Some of the most common probability density functions are:
  - Normal distribution
  - Standard normal distribution
  - Chi-square distribution
  - t distribution
  - F distribution
- The area between the probability density function and the horizontal axis is 1. This area is equivalent to a ratio or a probability.
- By using an Excel function or a table of probabilities for the appropriate distribution, you can calculate:
  - The probability that corresponds to a point on the horizontal axis
  - The point on the horizontal axis that corresponds to the probability



# 6

LET'S LOOK AT THE RELATIONSHIP  
BETWEEN TWO VARIABLES

くるへた

NICE WEATHER.

くるへた\*

\*SCRITCH, CLUMP

WHY ARE YOU  
WEARING THAT  
SANDAL?! YOU'RE  
WEARING TWO  
DIFFERENT  
SHOES!

OOPS!  
YOU'RE  
RIGHT.

NOT A BAD  
DAY TO STUDY  
OUTDOORS.

IF I WERE  
HERE WITH  
MR. IGARASHI...  
I'D BE SO HAPPY.

MR. IGARASHI...  
MR. IGARASHI...?

OH, NO! I AM  
BEGINNING TO  
LOSE MY MEMORY  
OF HIM.

TODAY, I AM GOING  
TO TALK ABOUT  
THE RELATIONSHIP  
BETWEEN TWO  
VARIABLES.

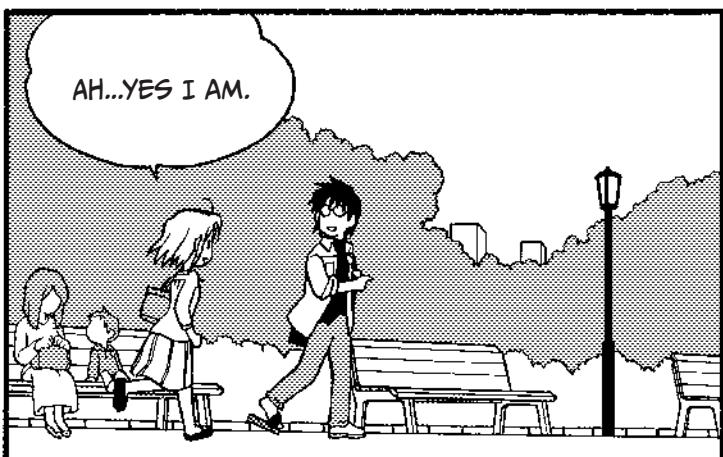
\*SCRITCH, CLUMP

くるへた

MR.  
YAMAMOTO'S  
QUIRKS ARE  
TOO STRONG,  
AND THAT'S  
MAKING ME  
FORGET  
MR. IGARASHI!



AH...YES I AM.



SO, FOR EXAMPLE, DOES  
A TALLER PERSON WEIGH  
MORE? OR, DO PEOPLE  
FAVOR DIFFERENT SODA  
BRANDS IF THEY ARE  
DIFFERENT IN AGE?

OR, DO PEOPLE SUPPORT  
DIFFERENT POLITICAL  
PARTIES IF THEY LIVE IN  
DIFFERENT AREAS?

OH! THANK YOU FOR WIPING  
THE BENCH FOR ME.

OH, I  
KNOW  
THAT  
SONG!

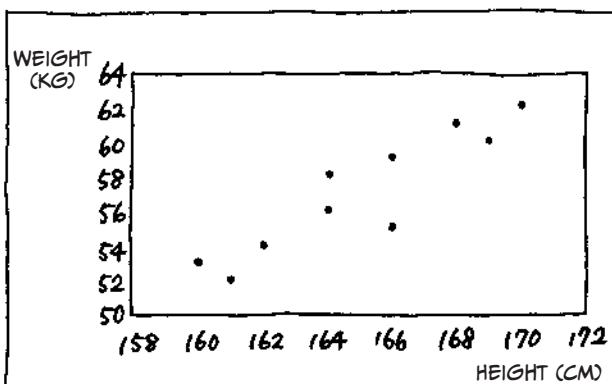
IS THAT SOMETHING LIKE  
"DO YOU LOVE ME, NOW  
THAT I CAN DANCE?"

NOW...

OH, HERE  
BEGINS THE  
LESSON!

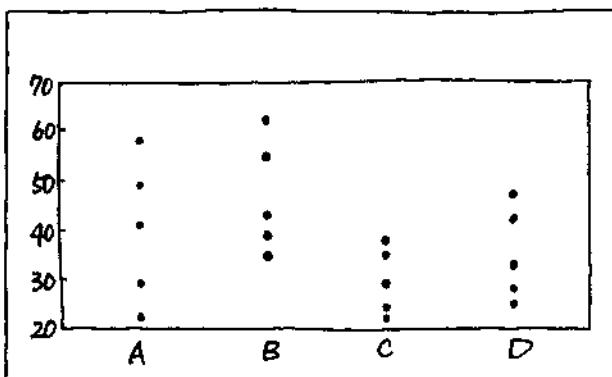
OPEN!

SCATTER CHART OF HEIGHT AND WEIGHT



NUMERICAL AND  
NUMERICAL

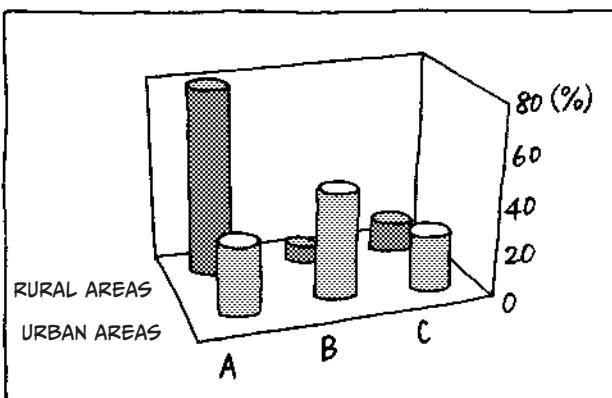
SCATTER CHART OF FAVORITE SODA BRAND AND AGE



NUMERICAL AND  
CATEGORICAL

YOU CAN SEE  
WHETHER OR NOT  
TWO VARIABLES ARE  
RELATED TO EACH  
OTHER BY DRAWING A  
CHART.

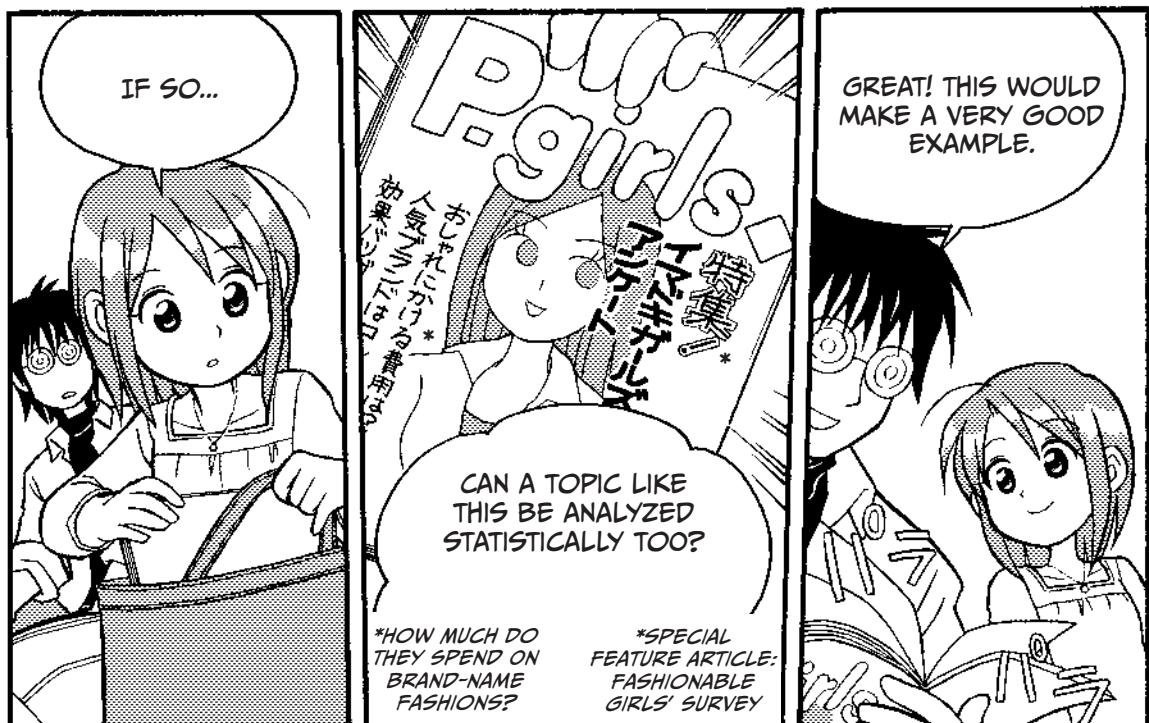
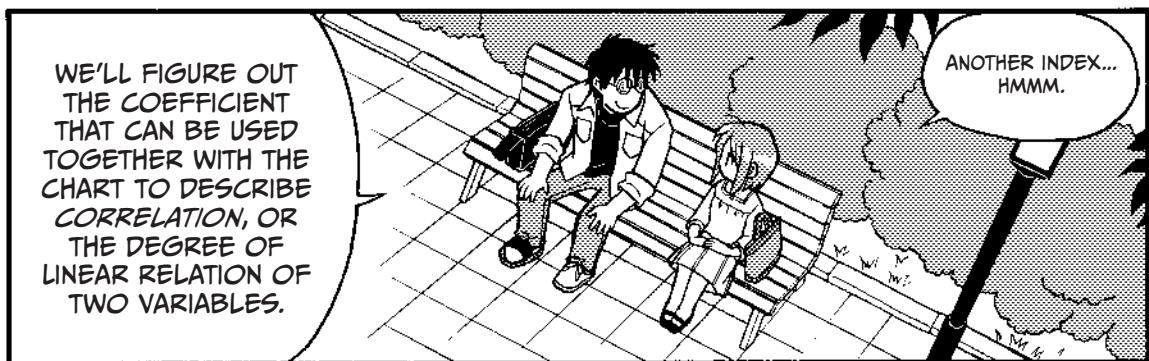
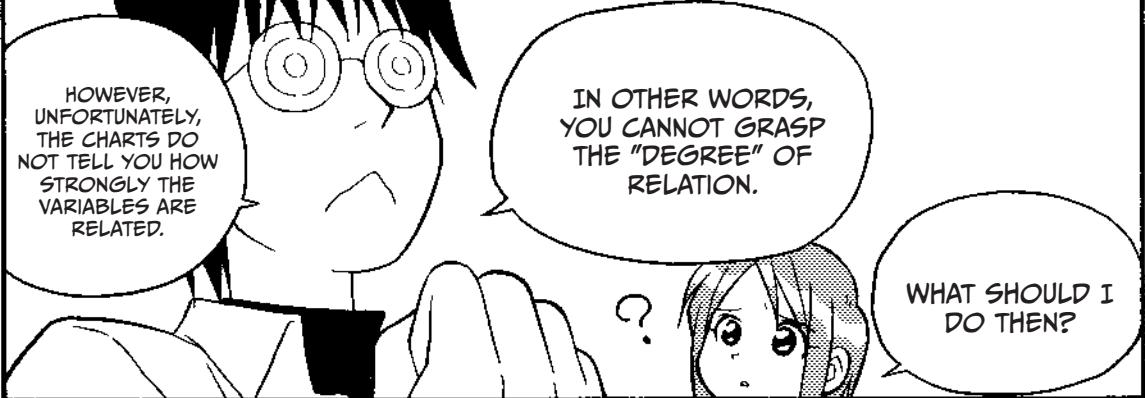
CYLINDER CHART OF PLACE OF RESIDENCE  
AND SUPPORT OF POLITICAL PARTY X



CATEGORICAL  
AND  
CATEGORICAL

AHA!





## 1. CORRELATION COEFFICIENT

OH, HERE IS A SURVEY ON  
MAKEUP EXPENDITURES  
AND CLOTHES  
EXPENDITURES.

BOTH  
VARIABLES  
ARE  
NUMERICAL!

Street  
survey!~

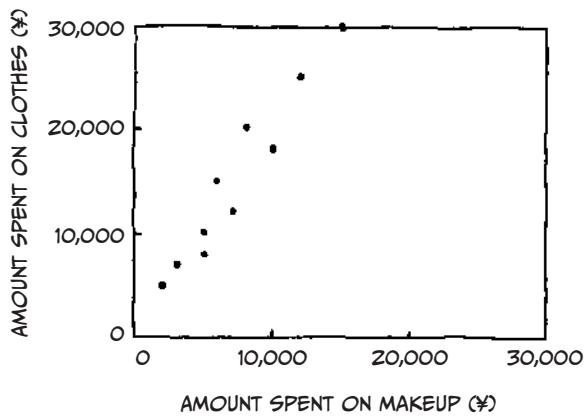
Ten ladies in their 20s answered  
Monthly Expenditures on Makeup and Clothes

Respondent	Amount spent on makeup (¥)	Amount spent on clothes (¥)
Ms. A	3,000	7,000
Ms. B	5,000	8,000
Ms. C	12,000	25,000
Ms. D	2,000	5,000
Ms. E	7,000	12,000
Ms. F	15,000	30,000
Ms. G	5,000	10,000
Ms. H	6,000	15,000
Ms. I	8,000	20,000
Ms. J	10,000	18,000

WHY DON'T YOU  
MAKE A CHART  
FIRST.

YES, SIR!

SCATTER CHART OF MONTHLY EXPENDITURES ON  
MAKEUP AND CLOTHES

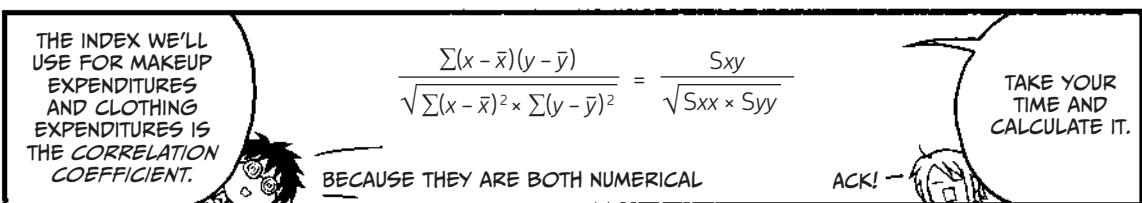


OBVIOUSLY, PEOPLE WHO  
SPEND MORE ON MAKEUP  
SPEND MORE ON THEIR  
CLOTHES AS WELL.

THEN, WHY DON'T  
WE TRY FIGURING  
OUT THE DEGREE  
OF RELATIONSHIP?

Data types	Index	Value range	Formula
Numerical and numerical	Correlation coefficient	-1 - 1	$\frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \times \sum(y - \bar{y})^2}} = \frac{S_{xy}}{\sqrt{S_{xx} \times S_{yy}}}$
Numerical and categorical	Correlation ratio*	0 - 1	interclass variance intraclass variance + interclass variance
Categorical and categorical	Cramer's coefficient*	0 - 1	$\chi_0^2$ $\frac{\text{the total number of values} \times \\ (\min\{\text{the number of lines in the cross tabulation, the number of rows in the cross tabulation}\} - 1)}$

\* See page 121, "Correlation Ratio," and page 127, "Cramer's Coefficient."



HERE WE GO!

THIS FREAKS ME OUT!

THE PROCESS FOR CALCULATING THE CORRELATION COEFFICIENT FOR MONTHLY EXPENDITURES ON MAKEUP AND CLOTHES

Amount spent on makeup (¥)	Amount spent on clothes (¥)						
		x	y	x - $\bar{x}$	y - $\bar{y}$	(x - $\bar{x}$ ) <sup>2</sup>	(y - $\bar{y}$ ) <sup>2</sup>
Ms. A	3,000	7,000	4,300	-8,000	18,490,000	64,000,000	34,400,000
Ms. B	5,000	8,000	-2,300	-7,000	5,290,000	49,000,000	16,100,000
Ms. C	12,000	25,000	4,700	10,000	22,090,000	100,000,000	47,000,000
Ms. D	2,000	5,000	-5,300	-10,000	28,090,000	100,000,000	53,000,000
Ms. E	7,000	12,000	-300	-3,000	90,000	9,000,000	900,000
Ms. F	15,000	30,000	7,700	15,000	59,290,000	225,000,000	115,500,000
Ms. G	5,000	10,000	-2,300	-5,000	5,290,000	25,000,000	11,500,000
Ms. H	6,000	15,000	-1,300	0	1,690,000	0	0
Ms. I	8,000	20,000	700	5,000	490,000	25,000,000	3,500,000
Ms. J	10,000	18,000	2,700	3,000	7,290,000	9,000,000	8,100,000
<b>Sum</b>	73,000	150,000	0	0	148,100,000	606,000,000	290,000,000
<b>Mean</b>	7,300	15,000					

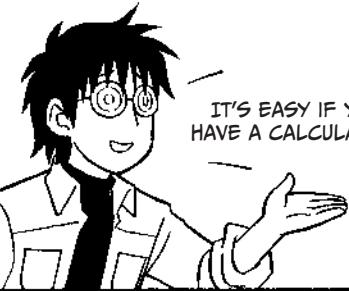
$\bar{x}$        $\bar{y}$       S<sub>xx</sub>      S<sub>yy</sub>      S<sub>xy</sub>

NOW, ASSIGN THE VALUES TO THE FORMULA.

$$\frac{s_{xy}}{\sqrt{s_{xx} \times s_{yy}}} = \frac{290,000,000}{\sqrt{148,100,000 \times 606,000,000}} = 0.9680$$

IT'S EASY IF YOU HAVE A CALCULATOR.

THE CORRELATION COEFFICIENT IS...0.9680!



THE CORRELATION COEFFICIENT GETS CLOSER TO  $\pm 1$  IF THE LINEAR RELATIONSHIP BETWEEN THE TWO VARIABLES IS STRONGER.

AS THE RELATIONSHIP GETS WEAKER, IT GETS CLOSER TO 0.



THAT'S INTERESTING.

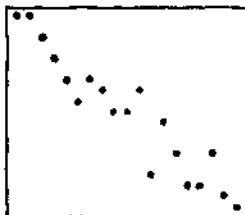
THE RESULT I JUST CALCULATED IS QUITE CLOSE TO 1, SO THAT IMPLIES THAT MAKEUP EXPENDITURES AND CLOTHING EXPENDITURES ARE VERY CLOSELY RELATED.

YOU ARE QUITE CORRECT.

WHEN DOES IT GET CLOSE TO -1?

THAT WOULD HAPPEN IF THE CLOTHING EXPENDITURES FELL AS THE MAKEUP EXPENDITURES ROSE.

NEGATIVE CORRELATION



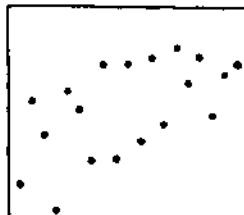
APPROX. -1

ZERO CORRELATION

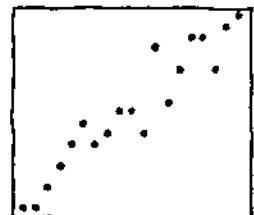


APPROX. 0

POSITIVE CORRELATION



APPROX. 0.5



APPROX. 1

### CORRELATION COEFFICIENT



IF THE CORRELATION COEFFICIENT IS POSITIVE, AS IN THIS CASE, WE SAY, "THERE IS A POSITIVE CORRELATION," AND IF IT IS NEGATIVE, WE SAY, "THERE IS A NEGATIVE CORRELATION."

IF IT IS 0, WE SAY THAT "THEY ARE UNCORRELATED."

I UNDERSTAND COMPLETELY.



NOW, ABOUT THE CORRELATION COEFFICIENT...

UNFORTUNATELY, THERE ARE NO STATISTICAL STANDARDS TO ASSURE YOU THAT THE TWO VARIABLES HAVE A STRONG RELATIONSHIP.

WHAT AN UNRELIABLE INDEX...



## INFORMAL STANDARDS OF THE CORRELATION COEFFICIENT

Absolute value of the correlation coefficient	Detailed description	Rough description
1.0–0.9	⇒ Very strongly related	
0.9–0.7	⇒ Fairly strongly related	Related
0.7–0.5	⇒ Fairly weakly related	
Below 0.5	⇒ Very weakly related	Not related



JUST FOR YOUR INFORMATION,  
INFORMAL STANDARDS  
ARE GIVEN ABOVE.



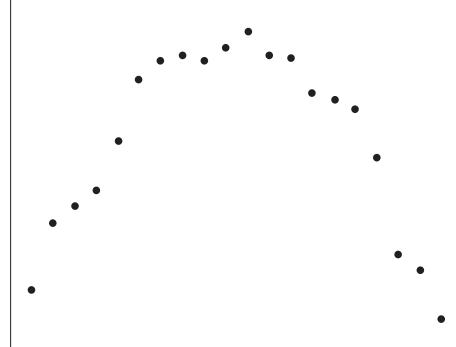
## WARNING

I mentioned earlier that the correlation coefficient is an index that shows the degree of *linear* relation between two numerical variables.



### SAMPLE OF DATA UNSUITABLE FOR CORRELATION COEFFICIENT

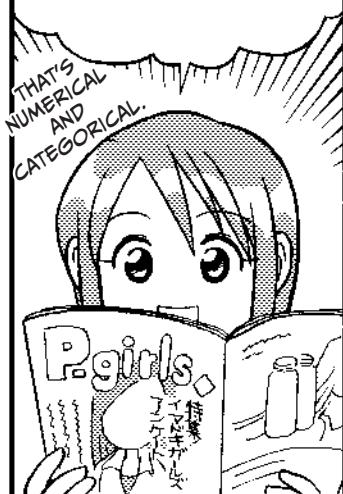
CORRELATION COEFFICIENT = -0.0825



For example, the two variables are obviously related in this chart. However, the correlation coefficient is almost 0 because the relationship is *non-linear*.

## 2. CORRELATION RATIO

ON WE GO!  
THEY HAVE ALSO  
SURVEYED AGE  
AND FAVORITE  
FASHION BRAND!

