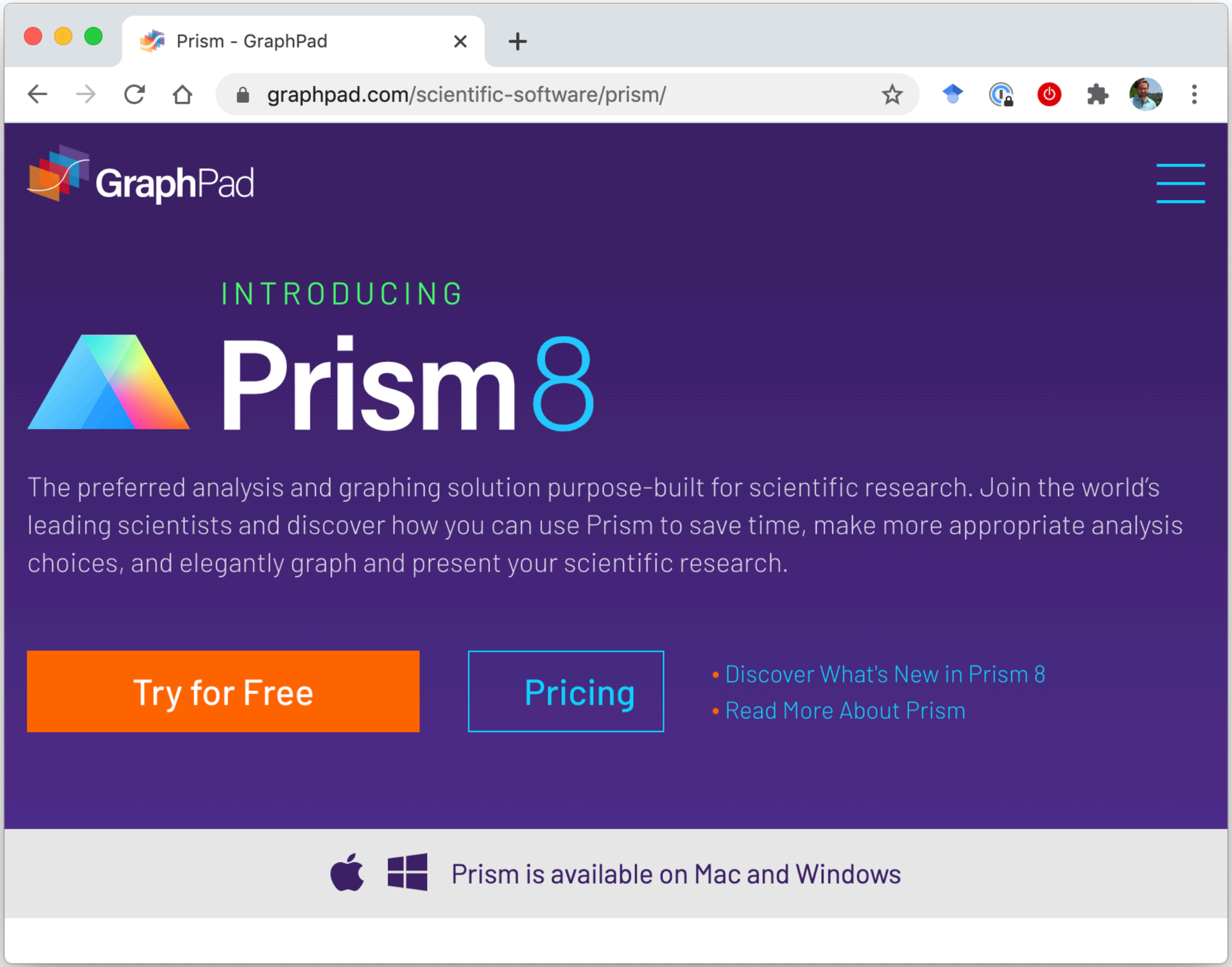
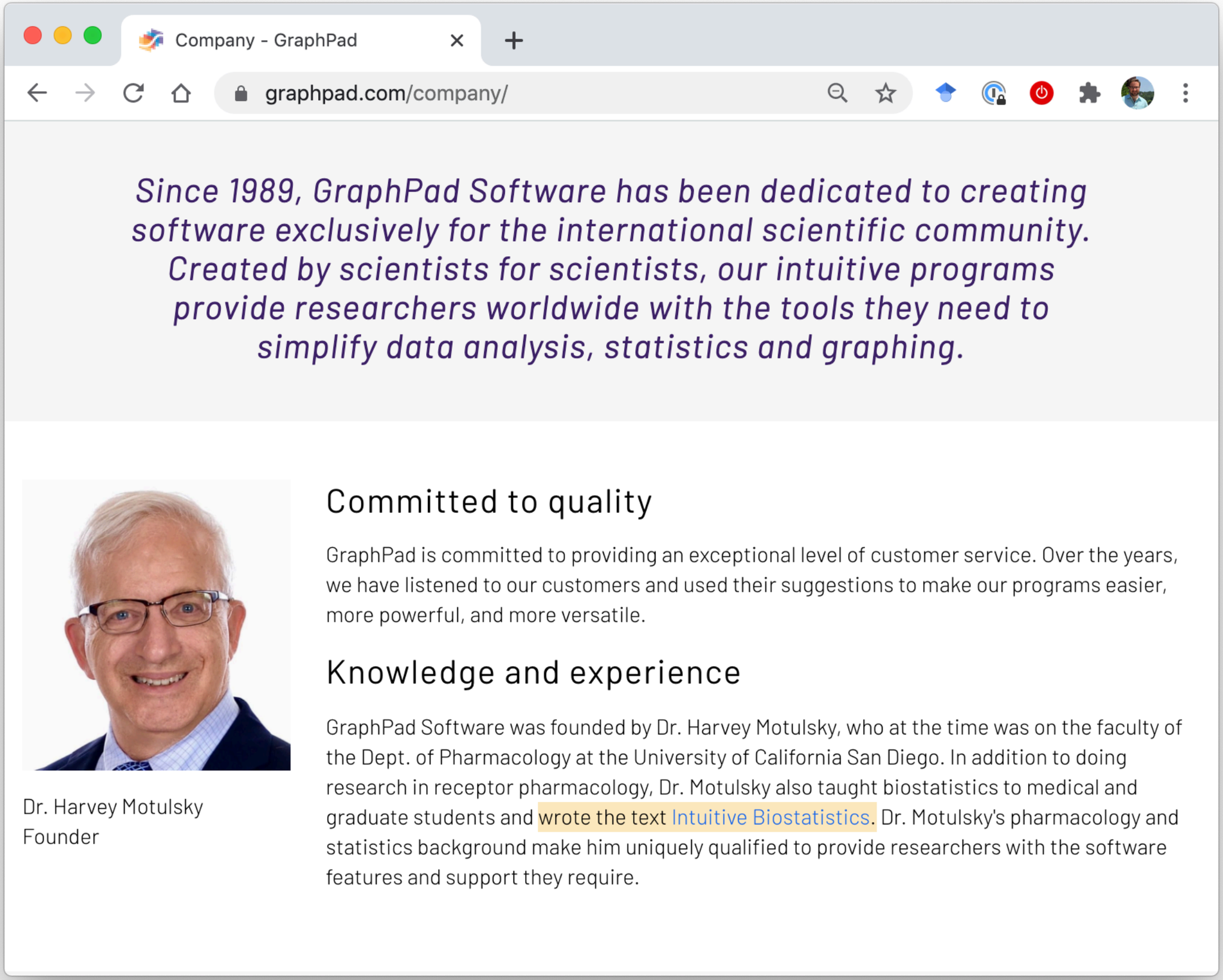
Overview of Prism
Sensitivity vs Specificity
Contingency Tables
Fisher's Exact Test

Biostatistics Course 2023
Lecture 1
Monday, 24 July 2023
1:00pm - 3:00pm

Overview of Prism

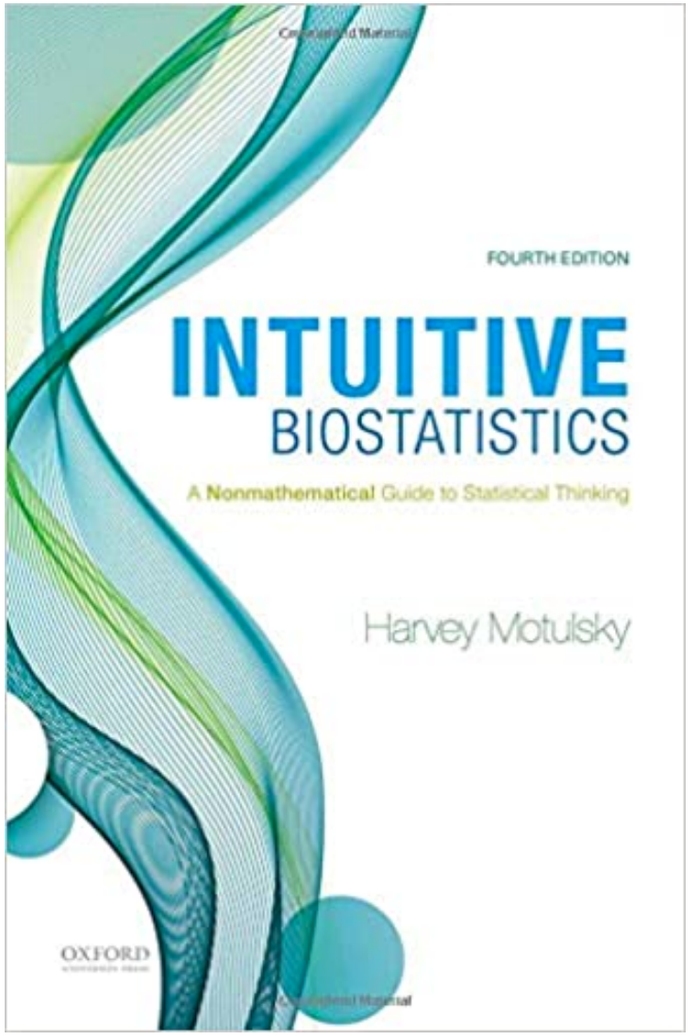


Harvey Motulsky



Dr. Harvey Motulsky
Founder

Main reference book



Motulsky, 2017
Intuitive Biostatistics
4th Edition

"Intuitive Biostatistics is both an introduction and review of statistics.Compared to other books, it has:

