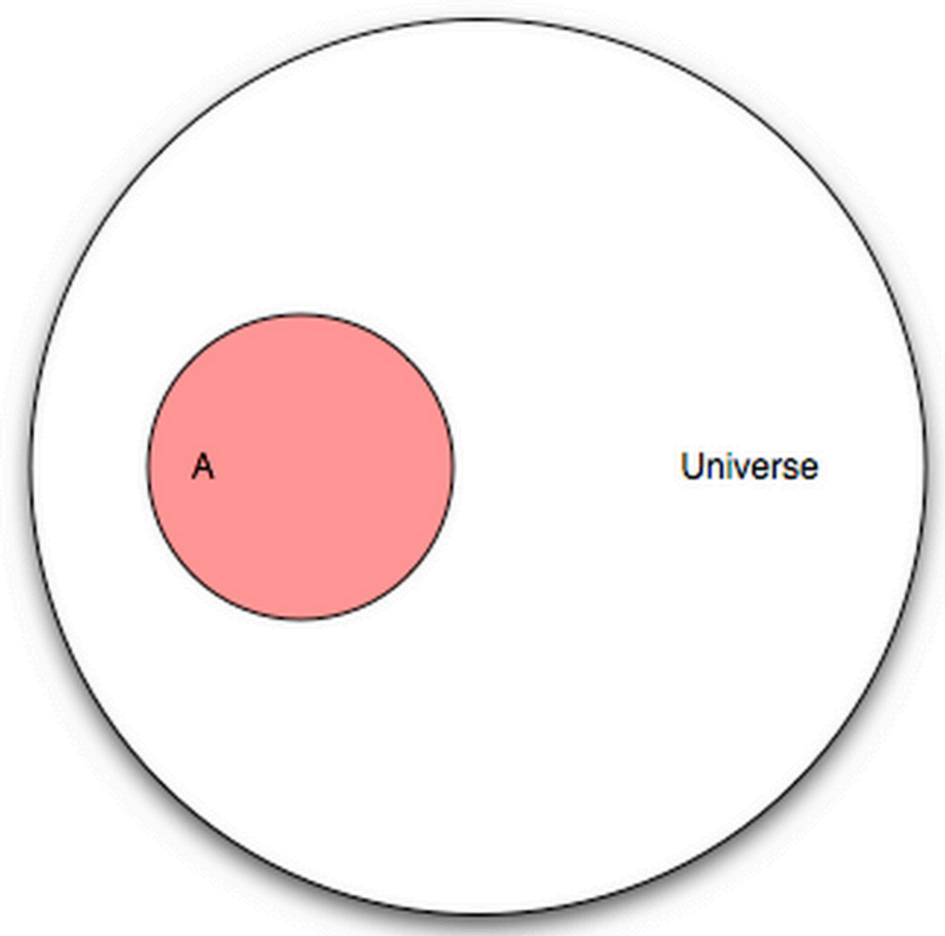
Bayes