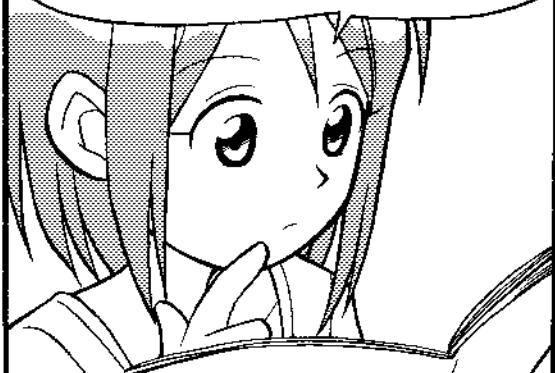


### Street Survey in Everyhills

#### Age and Favorite Fashion Brand

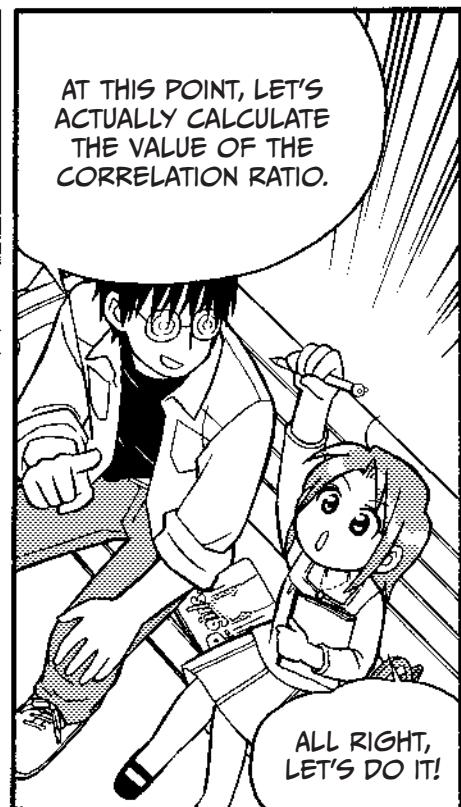
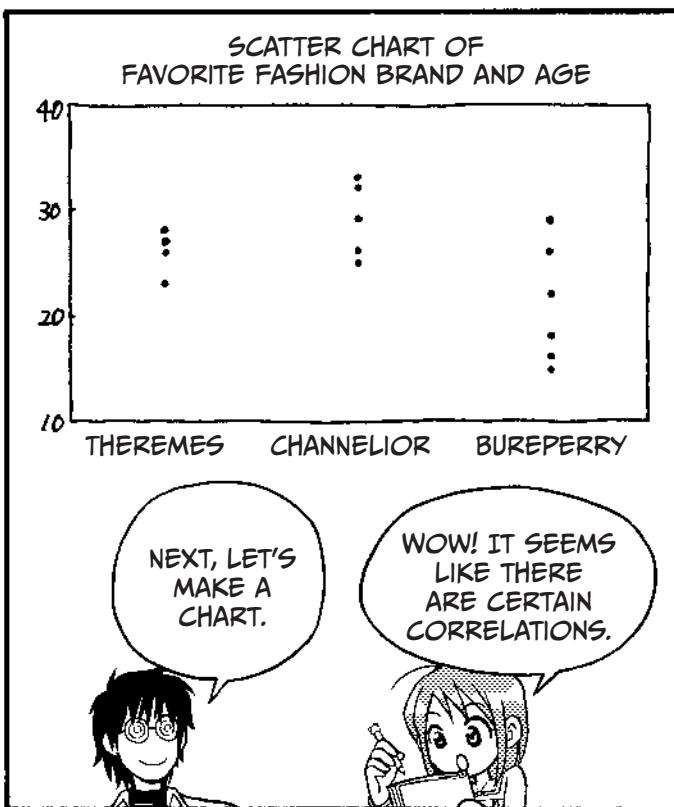
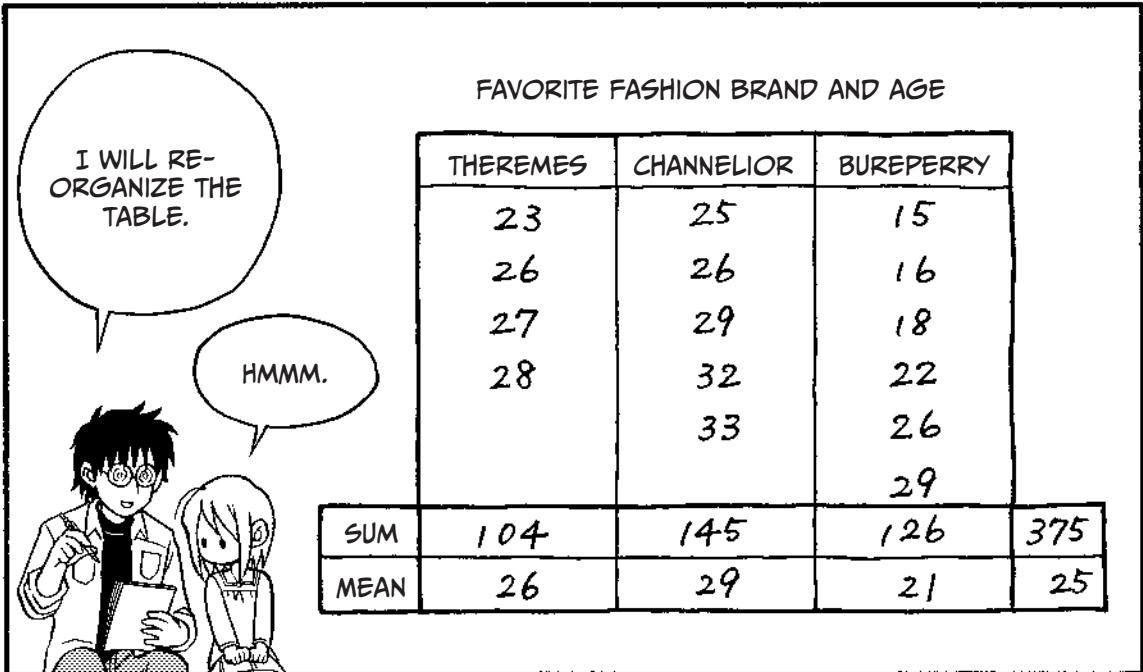
Respondent	Age	Brand
Ms. A	27	Theremes
Ms. B	33	Channelior
Ms. C	16	Bureperry
Ms. D	29	Bureperry
Ms. E	32	Channelior
Ms. F	23	Theremes
Ms. G	25	Channelior
Ms. H	28	Theremes
Ms. I	22	Bureperry
Ms. J	18	Bureperry
Ms. K	26	Channelior
Ms. L	26	Theremes
Ms. M	15	Bureperry
Ms. N	29	Channelior
Ms. O	26	Bureperry

FOR NUMERICAL DATA AND  
CATEGORICAL DATA, WE USE THE  
CORRELATION RATIO.  
ITS VALUE IS...BETWEEN 0 AND 1.



IS THE RELATIONSHIP  
STRONGER IF THE VALUE IS  
CLOSER TO 1 IN THIS CASE,  
TOO?





The value of the correlation ratio can be calculated by following steps 1 through 4 below.



### Step 1

Do the calculations in the table below.

	Sum
(Theremes – average for Theremes) <sup>2</sup>	$(23 - 26)^2 = (-3)^2 = 9$ $(26 - 26)^2 = 0^2 = 0$ $(27 - 26)^2 = 1^2 = 1$ $(28 - 26)^2 = 2^2 = 4$  <b>14</b>
(Channelior – average for Channelior) <sup>2</sup>	$(25 - 29)^2 = (-4)^2 = 16$ $(26 - 29)^2 = (-3)^2 = 9$ $(29 - 29)^2 = 0^2 = 0$ $(32 - 29)^2 = 3^2 = 9$ $(33 - 29)^2 = 4^2 = 16$  <b>50</b>
(Bureperry – average for Bureperry) <sup>2</sup>	$(15 - 21)^2 = (-6)^2 = 36$ $(16 - 21)^2 = (-5)^2 = 25$ $(18 - 21)^2 = (-3)^2 = 9$ $(22 - 21)^2 = 1^2 = 1$ $(26 - 21)^2 = 5^2 = 25$ $(29 - 21)^2 = 8^2 = 64$  <b>160</b>

### Step 2

Calculate the intraclass variance ( $S_{TT} + S_{CC} + S_{BB}$  = how much the data within each category varies).

$$S_{TT} + S_{CC} + S_{BB} = 14 + 50 + 160 = 224$$

### Step 3

Calculate the interclass variance, or how different the categories are from each other.

$$\begin{aligned} & (\text{number of votes for Theremes}) \times (\text{average for Theremes} - \text{average for all data})^2 \\ & + (\text{number of votes for Channelior}) \times (\text{average for Channelior} - \text{average for all data})^2 \\ & + (\text{number of votes for Bureperry}) \times (\text{average for Bureperry} - \text{average for all data})^2 \end{aligned}$$

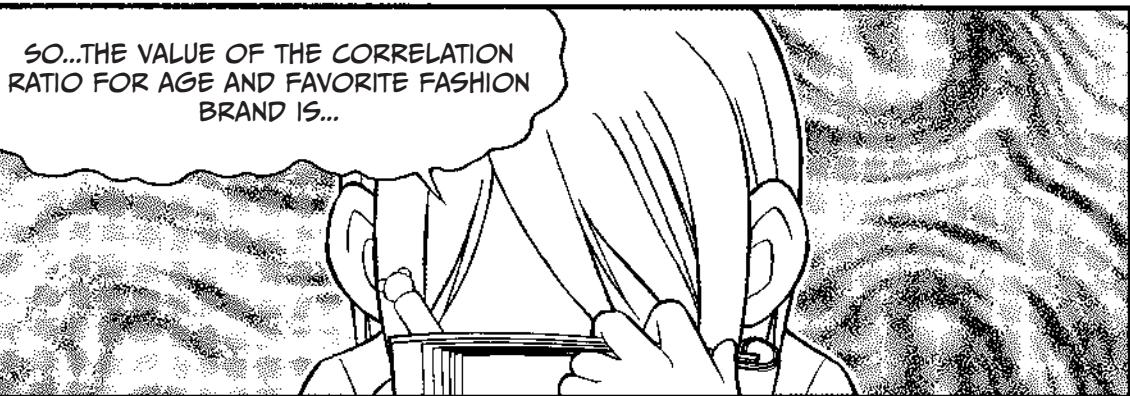
$$\begin{aligned} & 4 \times (26 - 25)^2 + 5 \times (29 - 25)^2 + 6 \times (21 - 25)^2 \\ & = 4 \times 1 + 5 \times 16 + 6 \times 16 \\ & = 4 + 80 + 96 \\ & = 180 \end{aligned}$$

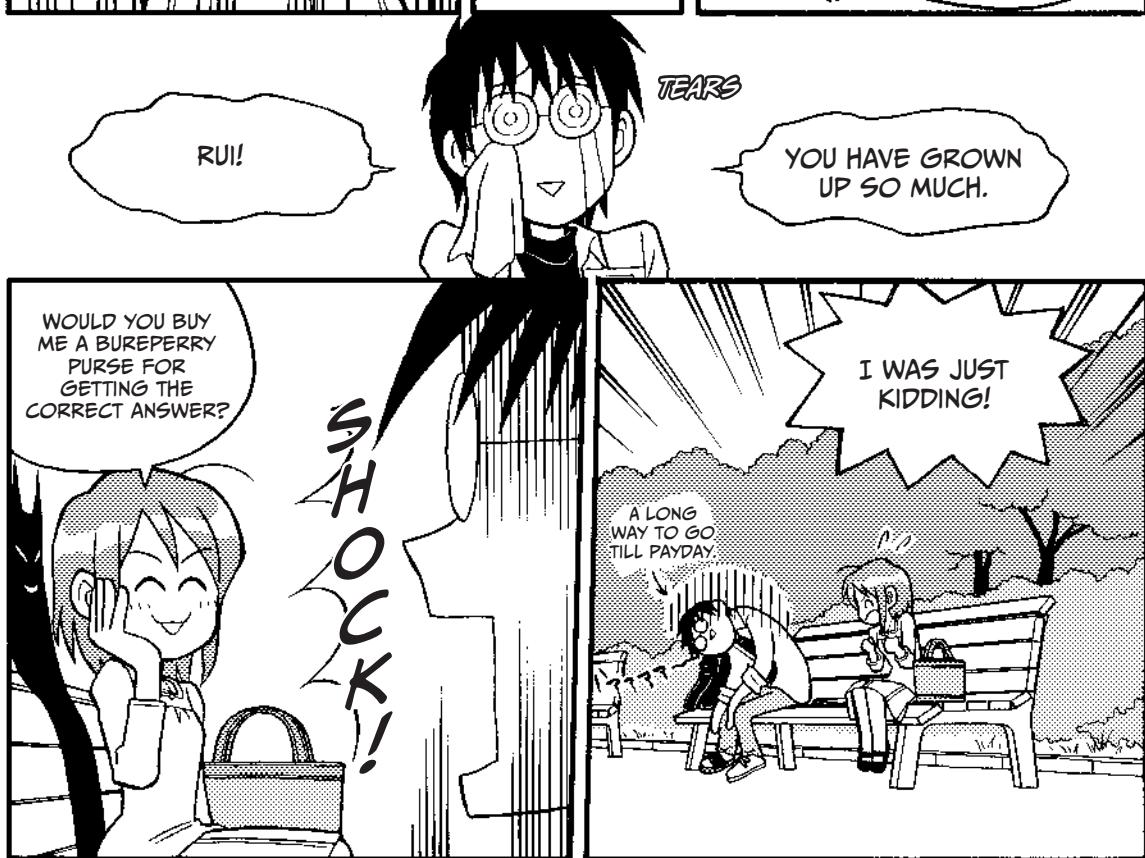
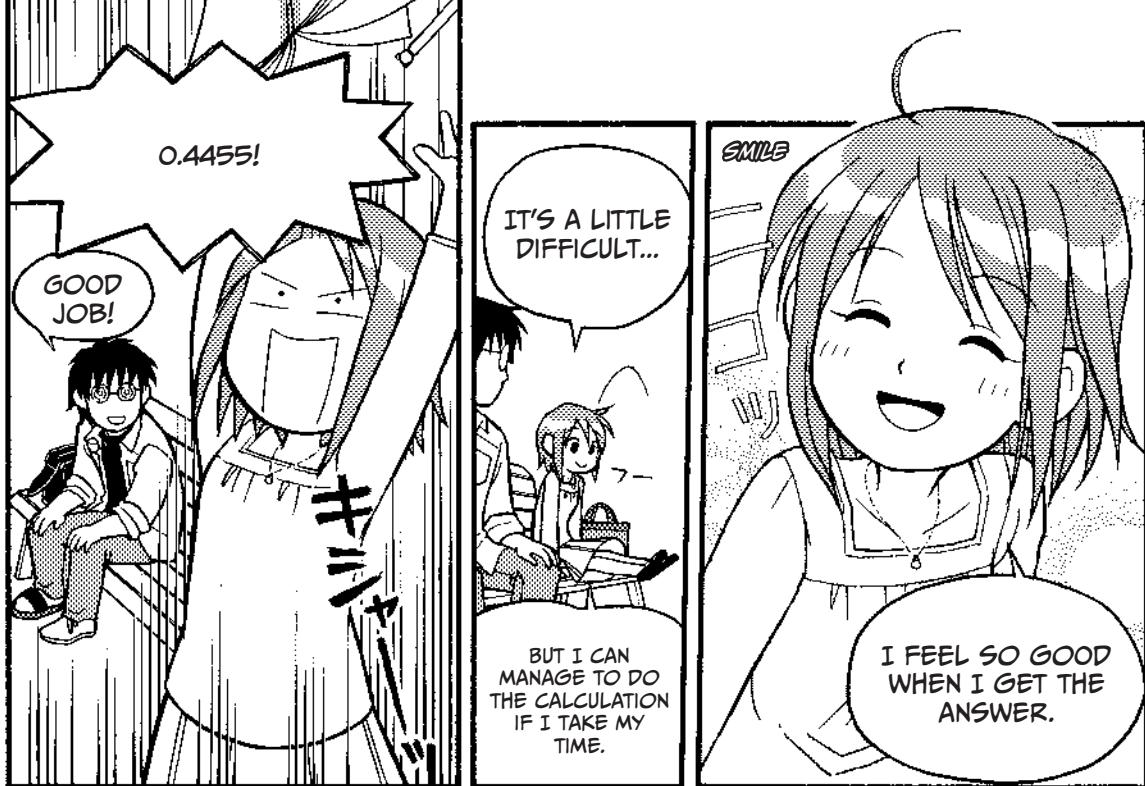
### Step 4

Calculate the value of the correlation ratio.

$$\frac{\text{interclass variance}}{\text{intraclass variance} + \text{interclass variance}}$$

$$\frac{180}{224 + 180} = \frac{180}{404} = 0.4455$$

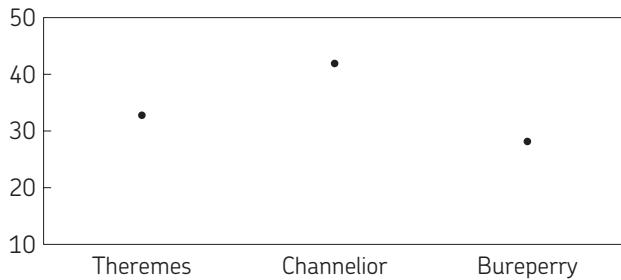




As explained earlier, the value of the correlation ratio is between 0 and 1. The stronger the correlation is between the two variables, the closer the value is to 1, and the weaker the correlation is between two variables, the closer the value is to 0. Refer to the charts below for more details.

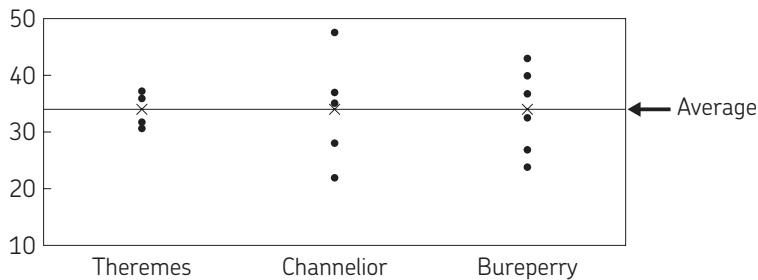


Here is a scatter chart of favorite fashion brand and age (when the correlation ratio is 1).



correlation ratio is 1  $\Leftrightarrow$  data included in each group is the same  $\Leftrightarrow$  intraclass variance is 0

Here is a scatter chart of favorite fashion brand and age (when the correlation ratio is 0).



correlation ratio is 0  $\Leftrightarrow$  average for each group is the same  $\Leftrightarrow$  intraclass variance is 0



Unfortunately, there are no statistical standards such as "the two variables have a strong correlation if the correlation ratio is above a certain benchmark." However, informal standards are given below.

### INFORMAL STANDARDS OF THE CORRELATION RATIO

Correlation ratio	Detailed description	Rough description
1.0–0.8	⇒ Very strongly related	
0.8–0.5	⇒ Fairly strongly related	Related
0.5–0.25	⇒ Fairly weakly related	
Below 0.25	⇒ Very weakly related	Not related

The result of the calculation for the case in question was 0.4455, so the variables are fairly weakly related!



### 3. CRAMER'S COEFFICIENT

I WONDER IF THERE IS A GOOD EXAMPLE I CAN USE TO EXPLAIN THE CORRELATION OF TWO CATEGORICAL VARIABLES.



HOW ABOUT THIS?

告白されるしたら  
どの方法でされたい?

WE ASKED 300 HIGH SCHOOL STUDENTS, "HOW WOULD YOU LIKE TO BE ASKED OUT?"



CROSS TABULATION OF SEX AND DESIRED WAY OF BEING ASKED OUT

		DESIRED WAY OF BEING ASKED OUT			SUM
		PHONE	E-MAIL	FACE TO FACE	
SEX	FEMALE	34	61	53	148
	MALE	38	40	74	152
	SUM	72	101	127	300

This indicates that 74 out of 152 males answered that they'd like to be asked out directly.

CROSS TABULATION OF SEX AND DESIRED WAY OF BEING ASKED OUT  
(HORIZONTAL PERCENTAGE TABLE)

		DESIRED WAY OF BEING ASKED OUT			SUM
		PHONE	E-MAIL	FACE TO FACE	
SEX	FEMALE	23%	41%	36%	100%
	MALE	25%	26%	49%	100%
	SUM	24%	34%	42%	100%

This shows that 49% ( $\frac{74}{152} \times 100$ ) of the 152 males would like to be asked out directly.

A TABLE THAT JOINS TWO VARIABLES LIKE THIS ONE IS CALLED A CROSS TABULATION.



IT INDEED SEEMS THAT THERE IS A DIFFERENCE IN THE DESIRED WAY OF BEING ASKED OUT BETWEEN GIRLS AND BOYS.

IN OTHER WORDS, THERE IS A CORRELATION BETWEEN SEX AND DESIRED WAY OF BEING ASKED OUT.

RUI? ARE YOU LISTENING?

SURE, I AM.

I SHOULD CONTACT MR. IGARASHI DIRECTLY IF I AM GOING TO ASK HIM OUT...

WHAT WAS THE INDEX TO EXPRESS THE DEGREE OF CORRELATION BETWEEN TWO PIECES OF CATEGORICAL DATA?

THE CRAMER'S COEFFICIENT!

THE CRAMER'S COEFFICIENT IS ALSO CALLED THE CRAMER'S V OR AN INDEPENDENT COEFFICIENT.

I CANNOT CRAM SO MUCH NEW VOCABULARY INTO MY HEAD!

WELL, THAT WAS KIND OF FUNNY.

YOU DON'T HAVE TO BE NICE TO ME.

\*BAD JOKE AGAIN..

The Cramer's coefficient can be calculated by following steps 1 through 5 below.



### Step 1

Prepare a cross tabulation. The values surrounded by the bold frame are called *actual measurement frequencies*.

		Desired way of being asked out			Sum
Sex	Female	Phone	E-mail	Face to face	
		34	61	53	148
	Male	38	40	74	152
Sum		72	101	127	300

### Step 2

Do the calculations in the table below. The values surrounded by the bold frame are called *expected frequencies*.