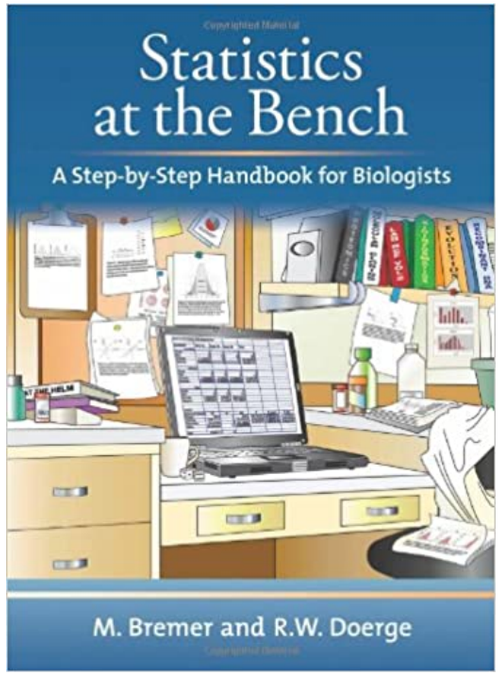
- Breadth rather than depth. It is a guidebook, not a cookbook.
- Words rather than math. It has few equations.
- Explanations rather than recipes. This book presents few details of statistical methods and only a few tables required to complete the calculations….

I wrote Intuitive Biostatistics for three audiences:

- Medical (and other) professionals who want to understand the statistical portions of journals they read. These readers don't need to analyze any data, but need to understand analyses published by others. I've tried to explain the big picture, without getting bogged down in too many details.
- Undergraduate and graduate students, post-docs and researchers who will analyze data. This book explains general principles of data analysis, but it won't teach you how to do statistical calculations or how to use any particular statistical program. It makes a great companion to the more traditional statistics texts and to the documentation of statistical software.
- Scientists who consult with statisticians. Statistics often seems like a foreign language, and this text can serve as a phrase book to bridge the gap between scientists and statisticians. Sprinkled throughout the book are "Lingo" sections that explain statistical terminology, and point out when statistics gives ordinary words very specialized meanings (the source of much confusion)."

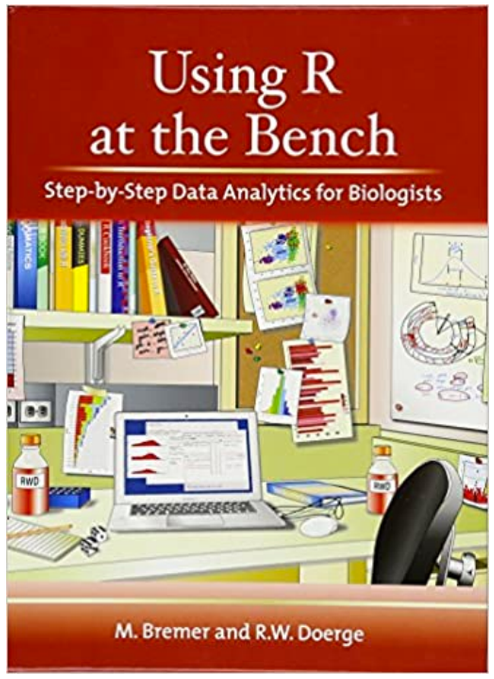
http://www.intuitivebiostatistics.com/

Other useful books



Bremmer & Doerge, 2009

- Present basic statistical equations (without derivation).
- Best read linearly, not just as references (despite the titles).
- A good refresher for those who have had some statistics training.
- Does not provide as much intuition or practical guidance as Motulsky.