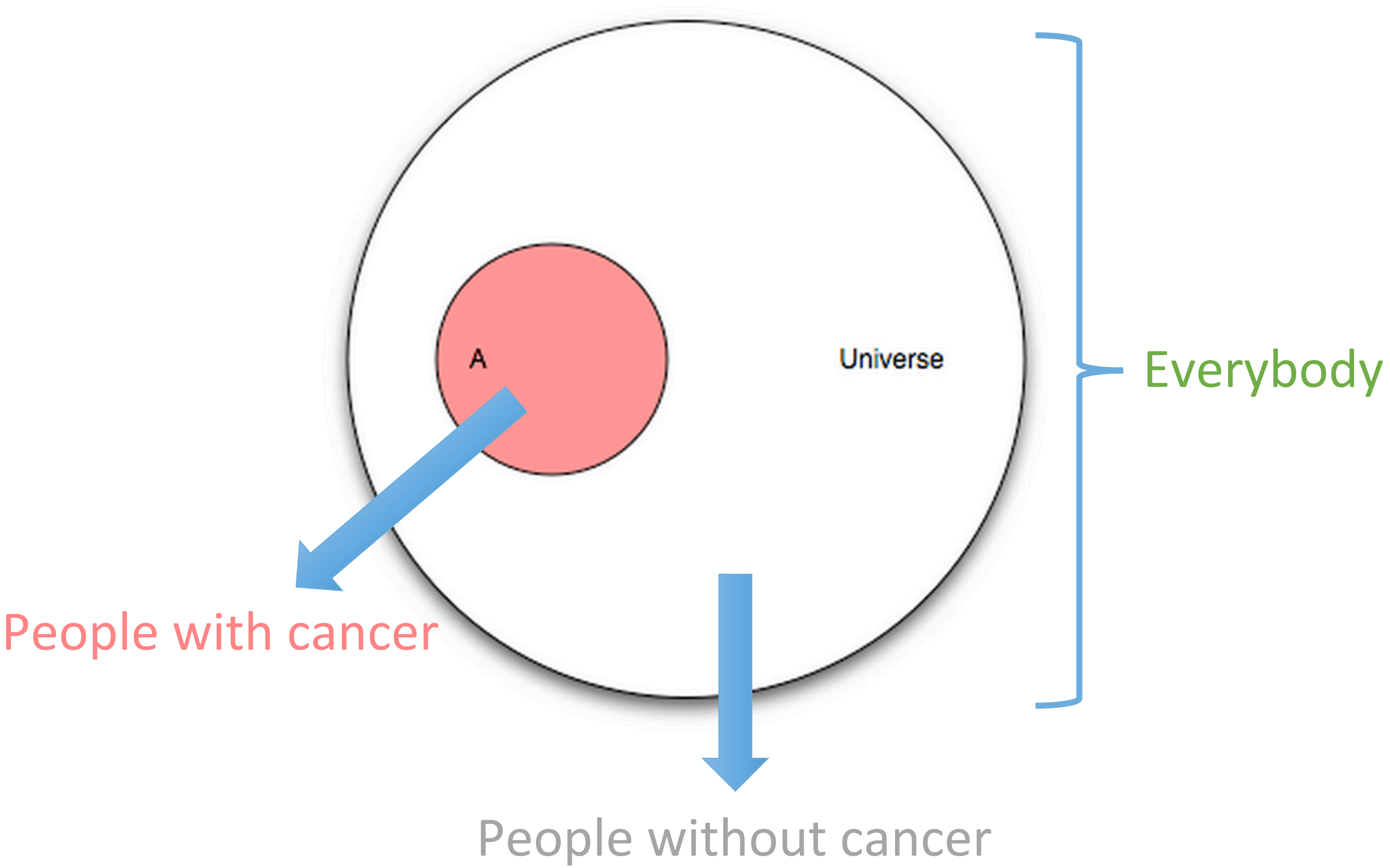
DATA SCIENCE BOOTCAMP

Thug Life. Gangsta.