		Desired way of being asked out			Sum
Sex	Female	Phone	E-mail	Face to face	
		$\frac{148 \times 72}{300}$	$\frac{148 \times 101}{300}$	$\frac{148 \times 127}{300}$	148
	Male	$\frac{152 \times 72}{300}$	$\frac{152 \times 101}{300}$	$\frac{152 \times 127}{300}$	152
Sum		72	101	127	300

$$\frac{\text{sum of male} \times \text{sum of face to face}}{\text{total number of values}}$$

Formula A

If sex and desired way of being asked out have no relationship, the ratio between phone, e-mail, and face to face should be

$$72 : 101 : 127 = \frac{72}{72 + 101 + 127} : \frac{101}{72 + 101 + 127} : \frac{127}{72 + 101 + 127}$$

$$= \frac{72}{300} : \frac{101}{300} : \frac{127}{300}$$

for both males and females, according to the sum column in the table in step 2. Thus, our expected frequency (Formula A) shows the predicted number of males who wish to be asked out directly when there is no relationship between sex and desired way of being asked out is  $152 \times (127 \div 300) = (152 \times 127) \div 300$ , or

$$152 \times \frac{127}{300} = \frac{152 \times 127}{300} = 64.3$$



### Step 3

Calculate  $\frac{(\text{actual frequency} - \text{expected frequency})^2}{\text{expected frequency}}$  for each square.

		Desired way of being asked out			Sum
		Phone	E-mail	Face to face	
Sex	Female	$\left(34 - \frac{148 \times 72}{300}\right)^2$ $\frac{148 \times 72}{300}$	$\left(61 - \frac{148 \times 101}{300}\right)^2$ $\frac{148 \times 101}{300}$	$\left(53 - \frac{148 \times 127}{300}\right)^2$ $\frac{148 \times 127}{300}$	148
	Male	$\left(38 - \frac{152 \times 72}{300}\right)^2$ $\frac{152 \times 72}{300}$	$\left(40 - \frac{152 \times 101}{300}\right)^2$ $\frac{152 \times 101}{300}$	$\left(74 - \frac{152 \times 127}{300}\right)^2$ $\frac{152 \times 127}{300}$	152
Sum		72	101	127	300



The bigger the gap between the actual frequencies and the expected frequencies, the larger the values in each square become.

#### Step 4

Calculate the sum of the value inside the bold frame in the table of step 3. This value is called *Pearson's chi-square test statistic*. It will be written as  $\chi_0^2$  from now on.

$$\begin{aligned}\chi_0^2 &= \frac{\left(34 - \frac{148 \times 72}{300}\right)^2}{\frac{148 \times 72}{300}} + \frac{\left(61 - \frac{148 \times 101}{300}\right)^2}{\frac{148 \times 101}{300}} + \frac{\left(53 - \frac{148 \times 127}{300}\right)^2}{\frac{148 \times 127}{300}} \\ &+ \frac{\left(38 - \frac{152 \times 72}{300}\right)^2}{\frac{152 \times 72}{300}} + \frac{\left(40 - \frac{152 \times 101}{300}\right)^2}{\frac{152 \times 101}{300}} + \frac{\left(74 - \frac{152 \times 127}{300}\right)^2}{\frac{152 \times 127}{300}} \\ &= 8.0091\end{aligned}$$

As can be understood from step 3, the more the actual measurements diverge from their expected frequencies, or the greater the correlation between sex and desired way of being asked out, the larger Pearson's chi-square test statistic ( $\chi_0^2$ ) becomes.



### Step 5

Calculate the Cramer's coefficient.

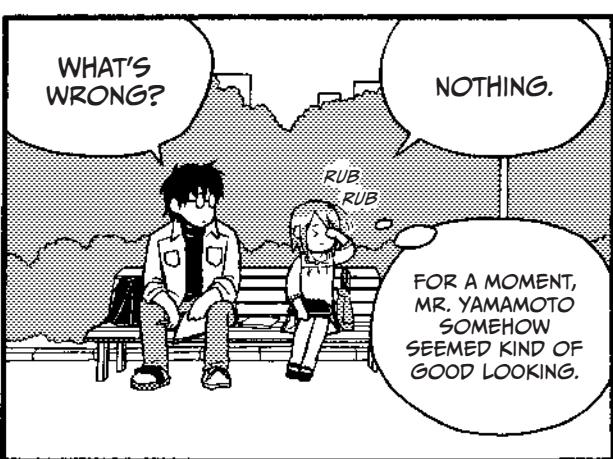
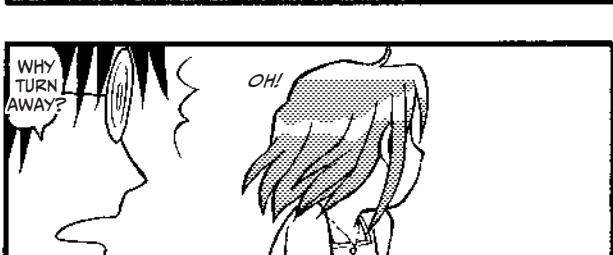
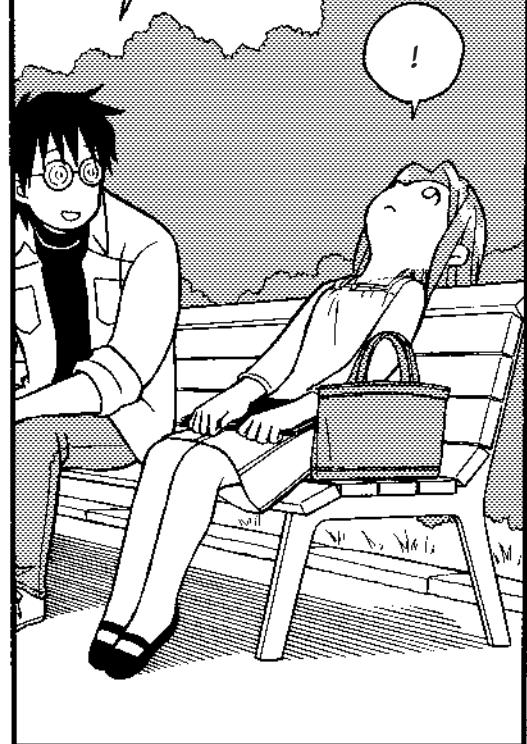
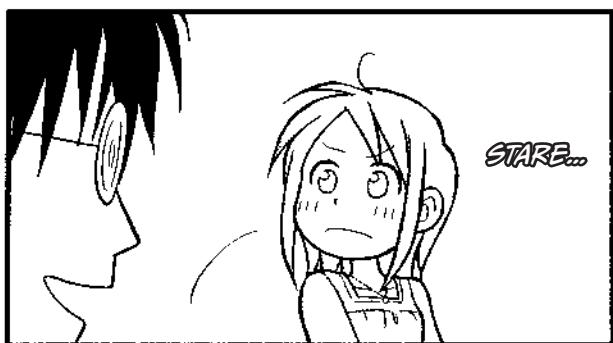
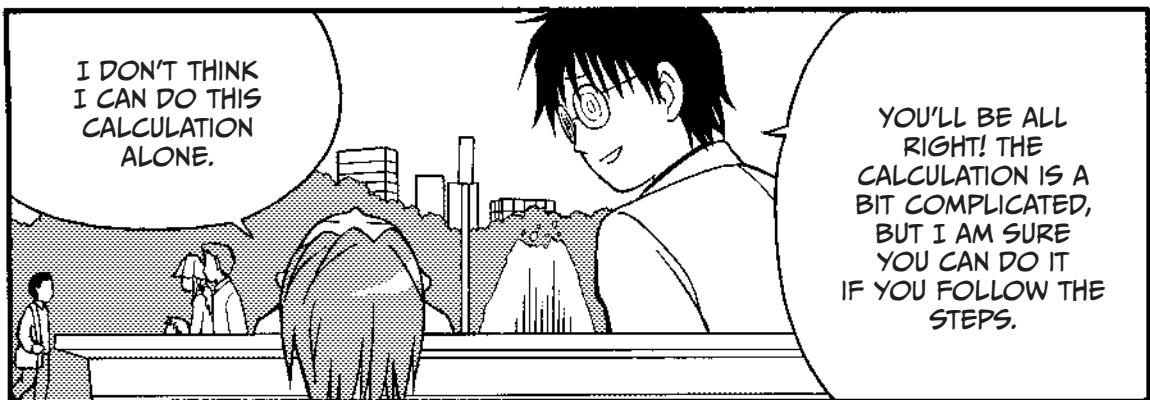
$$\sqrt{\frac{\chi_0^2}{\text{the total number of values} \times (\min\{\text{the number of lines in the cross tabulation, the number of rows in the cross tabulation}\} - 1)}}$$

$\min\{a,b\}$  means "whichever is smaller,  $a$  or  $b$ ."

$$\sqrt{\frac{8.0091}{300 \times \min\{2,3\} - 1}} = \sqrt{\frac{8.0091}{300 \times (2 - 1)}} = \sqrt{\frac{8.0091}{300}} = 0.1634$$

THUS, THE CRAMER'S COEFFICIENT IS 0.1634.

HELP. I'M FEELING DIZZY.



As explained earlier, the Cramer's coefficient is between 0 and 1. The stronger the correlation between two variables, the closer the coefficient gets to 1, and the weaker the correlation, the closer the coefficient gets to 0. See the cross tabulation (horizontal percentage table) below for more details.



Here is the cross tabulation of sex and desired way of being asked out (horizontal percentage table) when the value of the Cramer's coefficient is 1.

		Desired way of being asked out			Sum
		Phone	E-mail	Face to face	
Sex	Female	17%	83%	0%	100%
	Male	0%	0%	100%	100%

Cramer's coefficient is 1  $\Leftrightarrow$  the preferences of female and male are completely different

Here is the cross tabulation of sex and desired way of being asked out (horizontal percentage table) when the value of the Cramer's coefficient is 0.

		Desired way of being asked out			Sum
		Phone	E-mail	Face to face	
Sex	Female	17%	48%	35%	100%
	Male	17%	48%	35%	100%

Cramer's coefficient is 0  $\Leftrightarrow$  the preferences of female and male are the same



Unfortunately, there are no statistical standards such as “the two variables have a strong correlation if the Cramer’s coefficient is above a certain benchmark.” However, informal standards are given below.

#### INFORMAL STANDARDS OF THE CRAMER’S COEFFICIENT

Cramer's coefficient	Detailed description	Rough description
1.0–0.8	⇒ Very strongly related	
0.8–0.5	⇒ Fairly strongly related	Related
0.5–0.25	⇒ Fairly weakly related	
Below 0.25	⇒ Very weakly related	Not related

SO, AS THE CONCLUSION FOR THIS EXAMPLE, WE CAN SAY THAT THEY ARE VERY WEAKLY RELATED.

THIS IS THE END OF TODAY'S LESSON.

I UNDERSTAND THAT.

THANK YOU.

IN THE LAST PART OF  
TODAY'S LESSON, I  
TAUGHT YOU ABOUT THE  
CRAMER'S COEFFICIENT.

BASED ON WHAT I HAVE  
TAUGHT YOU TODAY, WE  
WILL STUDY TESTS OF  
INDEPENDENCE IN THE  
NEXT LESSON.

TESTS OF  
INDEPENDENCE?

TESTS OF INDEPENDENCE  
ARE OFTEN USED IN  
SURVEY ANALYSIS.

ONCE YOU HAVE  
MASTERED THEM, YOU  
WILL HAVE MASTERED  
THE FUNDAMENTALS OF  
STATISTICS.

DOES THAT MEAN THAT  
OUR NEXT LESSON WILL  
BE THE LAST?

FOR THE TIME  
BEING, YES.

FINALLY!

## EXERCISE AND ANSWER



### EXERCISE

Company X runs a casual dining restaurant. Its financial status was declining recently. Thus, Company X decided to study its customers' needs and conducted a survey of randomly chosen people, age 20 or older, residing in Japan. The table below shows the results of this survey.

Respondent	What food do you often have in a casual dining restaurant?	If a free drink is to be served after a meal, which would you prefer? Coffee or tea?
1	Chinese	Coffee
2	European	Coffee
...	...	...
250	Japanese	Tea

Below is a cross tabulation made using the table above.

		Preference for coffee or tea		Sum
		Coffee	Tea	
Type of food often ordered	Japanese	43	33	76
	European	51	53	104
	Chinese	29	41	70
Sum		123	127	250

Calculate the Cramer's coefficient for the food often ordered in casual dining restaurants and the preferred free drink of either coffee or tea.

## ANSWER

### Step 1

Prepare a cross tabulation.

		Preference for coffee or tea		Sum
		Coffee	Tea	
Type of food often ordered	Japanese	43	33	76
	European	51	53	104
	Chinese	29	41	70
Sum		123	127	250

### Step 2

Calculate the expected frequency.

		Preference for coffee or tea		Sum
		Coffee	Tea	
Type of food often ordered	Japanese	$\frac{76 \times 123}{250}$	$\frac{76 \times 127}{250}$	76
	European	$\frac{104 \times 123}{250}$	$\frac{104 \times 127}{250}$	104
	Chinese	$\frac{70 \times 123}{250}$	$\frac{70 \times 127}{250}$	70
Sum		123	127	250

**Step 3**

Calculate

$$\frac{(\text{actual measurement frequency} - \text{expected frequency})^2}{\text{expected frequency}}$$

for each square.

		Preference for coffee or tea		Sum
		Coffee	Tea	
Type of food often ordered	Japanese	$\left(43 - \frac{76 \times 123}{250}\right)^2$ $\frac{76 \times 123}{250}$	$\left(33 - \frac{76 \times 127}{250}\right)^2$ $\frac{76 \times 127}{250}$	76
	European	$\left(51 - \frac{104 \times 123}{250}\right)^2$ $\frac{104 \times 123}{250}$	$\left(53 - \frac{104 \times 127}{250}\right)^2$ $\frac{104 \times 127}{250}$	104
	Chinese	$\left(29 - \frac{70 \times 123}{250}\right)^2$ $\frac{70 \times 123}{250}$	$\left(41 - \frac{70 \times 127}{250}\right)^2$ $\frac{70 \times 127}{250}$	70
	Sum	123	127	250

#### Step 4

Calculate the sum of the value inside the bold frame in the table in step 3, which is the value of Pearson's chi-square test statistic ( $\chi_0^2$ ).

$$\begin{aligned}\chi_0^2 &= \frac{\left(43 - \frac{76 \times 123}{250}\right)^2}{\frac{76 \times 123}{250}} + \frac{\left(33 - \frac{76 \times 127}{250}\right)^2}{\frac{76 \times 127}{250}} \\ &\quad + \frac{\left(51 - \frac{104 \times 123}{250}\right)^2}{\frac{104 \times 123}{250}} + \frac{\left(53 - \frac{104 \times 127}{250}\right)^2}{\frac{104 \times 127}{250}} \\ &\quad + \frac{\left(29 - \frac{70 \times 123}{250}\right)^2}{\frac{70 \times 123}{250}} + \frac{\left(41 - \frac{70 \times 127}{250}\right)^2}{\frac{70 \times 127}{250}} \\ &= 3.3483\end{aligned}$$

#### Step 5

Calculate the Cramer's coefficient.

$$\sqrt{\frac{\chi_0^2}{\text{the total number of values} \times (\min\{\text{the number of lines in the cross tabulation}, \text{the number of rows in the cross tabulation}\} - 1)}}$$

$$\sqrt{\frac{3.3483}{250 \times (\min\{3,2\} - 1)}} = \sqrt{\frac{3.3483}{250 \times (2 - 1)}} = \sqrt{\frac{3.3483}{250}} = 0.1157$$

## SUMMARY



- The index used to describe the degree of correlation between numerical data and numerical data is the *correlation coefficient*.
- The index used to describe the degree of correlation between numerical data and categorical data is the *correlation ratio*.
- The index used to describe the degree of correlation between categorical data and categorical data is the *Cramer's coefficient* (sometimes called the *Cramer's V* or an *independent coefficient*).
- The characteristics of the correlation coefficient, correlation ratio, and Cramer's coefficient are shown in the table below.

	Minimum	Maximum	The value when the two variables are not correlated at all	The value when the two variables are most strongly correlated
Correlation coefficient	-1	1	0	-1 or 1
Correlation ratio	0	1	0	1
Cramer's coefficient	0	1	0	1

- There are no statistical standards for the correlation coefficient, correlation ratio, and Cramer's coefficient, such as "the two variables have a strong correlation if the value is above a certain benchmark."

# 7

LET'S EXPLORE  
THE HYPOTHESIS TESTS



REMEMBER LEARNING  
ABOUT THE CRAMER'S  
COEFFICIENT IN OUR LAST  
LESSON?

\*WE ASKED 300 HIGH SCHOOL  
STUDENTS, "HOW WOULD YOU  
LIKE TO BE ASKED OUT?"

高橋は300人を対象して  
「告白する方法」として  
「どうすればいい？」

YOU MEAN THAT  
SURVEY ON HOW  
TO ASK OUT  
SOMEONE?

IN THAT EXAMPLE, THE  
CRAMER'S COEFFICIENT  
WAS 0.1634, AND THE RESULT  
TURNED OUT TO BE VERY  
WEAKLY CORRELATED.

NOW, THINK  
CAREFULLY,  
RUI.

THE RESULT OF THAT SURVEY  
WAS OBTAINED FROM THE  
RESPONSES OF 300 PEOPLE...

YES, I REMEMBER  
THAT.

...WHO WERE CHOSEN  
RANDOMLY FROM ALL  
HIGH SCHOOL STUDENTS  
RESIDING IN JAPAN.

IF A DIFFERENT 300  
PEOPLE WERE CHOSEN,  
THE CRAMER'S COEFFICIENT  
WOULD NOT HAVE BEEN  
0.1634.

COME TO THINK OF IT,  
YOU ARE RIGHT.

DO YOU HAVE ANY IDEA  
WHAT THE VALUE OF THE  
CRAMER'S COEFFICIENT  
FOR THE POPULATION  
OF THIS EXAMPLE, ALL  
HIGH SCHOOL STUDENTS  
RESIDING IN JAPAN,  
WOULD BE IN THE FIRST  
PLACE?

HOW AM I  
SUPPOSED TO  
KNOW THAT?

THAT'S A NATURAL REACTION.

UNFORTUNATELY, NO ONE  
KNOWS, BECAUSE IT IS  
IMPOSSIBLE TO ASK THIS  
QUESTION OF EVERY SINGLE  
STUDENT IN JAPAN.

UH-HUH.

IT IS NOT ONLY IN  
THIS EXAMPLE THAT  
YOU CANNOT GET THE  
CRAMER'S COEFFICIENT  
FOR THE POPULATION. IT IS  
GENERALLY IMPOSSIBLE IN  
ALL CASES.

THAT IS WHY  
WE HAVE NO  
CHOICE BUT  
TO...

MAKE AN  
INFORMED  
DECISION ABOUT  
THE CRAMER'S  
COEFFICIENT,  
SUCH AS,

"SINCE THE CRAMER'S COEFFICIENT OBTAINED  
FROM MY RANDOM SAMPLE OF 300 PEOPLE  
IS 0.1634,

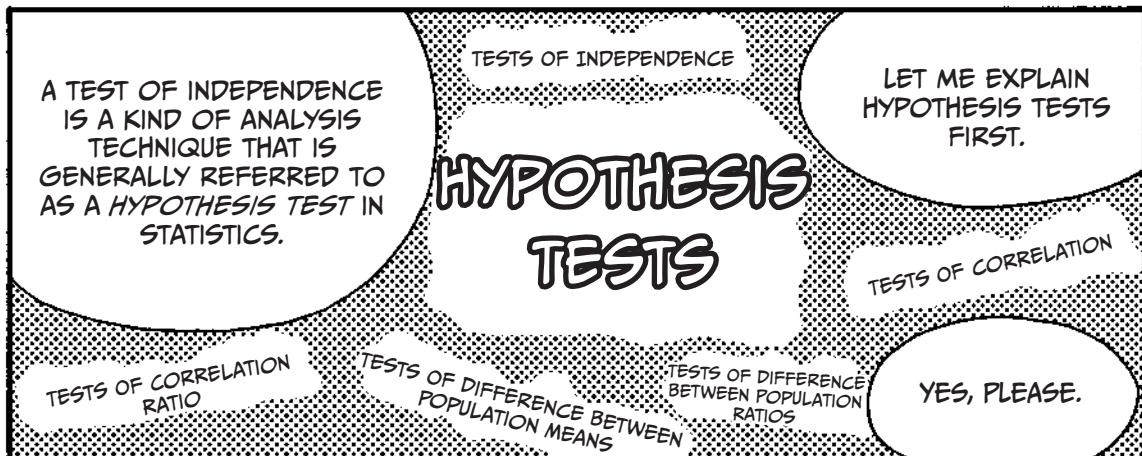
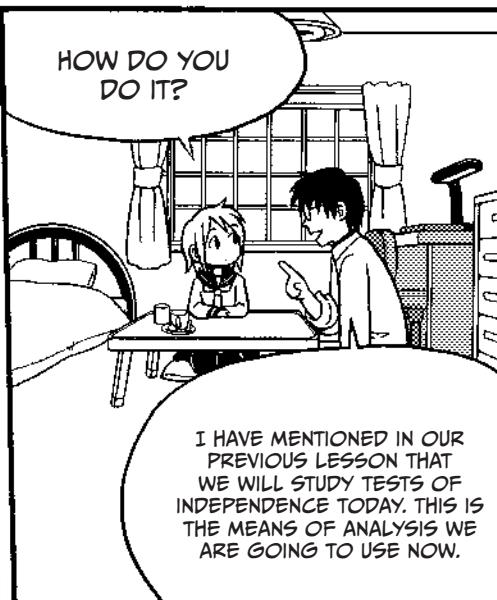
THE CRAMER'S COEFFICIENT  
FOR THE POPULATION MUST BE  
SOMETHING LIKE THAT."

THAT'S NOT AS  
CONVINCING AS  
I THOUGHT.

I BET THERE IS A WAY  
TO DO SOMETHING  
ABOUT IT USING  
STATISTICS AS IN  
OTHER CASES.

ビ"'"

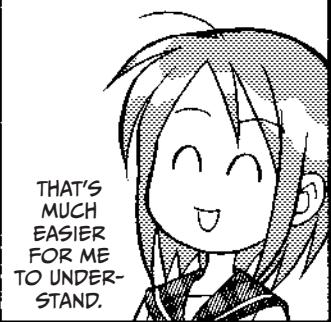
EVEN IF YOU MAKE FULL USE  
OF STATISTICS, THE PRECISE  
CRAMER'S COEFFICIENT FOR  
A POPULATION WILL NEVER  
BE OBTAINED, BECAUSE IT'S  
IMPOSSIBLE TO SURVEY  
EVERY SINGLE MEMBER  
OF THE POPULATION. SO...  
SORRY TO DISAPPOINT  
YOU, BUT NO.