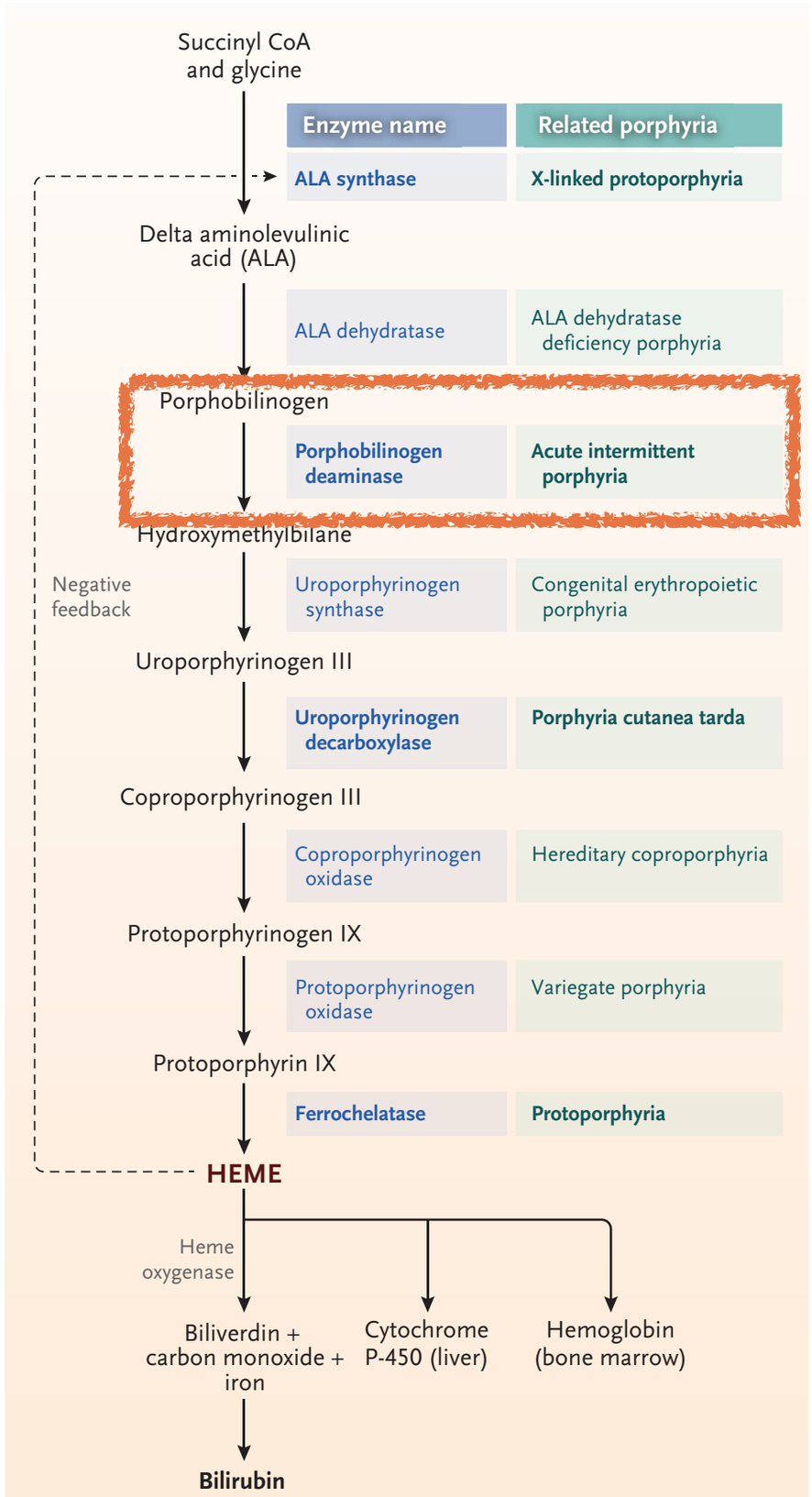


Bremmer & Doerge, 2015

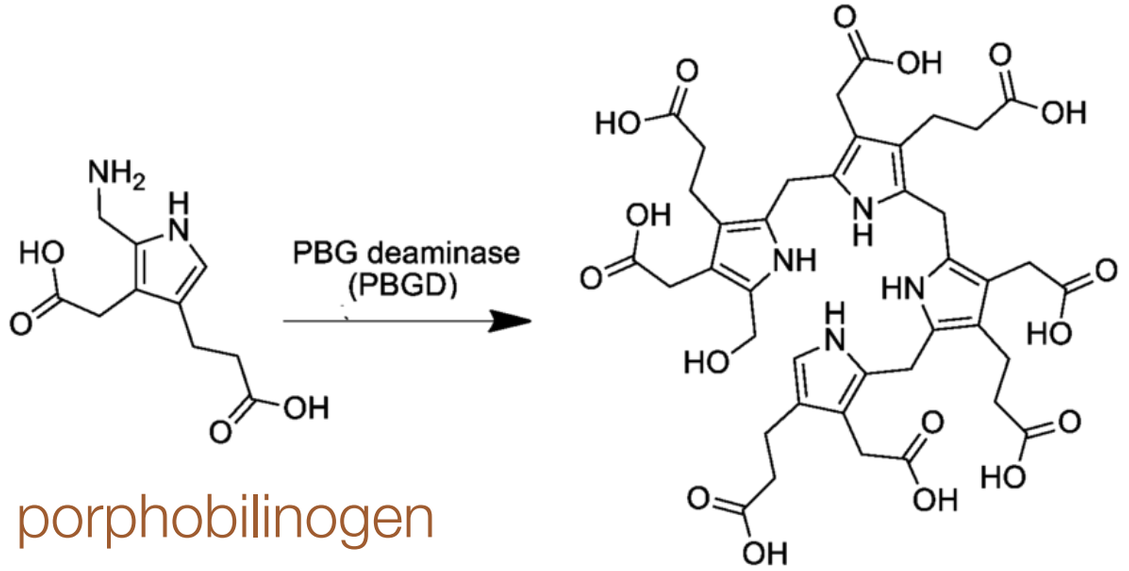
- For novices I recommend reading this after Motusky's book.
- 2009 book provides recipes to use in Microsoft Excel (best to avoid doing this)
- 2015 book provides recipes to use in R. R is much more powerful than GrapPad Prism, but it's also much easier to mess up statistical calculations in R.
- I recommend using Prism unless you have confidence in your understanding of statistical equations.

Contingency table: sensitivity vs. specificity

Porphyria is a class of diseases caused by impaired heme synthesis



We focus on Acute Intermediate Porphyria, which is caused by loss-of-function mutations in porphobilinogen deaminase and leads to a build-up of porphobilinogen.



porphobilinogen

Bissell et al., 2017, NEJM

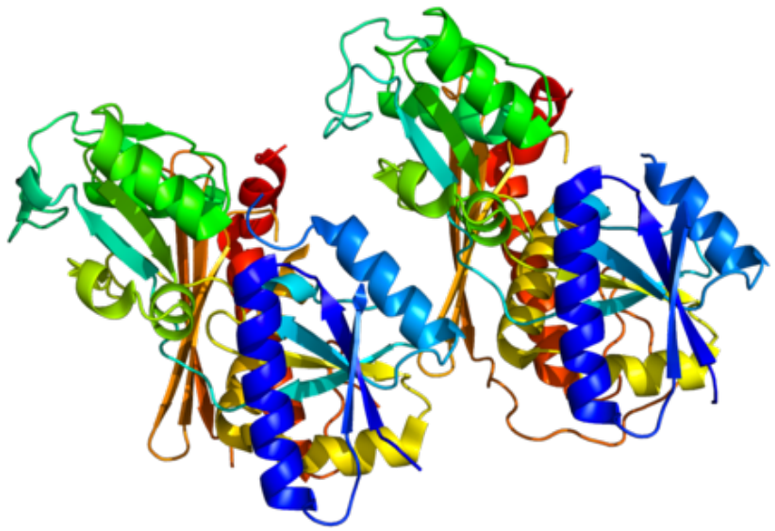
AIP is not a pleasant disease

"The typical patient with an attack of acute intermittent porphyria is a previously healthy young woman who has had several days of severe fatigue and an inability to concentrate, followed by progressively worsening abdominal pain, nausea, vomiting, and subtle neurologic signs."

Bissell et al., 2017, NEJM

Screening tests are low-cost non-invasive tests given to healthy individuals

There is a screening test for AIP,
based on the measurement of reduced levels of
porphobilinogen deaminase (PBGD) activity in
urine or serum.



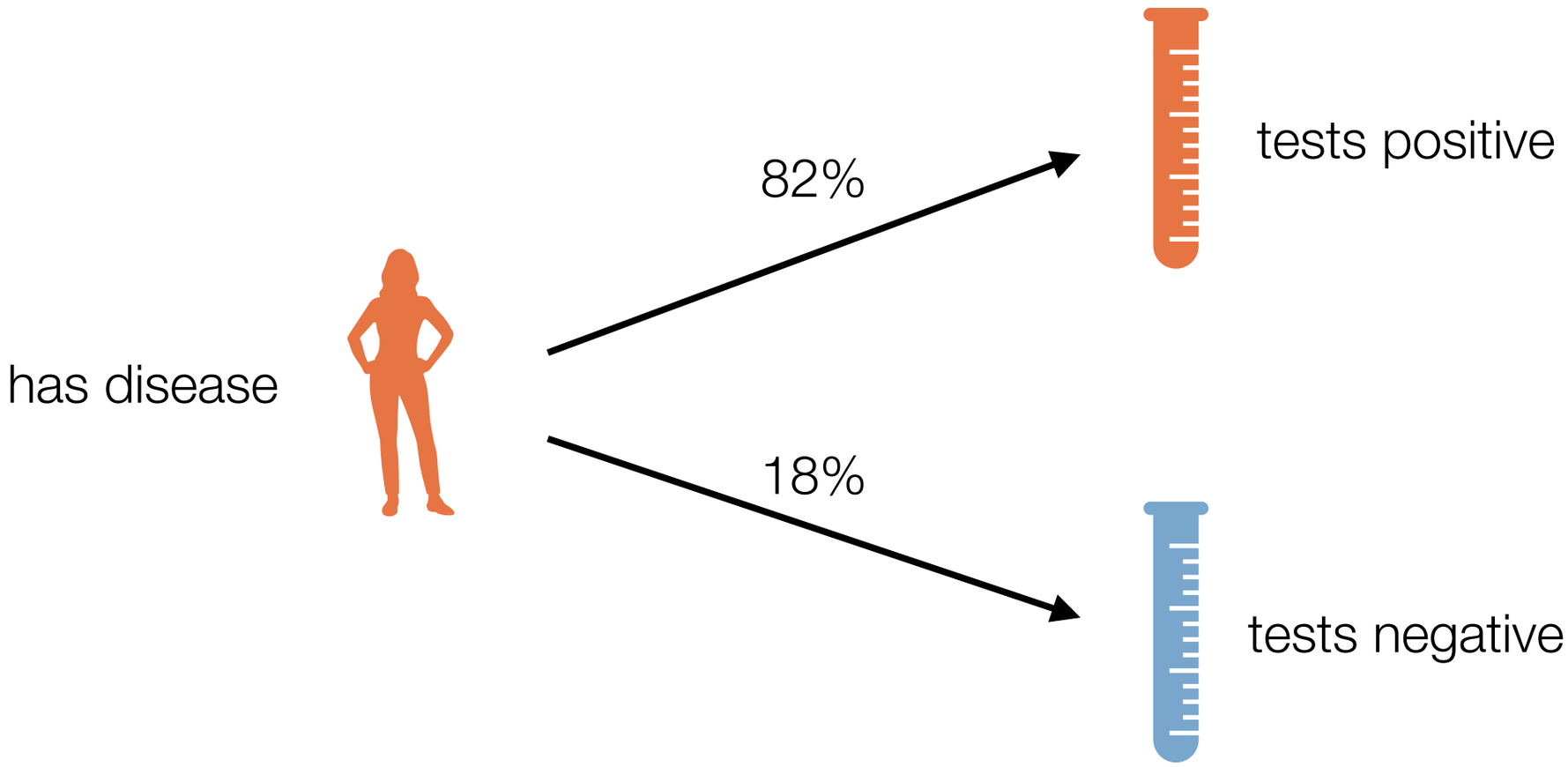
Question:
If you test positive for AIP in this screening test,
what is the probability that you actually have AIP?

https://en.wikipedia.org/wiki/Porphobilinogen_deaminase

Sensitivity is the probability of testing positive given that the subject has the disease.