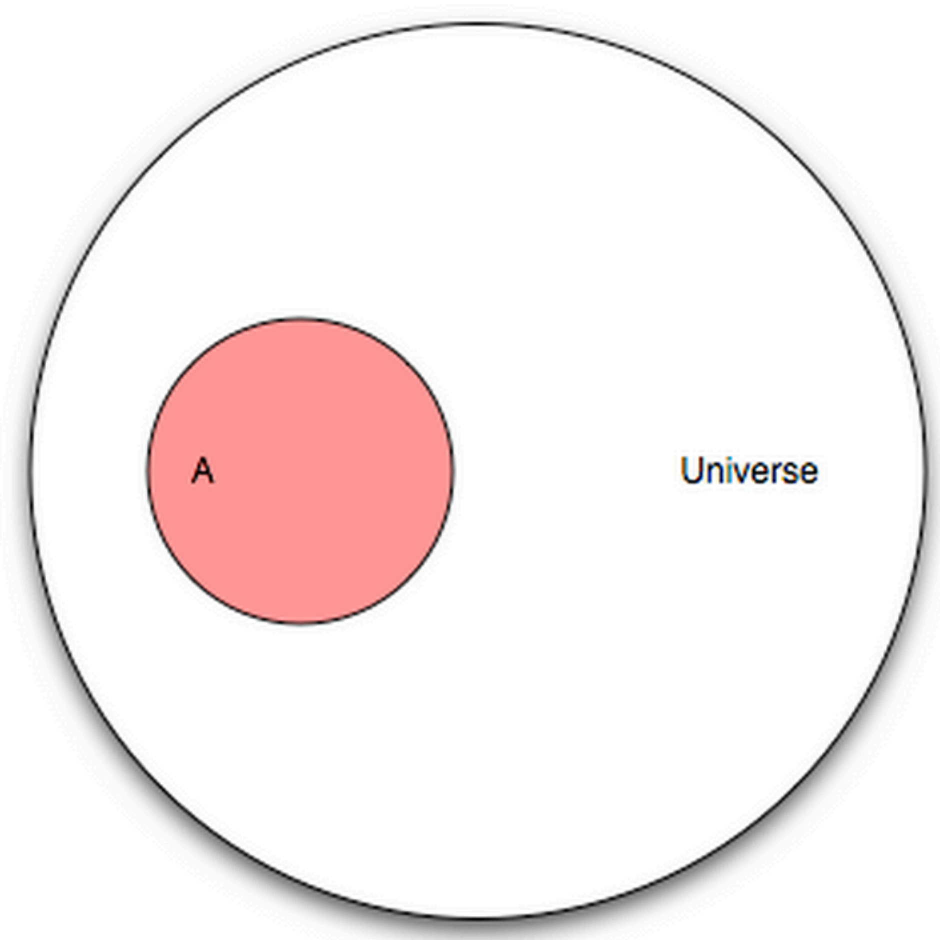
If a person **tested positive** for cancer,
what is the probability of him/her actually having cancer?



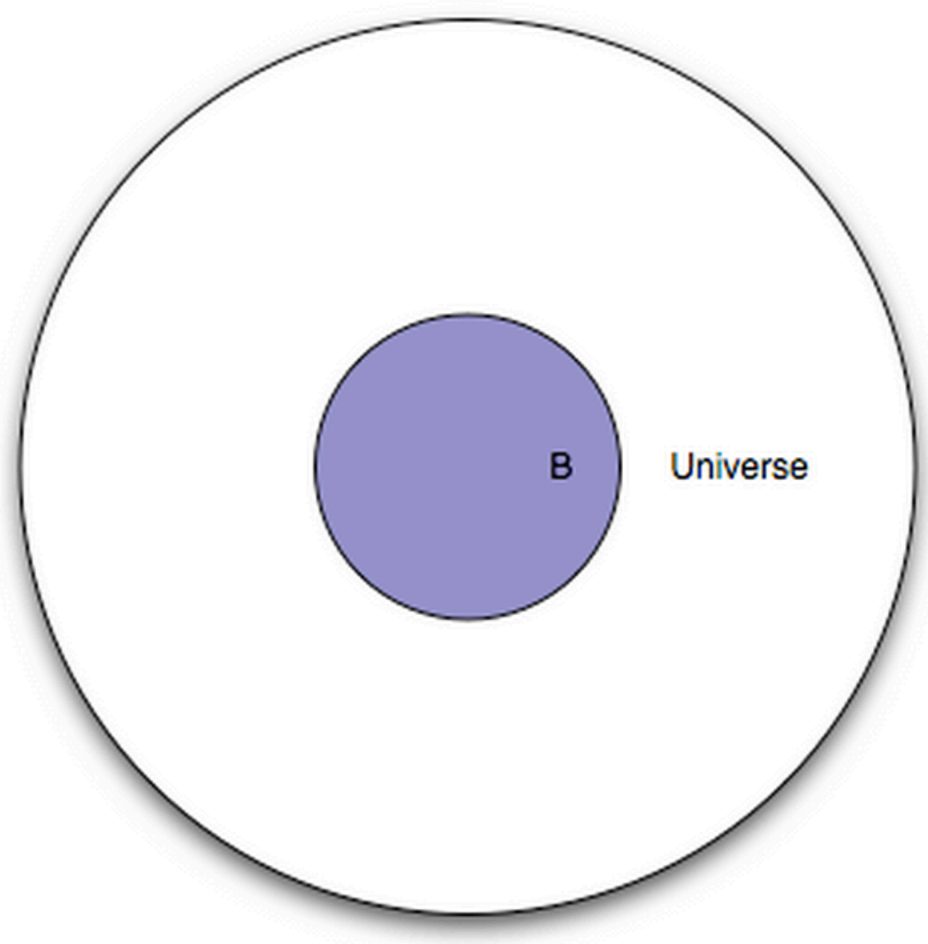
http://oscarbonilla.com/2009/05/visualizing-bayes-theorem/