A HYPOTHESIS TEST IS AN ANALYSIS TECHNIQUE USED TO ESTIMATE WHETHER THE ANALYST'S HYPOTHESIS ABOUT THE POPULATION IS CORRECT, USING THE SAMPLE DATA.



THE FORMAL NAME FOR A HYPOTHESIS TEST IS STATISTICAL HYPOTHESIS TESTING.



THAT'S MUCH EASIER FOR ME TO UNDERSTAND.



THERE ARE SEVERAL TYPES OF HYPOTHESIS TESTS.

### EXAMPLES OF HYPOTHESIS TESTS

Name	Example of use
Tests of independence	Estimates whether the value of the Cramer's coefficient for sex and desired way of being asked out is zero for a population
Tests of correlation ratio	Estimates whether the value of the correlation ratio for favorite fashion brand and age is zero for a population
Tests of correlation	Estimates whether the correlation coefficient for amount spent on makeup and amount spent on clothes is zero for a population
Tests of difference between population means	Estimates whether allowances are different between high school girls in Tokyo and Osaka*
Tests of difference between population ratios	Estimates whether the approval rating of cabinet X is different between voters residing in urban areas and rural areas*

\* Note that two populations are being considered.



### PROCEDURE FOR A HYPOTHESIS TEST

- 
- Step 1** Define the population.
  - Step 2** Set up a null hypothesis and an alternative hypothesis.
  - Step 3** Select which hypothesis test to conduct.
  - Step 4** Determine the significance level.
  - Step 5** Obtain the test statistic from the sample data.
  - Step 6** Determine whether the test statistic obtained in step 5 is in the critical region.
  - Step 7** If the test statistic is in the critical region, you must reject the null hypothesis.  
If not, you fail to reject the null hypothesis.
- 



## 2. THE CHI-SQUARE TEST OF INDEPENDENCE

NOW I WILL EXPLAIN TODAY'S MAIN TOPIC, A TEST OF INDEPENDENCE.



I TOLD YOU THAT A TEST OF INDEPENDENCE IS AN ANALYSIS TECHNIQUE USED TO ESTIMATE WHETHER THE CRAMER'S COEFFICIENT FOR A POPULATION IS ZERO.

YES, YOU DID.

TO PUT IT DIFFERENTLY, IT IS AN ANALYSIS TECHNIQUE USED TO ESTIMATE WHETHER TWO VARIABLES IN A CROSS TABULATION ARE CORRELATED.

I SEE! THAT IS WHY IT IS APPLIED TO SURVEY ANALYSES.

		DESIRED WAY OF BEING ASKED OUT			SUM
SEX	F	PHONE	E-MAIL	FACE TO FACE	
		34	61	53	
M	F	38	40	53	148
	M	72	101	74	152
SUM					127

THIS TEST OF INDEPENDENCE IS ALSO CALLED A CHI-SQUARE TEST.

NOT THAT CHI-WHATEVER AGAIN!

## EXPLANATION

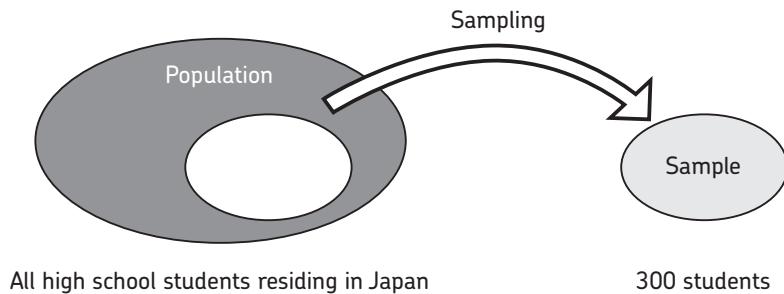
### Pearson's chi-square test statistic ( $\chi_0^2$ ) and chi-square distribution



Before giving an actual example of a test of independence, I would like to explain an important fact that is fundamental to tests of independence. Though it is impossible to do this in reality, suppose the below experiment is conducted.

#### Step 1

Take a random sample of 300 students from the population “all high school students residing in Japan.”



#### Step 2

Conduct the survey on page 127 with the 300 people chosen in step 1 to obtain the chi-square statistic ( $\chi_0^2$ ).

#### Step 3

Put the 300 people back into the population.

#### Step 4

Repeat steps 1 through 3 over and over.

In this experiment, if the value of the Cramer’s coefficient for the population “all high school students residing in Japan” is 0, the graph of Pearson’s chi-square test statistic ( $\chi_0^2$ ) turns out to be a chi-square distribution with 2 degrees of freedom. In other words, if the value of the Cramer’s coefficient for the population “all high school students residing in Japan” is 0, then Pearson’s chi-square test statistic ( $\chi_0^2$ ) follows a chi-square distribution with 2 degrees of freedom.

- See pages 130–133 for information on how to obtain Pearson’s chi-square test statistic ( $\chi_0^2$ ).
- See page 100 for information on a chi-square distribution with 2 degrees of freedom.

We have actually conducted this experiment. In carrying out the experiment, we set the restrictions below.



- As it is impossible to experiment with the actual population of “all high school students residing in Japan,” the group of 10,000 people in Table 7-1 will be regarded as “all high school students residing in Japan” instead.
- We assume that the Cramer’s coefficient for “all high school students residing in Japan” is 0. This means that the ratio of those who prefer being asked out by phone to those who prefer being asked out by e-mail to those who prefer being asked out directly is equal for girls and boys (see page 135). The cross tabulation for Table 7-1 is Table 7-2.
- Since it is otherwise endless, we will stop repeating steps 1 through 3 after 10,000 times.

TABLE 7-1: DESIRED WAY OF BEING ASKED OUT  
(ALL HIGH SCHOOL STUDENTS RESIDING IN JAPAN)

Respondent	Sex	Desired way of being asked out
1	Female	Face to face
2	Female	Phone
...	...	...
10,000	Male	E-mail

TABLE 7-2: CROSS TABULATION OF SEX AND DESIRED WAY OF BEING ASKED OUT

		Desired way of being asked out			Sum
		Phone	E-mail	Face to face	
Sex	Female	400	1,600	2,000	4,000
	Male	600	2,400	3,000	6,000
Sum		1,000	4,000	5,000	10,000

Table 7-3 shows the result of the experiment. Figure 7-1 is a histogram made according to Table 7-3.

TABLE 7-3: RESULT OF EXPERIMENT

Experiment	Pearson's chi-square test statistic ( $\chi_0^2$ )
1	0.8598
2	0.7557
...	...
10,000	2.7953

FIGURE 7-1: A HISTOGRAM BASED ON TABLE 7-3 (RANGE OF CLASS = 1)

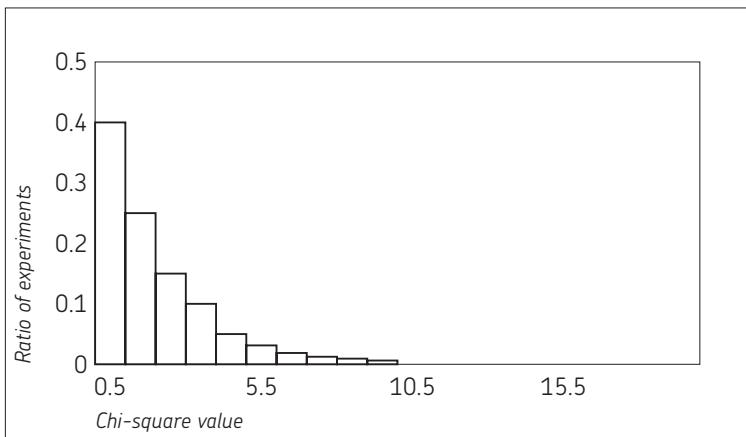


Figure 7-1 indeed looks similar to the graph on page 100, “2 Degrees of Freedom.” It seems to be correct that Pearson’s chi-square test statistic ( $\chi_0^2$ ) follows a chi-square distribution with 2 degrees of freedom. Though this has nothing to do with the experiment itself, here is one point to note. Two degrees of freedom comes from:

$$(2 - 1) \times (3 - 1) = 1 \times 2 = 2$$

↑                      ↑  
2 patterns:        3 patterns:  
female and male    phone, e-mail, and face to face

I will not go into why such a strange calculation is applied, as it is a topic much too advanced for the level of this book. But don’t worry—even if you don’t fully understand the calculation, you won’t be at any disadvantage.



I SEE THAT THE VALUE OF THE CRAMER'S COEFFICIENT FOR "ALL HIGH SCHOOL STUDENTS RESIDING IN JAPAN" IS ZERO... WHICH MEANS THERE WAS NO RELATIONSHIP BETWEEN SEX AND DESIRED WAY OF BEING ASKED OUT.

I SUPPOSE...

THE RATIO OF PREFERENCE IS THE SAME FOR FEMALES AND MALES!

THEN, I SURVEY 300 PEOPLE SELECTED FROM "ALL HIGH SCHOOL STUDENTS RESIDING IN JAPAN."

REPEAT THAT OVER AND OVER AND OVER AND OVER!

Surveys  
Surveys

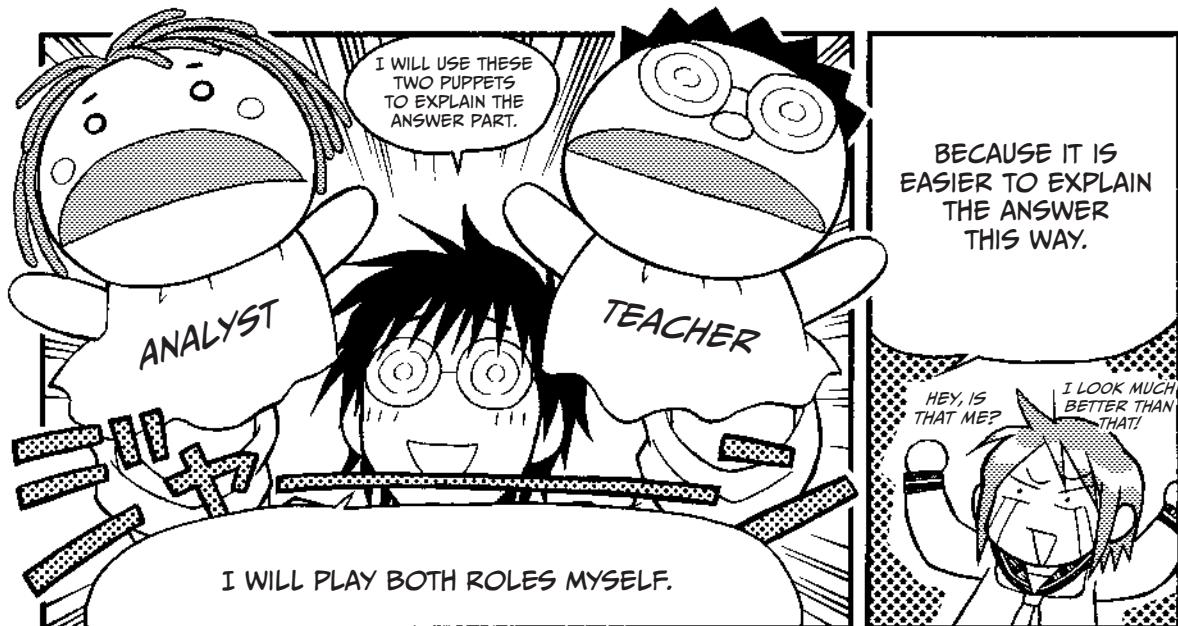
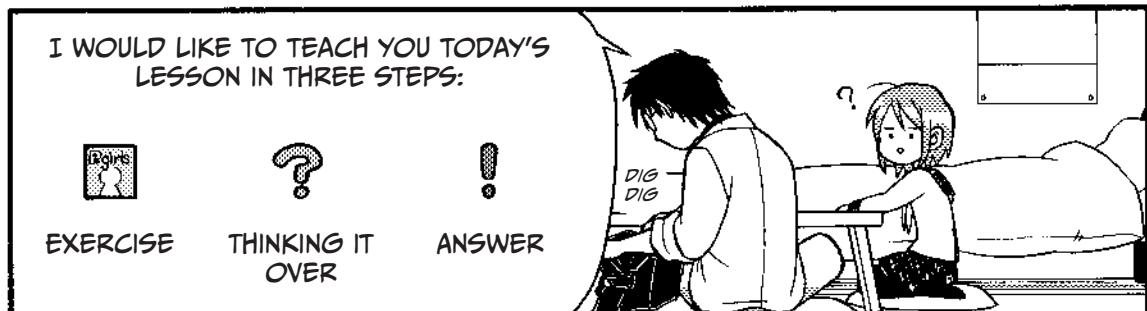
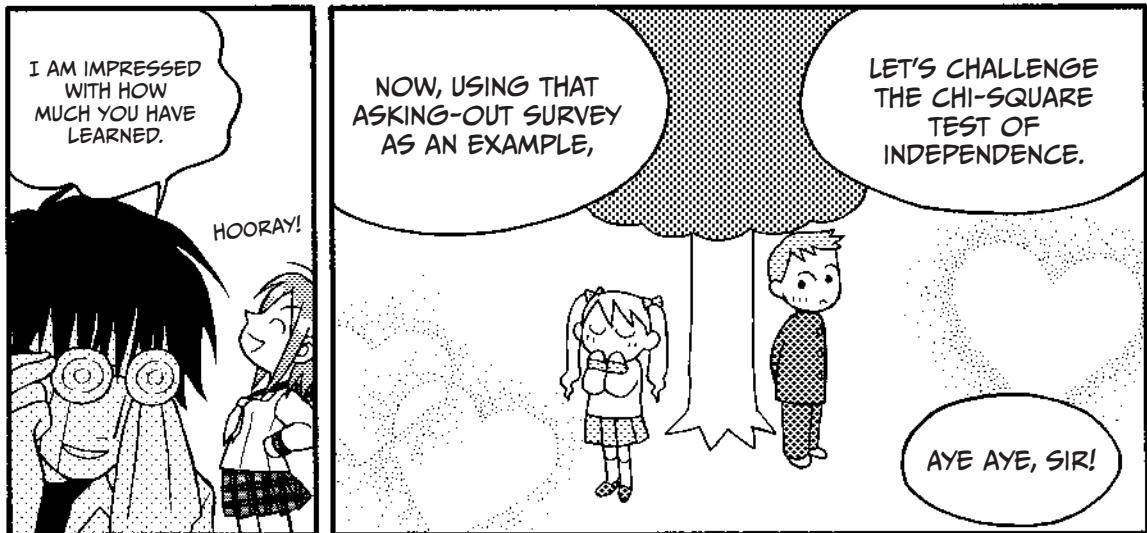
AFTER THAT, I CALCULATE PEARSON'S CHI-SQUARE TEST STATISTIC.

ADD  $\frac{(\text{ACTUAL MEASUREMENT FREQUENCY} - \text{EXPECTED FREQUENCY})^2}{\text{EXPECTED FREQUENCY}}$  IN EACH SQUARE

I FINALLY...

HAVE THE ANSWER!

THE GRAPH OBTAINED FROM THE RESULT IS A CHI-SQUARE DISTRIBUTION WITH 2 DEGREES OF FREEDOM!





## EXERCISE

P-Girls Magazine decided to publish an article titled “We Asked 300 High School Students, ‘How Would You Like to Be Asked Out?’” In order to prepare the article, a journalist randomly chose 300 people from all the high school students residing in Japan and took a survey. The table below is the result of this survey.

Respondent	Desired way of being asked out	Age	Sex
1	Face to face	17	Female
2	Phone	15	Female
...	...	...	...
300	E-mail	18	Male

The table below is the cross tabulation of sex and desired way of being asked out.

		Desired way of being asked out			Sum
		Phone	E-mail	Face to face	
Sex	Female	34	61	53	148
	Male	38	40	74	152
Sum		72	101	127	300

Using the chi-square test of independence, estimate if the Cramer’s coefficient for sex and desired way of being asked out in the population “all high school students residing in Japan” is greater than 0. This is the same as estimating with a test of independence whether sex and desired way of being asked out are correlated. Remember that the significance level (explained later) is 0.05.

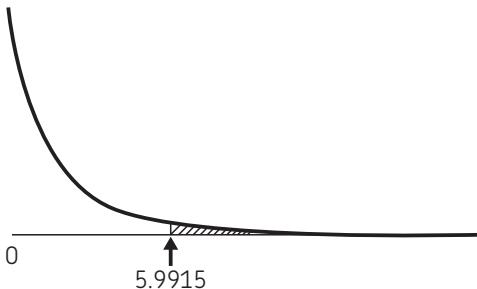


## THINKING IT OVER

As explained on pages 152–154, Pearson's chi-square test statistic ( $\chi_0^2$ ) follows a chi-square distribution with 2 degrees of freedom if the null hypothesis states that the value of the Cramer's coefficient for the population “all high school students residing in Japan” is 0. If that's true, then the probability that  $\chi_0^2$  obtained from the 300 people who have been chosen randomly is 5.9915 or more is 0.05.



FIGURE 7-2: PROBABILITY THAT  $\chi_0^2$  IS 5.9915 OR MORE



This is clear from the table of chi-square distribution on page 103.

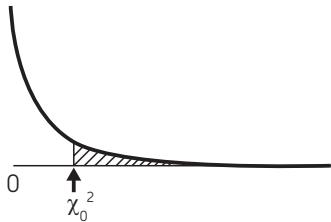
$\chi_0^2$  for this exercise has already been calculated on page 132. It is 8.0091. True, this figure has been calculated based on data from 300 randomly chosen people, but doesn't this seem too large? Taking into consideration the comment on page 132, isn't it natural to assume that the Cramer's coefficient for the population “all high school students residing in Japan” is greater than 0?

Remember that the process for a chi-square test of independence (not limited to this exercise) goes like this:

1. Assume a null hypothesis that “the Cramer's coefficient for the population is 0” for the time being.
2. Calculate  $\chi_0^2$  from the sample data.
3. If  $\chi_0^2$  is too large, reject the null hypothesis and conclude that “the Cramer's coefficient for the population is greater than 0.”

As  $\chi^2$  becomes larger, the probability shown as the shaded area in Figure 7-3 naturally becomes smaller.

FIGURE 7-3: PROBABILITY IN CORRESPONDENCE TO  $\chi^2_0$

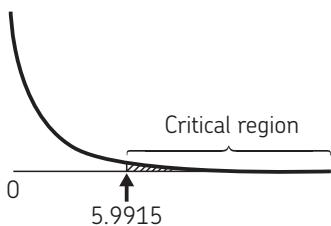


In chi-square tests of independence, if the probability shown as the shaded area in Figure 7-3 is less than or equal to the value called the *significance level*, reject the null hypothesis and conclude that “the Cramer’s coefficient for the population is greater than 0.” In general, the significance level (also called the *alpha value* and expressed by the symbol  $\alpha$ ) is considered to be 0.05 or 0.01.

It is up to the analyst which significance level to use. Suppose we decide to use 0.05 as the significance level in this case. The significance level is in fact the probability expressed as the shaded area in Figure 7-3.

The shaded area in Figure 7-4 is called the *critical region*.

FIGURE 7-4: CRITICAL REGION  
(WHEN SIGNIFICANCE LEVEL IS 0.05)



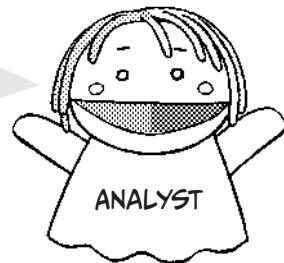
## ! ANSWER

### Step 1

Define the population.

The population is:

ALL HIGH SCHOOL  
STUDENTS  
RESIDING IN JAPAN



In this exercise, the population was defined as “all high school students residing in Japan.” Thus, in this particular exercise, step 1 is unnecessary.

However, for “Tests of difference between population ratios” in the table on page 149, the populations in question are “voters residing in urban areas” and “voters residing in rural areas.” Where are the urban areas exactly? Are they Tokyo and Osaka? Or are they the capitals of the prefectures? This must be specified by the analyst.

I repeat: When you are actually doing a hypothesis test, you must determine the population. No matter which hypothesis test you are trying to carry out, you must not fail to properly define the population.

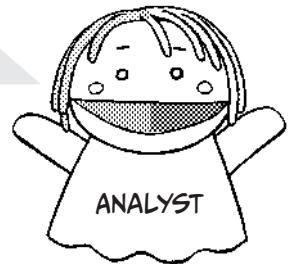
Otherwise, you might fall into a situation in which you are lost, wondering, “What was I trying to estimate?” Lots of statisticians fall into traps like this. Take great care about this point.

## Step 2

Set up a null hypothesis and an alternative hypothesis.

The null hypothesis is: "The Cramer's coefficient for the population is 0. In other words, sex and desired way of being asked out are not correlated."

The alternative hypothesis is: "The Cramer's coefficient for the population is greater than 0. In other words, sex and desired way of being asked out are correlated."

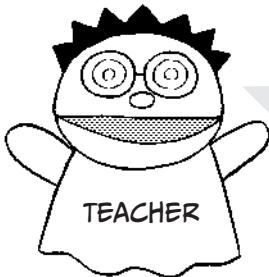
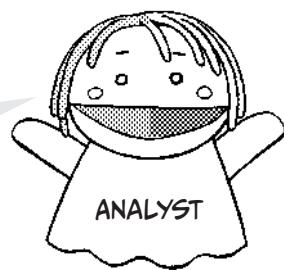


An explanation of null hypotheses and alternative hypotheses is given on page 170.

### Step 3

Choose which hypothesis test to do.

I am going to do a chi-square test of independence.



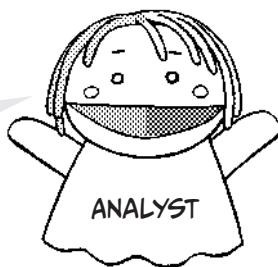
This exercise asks you to do a chi-square test of independence. So in this particular exercise, step 3 is unnecessary.

(When you are actually doing a hypothesis test and not an exercise, you must select the hypothesis test suitable for the objective of analysis on your own.)

#### Step 4

Determine the significance level.

I will use 0.05 as the significance level.

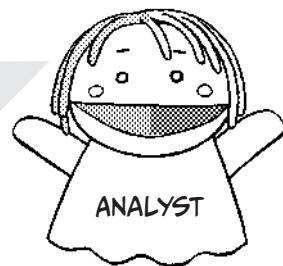


The exercise assigns 0.05 as the significance level, so in this particular exercise, step 4 is unnecessary. When you are actually doing a hypothesis test and not an exercise, you must determine the significance level. As mentioned earlier, normally either 0.05 or 0.01 is used. The smaller the P-value computed from the sample data, the stronger the evidence is against the null hypothesis. In general, the symbol  $\alpha$  is used to express the significance level (alpha value).