For the AIP test:

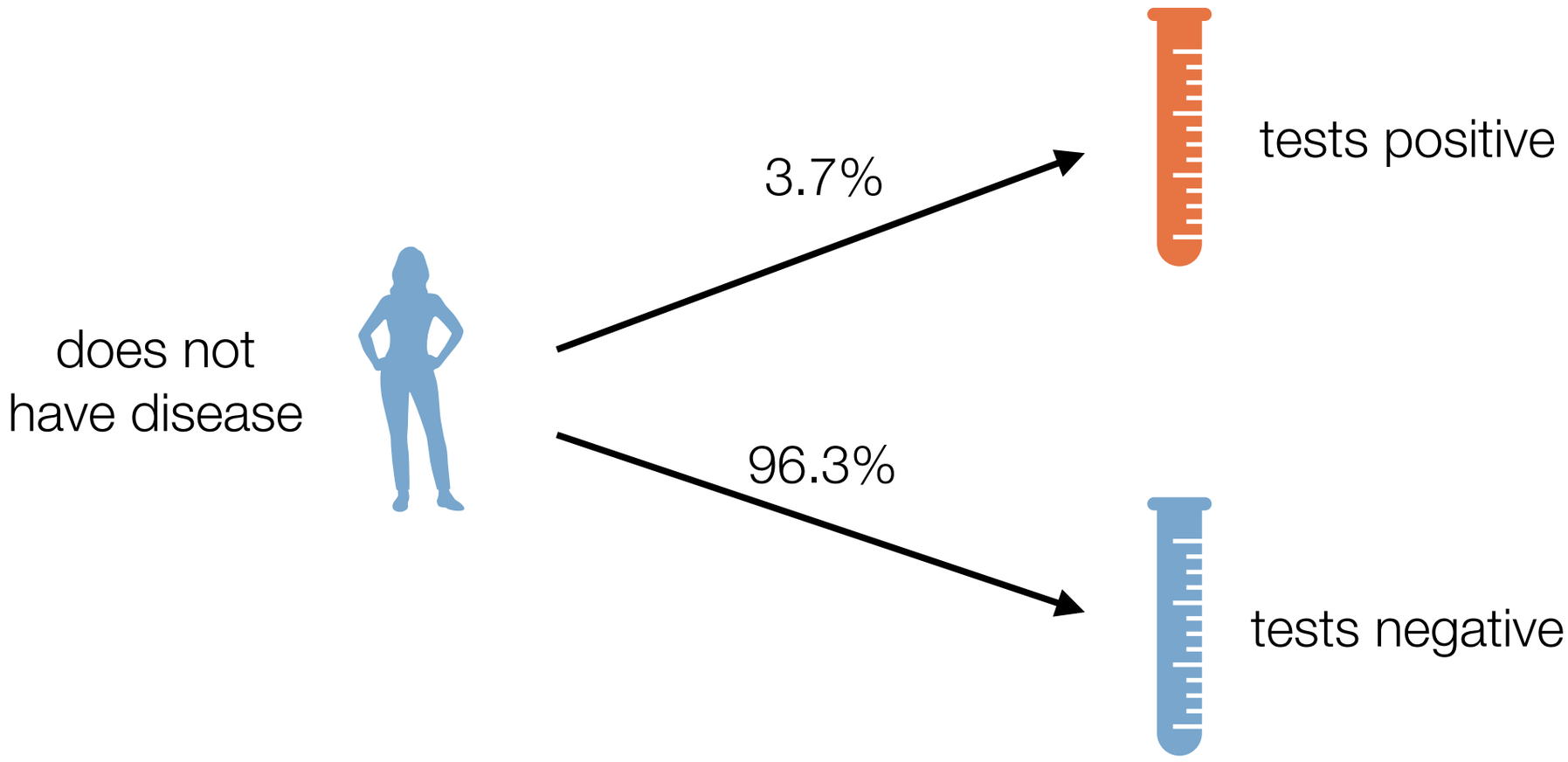
$$\textbf{Sensitivity} = p(\text{test}^+ \mid \text{disease}^+) = 82\%$$



Specificity is the probability of a negative test given that the subject does not have the disease.

For the AIP test:

Specificity = $p(\text{test}^- \mid \text{disease}^-) = 96.3\%$

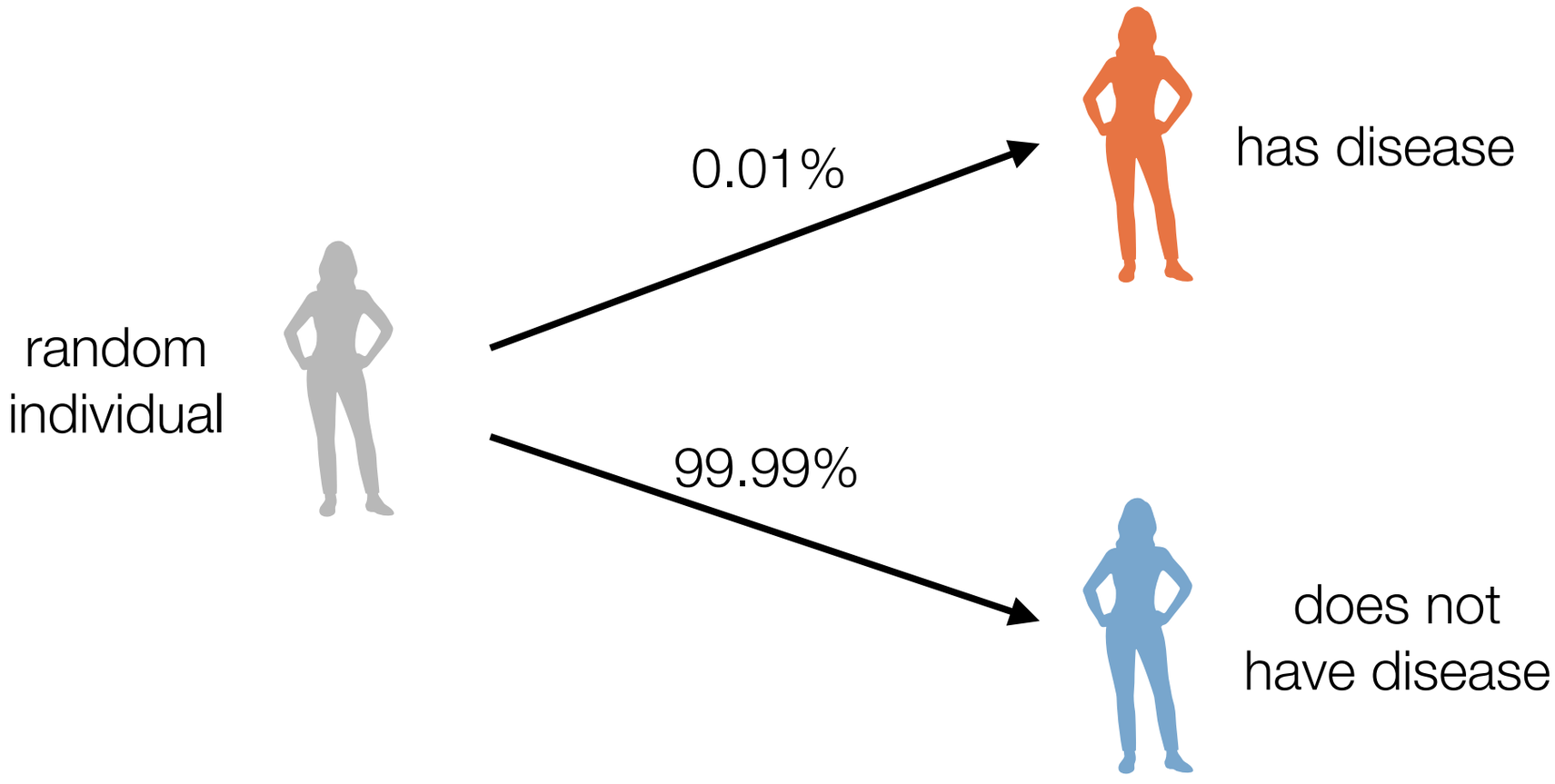


Prevalence is the fraction of individuals in a population who have a disease.

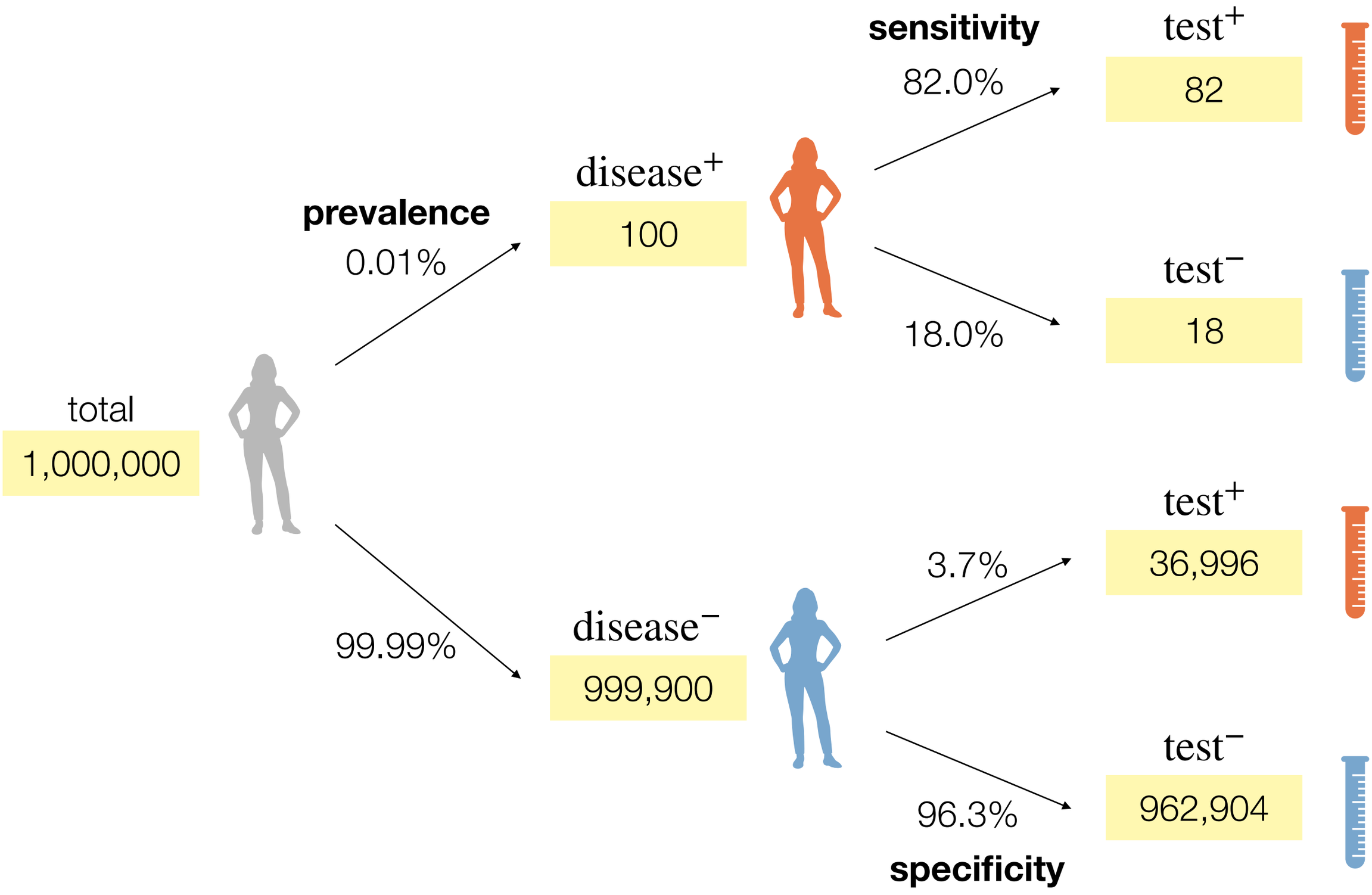
Understanding the results of a medical screening test requires also knowing the prevalence of a disease

