

Life of Fred[®]
Statistics
Expanded Edition

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Polka Dot Publishing

Statistics

Decisions! Decisions! Decisions! Do you attend Harvard University or KITTENS University? Do you marry this person or not? Does your pizza company continue the television advertising campaign that features the “Pizza for People Who Like to Canoodle” slogan?

Success in life is 90% making the right decisions in the first place. And only 10% carrying out those decisions.

People with good decision-making skills are rare. They are also the most valuable persons in any business, army, or orchestra. These CEOs, generals, and conductors all have the same job: they take massive amounts of data and boil them down to yes-or-no decisions.

- ✓ Shall we sell all the stock we own? (It’s September 1929.)
- ✓ Shall we launch the invasion today? (It’s June 6, 1944.)
- ✓ Shall we send our orchestra on a worldwide tour this month? (It’s early December 1941.)

And where there are numbers involved, statistics is an important aid in making good decisions. At its best, statistics is a way of melting down a heap of numerical data into a simple yes or no. *It’s a way of getting rid of numbers!*

If you really hate to see big piles of numbers, you and statistics were made for each other.

A Note to Students

One morning in the life of Fred. A Saturday just after his sixth birthday. In his everyday life Fred will run into the need for every kind of statistics. Each time we do a little statistics, we see how it helps him get through his morning.

HOW MUCH STATISTICS IS COVERED IN THIS BOOK?

We start at the beginning with simple descriptive statistics (averages, standard deviation, etc.) and then do some probability, including conditional probability with Bayes' theorem.

Next comes inferential statistics—the heart of statistics—in which we study a zillion* different procedures. We describe each in detail and tell you when and where each test is appropriate. You get plenty of worked-out examples for each test.

All the popular tests such as the Normal Distribution and the Chi-squared test are included. Many advanced tests such as the Kolmogorov-Smirnov test and the Two-Factor ANOVA for multiple observations per cell are covered. When the Chi-squared test won't work because the sample sizes are too small, we turn to Fisher's Exact test. Most beginning statistics books don't include that test.

We have one test *that no other statistics book mentions*—at least not until future authors copy it out of this book. It deals with A SMALL SAMPLE FROM A BINOMIAL DISTRIBUTION. Suppose, for example, a new species of fish is discovered in the ocean and of the first ten caught, three had red fins. What is the number of red-finned fish you might expect if you caught 10,000? (Answer: 95% of the time, you would expect between 1093 and 6096.) This question would stump most statistics teachers (who don't have a copy of this book).

After the descriptive and inferential statistics, we spend the last hour or so of Fred's morning working with regression equations including nonlinear curve fitting and logistic regression.

This book has much more material than is normally covered in a beginning university statistics course.

* 46 by actual count

HOW THEORETICAL IS THIS BOOK?

Life is practical. This is a book that will teach you how to *do* statistics—lots of it. Even if you are going to get a Ph.D. in statistics and are dying to go through tons of theory and proofs, your first logical step should be to learn how to do the various tests. Then, in a later course, the proofs would be appropriate. In beginning algebra, for example, you were first told that a negative number times a negative number gives a positive answer. Later, you might have seen the proof.

In this book you learn how to perform the Kruskal-Wallis test for three or more independent samples, but we're not going to fill up the pages with a proof.

There are two exceptions. The first is a little three-line proof of Bayes' theorem, which is so cute that I couldn't resist including it. And the second is the underpinnings of the SMALL SAMPLE FROM A BINOMIAL DISTRIBUTION TEST that I mentioned on the previous page. Since no other book has this test, I placed this material in its own separate little chapter (Chapter 5½) and laid out the reasoning to show why this test works. This little chapter is the only place in the book in which there is any calculus. And even there, the calculus is very basic. It deals with the area under a curve described by a polynomial. If you go directly from Chapter 5 to Chapter 6 and bypass Chapter 5½, you will be protected from all calculus.

In doing their proofs, some books go nuts with subscripts, primes, "hats," and Greek letters. They wind up with expressions like $\hat{y}'_{i,j} + \epsilon$, which certainly don't help anyone's digestion. Those things are kept to a minimum in *Life of Fred: Statistics Expanded Edition*. (\hat{y} is read "y-hat.")

WHAT BACKGROUND DO I NEED?