## Step 5

Calculate the test statistic from the sample data.

I am trying to do a chi-square test of independence. Thus the test statistic is Pearson's chi-square test statistic ( $\chi_0^2$ ). The value of  $\chi_0^2$  for this exercise has already been calculated on page 132:  $\chi_0^2 = 8.0091$ .



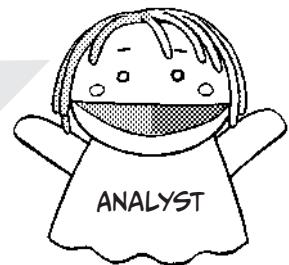
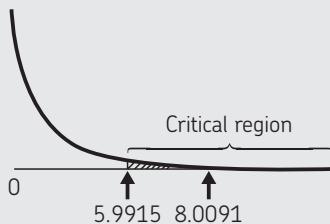
The test statistic is obtained from a function that calculates a single value from the sample data. Different kinds of hypothesis tests have different test statistics. As mentioned above, the value for a test of independence is  $\chi_0^2$ , and in the case of tests of correlation (see page 149), the test statistic is as below.

$$\frac{\text{correlation coefficient}^2 \times \sqrt{\text{number of values} - 2}}{1 - \sqrt{\text{correlation coefficient}^2}}$$

### Step 6

Determine whether or not the test statistic from step 5 is in the critical region.

Pearson's chi-square test statistic ( $\chi_0^2$ ) is 8.0091. As the significance level ( $\alpha$ ) is 0.05, the critical region is 5.9915 or above, according to the table of chi-square distribution on page 103. As shown in the chart below, the test statistic is within the critical region.

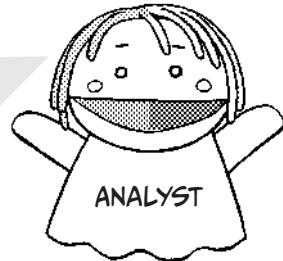


The critical region changes depending on the significance level ( $\alpha$ ). If  $\alpha$  in this exercise was 0.01 instead of 0.05, the critical region would be 9.2104 or above, according to the table of chi-square distribution on page 103.

### Step 7

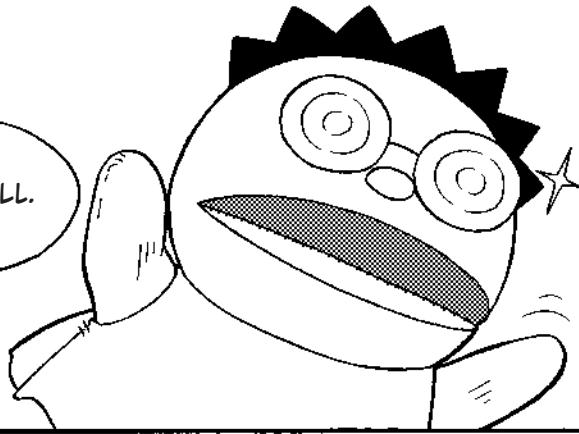
If the test statistic is in the critical region in step 6, you reject the null hypothesis. If not, you fail to reject the null hypothesis. In this case, the test statistic was in the critical region.

Thus the alternative hypothesis, “the Cramer’s coefficient for the population is greater than 0,” is correct!



You cannot conclude that the alternative hypothesis is absolutely correct in a hypothesis test, even if the test statistic is within the critical region. The only conclusion you can make is, “I would like to say that the alternative hypothesis is ‘absolutely’ correct . . . but there is, at most, a  $(\alpha \times 100)\%$  possibility that the null hypothesis is correct.”

THAT'S ABOUT ALL.



I SEE...

BUT STILL, SOMETHING  
ABOUT STEP 7  
SEEMS RATHER  
UNCONVINCING.

?

I FEEL THAT YOU CAN SAY  
THAT "THE NULL HYPOTHESIS  
IS CORRECT" IF THE TEST  
STATISTIC IS NOT IN THE  
CRITICAL REGION.



CRITICAL REGION

0

5.9915

UNFORTUNATELY, YOU CANNOT.  
ALL YOU CAN SAY IS, "I FAIL TO REJECT  
THE NULL HYPOTHESIS."

FOR  
EXAMPLE,

SUPPOSE  $\chi^2$  WAS  
2.5013 IN THAT  
EXERCISE WE WERE  
SOLVING.

CRITICAL REGION

0 2.5013

5.9915

IS THAT SO...?

IT IS NOT INSIDE  
THE CRITICAL  
REGION, IS IT?

AS A MATTER OF COURSE,  
YOU CANNOT ACCEPT THE  
ALTERNATIVE HYPOTHESIS  
THAT "THE CRAMER'S  
COEFFICIENT FOR THE  
POPULATION IS GREATER  
THAN 0."

745 ~~~

HOWEVER, THERE IS NO  
WAY YOU CAN AFFIRM THE  
NULL HYPOTHESIS THAT "THE  
CRAMER'S COEFFICIENT FOR  
THE POPULATION IS 0."

HERE'S A LITTLE  
STORY THAT  
MIGHT HELP YOU  
UNDERSTAND IT  
BETTER.

SUPPOSE SOMEONE STOLE  
AND ATE A PUDDING YOU  
WERE SAVING TO EAT LATER.

WHO STOLE MY  
PUDDING!?

YUMI'S NAME CAME UP AS  
THE SUSPECT.

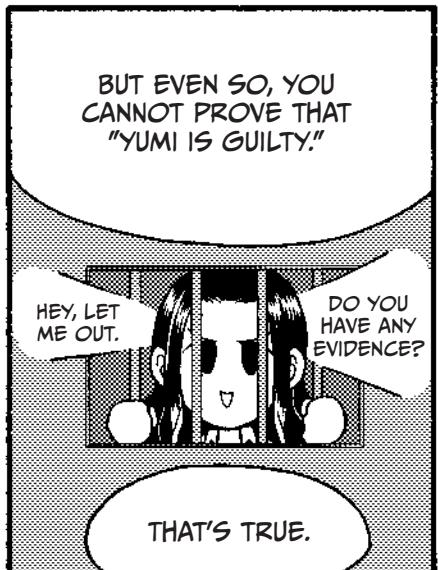
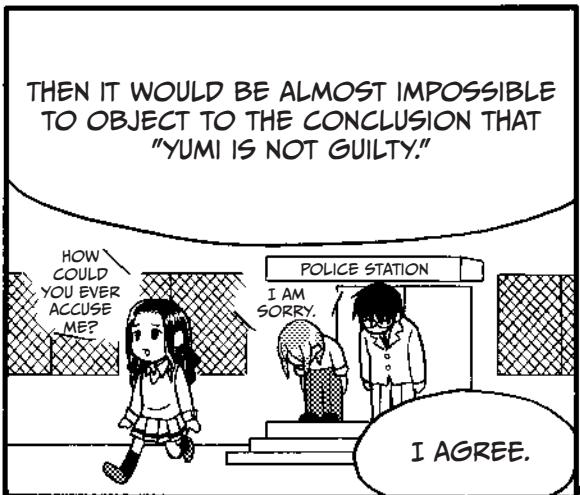
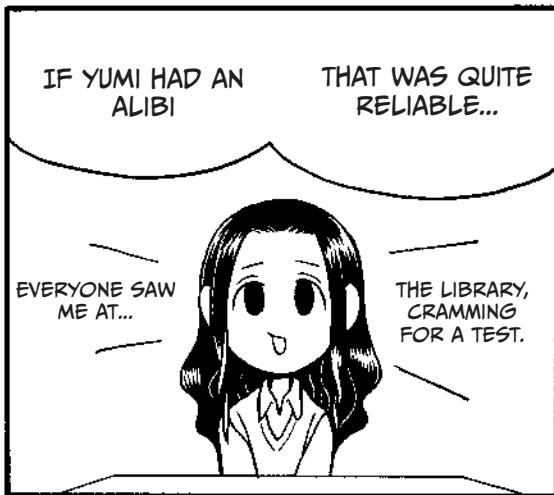
YUMI!! I THOUGHT  
YOU WERE MY  
FRIEND!

THIS IS JUST A MAKE-BELIEVE STORY!

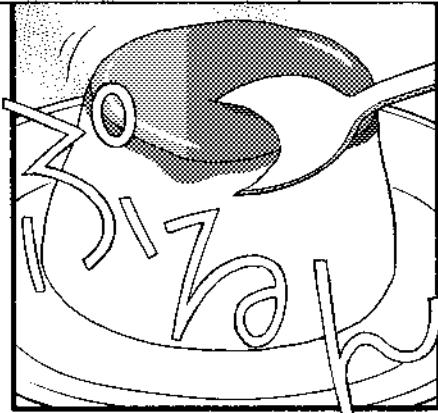
LET'S PUT ASIDE DETAILS LIKE THE  
TYPES OF HYPOTHESIS TESTS OR  
SIGNIFICANCE LEVEL...

NULL HYPOTHESIS	YUMI IS NOT GUILTY.
ALTERNATIVE HYPOTHESIS	YUMI IS GUILTY.

AND MERELY DO A HYPOTHESIS TEST  
AGAINST THESE HYPOTHESES.



3. NULL HYPOTHESES AND ALTERNATIVE HYPOTHESES



YOUR STORY  
REMINDED ME THAT  
THERE WAS PUDDING  
IN THE FRIDGE.



I SAID THAT YOU  
MUST ALWAYS SET UP  
A NULL HYPOTHESIS  
AND ALTERNATIVE  
HYPOTHESIS

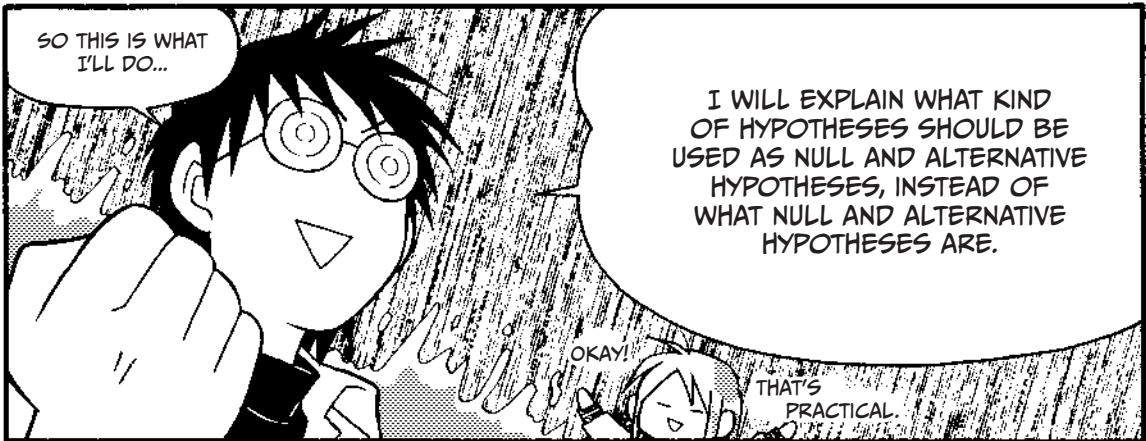
WHEN YOU DO A  
HYPOTHESIS TEST.

YEAH, BUT WHAT ARE THE  
NULL HYPOTHESIS AND  
ALTERNATIVE HYPOTHESIS?

YOU SAID THAT YOU  
WOULD EXPLAIN  
LATER, BUT SO FAR NO  
EXPLANATION HAS BEEN  
GIVEN.

I MUST CONFESS THAT IT IS  
QUITE DIFFICULT TO EXPLAIN  
THESE TWO HYPOTHESES  
SIMPLY.

WHAT?



### EXAMPLES OF HYPOTHESIS TESTS

Name	Example of use
Tests of independence	Estimates whether the value of the Cramer's coefficient for sex and desired way of being asked out is zero for a population
Tests of correlation ratio	Estimates whether the value of the correlation ratio for favorite fashion brand and age is zero for a population
Tests of correlation	Estimates whether the correlation coefficient for amount spent on makeup and amount spent on clothes is zero for a population
Tests of difference between population means	Estimates whether allowances are different between high school girls in Tokyo and Osaka*
Tests of difference between population ratios	Estimates whether the approval rating of cabinet X is different between voters residing in urban areas and rural areas*

\* Note that two populations are being considered.



#### TESTS OF INDEPENDENCE

Null hypothesis	The Cramer's coefficient for sex and desired way of being asked out is 0 for a population.
Alternative hypothesis	The Cramer's coefficient for sex and desired way of being asked out is greater than 0 for a population.

#### TESTS OF CORRELATION RATIO

Null hypothesis	The correlation ratio for favorite fashion brand and age is 0 for a population.
Alternative hypothesis	The correlation ratio for favorite fashion brand and age is greater than 0 for a population.

#### TESTS OF CORRELATION

Null hypothesis	The correlation coefficient for amount spent on makeup and amount spent on clothes is 0 for a population.
Alternative hypothesis	<p>The correlation coefficient for amount spent on makeup and amount spent on clothes is not 0 for a population.</p> <p>or</p> <p>The correlation coefficient for amount spent on makeup and amount spent on clothes is greater than 0 for a population.</p> <p>or</p> <p>The correlation coefficient for amount spent on makeup and amount spent on clothes is less than 0 for a population.</p>

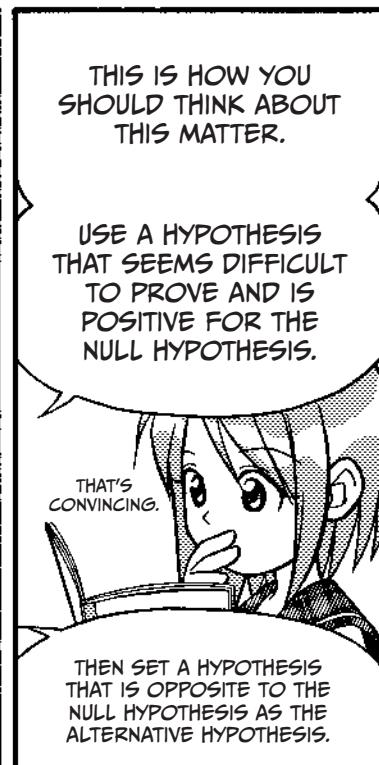
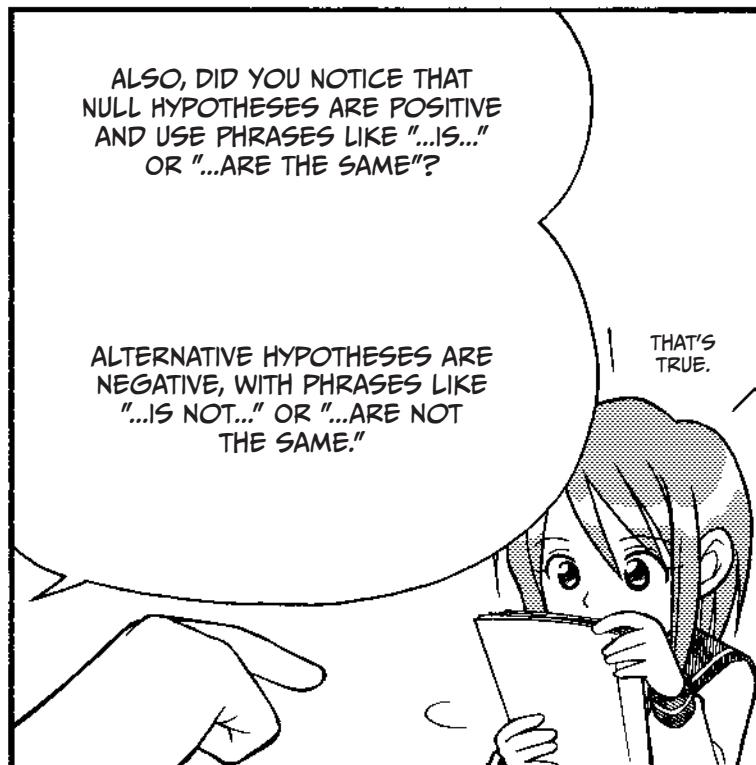
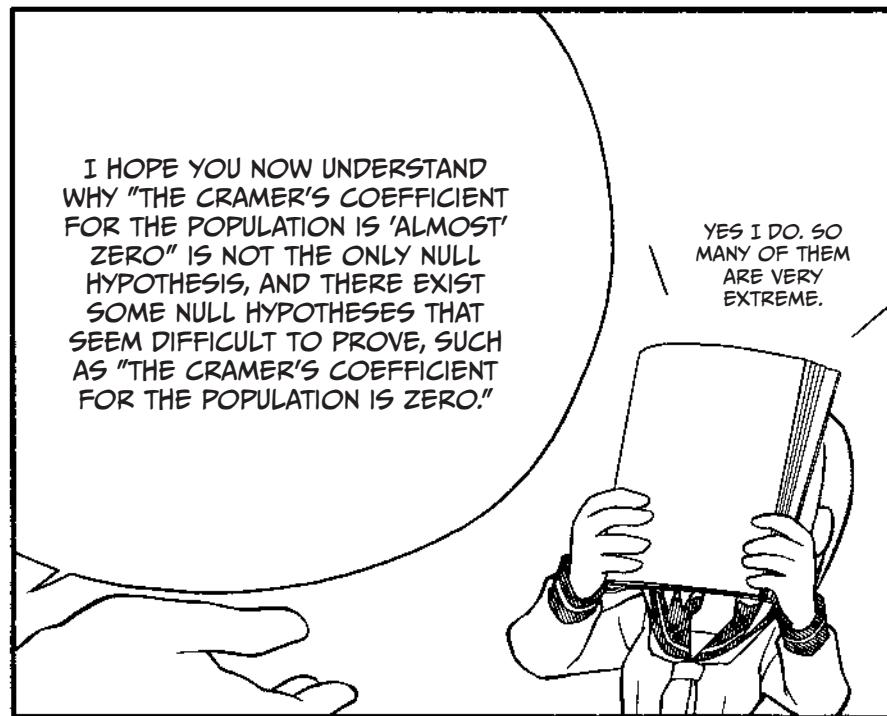
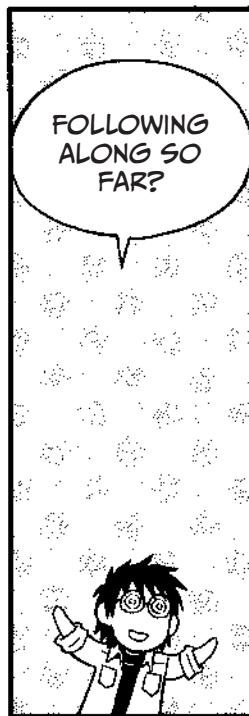
#### TESTS OF DIFFERENCE BETWEEN POPULATION MEANS

Null hypothesis	The allowances of high school girls in Tokyo and Osaka are the same.
Alternative hypothesis	<p>The allowances of high school girls in Tokyo and Osaka are not the same. or The allowances of high school girls in Tokyo are larger than those of high school girls in Osaka. or The allowances of high school girls in Tokyo are smaller than those of high school girls in Osaka.</p>

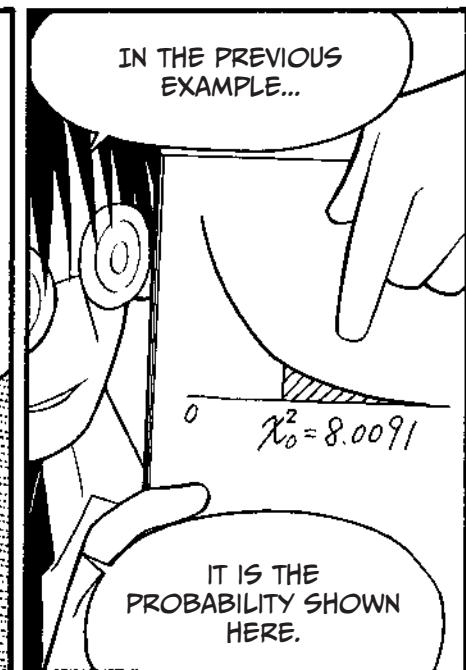
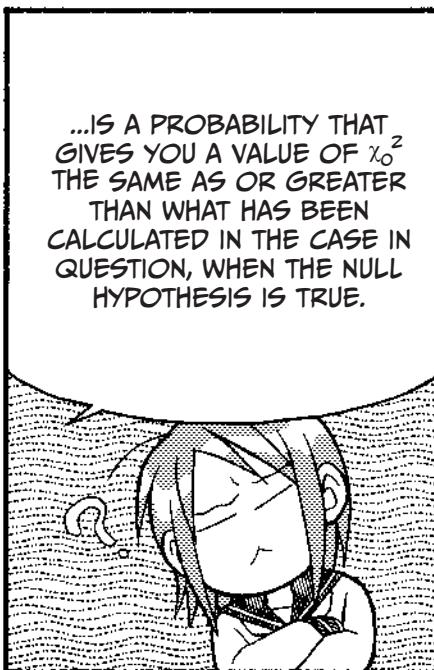
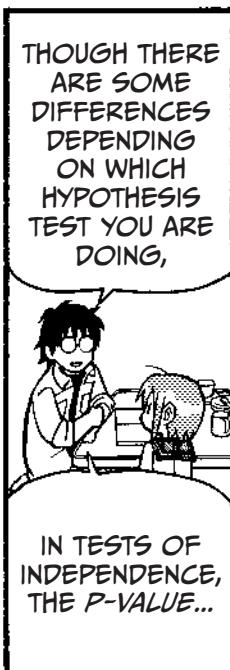
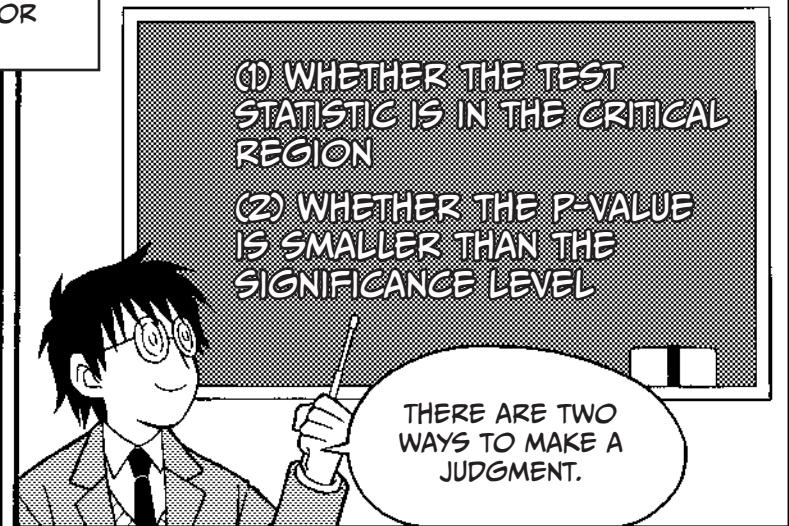
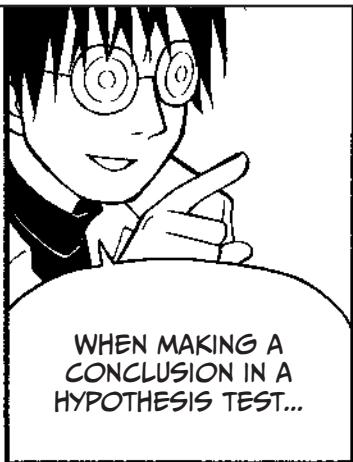
#### TESTS OF DIFFERENCE BETWEEN POPULATION RATIOS