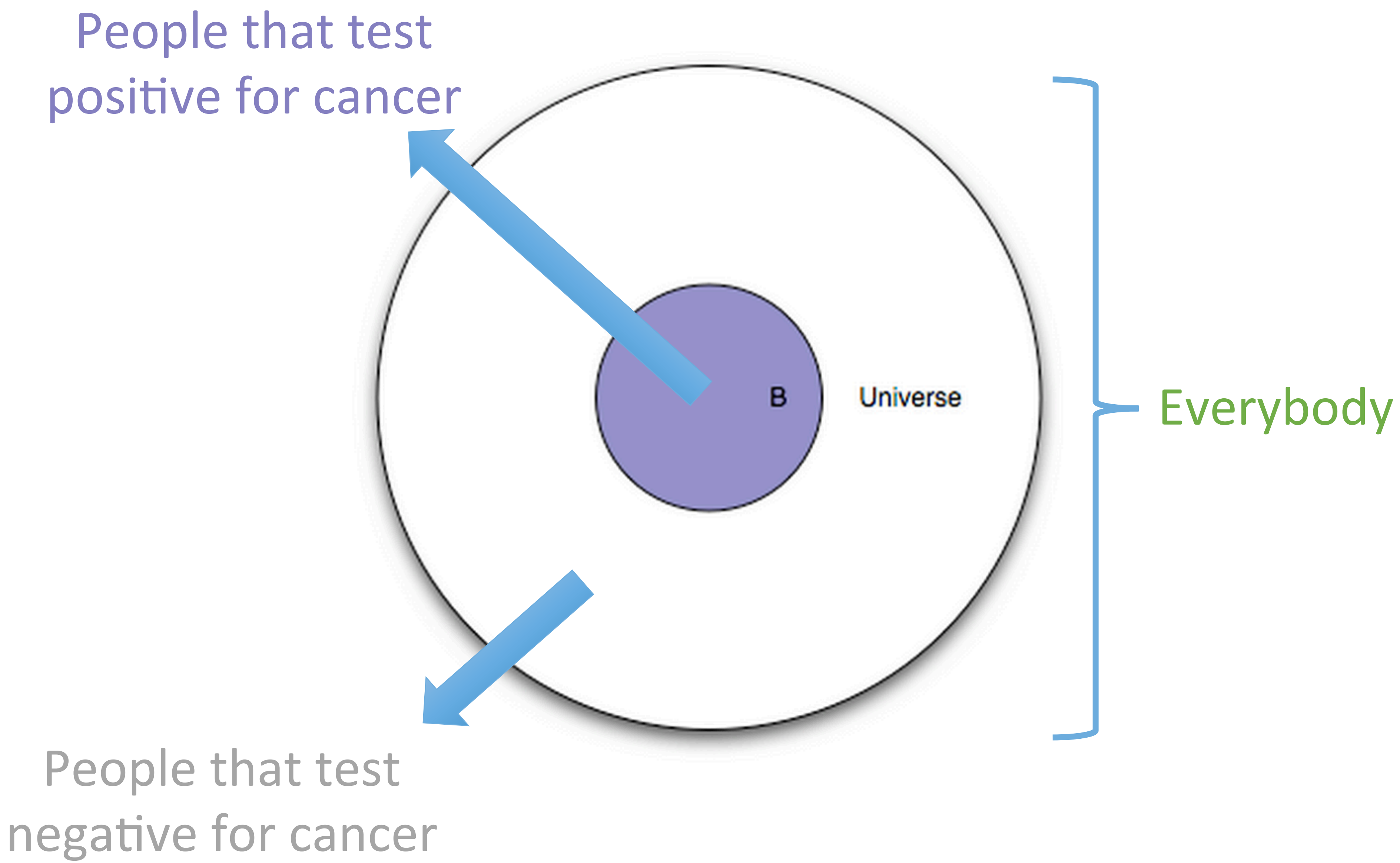

A
Universe
Everybody
People with cancer
People without cancer

If I picked a random person from the universe, what is the probability of him/her having cancer?