It would be nice to have a little algebra so that x^2 , absolute values, and square roots don't mystify you. But that's about it. I can't think of anywhere in the book where you'll need to do any algebra word problems.*

We'll use the greater than sign ($>$) and plus-or-minus (\pm).

* None of those old word problems like: JACKIE IS CHASING DALE DOWN THE HALL WITH AN AX. JACKIE IS TRAVELING 7 FT/SEC AND DALE IS RUNNING AT 5 FT/SEC. THEY ARE 8 FEET APART. HOW SOON SHOULD DALE START APOLOGIZING?

See if these all make sense to you:

- ☞ $7^2 = 49$
- ☞ $|-3| = 3$
- ☞ $64 > 29$
- ☞ 7 ± 2 means 5 or 9.
- ☞ Using your calculator $\sqrt{3}$ gives **1.7320508**.

If so, you are ready.

DO I NEED A COMPUTER?

No.

DO I NEED A GRAPHING CALCULATOR?

No. All you need is a handheld calculator that has keys like \sin , \cos , and \log . Those calculators don't cost that much. Certainly under \$20. (I have seen them under \$8.) In a couple of years they will probably be included free in cereal boxes.

ANY SPECIAL SUGGESTIONS BEFORE I START CHAPTER 1?

Yes. I have a couple of ideas.

First, in each chapter there are *Your Turn to Play* sections. These have representative problems along with completely worked-out solutions. Please solve these problems before you glance at the solutions. Just reading the problems and eyeballing the solutions is a real temptation for some readers, but unless you're smarter than Einstein, you won't learn much doing that.

At the end of each chapter are six sets of exercises which I call Cities. In this Expanded Edition, all the answers are supplied.

Second, I need to know if you are in a real hurry.



If that's the case, then don't start by turning to the first page of Chapter 1, or to the Table of Contents, or to the Index.

Instead, turn to the Emergency Statistics Guide which begins on page 353. The Emergency Statistics Guide will tell you:

- ① what test to use,
- ② where to find an explanation of the test as it occurred in Fred's life,
- ③ where it's listed in the Field Guide, and
- ④ what table to use.

The Emergency Statistics Guide will move you from baffled to brilliant in twelve seconds flat.

A Note to Teachers

Sometimes life suddenly gets a lot easier. *Life of Fred: Statistics Expanded Edition* might be the best teaching assistant that you've ever had. For your students this book will be much more than just a source of homework. Open this book at random and you will see why many of your students will actually read this textbook. (Gasp! Shock!) That will make your job significantly easier.

This book has lots and lots of statistics. More than enough for most classroom courses. How many other beginning statistics books teach all of:

Kolmogorov-Smirnov
Fisher's Exact Test
 χ^2 with Yates correction
Smith-Satterthwaite Test
Two-Factor ANOVA with many observations per cell
Agresti-Coull confidence intervals

along with all of the more familiar topics (finding the mean average, finding the standard deviation, drawing a histogram, etc.) that every textbook has? With all these topics in this book, you have plenty of flexibility to include just those items that you most enjoy teaching. Just take a peek at the Table of Contents on page 15.

Your students will appreciate the fact that you have chosen a textbook that:

- . . . is fun to read,
- . . . costs about one-third of other beginning statistics books,
- . . . has a Field Guide, starting on page 420, which brings each test into sharp focus,
- . . . includes an Emergency Statistics Guide, starting on page 353, which (almost) instantly can direct you from any problem to the right test to use.

This is not one of those textbooks that tells you to "Turn to Example 18-6" and doesn't tell you what page it's on. Or Table 18-6. Or Problem 18-6. Or Equation 18-6. Or Figure 18-6. It can be maddening to have to turn back through 20 pages looking for that example/table/problem/equation/figure. That won't happen in this book. We use page numbers.

Some Ideas on Teaching with *LOF: Statistics*

1. Each chapter has several *Your Turn to Play* sections with representative problems and their complete solutions. Many teachers find this the ideal place to begin their discussions.
2. At the end of each chapter are six sets of problems (called Cities). Each City may take your students 20–40 minutes to work through. The answers are all supplied, but not the complete solutions. With the answers given, students will know whether they have done the problem correctly. Without the solutions supplied in the text, you will be able to tell whether the students have actually worked the problem.