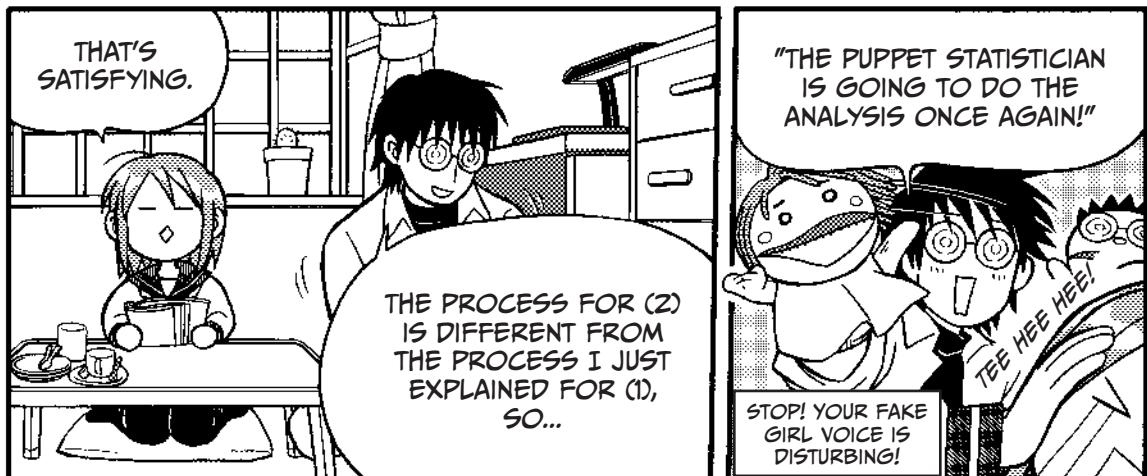
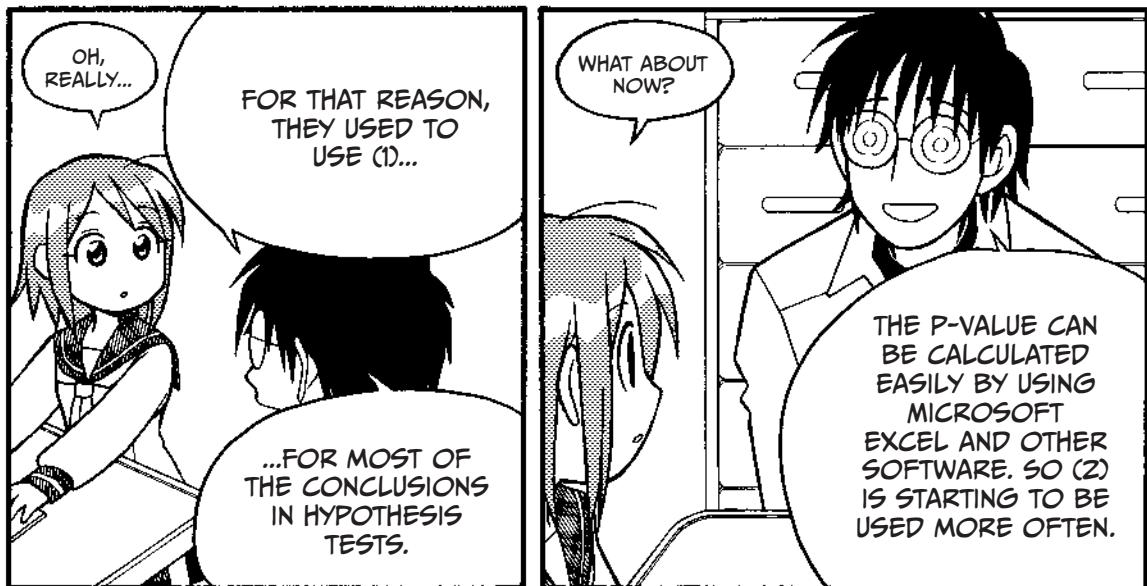
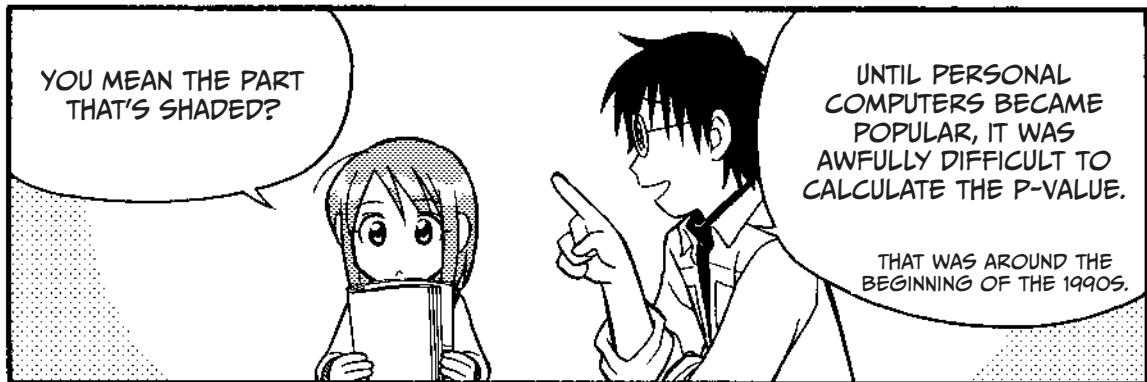
Null hypothesis	The approval ratings of cabinet X for voters residing in urban areas and rural areas are the same.
Alternative hypothesis	<p>The approval ratings of cabinet X for voters residing in urban areas and rural areas are not the same. or The approval rating of cabinet X for voters residing in urban areas is higher than that of voters residing in rural areas. or The approval rating of cabinet X for voters residing in urban areas is lower than that of voters residing in rural areas.</p>





#### 4. P-VALUE AND PROCEDURE FOR HYPOTHESIS TESTS





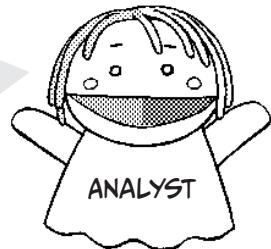
## Step 6p

Determine whether or not the P-value corresponding to the test statistic obtained in step 5 is smaller than the significance level.

The significance level is 0.05. Since Pearson's chi-square test statistic ( $\chi_0^2$ , which is the test statistic in this case) is 8.0091, the P-value is 0.0182.

$$0.0182 < 0.05$$

Thus the P-value is smaller.

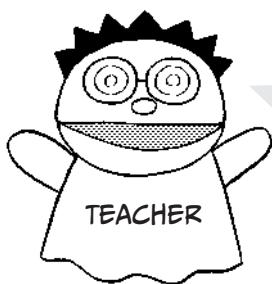
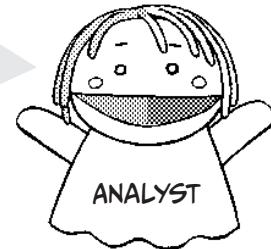


As mentioned before, you can calculate the P-value using Excel (though this depends on what type of hypothesis test you are doing). See page 208 for details.

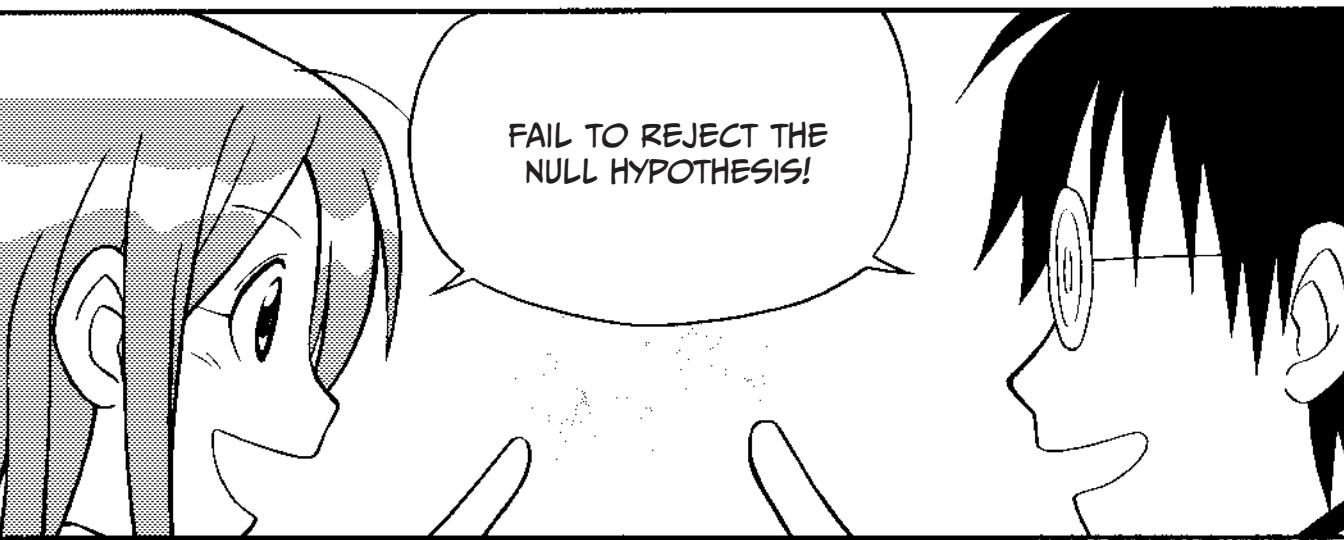
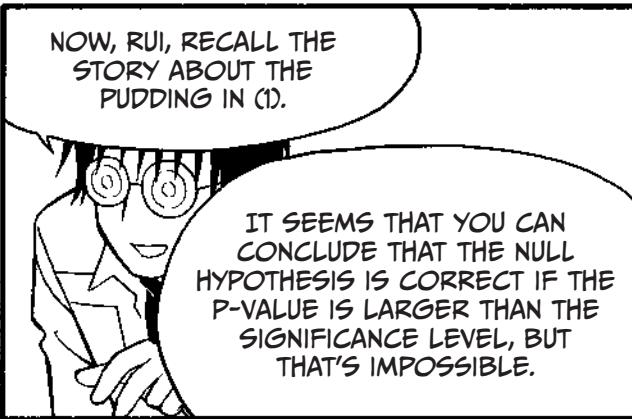
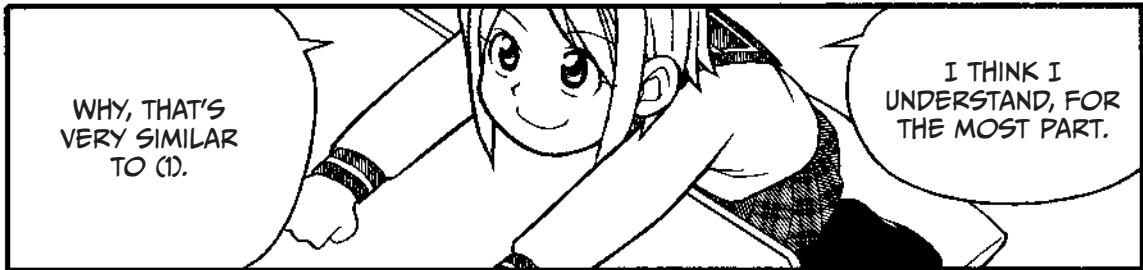
### Step 7p

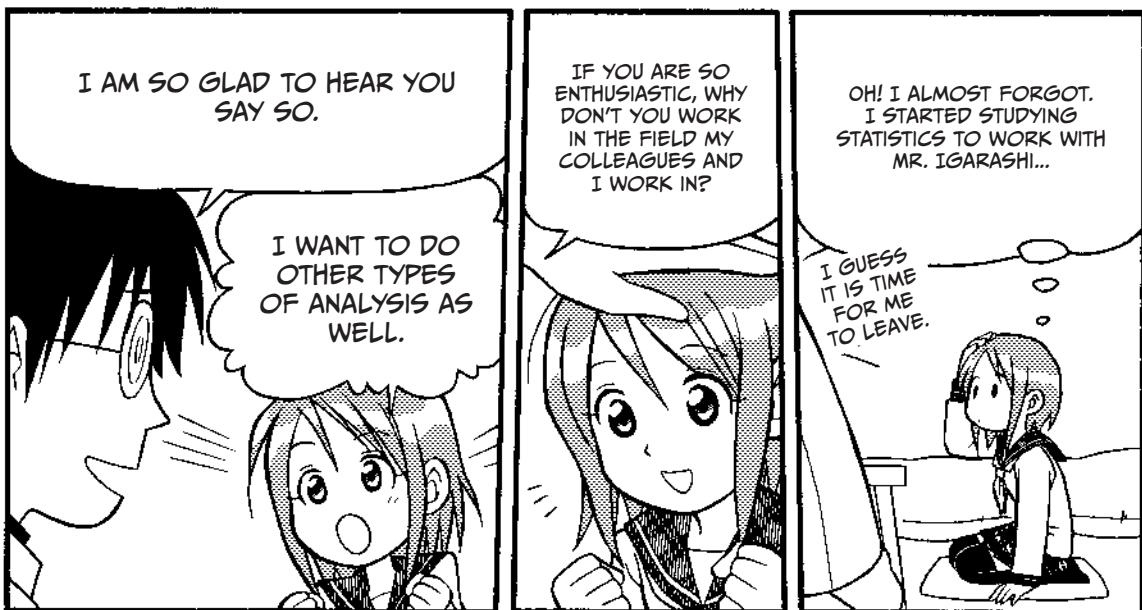
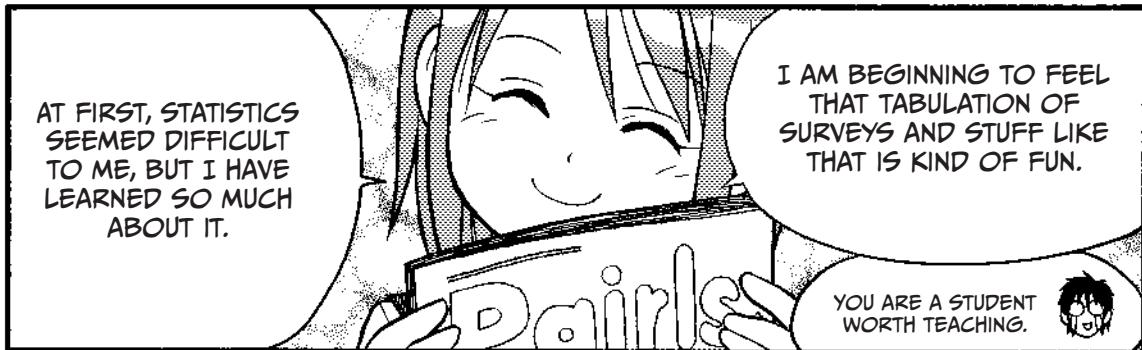
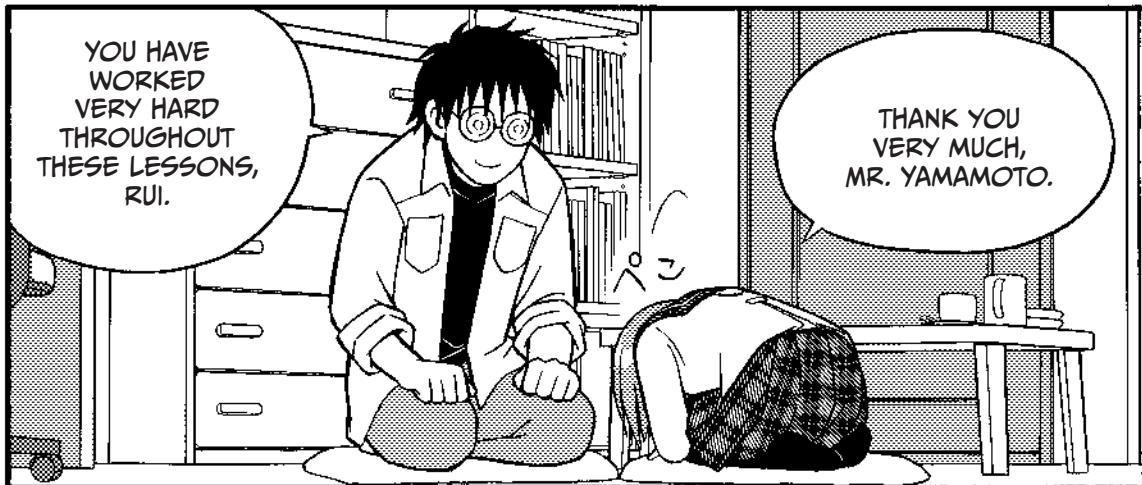
If the P-value is smaller than the significance level in step 6p, you reject the null hypothesis. If not, you fail to reject the null hypothesis.

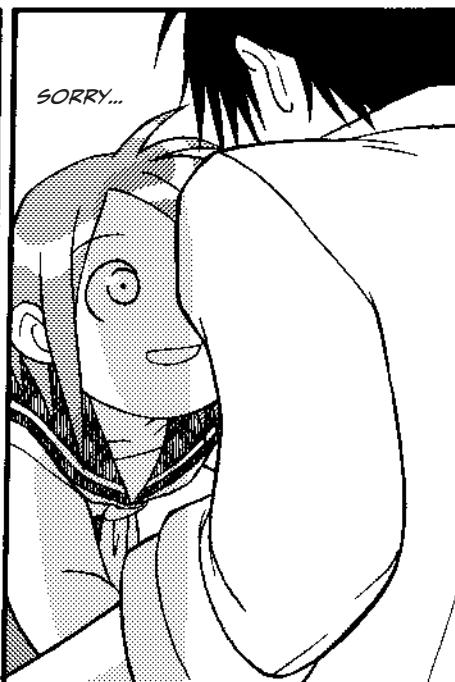
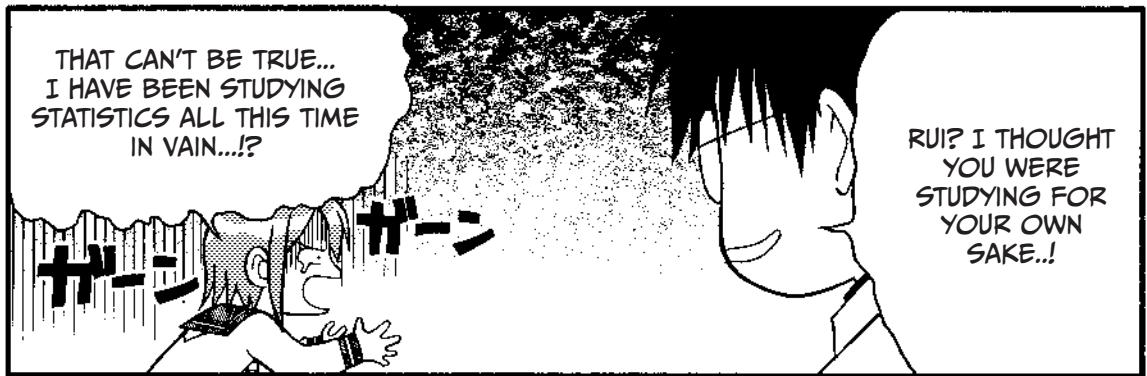
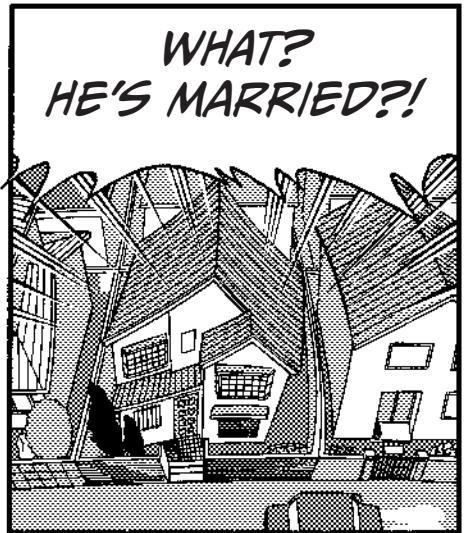
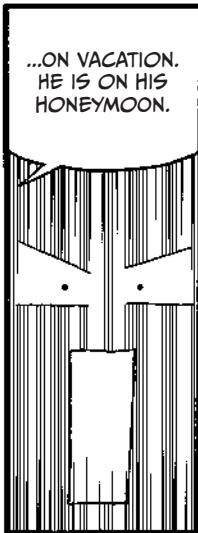
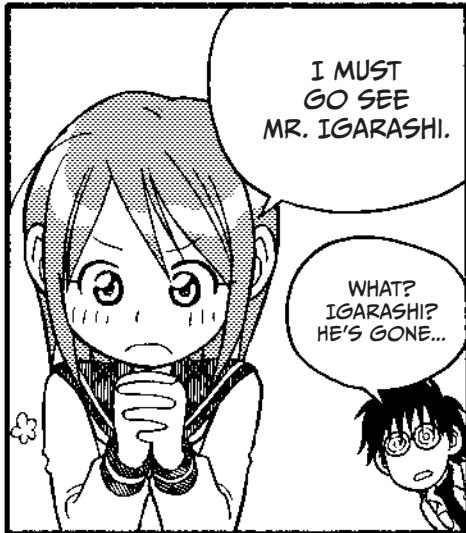
The P-value was smaller than the significance level. Therefore, you conclude in favor of the alternative hypothesis, “the Cramer’s coefficient for the population is greater than 0.”