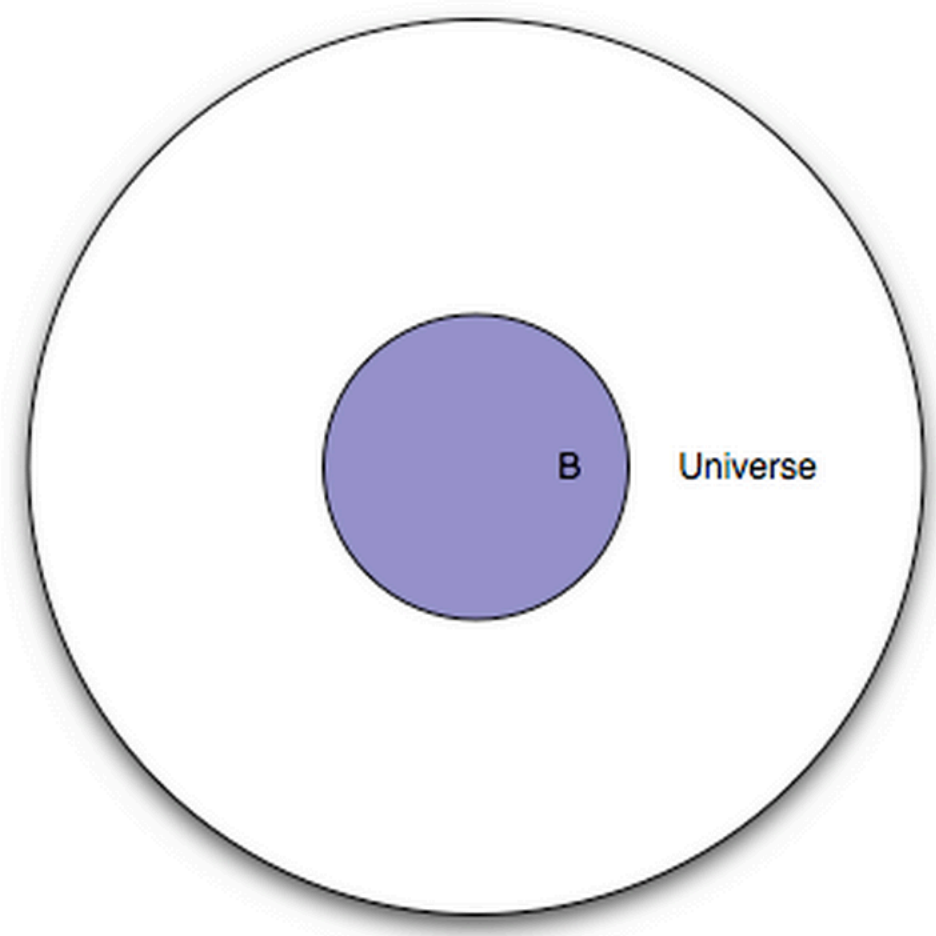


$$P(A) = \frac{|A|}{|U|}$$

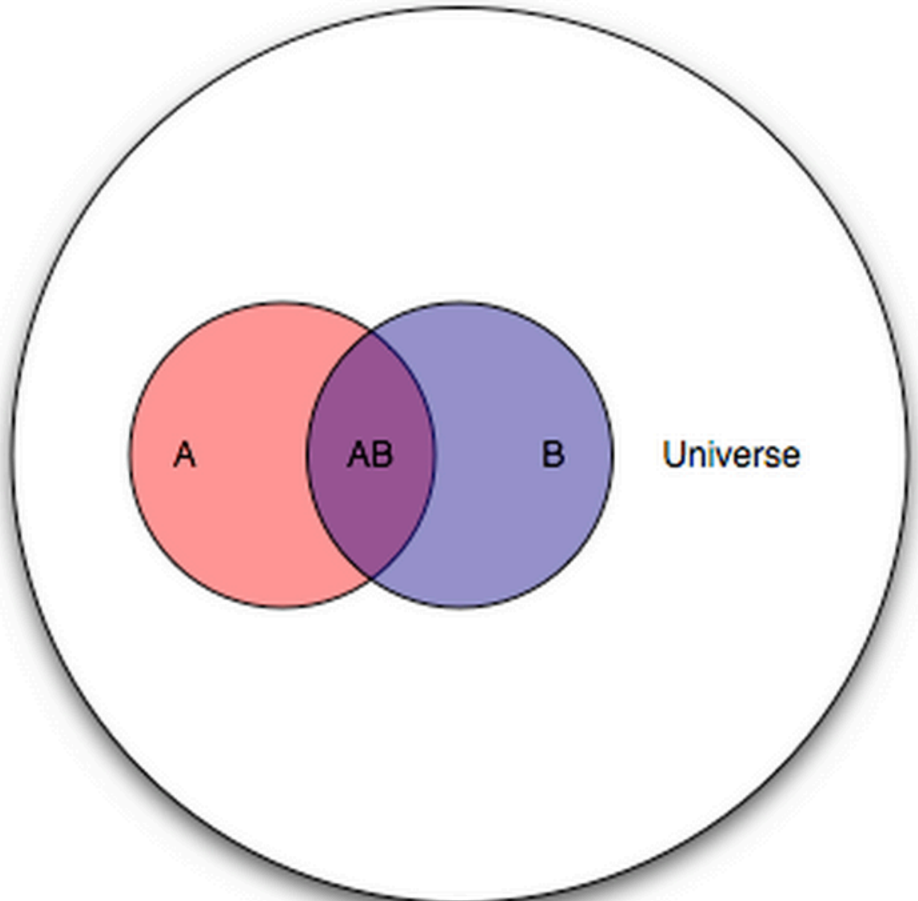

B
Universe

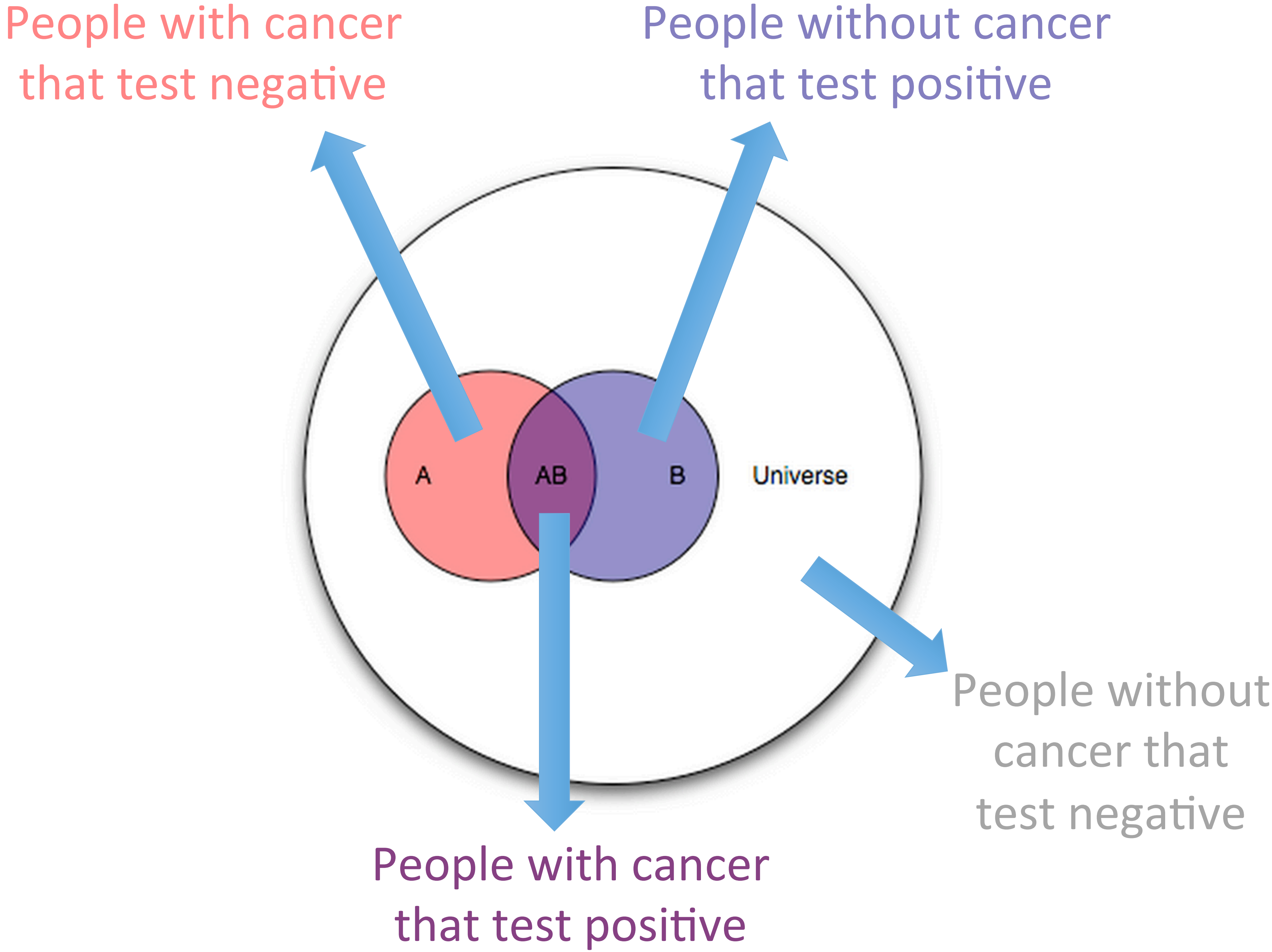

People that test positive for cancer
B
Universe
Everybody
People that test negative for cancer

If I picked a random person from the universe, what is the probability of him/her testing positive for cancer?