Why *Cities*? This makes it easier on you if all you have to say is, “Do San Francisco for homework” rather than the old, “Do every third problem on page 231.”
3. It is expected that each student will work through all the *Your Turn to Play* sections and all of the Cities problems.
4. Ask your students to read the material the night before you cover it in class. *The nature of this book makes that kind of assignment possible.* That will make your teaching of the material much more pleasant.
5. The heart of the book—at least for me—is “The Art of the Sample,” which is Chapter 4½ that begins on page 133. Students who master all 46 statistical tests in this book will have a powerful arsenal at their disposal which can be used to spread truth or to deceive. The Ten Rules of Fair Play as described in Chapter 4½ set out some ethical guidelines for the use of that arsenal of tests. This can promote some very interesting classroom discussions. Some students love to find the “gray areas” in any set of rules they’re expected to follow. Rule #1, for example, prohibits data mining. A discussion might revolve around, “Is it really data mining if you happen to notice that many politicians seem to cheat on their income taxes and then you do a survey on that topic?”

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Future—The population is known and you want to know what the sample *will* look like. You start with zero samples.

- Hypergeometric Distribution
- Extended Hypergeometric Distribution
- Binomial Distribution
- Multinomial Distribution
- Poisson Distribution
- Exponential Distribution
- Normal Distribution

Past—The sample is known and you want to know what the population *was* that gave this sample. You start with one sample.

- Normal Distribution— $n > 30$ and the sample is small compared with the population.
- Normal Distribution— $n > 30$ and the sample is large compared with the population.
- Student's *t*-distribution
- Binomial Distribution (large sample, $n > 30$)
- Binomial Distribution (small sample, $n \leq 30$)
- Kolmogorov-Smirnov goodness-of-fit test
- Lilliefors test
- Wilcoxon Signed Ranks test
- Sign test—Does the population have that median?
- Sign test for Nominal Data
- Chi-squared test (goodness of fit)
- Chi-squared test (Lie Detector)
- Chi-squared test (Is the population too variable?)
- Runs test

Present—You start with *two samples* and want to know how *do* they compare with each other.

- Two Paired Samples ($\mu_1 - \mu_2$)
- Wilcoxon Signed Ranks test
- Sign test for two paired samples
- Sign test for two paired samples of nominal data.
- Two Proportions in two categories.
- Two Large Independent Samples, $n \geq 30$
- Two Independent Samples (σ_1 and σ_2 known)
- F*-distribution test
- Two Small Independent Samples, roughly equal standard deviations
- Two Small Independent Samples (Smith-Satterthwaite) with very different standard deviations.
- Mann-Whitney test (a.k.a. Wilcoxon Rank-Sum test)
- Chi-squared test (χ^2), two samples of nominal data in multiple categories.

One Sample with Two Variables
 Chi-squared test (χ^2)—Yates correction
 Fisher’s Exact test

Present—You start with *three or more samples* and want to know how *do* they compare with each other.

One-Way ANOVA (independent samples)
 Post-test for One-Way ANOVA (independent samples)
 One-Way ANOVA (matched samples)
 Post-test for One-Way ANOVA (matched samples)
 Two-Factor ANOVA (one observation per cell)
 Post-test for Two-Factor ANOVA (one observation per cell)
 Two-Factor ANOVA (multiple observations per cell)
 Kruskal-Wallis test
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Chapter One

Descriptive Statistics

Tink! Fred’s eyes popped open. He had just heard one of the sweetest sounds. He looked at his watch. 4:13 A.M. With his mouth open, he listened in the dark. Tink! Yes, he thought to himself it’s happened. Tink!

Drops of water were falling from the ceiling. Fred threw off his bedcovers and emerged from under his desk. He looked at the pot on his desktop and saw three drops of water. Tink! Make that four drops.

His watch clicked over to 4:14 A.M. and he smiled as six more drops fell into the pot. It’s a little early to telephone Alexander Fred thought but it won’t hurt if I email him. Fred rolled up his three-foot sleeping bag and put it in the closet. He turned on the computer, changed out of his pajamas, turned off his nightlight, and looked out the window. From the window in his office/home he could look out over the university campus. For the first time in months, the sky was inky black and filled with stars. It was a welcome change from what he called the “dodo bird” sky of Kansas in winter.

From September through May, the cloud cover always reminded Fred of the soft, gray feathers of that extinct bird.

He opened the window and felt a warm breeze. So much to be grateful for. I teach at a wonderful university. I have my health. I have wonderful friends like Alexander and Betty. Fred uttered the prayer that God most likes to hear (“Thank you”) and then turned to his computer that was in the final stages of booting up. He put three phone books on a chair and hopped on top of them. When you’re only six years old and 36 inches tall, you need to make those kinds of adjustments in order to sit at a big-people’s desk.