For AIP:

Prevalence $= p(\text{disease}^+) = 0.01\%$



Consider the expected outcome in 1,000,000 randomly chosen individuals



Contingency tables summarize these results

Contingency table showing the expected results of the AIP test on 1,000,000 random individuals

	disease+	disease-
test+	**True positive (TP)** 82	**False positive (FP)** 36,996 **Type I error**
test-	**False negative (FN)** 18 **Type II error**	**True negative (TN)** 962,904

What person who tests positive truly cares about is the positive predictive value.

	disease$^+$	disease$^-$
test$^+$	82 **(TP)**	36,996 **(FP)**
test$^-$	18 **(FN)**	962,904 **(TN)**

Positive predictive value (PPV):

$$p(\text{disease}^+ \mid \text{test}^+) = \frac{\text{TP}}{\text{TP} + \text{FP}} = \frac{82}{82 + 36{,}996} = \textbf{0.22\% (!!!)}$$

Even if you test positive, the probability of you having AIP is still very, very low.

PPV is often far less than sensitivity in screening tests for rare diseases

PPV: $p(\text{disease}^+ \mid \text{test}^+) = \dfrac{\text{TP}}{\text{TP} + \text{FP}} = \dfrac{82}{82 + 36{,}996} = 0.22\%$

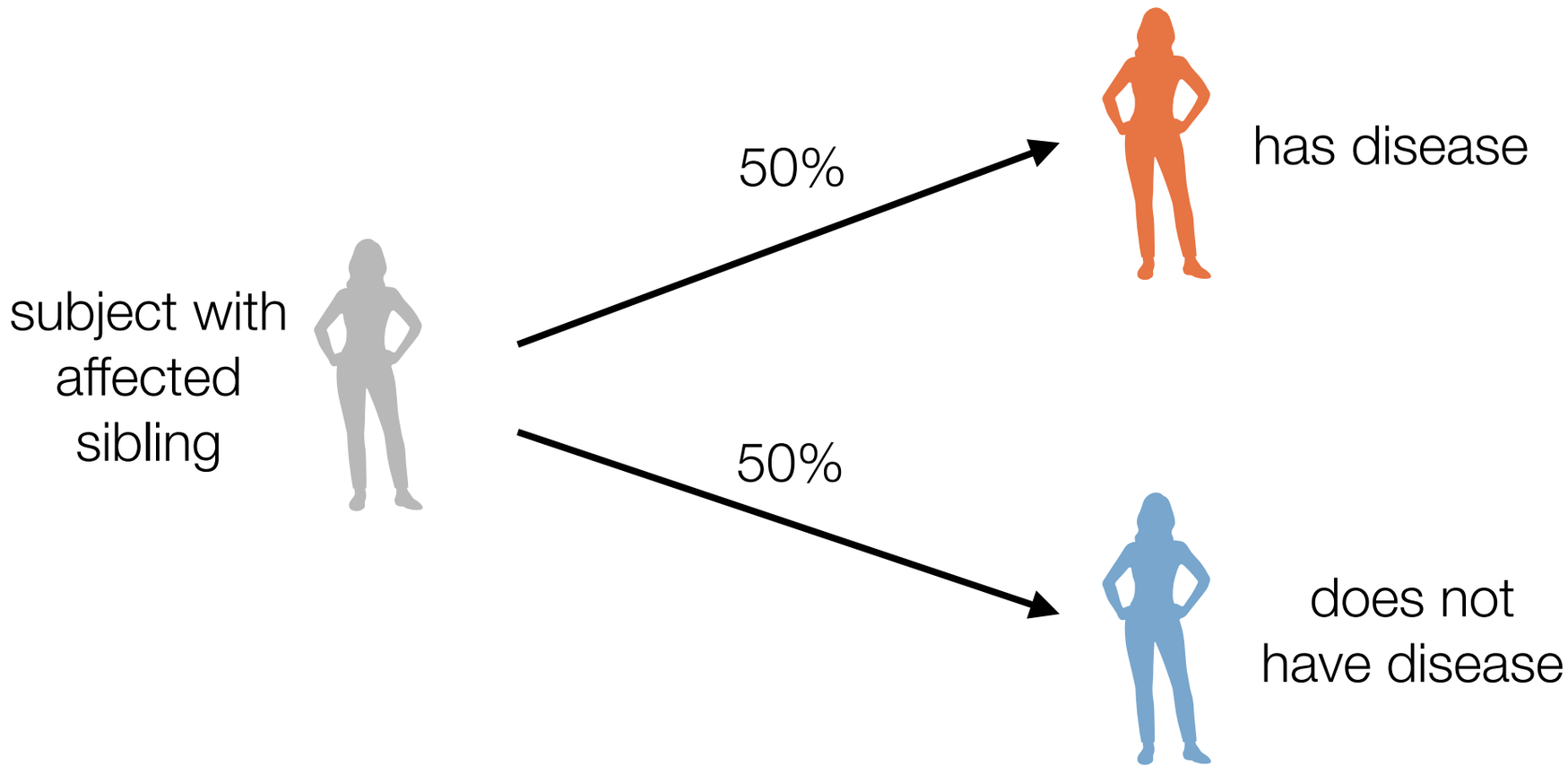
sensitivity: $p(\text{test}^+ \mid \text{disease}^+) = \dfrac{\text{TP}}{\text{TP} + \text{FN}} = \dfrac{82}{82 + 18} = 82\%$

PPV $\ll$ sensitivity because $\text{FP} \gg \text{FN}$ because $\text{disease}^- \gg \text{disease}^+$