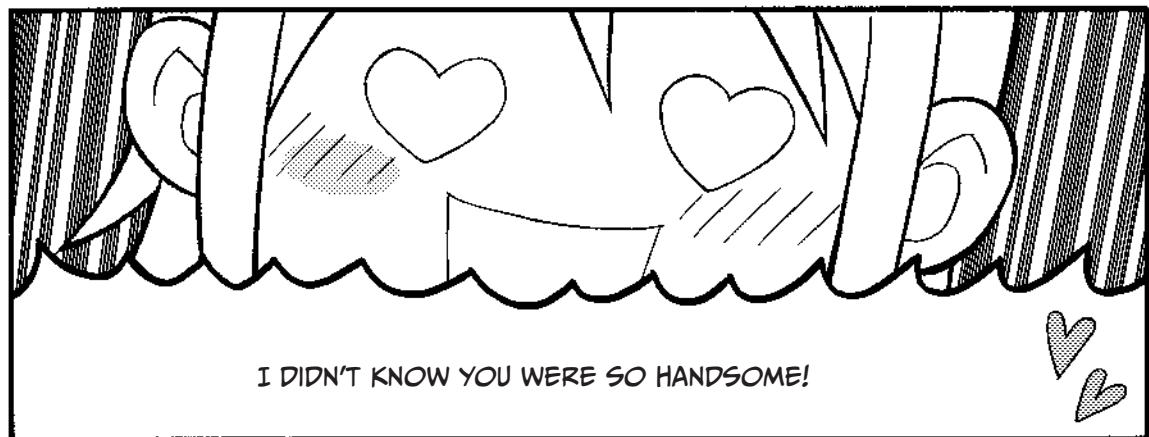


Even if the P-value was smaller than the significance level, you cannot really conclude that the alternative hypothesis is “absolutely” correct in a hypothesis test. The only conclusion you can make is: “I would like to say that the alternative hypothesis is ‘absolutely’ correct . . . but there is a  $(\alpha \times 100)\%$  possibility that the null hypothesis is correct.”











MR. YAMAMOTO, PLEASE  
DO KEEP TEACHING ME  
THIS AND THAT!

AND SO THEIR LESSONS WILL  
CONTINUE...

...MAYBE...MAYBE NOT.

## **5. TESTS OF INDEPENDENCE AND TESTS OF HOMOGENEITY**



There is a hypothesis test very similar to a test of independence called a *test of homogeneity*. Below is an example of a test of homogeneity. As you read it, think about how it is different from a test of independence.

### **EXAMPLE**

*P-Girls Magazine* published an article titled, "We Asked 300 High School Students, 'How Would You Like to Be Asked Out?'" The choices were phone, e-mail, or face to face.

**HYPOTHESIS: THE RATIO OF PHONE TO E-MAIL TO FACE-TO-FACE IS DIFFERENT BETWEEN HIGH SCHOOL GIRLS AND BOYS.**

To find out if this hypothesis is true or not, a journalist actually conducted a survey by randomly choosing respondents from each of the two groups, "all high school girls residing in Japan" and "all high school boys residing in Japan." The table below is the result.

<b>Respondent</b>	<b>Desired way of being asked out</b>	<b>Age</b>	<b>Sex</b>
1	Face to face	17	Female
...	...	...	...
148	E-mail	16	Female
149	Phone	15	Male
...	...	...	...
300	E-mail	18	Male

The cross tabulation of sex and desired way of being asked out is the table below.

		Desired way of being asked out			<b>Sum</b>
		<b>Phone</b>	<b>E-mail</b>	<b>Face to face</b>	
<b>Sex</b>	<b>Female</b>	34	61	53	148
	<b>Male</b>	38	40	74	152
<b>Sum</b>		72	101	127	300

Estimate whether or not the hypothesis stated above is correct using a test of homogeneity. Use 0.05 as the significance level.

## PROCEDURE

<b>Step 1</b>	Define the population.	The population in this case is “all high school girls residing in Japan” and “all high school boys residing in Japan.”
<b>Step 2</b>	Set up a null hypothesis and an alternative hypothesis.	The null hypothesis is “the ratio of phone to e-mail to face to face is the same for high school girls and boys.” The alternative hypothesis is “the ratio of phone to e-mail to face to face is different between high school girls and boys.”
<b>Step 3</b>	Choose which hypothesis test to do.	A test of homogeneity will be applied.
<b>Step 4</b>	Determine the significance level.	The significance level is 0.05.
<b>Step 5</b>	Calculate the test statistic from the sample data.	A test of homogeneity is being used in this exercise. Therefore, the test statistic is Pearson’s chi-square test statistic. The value of $\chi_0^2$ in this exercise has already been calculated on page 132. $\chi_0^2 = 8.0091$ Pearson’s chi-square test statistic ( $\chi_0^2$ ) in this exercise follows a chi-square distribution of degrees of freedom $(2 - 1) \times (3 - 1) = 1 \times 2 = 2$ , if the null hypothesis is true.
<b>Step 6</b>	Determine whether the test statistic in step 5 is in the critical region.	The test statistic $\chi_0^2$ is 8.0091. Since the significance level is 0.05, the critical region is 5.9915 or more, according to the table of chi-square distribution on page 103. The test statistic is within the critical region.
<b>Step 7</b>	If the test statistic is in the critical region in step 6, reject the null hypothesis and conclude in favor of the alternative. If not, fail to reject the null hypothesis.	The test statistic was within the critical region. Thus, you conclude in favor of the alternative hypothesis, “the ratio of phone to e-mail to face to face is different between high school girls and boys.”



Don't you think that both the exercise and procedure are quite similar to those for a test of independence? Let's now look at the differences between tests of independence and tests of homogeneity. There are three things to note.

First, the population defined is different. There is only one population ("all high school students residing in Japan") in the former. In the latter, there are two populations: "all high school girls residing in Japan" and "all high school boys residing in Japan."

Also, the hypotheses are different. In the former,

Null hypothesis	The Cramer's coefficient for the population is 0. In other words, sex and desired way of being asked out are not correlated.
Alternative hypothesis	The Cramer's coefficient for the population is greater than 0. In other words, sex and desired way of being asked out are correlated.

In the latter,

Null hypothesis	The ratio of phone to e-mail to face to face is the same for high school girls and boys.
Alternative hypothesis	The ratio of phone to e-mail to face to face is different between high school girls and boys.

Finally, the order of procedure is different. In the former, the hypothesis is set after the data is collected, whereas the hypothesis is set before collecting the data in the latter.

As confirmed in the previous paragraph, tests of independence and tests of homogeneity have obvious differences. However, in practice, people tend to do tests of homogeneity when they are actually intending to do tests of independence, or vice versa. Be careful.

## 6. HYPOTHESIS TEST CONCLUSIONS

Up to this point, we have expressed the conclusion of a hypothesis test as follows:

**IF THE TEST STATISTIC IS IN THE CRITICAL REGION, YOU CAN CONCLUDE, "I REJECT THE NULL HYPOTHESIS." IF NOT, YOU CONCLUDE, "I FAIL TO REJECT THE NULL HYPOTHESIS."**

But there are other ways to express the conclusions of hypothesis tests. They are summarized below.

TABLE 7-4: EXPRESSIONS OF HYPOTHESIS TEST CONCLUSIONS

When the test statistic is in the critical region	When the test statistic is not in the critical region
<ul style="list-style-type: none"><li>• Conclude in favor of the alternative hypothesis</li><li>• Conclude that the result is statistically significant</li><li>• Reject the null hypothesis</li></ul>	<ul style="list-style-type: none"><li>• Fail to reject the null hypothesis</li><li>• Conclude that the result is not statistically significant</li><li>• Accept the null hypothesis</li></ul>

The expressions “it is statistically significant” and “it is not statistically significant” seem to be popular in introductions to statistics. So why did we use an unpopular expression on purpose? I recognize that many beginners to hypothesis tests use the expression “it is significant” without actually understanding the meaning of the phrase. They seem to be merely confirming the test statistic or P-value. If you do not set a proper null and alternative hypothesis, the meaning of *significant* will be ambiguous. Beginners’ definitions of their populations are frequently unclear as well.

I used to think I shouldn’t be so strict with beginners. But it’s impossible to make an accurate conclusion with uncertain null and alternative hypotheses. So in this book, I use the expressions “reject the null hypothesis” and “fail to reject the null hypothesis” so that you will get into the habit of thinking hard about your hypotheses.

## EXERCISE AND ANSWER

### EXERCISE

The table below is the same as the cross tabulation found on page 138.

		Preference for coffee or tea		Sum
		Coffee	Tea	
Type of food often ordered	Japanese	43	33	76
	European	51	53	104
	Chinese	29	41	70
Sum		123	127	250

Using a chi-square test of independence, estimate if the Cramer's coefficient for type of food often ordered and preference for coffee or tea in the population “people of age 20 or older residing in Japan” is greater than 0. This is the same as estimating whether there is a correlation between type of food often ordered and preference for coffee or tea. Use 0.01 as the significance level.

### ANSWER

- Step 1** Define the population.  
The population in this case is “people of age 20 or older residing in Japan.”
- Step 2** Set up a null hypothesis and an alternative hypothesis.  
The null hypothesis is “type of food often ordered and preference for coffee or tea are not correlated.” The alternative hypothesis is “type of food often ordered and preference for coffee or tea are correlated.”
- Step 3** Choose which hypothesis test to do.  
A chi-square test of independence will be applied.
- Step 4** Determine the significance level.  
The significance level is 0.01.
- Step 5** Calculate the test statistic from the sample data.  
A chi-square test of independence is being used in this exercise. Therefore, the test statistic is Pearson's chi-square test statistic ( $\chi_0^2$ ). The value of  $\chi_0^2$  in this exercise has already been calculated on page 141.  $\chi_0^2 = 3.3483$
- Step 6** Determine whether the test statistic obtained in step 5 is in the critical region.  
The test statistic  $\chi_0^2$  is 3.3483. Because the significance level ( $\alpha$ ) is 0.01, the critical region is 9.2104 or above, according to the table of chi-square distribution on page 103. The test statistic is not within the critical region.
- Step 7** If the test statistic is in the critical region in step 6, reject the null hypothesis. If not, fail to reject the null hypothesis.  
The test statistic was not within the critical region. Thus, the null hypothesis “type of food often ordered and preference for coffee or tea are not correlated” cannot be rejected.

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## SUMMARY

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- A *hypothesis test* is an analysis technique used to estimate whether the analyst's hypothesis about the population is correct using the sample data.
- The formal name for a hypothesis test is *statistical hypothesis testing*.
- Test statistics are obtained from a function that calculates a single value from the sample data.
- In general, 0.05 or 0.01 is used as the significance level.
- The *critical region* is an area that corresponds to the significance level (also called the *alpha value* and expressed by the symbol  $\alpha$ ).
- A *chi-square test of independence* is an analysis technique used to estimate whether the Cramer's coefficient for a population is 0. It can also be said that it is an analysis technique used to estimate whether the two variables in a cross tabulation are correlated.
- If the Cramer's coefficient for a population is 0, Pearson's chi-square test statistic follows a chi-square distribution.
- The *P-value* in a test of independence is a probability that gives a Pearson's chi-square test statistic equal to or greater than the value earned in the case when the null hypothesis is true.
- When making a conclusion in a hypothesis test, there are two bases of judgment:
  1. Whether the test statistic is in the critical region
  2. Whether the P-value is smaller than the significance level
- The process of analysis in any hypothesis test is the same as the process for the test of independence or any other kind of test. The actual procedure is:

---

<b>Step 1</b>	Define the population.
<b>Step 2</b>	Set up a null hypothesis and an alternative hypothesis.
<b>Step 3</b>	Choose which hypothesis test to do.
<b>Step 4</b>	Determine the significance level.
<b>Step 5</b>	Calculate the value of the test statistic from the sample data.
<b>Step 6</b>	Determine whether the test statistic obtained in step 5 is in the critical region.
<b>Step 7</b>	If the test statistic is in the critical region in step 6, reject the null hypothesis. If not, fail to reject the null hypothesis.
<b>Step 6p</b>	Determine whether the P-value corresponding to the test statistic obtained in step 5 is smaller than the significance level.
<b>Step 7p</b>	If the P-value is smaller than the significance level in step 6p, reject the null hypothesis. If not, fail to reject the null hypothesis.

---



**LET'S CALCULATE USING EXCEL**



This appendix contains instructions for calculating various statistics using Microsoft Excel. You'll learn how to do the following things:

1. Make a frequency table
2. Calculate arithmetic mean, median, and standard deviation
3. Make a cross tabulation
4. Calculate the standard score and the deviation score
5. Calculate the probability of the standard normal distribution
6. Calculate the point on the horizontal axis of the chi-square distribution
7. Calculate the correlation coefficient
8. Perform tests of independence

You can download these Excel files and follow along (get them at [http://www.nostarch.com/mg\\_statistics.htm](http://www.nostarch.com/mg_statistics.htm)). Readers who are not familiar with Excel should try “Calculating Arithmetic Mean, Median, and Standard Deviation” on page 195 first.

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## 1. MAKING A FREQUENCY TABLE

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This exercise uses the ramen restaurant prices on page 33.

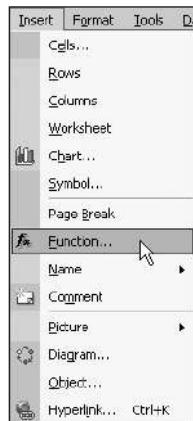
### Step 1

Select cell J3.

I	B	C	D	E	F	G	H	I	J
1	Price (yen)			Price (yen)					
2	Ramen shop 1	700	Ramen shop 26	780		Equal or greater	Less than	Equal or less	Frequency
3	Ramen shop 2	850	Ramen shop 27	590		500	600	599	
4	Ramen shop 3	600	Ramen shop 28	650		600	700	699	
5	Ramen shop 4	650	Ramen shop 29	580		700	800	799	
6	Ramen shop 5	900	Ramen shop 30	750		800	900	899	
7	Ramen shop 6	750	Ramen shop 31	800		900	1000	999	
8	Ramen shop 7	500	Ramen shop 32	550					
9	Ramen shop 8	890	Ramen shop 33	750					
10	Ramen shop 9	660	Ramen shop 34	700					
11	Ramen shop 10	700	Ramen shop 35	600					
12	Ramen shop 11	890	Ramen shop 36	800					
13	Ramen shop 12	720	Ramen shop 37	800					
14	Ramen shop 13	600	Ramen shop 38	900					
15	Ramen shop 14	650	Ramen shop 39	790					
16	Ramen shop 15	790	Ramen shop 40	790					
17	Ramen shop 16	670	Ramen shop 41	780					
18	Ramen shop 17	600	Ramen shop 42	600					
19	Ramen shop 18	900	Ramen shop 43	670					
20	Ramen shop 19	880	Ramen shop 44	680					
21	Ramen shop 20	720	Ramen shop 45	650					
22	Ramen shop 21	850	Ramen shop 46	890					
23	Ramen shop 22	700	Ramen shop 47	930					
24	Ramen shop 23	780	Ramen shop 48	650					
25	Ramen shop 24	850	Ramen shop 49	777					
26	Ramen shop 25	750	Ramen shop 50	700					

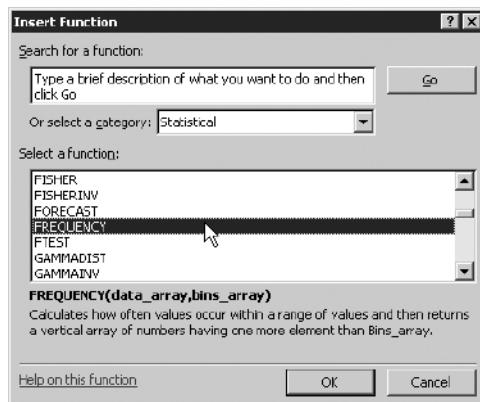
## Step 2

Select **Insert ▶ Function...**



## Step 3

Select **Statistical** from the category dropdown menu, and then select **FREQUENCY** as the name of the function.



#### Step 4

Select the area shown in the figure below, and click **OK**.

	A	B	C	D	E	F	G	H	I	J
1		Price (yen)			Price (yen)					
2	Ramen shop 1	700		Ramen shop 26	700		Equal or greater	Less than	Equal or less	Frequency
3	Ramen shop 2	850		Ramen shop 27	590		500	600	599	26(3:17)
4	Ramen shop 3	600		Ramen shop 28	650		600	700	699	
5	Ramen shop 4	650		Ramen shop 29	580		700	800	799	
6	Ramen shop 5	880		Ramen shop 30	750		800	900	899	
7	Ramen shop 6	750		Ramen shop 31	800		900	1000	999	
8	Ramen shop 7	500		Ramen shop 32	550					
9	Ramen shop 8	890		Ramen shop 33	750					
10	Ramen shop 9	880								
11	Ramen shop 10	700								
12	Ramen shop 11	890								
13	Ramen shop 12	720								
14	Ramen shop 13	680								
15	Ramen shop 14	650								
16	Ramen shop 15	790								
17	Ramen shop 16	670								
18	Ramen shop 17	680								
19	Ramen shop 18	900								
20	Ramen shop 19	880								
21	Ramen shop 20	720								
22	Ramen shop 21	850								
23	Ramen shop 22	700								
24	Ramen shop 23	780								
25	Ramen shop 24	850								
26	Ramen shop 25	750								
27										

The dialog box shows the following settings:

- Data\_array: E2:E26
- Bins\_array: I3:I17
- Description: Calculates how often values occur within a range of values and then returns a vertical array of numbers having one more element than Bins\_array.
- Formula result: 4

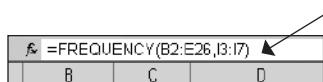
#### Step 5

Start with cell J3, and select the area from cell J3 to J7 as shown below.

G	H	I	J
Equal or greater	Less than	Equal or less	Frequency
500	600	599	4
600	700	699	
700	800	799	
800	900	899	
900	1000	999	

#### Step 6

Click this part in the formula bar.



#### Step 7

Press ENTER while holding down the SHIFT key and CTRL key at the same time.

### Step 8

Now you have the frequency of each class!

G	H	I	J
Equal or greater	Less than	Equal or less	Frequency
500	600	599	4
800	700	699	13
700	800	799	18
900	900	899	12
900	1000	999	3

## 2. CALCULATING ARITHMETIC MEAN, MEDIAN, AND STANDARD DEVIATION



This data comes from Rui's classmates' bowling scores on page 41.

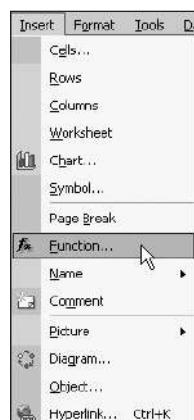
### Step 1

Select cell B10.

A	B
1	Team A
2	Rui-Rui
3	73
4	Yumi
5	124
6	Shizuka
7	111
8	Touko
9	90
10	Average
11	Median
12	Standard Deviation
13	

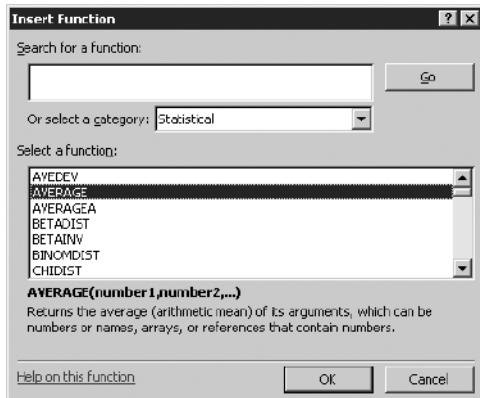
### Step 2

Select **Insert ▶ Function...**



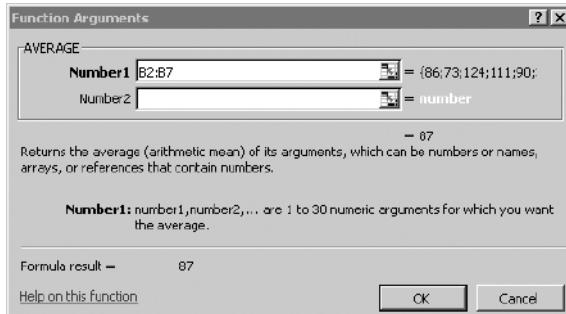
### Step 3

Select **Statistical** in the category dropdown, and then select **AVERAGE**.



### Step 4

Type the range shown in the figure below, and click **OK**.



### Step 5

Now you have the average score for the team.

	A	B
1		Team A
2	Rui-Rui	86
3	Jun	73
4	Yumi	124
5	Shizuka	111
6	Touko	90
7	Kaede	30
8		
9		
10	Average	87
11	Median	
12	Standard Deviation	

You can calculate the median and standard deviation by following steps 1 through 5 and using the functions MEDIAN and STDEVP in step 2.

### 3. MAKING A CROSS TABULATION



The data for this table is Rui's classmates' responses to the new uniform design, found on page 61.

#### Step 1

Select cell F20, then select **Insert ▶ Function**.

	A	B	C	D	E	F	G	H
1		Response			Response			Response
2	1	like		16	neither		31	neither
3	2	neither		17	like		32	neither
4	3	like		18	like		33	like
5	4	neither		19	like		34	dislike
6	5	dislike		20	like		35	like
7	6	like		21	like		36	like
8	7	like		22	like		37	like
9	8	like		23	dislike		38	like
10	9	like		24	neither		39	neither
11	10	like		25	like		40	like
12	11	like		26	like			
13	12	like		27	dislike			
14	13	neither		28	like			
15	14	like		29	like			
16	15	like		30	like			
17								
18								
19						Frequency		
20					like			
21					neither			
22					dislike			
23								

#### Step 2

Select **Statistical** in the category dropdown, and then select **COUNTIF** as the name of the function.

### Step 3

Select the area shown in the figure below, type *like* in the Criteria text box, and then click **OK**.

A	B	C	D	E	F	G	H	I
1	Response			Response			Response	
2	1 like		16	neither		31	neither	
3	2 neither		17	like		32	neither	
4	3 like							
5	4 neither							
6	5 dislike							
7	6 like							
8	7 like							
9	8 like							
10	9 like							
11	10 like							
12	11 like							
13	12 like							
14	13 neither							
15	14 like							
16	15 like							
17								
18								
19						Frequency		
20				like	16,like)			
21				neither				
22				dislike				
23								

The screenshot shows a Microsoft Excel spreadsheet with data in columns A through I. Column A contains row numbers from 1 to 22. Column B contains responses: like, neither, like, neither, dislike, like, like, like, like, like, like, like, like, neither, like, like, like, like, like, like, like, like, like. Columns C through I contain corresponding counts for each response category. A 'Function Arguments' dialog box is open over the range A2:I16, showing a COUNTIF formula with Range set to A2:I16 and Criteria set to like. The formula result is 0. The 'Frequency' column header is in cell E19, and the value 16 is in cell F19 under the like category.