On a clipboard he wrote out a little **frequency distribution** showing the data he had collected so far:

But that looked much too “numbery” for Fred’s taste. He liked to keep things simple. Instead of

| time | no. of drops |
|------|--------------|
| 4:13 | 4 |
| 4:14 | 6 |

4:13 A.M., Fred wrote “1” to stand for the first minute of spring, and “2” for the second minute.

His frequency distribution looked much nicer now:

| time | no. of drops |
|------|--------------|
| 1 | 4 |
| 2 | 6 |

He stared at the computer screen.

Three operating systems had been loaded, the anti-virus program and the anti-spam programs were activated, and the screen colors were being adjusted to match the university colors, and now the Internet service provider was being dialed.

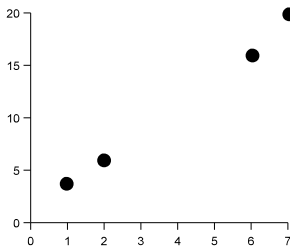
Fred had a very new machine (it was a gift from his students), but the university had very old phone lines. “ISP IS NOT RESPONDING” appeared on his screen. “ERROR 397 THE NUMBER IS BEING REDIALED.”

Fred went back to looking at the pot. It was 4:18 A.M. and during that minute Fred counted 16 drops coming from the ceiling into his pot. His screen flashed, “LOCAL NUMBER IS UNAVAILABLE. THE NEVADA NUMBER IS BEING DIALED.” Fred went back to counting. Twenty drops came in the next minute. “THE NEVADA NUMBER IS BUSY. URUGUAY IS BEING DIALED.”

Fred went back to his clipboard and expanded his frequency distribution:

| time | no. of drops |
|------|--------------|
| 1 | 4 |
| 2 | 6 |
| 6 | 16 |
| 7 | 20 |

To pass the time waiting for his computer, he drew a little graph.