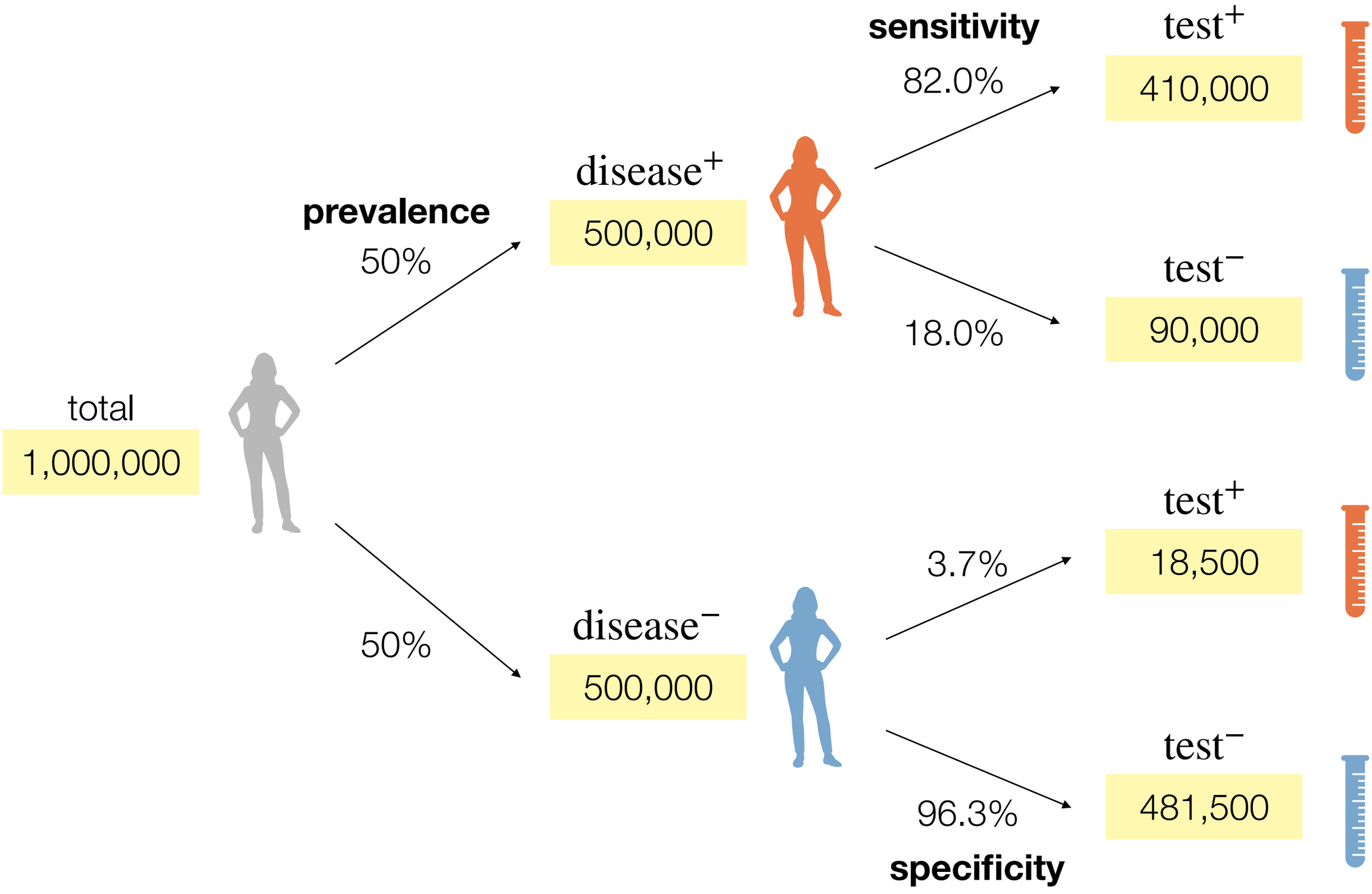
Porphyria is an autosomal dominant disease

If a subject's sibling has AIP,
there is a 50% chance that they do too.

$$\textbf{prevalence} = p(\text{disease}^{+}) = 50\%$$



Consider the expected outcome in 1,000,000 individuals with affected siblings



What person who tests positive truly cares about is the positive predictive value.

	disease$^+$		disease$^-$	
test$^+$	410,000	**(TP)**	18,500	**(FP)**
test$^-$	90,000	**(FN)**	481,500	**(TN)**

Positive predictive value (PPV):

$$p(\text{disease}^+ \mid \text{test}^+) = \frac{\text{TP}}{\text{TP} + \text{FP}} = \frac{41{,}000}{41{,}000 + 18{,}500} = \mathbf{95.7\%}$$

Just knowing that you sibling has AIP increases the PPV of the test enormously.

In medicine, there is a difference between screening tests and diagnostic tests.

The influence of population is a key reason that doctors distinguish between screening tests and diagnostic tests

	Screening tests	Diagnostic tests
Purpose	To detect potential disease indicators	To establish presence/absence of disease
Target population	Large numbers of asymptomatic, but potentially at risk individuals	Symptomatic individuals to establish diagnosis, or asymptomatic individuals with a positive screening test
Test method	Simple, acceptable to patients and staff	maybe invasive, expensive but justifiable as necessary to establish diagnosis
Positive result threshold	Generally chosen towards high sensitivity not to miss potential disease **implies many FPs!**	Chosen towards high specificity (true negatives). More weight given to accuracy and precision than to patient acceptability
Positive result	Essentially indicates suspicion of disease (often used in combination with other risk factors) that warrants confirmation	Result provides a definite diagnosis
Cost	Cheap, benefits should justify the costs since large numbers of people will need to be screened to identify a small number of potential cases	Higher costs associated with diagnostic test maybe justified to establish diagnosis.

https://www.healthknowledge.org.uk/public-health-textbook/disease-causation-diagnostic/2c-diagnosis-screening/screening-diagnostic-case-finding

The relationship between prevalence, sensitivity, specificity, and PPV is clarified by considering "odds"

posterior odds | **likelihood ratio** | **prior odds**

$$\frac{p(\text{disease}^+ \mid \text{test}^+)}{p(\text{disease}^- \mid \text{test}^+)} = \frac{p(\text{test}^+ \mid \text{disease}^+)}{p(\text{test}^+ \mid \text{disease}^-)} \times \frac{p(\text{disease}^+)}{p(\text{disease}^-)}$$

$$\| \qquad\qquad \| \qquad\qquad \|$$

$$\frac{\text{PPV}}{1 - \text{PPV}} \qquad \frac{\text{sensitivity}}{1 - \text{specificity}} \qquad \frac{\text{prevalence}}{1 - \text{prevalence}}$$

(what you care about) (property of test) (property of population)

$$\left[0.0022 = \frac{0.22\,\%}{99.78\,\%}\right] = \left[22.2 = \frac{82.0\,\%}{3.7\,\%}\right] \times \left[10^{-4} = \frac{0.01\,\%}{99.99\,\%}\right]$$ random individual

$$\|$$

$$\left[22.2 = \frac{95.7\,\%}{4.3\,\%}\right] = \left[22.2 = \frac{82.0\,\%}{3.7\,\%}\right] \times \left[1 = \frac{50\,\%}{50\,\%}\right]$$ sibling of affected individual

The base rate fallacy describes the human tendency to discount prior information

$$\text{posterior odds} = \text{likelihood ratio} \times \text{prior odds}$$

base rate fallacy: If presented with related base rate information (i.e. generic, general information) and specific information (information pertaining only to a certain case), the mind tends to ignore the former and focus on the latter.

https://en.wikipedia.org/wiki/Base_rate_fallacy

In all fairness, it can be very hard to quantify prior odds.

The “population” an individual comes from, and thus prior odds, are greatly affected by many hard-to-quantify factors

- Has the individual had any relevant symptoms?
- Does the individual have a relevant family history?
- What is the individual’s ethnicity (ancestry)?
- What is the individual’s sex?
- Has the individual been tested before? How?

Prior odds aren’t a property of an individual per se, but rather one’s state of knowledge about that individual.

Prior odds (and thus posterior odds) quantify subjective uncertainty.

Statistics is divided into two schools: Frequentist and Bayesian.

Frequentist statistics avoids calculations involving prior odds.

It therefore yields results that are prone to misinterpretation due the base rate fallacy.

However, frequentist statistics is used heavily in biological research, so you have to learn it anyway.

Frequentist statistics is still useful and informative if you know what to watch out for.

Bayesian statistics explicitly accounts for prior odds.

It therefore requires prior information that is often hard to quantify.

Bayesian statistics is central to modern machine learning and more advanced areas of quantitative biology.

Experimental researchers in biology tend not use Bayesian statistics, so in this specific course won't discuss it much.

Welcome to GraphPad Prism

GraphPad Prism
Version 8.4.3 (471)

NEW TABLE & GRAPH

- XY
- Column
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- Contingency
- Survival
- Parts of whole
- Multiple variables
- Nested

EXISTING FILE

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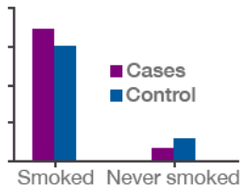
Contingency tables: Each row defines a treatment or exposure, each column defines an outcome, and each value is an exact count of objects or events

Table format Contingency		A	B
		Cases	Control
		Y	Y
1	Smoked		
2	Never smoked		



? Learn more

Data table:

- ○ Enter or import data into a new table
- ◉ Start with sample data to follow a tutorial

Select a tutorial data set:

- ○ Chi-square test of prospective data (aspirin and MI)
- ○ Fishers exact test of retrospective data (smoking and cancer)
- ◉ Sensitivity and specificity (HIV)
- ○ Chi-square test for trend

Prism Tips

Cancel

Create

Untitled

Search

- Data Tables
  - Sensitivity and specificity (HIV)
  - *New Data Table...*
- Info
  - Project info 1
  - *New Info...*
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  - Sensitivity and specificity (HIV)
  - *New Graph...*
- Layouts
  - *New Layout...*

Family

- Sensitivity and specificity (HIV)
- Sensitivity and specificity (HIV)

Table format: Contingency

		Outcome A	Outcome B	Outcome C	Outcome D	Outcome E	Outcome F	Outcom
		HIV antigen	No HIV	Title	Title	Title	Title	Title
		Y	Y	Y	Y	Y	Y	Y
1	p24 antigen +	48	0					
2	p24 antigen -	8	382					
3	Title							
4	Title							
5	Title							
6	Title							
7	Title							
8	Title							
9	Title							
10	Title							
11	Title							
12	Title							
13	Title							
14	Title							
15	Title							
16	Title							
17	Title							
18	Title							
19	Title							
20	Title							
21	Title							
22	Title							

How the data are organized
The columns represent presence or absence of HIV antigen among patients with symptoms suggestive of HIV infection. The rows represent the results of a simpler test. The values are the number of subjects in each group. Data from: Daar et. al., Annals of Internal Medicine, 134:25-29 (2001).