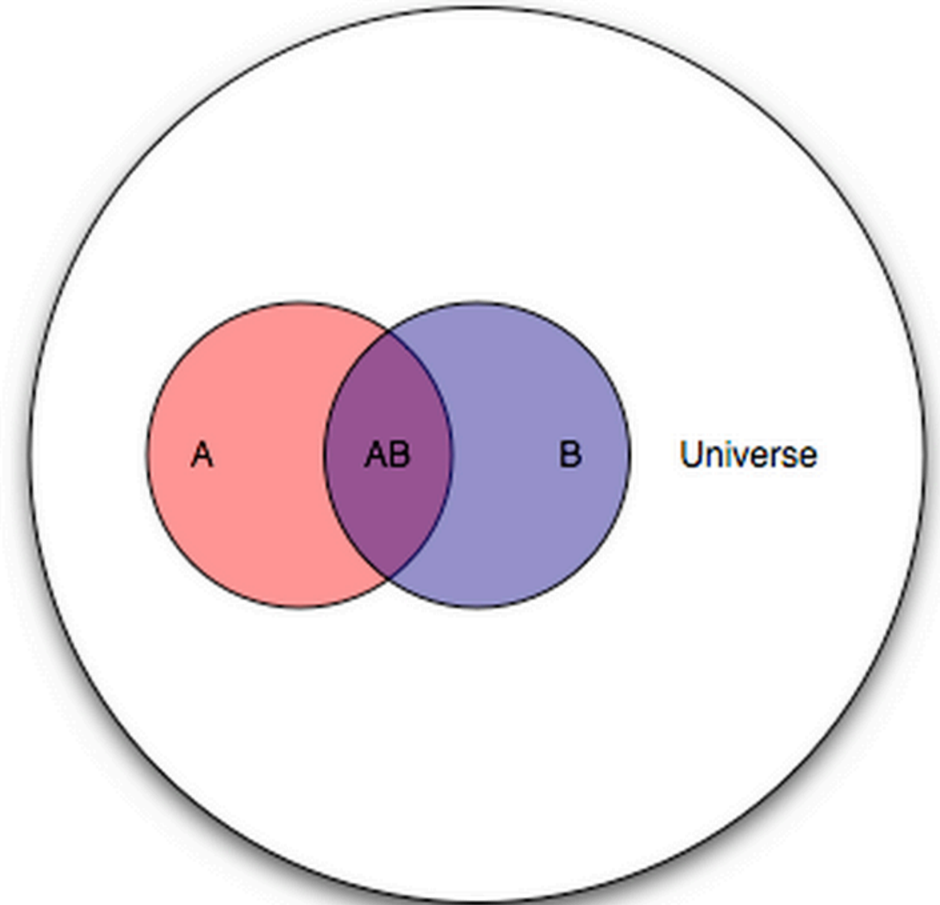


$$P(B) = \frac{|B|}{|U|}$$


A
AB
B
Universe


People with cancer that test negative
People without cancer that test positive
A
AB
B
Universe