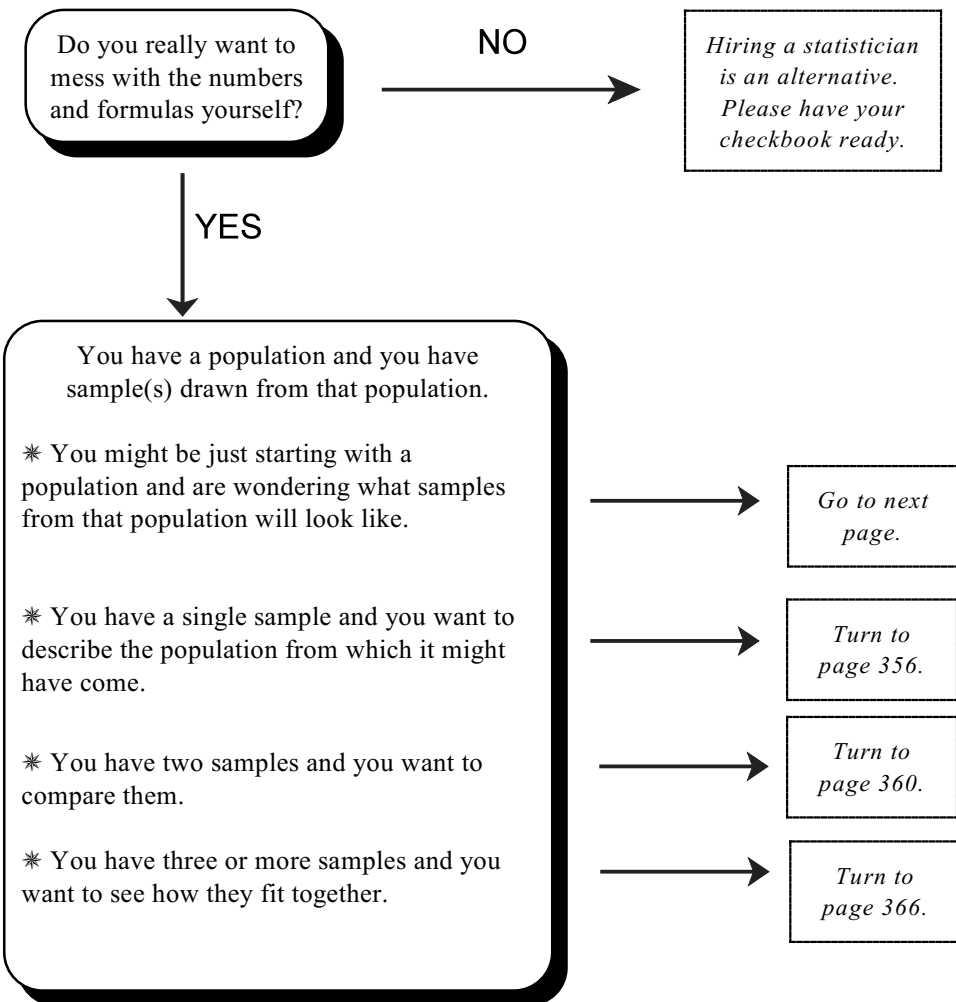


Fred's Scatter Diagram

A bunch of dots on a graph (where paired observations are plotted) is called a **scatter diagram**.)

Quick! No time to wade through a table of contents or an index. Do you use the Kolmogorov-Smirnov one-sample test or do you perform a Chi-squared test? Should you resort to the Wilcoxon Signed Ranks test? Or two-factor ANOVA?

Just answer these questions and follow the arrows. You'll learn exactly which statistics procedure you'll need.