### Step 4

Now you have the total number of Rui's classmates who like the new uniform.

A	B	C	D	E	F	G	H
1	Response			Response			Response
2	1 like		16	neither		31	neither
3	2 neither		17	like		32	neither
4	3 like		18	like		33	like
5	4 neither		19	like		34	dislike
6	5 dislike		20	like		35	like
7	6 like		21	like		36	like
8	7 like		22	like		37	like
9	8 like		23	dislike		38	like
10	9 like		24	neither		39	neither
11	10 like		25	like		40	like
12	11 like		26	like			
13	12 like		27	dislike			
14	13 neither		28	like			
15	14 like		29	like			
16	15 like		30	like			
17							
18							
19				Frequency			
20				like	28		
21				neither			
22				dislike			
23							

### Step 5

You can obtain the frequency of *neither* and *dislike* by following steps 1 through 4 and typing those words instead of *like* in step 3.

## 4. CALCULATING THE STANDARD SCORE AND THE DEVIATION SCORE



This exercise uses the test data from page 72.

Steps 1 through 8 show the process for obtaining the standard score.

Steps 9 through 11 show the process for obtaining the deviation score. There is an Excel function for calculating standard score, but there is no function for calculating deviation score. However, the deviation score can be calculated fairly easily if we use the result of the standard score calculation.

### Step 1

Select cell E2.

	A	B	C	D	E	F
1		History			Standard Score	Deviation Score
2	Rui	73	Rui			
3	Yumi	61	Yumi			
4	A	14	A			
5	B	41	B			
6	C	49	C			
7	D	87	D			
8	E	69	E			
9	F	65	F			
10	G	36	G			
11	H	7	H			
12	I	53	I			
13	J	100	J			
14	K	57	K			
15	L	45	L			
16	M	56	M			
17	N	34	N			
18	O	37	O			
19	P	70	P			
20	Average	53				
21	Standard Deviation	22.7				

### Step 2

Select **Insert ▶ Function**. Then select **Statistical**, and then select **STANDARDIZE** as the name of the function.

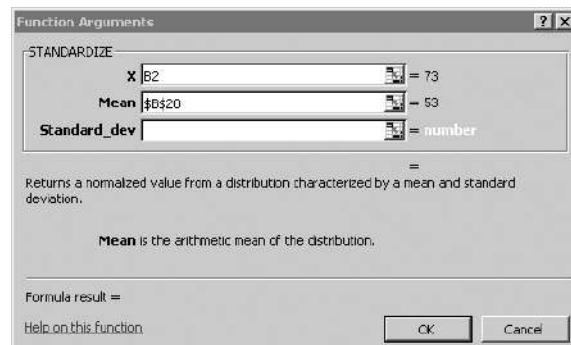
### Step 3

Select cell B2.

	A	B	C	D	E	F	G	H	I	J	K
1		History			Standard Score	Deviation Score					
2	Rui	73		Rui	=STANDARDIZE(B2)						
3	Yumi	61		Yumi							
4	A	14		A							
5	B	41		B							
6	C	49		C							
7	D	87		D							
8	E	69		E							
9	F	65		F							
10	G	36		G							
11	H	7		H							
12	I	53		I							
13	J	100		J							
14	K	57		K							
15	L	45		L							
16	M	56		M							
17	N	34		N							
18	O	37		O							
19	P	70		P							
20	Average	53									
21	Standard Deviation	22.7									

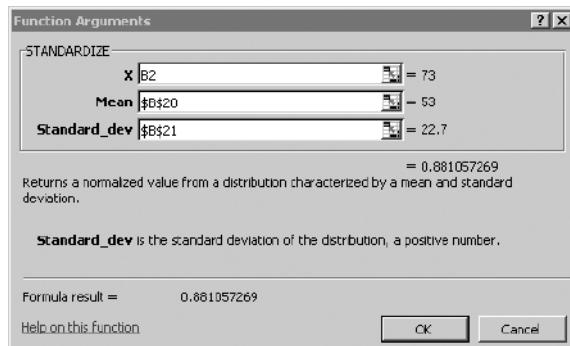
### Step 4

Select B20 for Mean, press F4 once, and confirm that B20 has changed to \$B\$20.



### Step 5

Select cell B21 for Standard\_dev, press F4 once, and after confirming that B21 has changed to \$B\$21, click **OK**.



### Step 6

Confirm that Rui's standard score has been calculated.

	A	B	C	D	E	F
1		History			Standard Score	Deviation Score
2	Rui	73		Rui	0.88	
3	Yumi	81		Yumi		
4	A	14		A		
5	B	41		B		
6	C	49		C		
7	D	87		D		
8	E	89		E		
9	F	85		F		
10	G	36		G		
11	H	7		H		
12	I	53		I		
13	J	100		J		
14	K	57		K		
15	L	45		L		
16	M	58		M		
17	N	34		N		
18	O	37		O		
19	P	70		P		
20	Average	53				
21	Standard Deviation	22.7				

### Step 7

Put the point of the arrow near the bottom-right side of cell E2, confirm that the arrow has changed to a black cross, drag down to cell E19 by holding down the left button of the mouse, and let go of the button when you finish dragging.

	A	B	C	D	E	F
1		History			Standard Score	Deviation Score
2	Rui	73		Rui	0.88	
3	Yumi	81		Yumi		
4	A	14		A		
5	B	41		B		
6	C	49		C		
7	D	87		D		
8	E	69		E		
9	F	65		F		
10	G	36		G		
11	H	7		H		
12	I	53		I		
13	J	100		J		
14	K	57		K		
15	L	45		L		
16	M	56		M		
17	N	34		N		
18	O	37		O		
19	P	70		P		
20	Average	53				
21	Standard Deviation	22.7				

### Step 8

Now you should have everyone's standard score!

	A	B	C	D	E	F
1		History			Standard Score	Deviation Score
2	Rui	73		Rui	0.88	
3	Yumi	81		Yumi	0.35	
4	A	14		A	-1.72	
5	B	41		B	-0.53	
6	C	49		C	-0.18	
7	D	87		D	1.50	
8	E	69		E	0.70	
9	F	65		F	0.53	
10	G	36		G	-0.75	
11	H	7		H	-2.03	
12	I	53		I	0.00	
13	J	100		J	2.07	
14	K	57		K	0.18	
15	L	45		L	-0.35	
16	M	56		M	0.13	
17	N	34		N	-0.84	
18	O	37		O	-0.70	
19	P	70		P	0.75	
20	Average	53				
21	Standard Deviation	22.7				

**Step 9**

Select cell F2 and type  $=E2*10+50$ , then press ENTER.

A	B	C	D	E	F
1		History		Standard Score	Deviation Score
2	Rui	73	Rui	0.88	$=E2*10+50$
3	Yumi	61	Yumi	0.35	
4	A	14	A	-1.72	
5	B	41	B	-0.53	
6	C	49	C	-0.18	
7	D	87	D	1.50	
8	E	69	E	0.70	
9	F	65	F	0.53	
10	G	36	G	-0.75	
11	H	7	H	-2.03	
12	I	53	I	0.00	
13	J	100	J	2.07	
14	K	57	K	0.18	
15	L	45	L	-0.35	
16	M	56	M	0.13	
17	N	34	N	-0.84	
18	O	37	O	-0.70	
19	P	70	P	0.75	
20	Average	53			
21	Standard Deviation	22.7			

**Step 10**

Drag down to cell F19, as you did in step 7.

**Step 11**

Now you have the class's deviation score.

A	B	C	D	E	F
1		History		Standard Score	Deviation Score
2	Rui	73	Rui	0.88	58.81
3	Yumi	61	Yumi	0.35	53.52
4	A	14	A	-1.72	32.82
5	B	41	B	-0.53	44.71
6	C	49	C	-0.18	48.24
7	D	87	D	1.50	84.88
8	E	69	E	0.70	57.05
9	F	65	F	0.53	55.29
10	G	36	G	-0.75	42.51
11	H	7	H	-2.03	29.74
12	I	53	I	0.00	50.00
13	J	100	J	2.07	70.70
14	K	57	K	0.18	51.76
15	L	45	L	-0.35	48.48
16	M	56	M	0.13	51.32
17	N	34	N	-0.84	41.03
18	O	37	O	-0.70	42.95
19	P	70	P	0.75	57.49
20	Average	53			
21	Standard Deviation	22.7			

## 5. CALCULATING THE PROBABILITY OF THE STANDARD NORMAL DISTRIBUTION



For this example, we'll use the data from page 93.

### Step 1

Select cell B2.

	A	B
1	z	1.96
2	halfway	
3	Area(=Percentage=Ratio)	

### Step 2

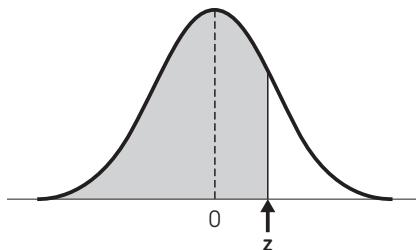
Select **Insert > Function**, then select **Statistical**, and then select **NORMSDIST**.

### Step 3

Select cell B1, and click **OK**.

The screenshot shows a Microsoft Excel spreadsheet and a 'Function Arguments' dialog box for the NORMSDIST function. The spreadsheet has rows 1 through 15. Row 1 contains 'z' in A1 and '1.96' in B1. Row 2 contains 'halfway' in A2 and 'ST(B1)' in B2. Row 3 contains 'Area(=Percentage=Ratio)' in A3. The 'Function Arguments' dialog box is open over the spreadsheet. It has a title bar 'Function Arguments'. The 'NORMSDIST' function is selected. In the 'Z' input field, 'B1' is selected, and its value '1.96' is shown in the preview field. Below the input fields, the function's description is: 'Returns the standard normal cumulative distribution (has a mean of zero and a standard deviation of one).'. A note below says 'Z is the value for which you want the distribution.' At the bottom of the dialog box, it says 'Formula result = 0.975002175' and has 'OK' and 'Cancel' buttons.

In fact, NORMSDIST is a function to calculate the probability shown in the figure below.



#### Step 4

Type =B2-0.5 in cell B3.

	A	B
1	z	1.96
2	halfway	0.975
3	Area(=Percentage=Ratio)	=B2-0.5

#### Step 5

Now you have the area.

	A	B
1	z	1.96
2	halfway	0.975
3	Area(=Percentage=Ratio)	0.475

---

## 6. CALCULATING THE POINT ON THE HORIZONTAL AXIS OF THE CHI-SQUARE DISTRIBUTION

---



The data for this exercise comes from page 104.

#### Step 1

Select cell B3.

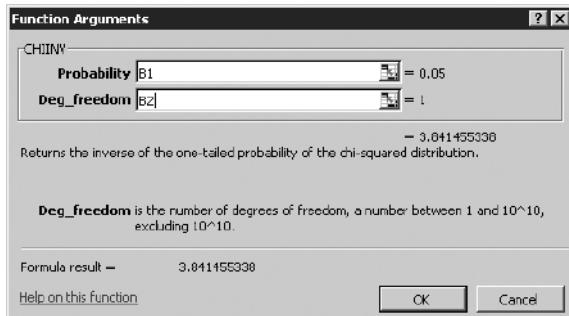
	A	B
1	P	0.05
2	Degrees of freedom	1
3	Chi-square	

#### Step 2

Select **Insert ▶ Function**, then select **Statistical**, and then select **CHIINV**.

### Step 3

Select cells B1 and B2, and then click **OK**.



### Step 4

Now you're done.

	A	B
1	P	0.05
2	Degrees of freedom	1
3	Chi-square	3.84146

---

## 7. CALCULATING THE CORRELATION COEFFICIENT

---



This data comes from the *P-Girls Magazine* survey found on page 116.

### Step 1

Select cell B14.

	A	B	C
1		Amount spent on makeup (yen)	Amount spent on clothes (yen)
2	Ms. A	3000	7000
3	Ms. B	5000	8000
4	Ms. C	12000	25000
5	Ms. D	2000	5000
6	Ms. E	7000	12000
7	Ms. F	15000	30000
8	Ms. G	5000	10000
9	Ms. H	6000	15000
10	Ms. I	8000	20000
11	Ms. J	10000	18000
12			
13			
14	Correlation coefficient		

## Step 2

Select **Insert ▶ Function**, then select **Statistical**, and then select **CORREL**.

## Step 3

Select the area shown in the figure below, and then click **OK**.

	A	B	C	D	E	F	G	H	I
1		Amount spent on makeup (yen)	Amount spent on clothes (yen)						
2	Ms. A	3000	7000						
3	Ms. B	5000	8000						
4	Ms. C	12000							
5	Ms. D	2000							
6	Ms. E	7000							
7	Ms. F	15000							
8	Ms. G	5000							
9	Ms. H	6000							
10	Ms. I	8000							
11	Ms. J	10000							
12									
13									
14	Correlation coefficient	B11,C2:C11)							
15									
16									

Function Arguments

-CORREL

Array1: B2:B11 = {3000;5000;12000;2000;7000;15000;5000;6000;8000;10000}

Array2: C2:C11 = {7000;8000;25000;5000;12000;30000;10000;15000;20000;18000}

= 0.968019613

Returns the correlation coefficient between two data sets.

Array2 is a second cell range of values. The values should be numbers, names, arrays, or references that contain numbers.

Formula result = 0.968019613

Help on this function

OK Cancel

## Step 4

Now you have the correlation coefficient.

	A	B	C
1		Amount spent on makeup (yen)	Amount spent on clothes (yen)
2	Ms. A	3000	7000
3	Ms. B	5000	8000
4	Ms. C	12000	25000
5	Ms. D	2000	5000
6	Ms. E	7000	12000
7	Ms. F	15000	30000
8	Ms. G	5000	10000
9	Ms. H	6000	15000
10	Ms. I	8000	20000
11	Ms. J	10000	18000
12			
13			
14	Correlation coefficient	0.968019613	

**NOTE** Unfortunately, there are no Excel functions for calculating the correlation ratio or the Cramer's coefficient.

## 8. PERFORMING TESTS OF INDEPENDENCE



This data is from the dating survey on page 157.

### Step 1

Select cell B8.

	A	B	C	D	E
1		Phone	E-mail	Face to face	Sum
2	Female	34	61	53	148
3	Male	38	40	74	152
4	Sum	72	101	127	300
5					
6					
7		Phone	E-mail	Face to face	
8	Female				
9	Male				
10					
11					
12	P-value				

### Step 2

Type  $=E2*B4/E4$  in cell B8. Do not press ENTER yet.

	A	B	C	D	E
1		Phone	E-mail	Face to face	Sum
2	Female	34	61	53	148
3	Male	38	40	74	152
4	Sum	72	101	127	300
5					
6					
7		Phone	E-mail	Face to face	
8	Female	=E2*B4/E4			
9	Male				
10					
11					
12	P-value				

### Step 3

Select E2 in the equation you just typed, press F4 three times, and confirm that E2 has changed to \$E2. Do not press ENTER yet.

	A	B	C	D	E
1		Phone	E-mail	Face to face	Sum
2	Female	34	61	53	148
3	Male	38	40	74	152
4	Sum	72	101	127	300
5					
6					
7		Phone	E-mail	Face to face	
8	Female	=E2*B4/E4			
9	Male				
10					
11					
12	P-value				

#### Step 4

Select *B4* in the equation in cell *B8*, press *F4* twice, and confirm that *B4* has changed to *B\$4*. Select *E4* in the equation in cell *B8*, press *F4* once, and confirm that *E4* has changed to *\$E\$4*. Then press *ENTER*.

	A	B	C	D	E
1		Phone	E-mail	Face to face	Sum
2	Female	34	61	53	148
3	Male	38	40	74	152
4	Sum	72	101	127	300
5					
6					
7		Phone	E-mail	Face to face	
8	Female	=\\$E2*B\$4/\$E\$4			
9	Male				
10					
11					
12	P-value				

#### Step 5

Select cell *B8*, put the point of the arrow near the bottom right side of cell *B8*, confirm that the arrow has changed to a black cross, drag down to cell *D8* by holding down the left button of the mouse, and let go of the button when you finish dragging.

	A	B	C	D	E
1		Phone	E-mail	Face to face	Sum
2	Female	34	61	53	148
3	Male	38	40	74	152
4	Sum	72	101	127	300
5					
6					
7		Phone	E-mail	Face to face	
8	Female	35.52			
9	Male				
10					
11					
12	P-value				

### Step 6

Select the area from cell B8 to D8, put the point of the arrow near the bottom right side of cell D8, confirm that the arrow has changed to a black cross, drag down to cell D9 by holding down the left button of the mouse, and let go of the button when you finish dragging.

	A	B	C	D	E
1		Phone	E-mail	Face to face	Sum
2	Female	34	61	53	148
3	Male	38	40	74	152
4	Sum	72	101	127	300
5					
6					
7		Phone	E-mail	Face to face	
8	Female	35.52	49.82667	62.6533333	
9	Male				
10					
11					
12	P-value	=			

### Step 7

Select cell B12, select **Insert ▶ Function**, then select **Statistical**, and then select **CHITEST**.

The screenshot shows a Microsoft Excel spreadsheet with data in rows 1 through 12. Row 1 contains column headers: A, B, C, D, E, F, G, H, I, J. Rows 2 and 3 show data for Female and Male respectively, with columns for Phone, E-mail, Face to face, and Sum. Row 4 is a sum row. Row 12 is empty and contains the formula = in cell B12. An 'Insert Function' dialog box is overlaid on the spreadsheet. The dialog box has a search bar with 'Type a brief description of what you want to do and then click Go'. It also has a dropdown for 'Or select a category: Most Recently Used'. The 'Select a function:' list is open, showing several statistical functions like CORREL, STANDARDIZE, COUNTIF, CHITEST, CHINV, NORMSDIST, and NORMDIST. The 'CHITEST' function is selected, and its description is visible: 'CHITEST(actual\_range,expected\_range) Returns the test for independence: the value from the chi-squared distribution for the statistic and the appropriate degrees of freedom.' At the bottom of the dialog box are 'Help on this function', 'OK', and 'Cancel' buttons.

### Step 8

Select the area shown in the figure below, and then click **OK**.

	A	B	C	D	E	F	G	H	I	J	K
1		Phone	E-mail	Face to face	Sum						
2	Female	34	61	53	148						
3	Male	38	40	74	152						
4	Sum	72	101								
5											
6											
7		Phone	E-mail	Face to face							
8	Female	35.52	49.82667	62.65333333							
9	Male	36.48	51.17333	64.34666667							
10											
11											
12	P-value	0.018233									
13											
14											
15											
16											
17											

Function Arguments dialog box for CHITEST function:

- Actual\_range: B2:D3 = {34,61,53;38,40,74}
- Expected\_range: B8:D9 = {35.52,49.82666667;36.48,51.17333333}
- Formula result: 0.01823258

Help on this function OK Cancel

### Step 9

Now you're done. You can confirm that the calculated value is equal to the P-value on page 177.

	A	B	C	D	E
1		Phone	E-mail	Face to face	Sum
2	Female	34	61	53	148
3	Male	38	40	74	152
4	Sum	72	101	127	300
5					
6					
7		Phone	E-mail	Face to face	
8	Female	35.52	49.82667	62.65333333	
9	Male	36.48	51.17333	64.34666667	
10					
11					
12	P-value	0.018233			



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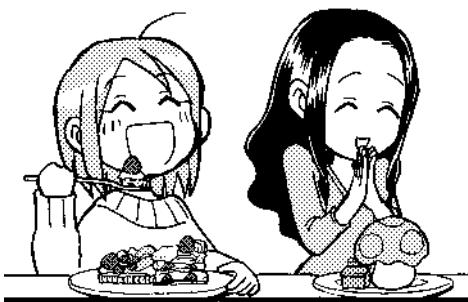
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Shin Takahashi graduated from the Graduate School of Design of Kyushu University. Takahashi has worked as a lecturer and a data analyst and is currently active as a technical writer. He also wrote *Factor Analysis* and *Regression Analysis* in the Manga Guide series.

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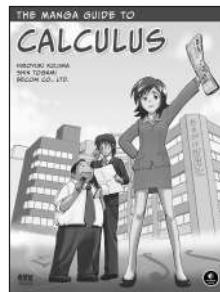
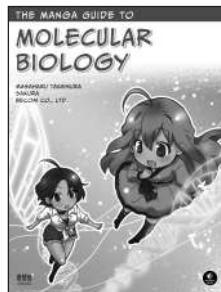
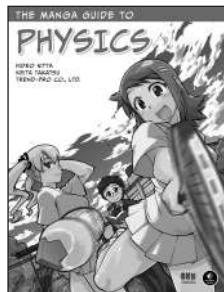
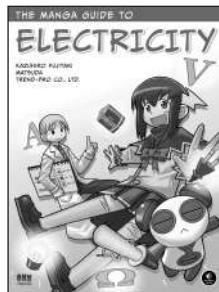
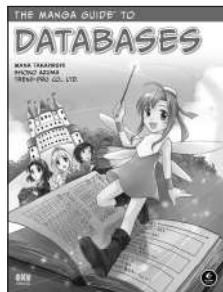
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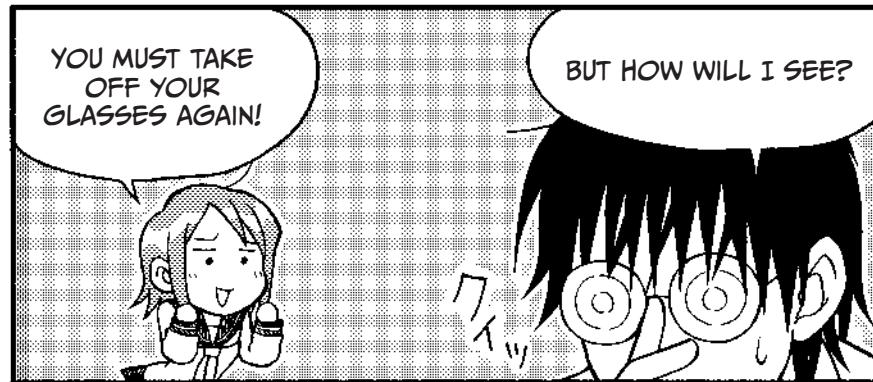
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