The goal
To quantify the sensitivity (what fraction of people with the disease are identified by the test) and specificity (what fraction of healthy people have a negative test result), with confidence intervals.

How to analyze the data
1. Click Analyze
2. Choose "Chi-square (and Fisher's exact) test" from the list of analyses for contingency tables.
3. Click OK.
4. Choose Fisher's exact test and check the option to compute the sensitivity, specificity and predictive values.

Step by step instructions for analyzing contingency tables

Sensitivity and specificity (H

Row 1, A: HIV ar

lec1_aip_test.pzfx — Edited

Search

- Data Tables
  - **Sensitivity and specificity (AIP)**
  - *New Data Table...*
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Family

- **Sensitivity and specificity (AIP)**
- **Sensitivity and specificity (AIP)**

	Table format: Contingency	Outcome A	Outcome B	Outcome C
		AIP disease +	AIP disease -	Title
		Y	Y	Y
1	PBGD test +	82	36996	
2	PBGD test -	18	962904	
3	Title			
4	Title			
5	Title			
6	Title			
7	Title			
8	Title			
9	Title			
10	Title			
11	Title			
12	Title			
13	Title			
14	Title			
15	Title			
16	Title			
17	Title			
18	Title			
19	Title			
20	Title			

Sensitivity and specificity (AI

Row 6,

Create New Analysis

Data to analyze

Table: Sensitivity and specificity (AIP)

Type of analysis

Which analysis?

- **Transform, Normalize...**
  - Transform
  - Transform concentrations (X)
  - Normalize
  - Prune rows
  - Remove baseline and column math
  - Transpose X and Y
  - Fraction of Total
- **XY analyses**
- **Column analyses**
- **Grouped analyses**
- **Contingency table analyses**
  - Chi-square (and Fisher's exact) test
  - Row means with SD or SEM
  - Fraction of Total
- **Survival analyses**
- **Parts of whole analyses**
- **Multiple variable analyses**
- **Nested analyses**
- **Generate curve**
- **Simulate data**
- **Recently used**

Analyze which data sets?

- [x] A:AIP disease +
- [x] B:AIP disease -

Select All | Deselect All

?

Cancel | OK

Parameters: Chi-square (and Fisher's exact) test

Main Calculations | Options

Effect sizes to report

- [ ] Relative Risk
  Used for prospective and experimental studies
- [ ] Difference between proportions (attributable risk) and NNT
  Used for prospective and experimental studies
- [ ] Odds ratio
  Used for retrospective case-control studies
- [x] Sensitivity, specificity and predictive values
  Used for diagnostic tests

Method to compute the P value

- (•) Fisher's exact test
- ( ) Yates' continuity corrected chi-square test
- ( ) Chi-square test
- ( ) Chi-square test for trend

Looking for the z test to compare proportions? Choose the chi-square test (with or without the Yates' correction). The chi-square and z tests are equivalent.

? Cancel OK

lec1_aip_test.pzfx — Edited

Search

- Data Tables
  - **Sensitivity and specificity (AIP)**
  - *New Data Table...*
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  - *New Graph...*
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  - *New Layout...*

Family

- **Sensitivity and specificity (AIP)**
  - **Contingency**

Contingency

1	**Table Analyzed**	Sensitivity and specificity (AIP)		
2				
3	**P value and statistical significance**			
4	Test	Fisher's exact test		
5	P value	<0.0001		
6	P value summary	****		
7	One- or two-sided	Two-sided		
8	Statistically significant (P < 0.05)?	Yes		
9				
10	**Effect size**	**Value**	**95% CI**	
11	Sensitivity	0.8200	0.7333 to 0.8830	
12	Specificity	0.9630	0.9626 to 0.9634	
13	Positive Predictive Value	0.002212	0.001782 to 0.002744	
14	Negative Predictive Value	1.000	1.000 to 1.000	
15	Likelihood Ratio	22.16		
16				
17	**Methods used to compute CIs**			
18	Sensitivity, specificity, etc.	Wilson-Brown		
19				
20	**Data analyzed**	**AIP disease +**	**AIP disease -**	**Total**
21	PBGD test +	82	36996	37078
22	PBGD test -	18	962904	962922
23	Total	100	999900	1000000
24				

Contingency of Sensitivity and specificity (AI

Row 1, Column A

Contingency table: prospective study

Does taking aspirin daily affect one's chance of myocardial infarction (MI)

	MI	no MI
placebo	189	10,845
aspirin	104	10,933

NEJM 318: 262-264 (1988)

Null hypothesis:
Aspirin usage has no effect on MI risk

Alternative hypothesis:
Aspirin increases or decreases MI risk.

Statistical test:
Fisher's exact test

Statistical test: Fisher's exact test

	column 1	column 2
row 1	a	b
row 2	c	d

Mathematical formalization:
Is there a statistical dependence between the row an observation falls in and the column that observation falls in?

Null hypothesis:
There is no statistical dependence: p(row,column) = p(row) x p(column)

Alternative hypothesis:
There is a statistical dependence: p(row,column) = p(row) x p(column)

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Fisher's exact test

From Wikipedia, the free encyclopedia

Fisher's exact test is a statistical significance test used in the analysis of contingency tables.[1][2][3] Although in practice it is employed when sample sizes are small, it is valid for all sample sizes. It is named after its inventor, Ronald Fisher, and is one of a class of exact tests, so called because the significance of the deviation from a null hypothesis (e.g., P-value) can be calculated exactly, rather than relying on an approximation that becomes exact in the limit as the sample size grows to infinity, as with many statistical tests.

Fisher is said to have devised the test following a comment from Muriel Bristol, who claimed to be able to detect whether the tea or the milk was added first to her cup. He tested her claim in the "lady tasting tea" experiment.[4]

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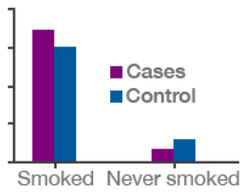

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Family

- **Prospective (aspirin and MI)**
- **Prospective (aspirin and MI)**

Table format: Contingency

		Outcome A	Outcome B	Outcome C	Outcome D	Outcome E	Outcome F	Out
		Myocardial Infarction	No MI	Title	Title	Title	Title	
		Y	Y	Y	Y	Y	Y	
1	Placebo	189	10845					
2	Aspirin	104	10933					
3	Title							
4	Title							
5	Title							
6	Title							
7	Title							
8	Title							
9	Title							
10	Title							
11	Title							
12	Title							
13	Title							
14	Title							
15	Title							
16	Title							
17	Title							
18	Title							
19	Title							
20	Title							
21	Title							
22	Title							
23	Title							

How the data are organized
This is a prospective study.The two rows represent two treatments assigned randomly to subjects. The two columns represent two alternative outcomes. The values are the number of subjects in each category. Data from: New England Journal Medicine 318: 262-264 (1988).

Goals
- To assess whether the discrepancy between incidence of myocardial infarction is more than expected by chance.
- To quantify the relative risk, with its 95% confidence interval.

How to analyze the data
Click Analyze, choose "Chi-square (and Fisher's exact) test" from the list of analyses for contingency tables, and then choose the chi-square test and computation of relative risk in the dialog. Click below for more detailed instructions, and to learn about contingency tables.

Step by step instructions for analyzing contingency tables

Prospective (aspirin and MI)

Row 1, A: Myocardial I

Create New Analysis

Data to analyze

Table: Prospective (aspirin and MI)

Type of analysis

Which analysis?

- **Transform, Normalize...**
  - Transform
  - Transform concentrations (X)
  - Normalize
  - Prune rows
  - Remove baseline and column math
  - Transpose X and Y
  - Fraction of Total
- **XY analyses**
- **Column analyses**
- **Grouped analyses**
- **Contingency table analyses**
  - Chi-square (and Fisher's exact) test
  - Row means with SD or SEM
  - Fraction of Total
- **Survival analyses**
- **Parts of whole analyses**
- **Multiple variable analyses**
- **Nested analyses**
- **Generate curve**
- **Simulate data**
- **Recently used**

Analyze which data sets?

- [x] A:Myocardial Infarction
- [x] B:No MI

Select All | Deselect All

?

Cancel | OK

Parameters: Chi-square (and Fisher's exact) test

Main Calculations | Options

Effect sizes to report

- [x] Relative Risk
  Used for prospective and experimental studies
- [x] Difference between proportions (attributable risk) and NNT
  Used for prospective and experimental studies
- [ ] Odds ratio
  Used for retrospective case-control studies
- [ ] Sensitivity, specificity and predictive values
  Used for diagnostic tests

Method to compute the P value

- (•) Fisher's exact test
- ( ) Yates' continuity corrected chi-square test
- ( ) Chi-square test
- ( ) Chi-square test for trend

Looking for the z test to compare proportions? Choose the chi-square test (with or without the Yates' correction). The chi-square and z tests are equivalent.

?