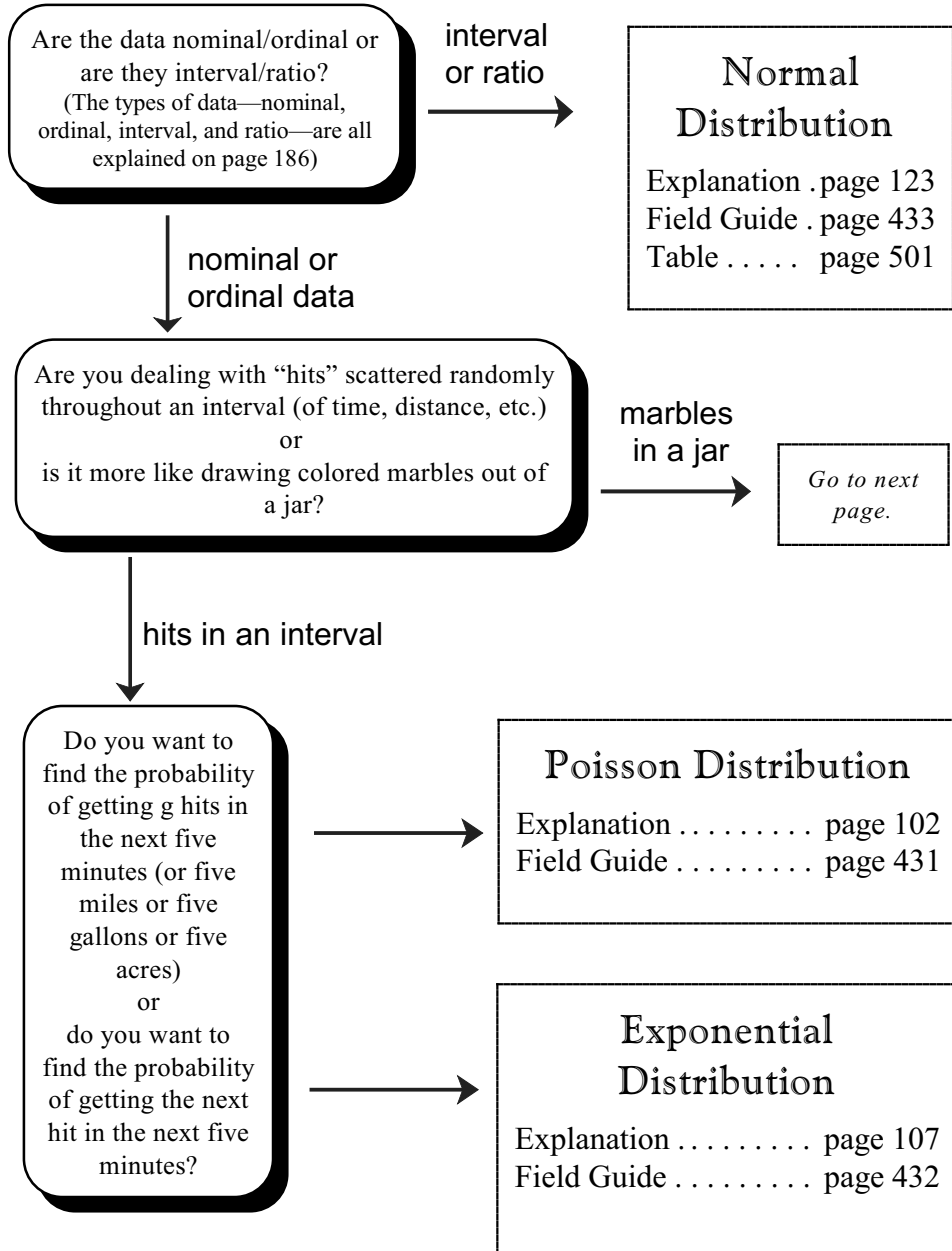


From the previous page.

You have a population and you want to know what samples from this population will look like.

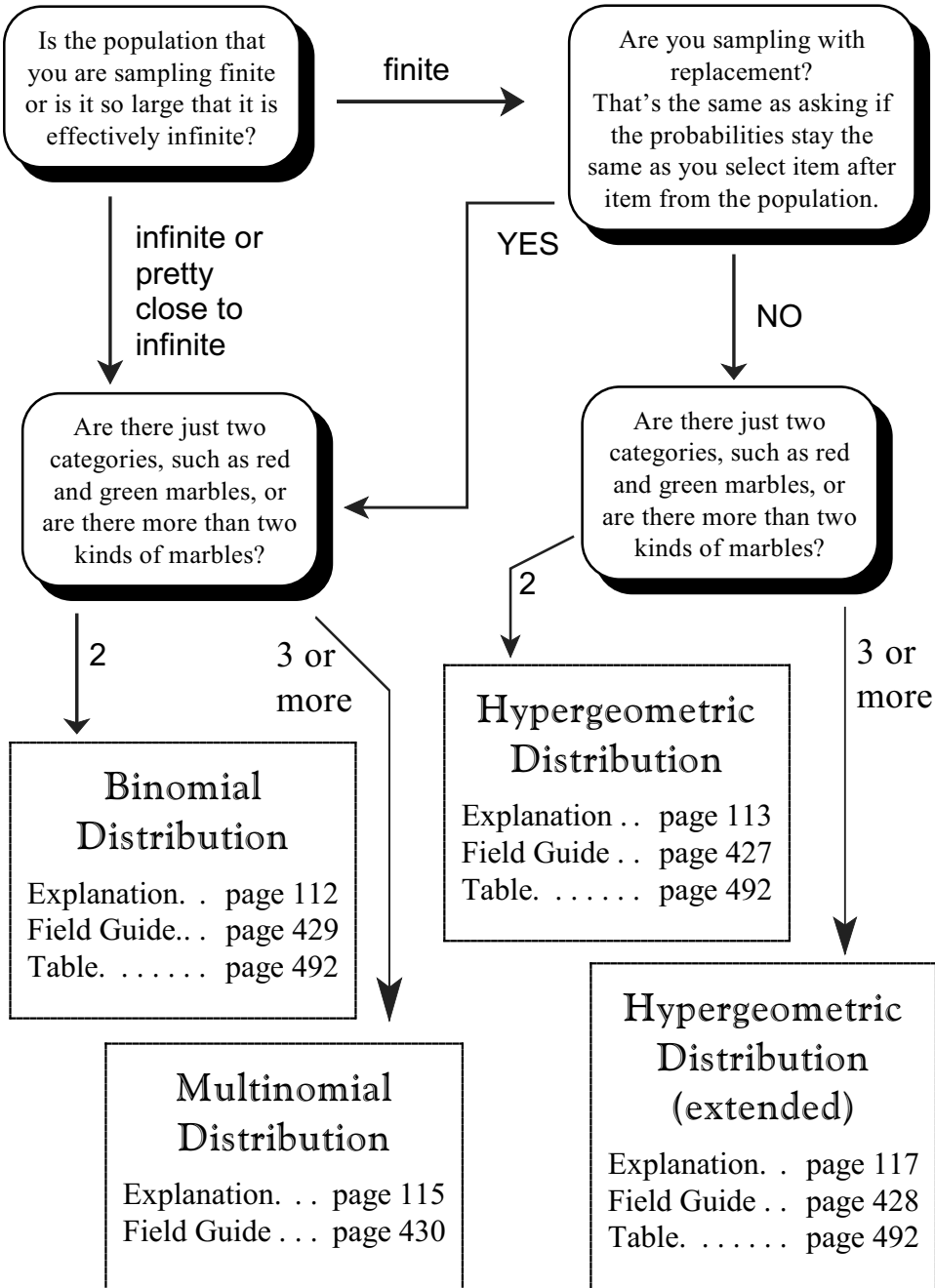
We call this the Future.

You are starting with zero samples.



From the previous page.

You are drawing colored marbles out of a jar.

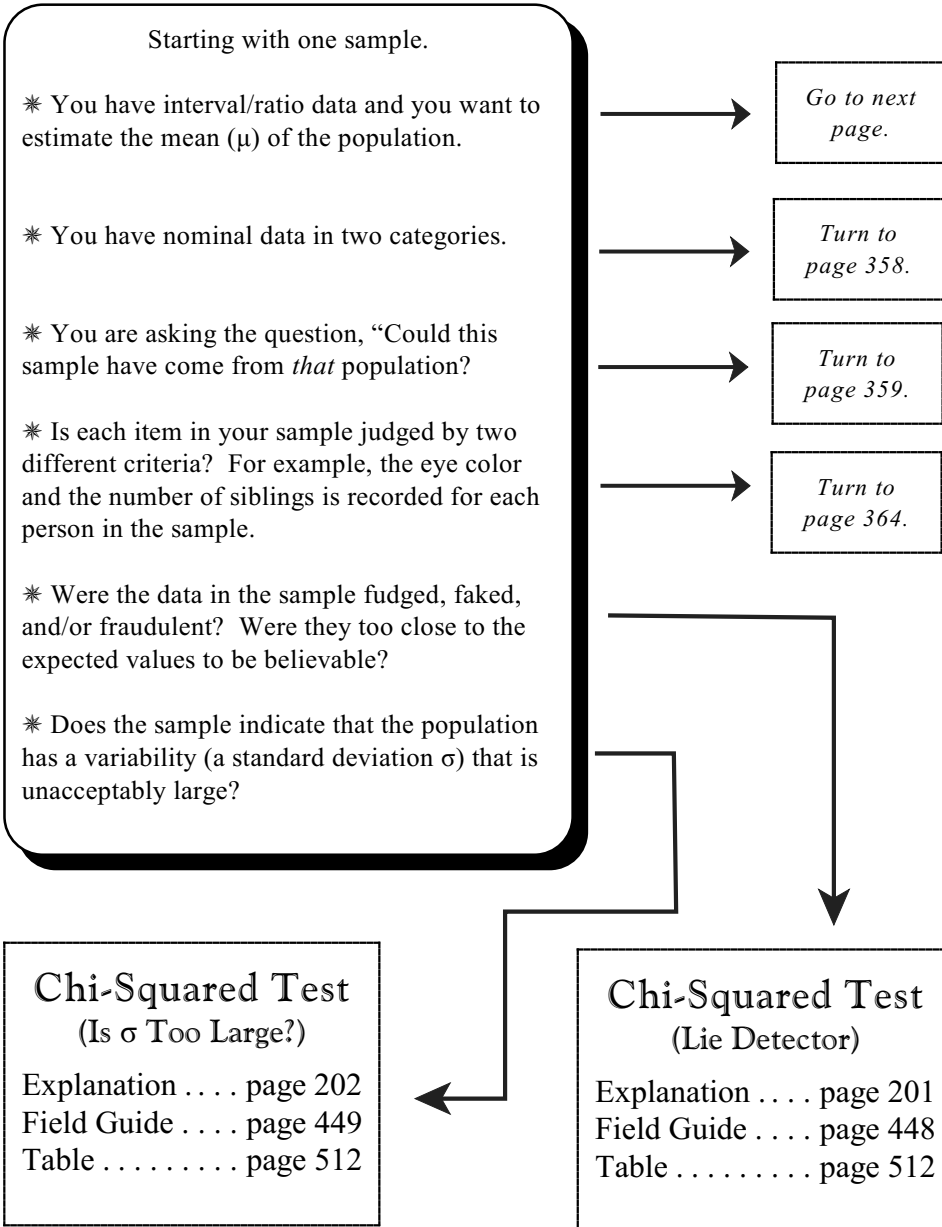


From page 353.

A single sample is known.

You want to describe the population from which it *came*.

We call this the Past.



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