Cancel

OK

Untitled — Edited

Search

- Data Tables
  - **Prospective (aspirin and MI)**
  - *New Data Table...*
- Info
  - Project info 1
  - *New Info...*
- Results
  - **Contingency of Prospective (aspi**
  - *New Analysis...*
- Graphs
  - Prospective (aspirin and MI)
  - *New Graph...*
- Layouts
  - *New Layout...*

Family

- **Prospective (aspirin and MI)**
  - **Contingency**

Contingency

1	**Table Analyzed**	Prospective (aspirin and MI)		
2				
3	**P value and statistical significance**			
4	Test	Fisher's exact test		
5	P value	<0.0001		
6	P value summary	****		
7	One- or two-sided	Two-sided		
8	Statistically significant (P < 0.05)?	Yes		
9				
10	**Effect size**	**Value**	**95% CI**	
11	Relative Risk	1.818	1.434 to 2.305	
12	Reciprocal of relative risk	0.5501	0.4339 to 0.6974	
13				
14	Attributable risk (P1 - P2)	0.007706	0.004638 to 0.01084	
15	NNT (reciprocal of attrib. risk)	129.8	92.27 to 215.6	
16				
17	**Methods used to compute CIs**			
18	Relative Risk	Koopman asymptotic score		
19	Attributable risk (P1 - P2)	Newcombe/Wilson with CC		
20				
21	**Data analyzed**	**Myocardial Infarction**	**No MI**	**Tota**
22	Placebo	189	10845	1103
23	Aspirin	104	10933	1103
24	Total	293	21778	2207

Contingency of Prospective

Results

- P value: < 0.0001 (****), is highly significant, so we **reject the null hypothesis**, concluding that Aspirin affects MI risk.
- **Relative risk**: 1.8 [1.4 to 2.3] meaning that NOT taking Aspirin increases risk of MI.
- **Reciprocal of relative risk**: 0.55 [.43 to .70] meaning that taking Aspirin reduces risk of MI.
- **Attributable risk**: 0.77% [0.46% to 1.08%] quantifies how much the probability of MI decreases due to taking Asprin
- **Number Needed to treat (NNT):** 130 [92 to 215] quantifies how many individuals would need to take Aspirin in order for one to avoid a MI event.

Caveats: Quantifications of risk apply only to MI events during the observational period used in the study; they do not quantify lifetime risk which of course will be higher.

Contingency table: retrospective study

Does smoking affect one's risk of lung cancer

	lung cancer	control
smoker	688	658
nonsmoker	21	59

Doll & Hill, British Med. J. (1950)

Null hypothesis:
Smoking does not affect lung cancer risk

Alternative hypothesis:
Smoking increases or decreases lung cancer risk

Statistical test:
Fisher's exact test

Welcome to GraphPad Prism

GraphPad Prism
Version 8.4.3 (471)

NEW TABLE & GRAPH

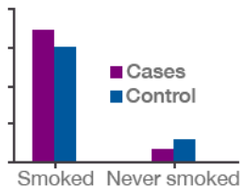
- XY
- Column
- Grouped
- Contingency
- Survival
- Parts of Whole
- Multiple variables
- Nested

EXISTING FILE

- Open a File
- LabArchives
- Clone a Graph
- Graph Portfolio

Contingency tables: Each row defines a treatment or exposure, each column defines an outcome, and each value is an exact count of objects or events

Table format Contingency		A	B
		Cases	Control
		Y	Y
1	Smoked		
2	Never smoked		



? Learn more

Data table:

- Enter or import data into a new table
- Start with sample data to follow a tutorial

Select a tutorial data set:

- Chi-square test of prospective data (aspirin and MI)
- Fishers exact test of retrospective data (smoking and cancer)
- Sensitivity and specificity (HIV)
- Chi-square test for trend

Prism Tips

Cancel

Create

Untitled — Edited

Search

Data Tables
- Retrospective (smoking and canc
- New Data Table...

Info
- Project info 1
- New Info...

Results
- New Analysis...

Gr hs
- ospective (smoking and canc
- New Graph...

Layout
- New Layout...

Family
- Retrospective (smoking and canc
- Retrospective (smoking and canc

	Table format: Contingency	Outcome A	Outcome B	Outcome C	Outcome D	Outcome E	Outcome F	Outcome G
		Cases (lung cancer)	Control	Title	Title	Title	Title	Title
		Y	Y	Y	Y	Y	Y	Y
1	Smoked	688	650					
2	Never smoked	21	59					
3	Title							
4	Title							
5	Title							
6	Title							
7	Title							
8	Title							
9	Title							
10	Title							
11	Title							
12	Title							
13	Title							
14	Title							
15	Title							
16	Title							
17	Title							
18	Title							
19	Title							
20	Title							
21	Title							

How the data are organized
This is a retrospective case-control study. The two columns represent two groups of subjects. The two rows represent two alternative exposures (smoking or not). The values are the number of subjects who fall into each category. Data are the first to show a relationship between smoking and cancer (Doll and Hill, British Med. J, 1950, 739-748).

Goals
- To assess whether the relationship between cancer and smoking is more than expected by chance.
- To quantify the odds ratio with its 95% confidence interval.

How to analyze the data
Click Analyze, choose "Chi-square (and Fisher's exact) test" from the list of analyses for contingency tables, and then choose the Fisher's exact test and check the option to compute the odd's ratio in the dialog. Click below for more detailed instructions, and to learn about contingency tables.

Step by step instructions for analyzing contingency tables

Retrospective (smoking and cancer)

Row 1, A: Case

Create New Analysis

Data to analyze

Table: Retrospective (smoking and cancer)

Type of analysis

Which analysis?

- **Transform, Normalize...**
  - Transform
  - Transform concentrations (X)
  - Normalize
  - Prune rows
  - Remove baseline and column math
  - Transpose X and Y
  - Fraction of Total
- **XY analyses**
- **Column analyses**
- **Grouped analyses**
- **Contingency table analyses**
  - Chi-square (and Fisher's exact) test
  - Row means with SD or SEM
  - Fraction of Total
- **Survival analyses**
- **Parts of whole analyses**
- **Multiple variable analyses**
- **Nested analyses**
- **Generate curve**
- **Simulate data**
- **Recently used**

Analyze which data sets?

- [x] A:Cases (lung cancer)
- [x] B:Control

Select All | Deselect All

?

Cancel | OK

Parameters: Chi-square (and Fisher's exact) test

Main Calculations | Options

Effect sizes to report

- [ ] Relative Risk
  Used for prospective and experimental studies
- [ ] Difference between proportions (attributable risk) and NNT
  Used for prospective and experimental studies
- [x] Odds ratio
  ed for retrospective case-control studies
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  Used for diagnostic tests

Method to compute the P value

- (•) Fisher's exact test
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- ( ) Chi-square test
- ( ) Chi-square test for trend

Looking for the z test to compare proportions? Choose the chi-square test (with or without the Yates' correction). The chi-square and z tests are equivalent.

? Cancel OK

Untitled — Edited

Search

- Data Tables
  - Retrospective (smoking and canc
  - *New Data Table...*
- Info
  - Project info 1
  - *New Info...*
- Results
  - Contingency of Retrospective (sn
  - *New Analysis...*
- Graphs
  - Retrospective (smoking and cancer
  - *New Graph...*
- Layouts
  - *New Layout...*

Family

- Retrospective (smoking and canc
  - Contingency

Contingency

1	**Table Analyzed**	Retrospective (smoking and cancer)			
2					
3	**P value and statistical significance**				
4	Test	Fisher's exact test			
5	P value	<0.0001			
6	P value summary	****			
7	One- or two-sided	Two-sided			
8	Statistically significant (P < 0.05)?	Yes			
9					
10	**Effect size**	**Value**	**95% CI**		
11	Odds ratio	2.974	1.819 to 4.900		
12	Reciprocal of odds ratio	0.3363	0.2041 to 0.5496		
13					
14	**Methods used to compute CIs**				
15	Odds ratio	Baptista-Pike			
16					
17	**Data analyzed**	**Cases (lung cancer)**	**Control**	**Total**	
18	Smoked	688	650	1338	
19	Never smoked	21	59	80	
20	Total	709	709	1418	
21					

Contingency of Retrospective (smoking and c

Row 1, Column A

Results

- P value: < 0.0001 (****), is highly significant, so we **reject the null hypothesis**, concluding that smoking and cancer are associated.

- **Odds ratio**: 3.0 [1.8 to 4.9] meaning that smoking is associated with a nearly 3-fold higher odds of getting cancer.

- **Reciprocal of odds ratio**: 0.34 [.20 to .55] NOT smoking is associated with a nearly 3-fold decrease in the odds of getting cancer.

Caveats: These results are from a a retrospective study, so we can't conclude that smoking causes cancer, only that it is associated with cancer.

Relative risk vs. Odds ratio

	Cancer (event)	No Cancer (no event)	Total
Smoker	a	b	$a+b$
Nonsmoker	c	d	$c+d$
Total	$a+c$	$b+d$	

Risk is the probability of an event

Risk for smokers: $a/(a+b)$

Risk for nonsmokers: $c/(c+d)$

Relative risk: $\dfrac{a/(a+b)}{c/(c+d)}$

Odds is the probability of an event divided by the probability of no event

Odds for smokers: a/b

Odds for nonsmokers: c/d

Odds ratio: $\dfrac{a/b}{c/d}$

Odds is not affected by the relative number of events vs. no events, and is preferable when this ratio reflects the design of the study, not natural phenomena.

Questions?