People without cancer that test negative
People with cancer that test positive

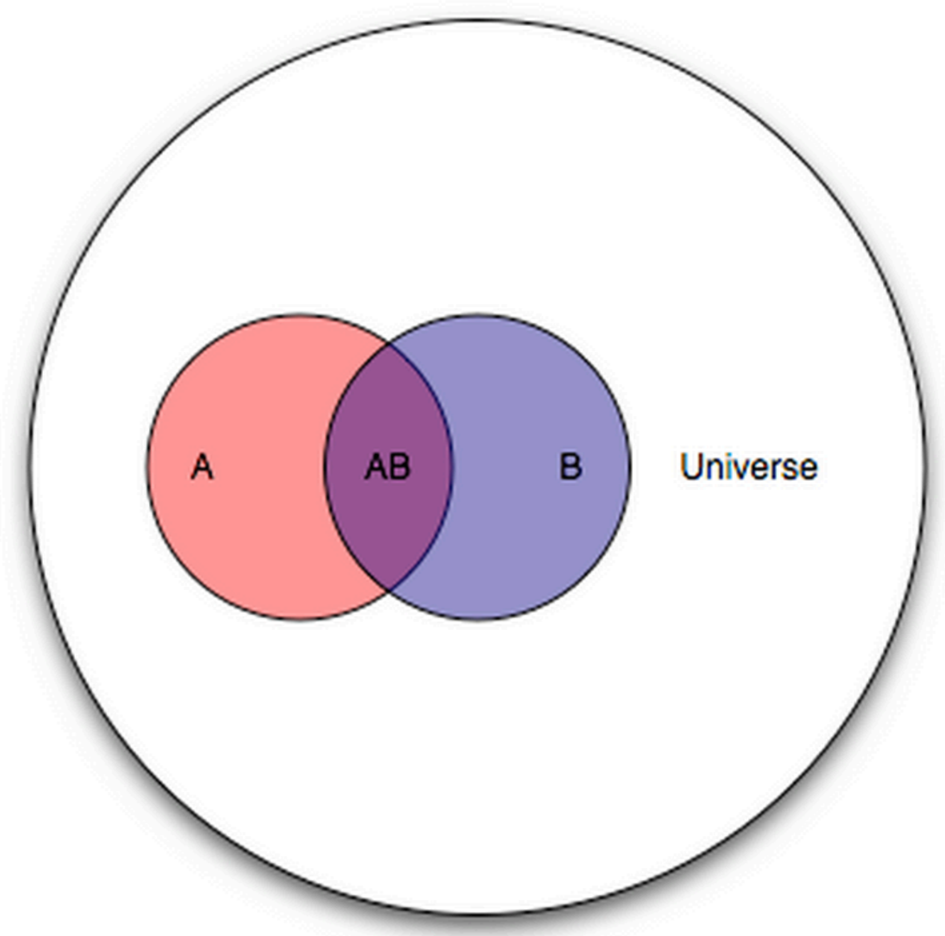
If I picked a random person from the universe, what is the prob. of them having cancer **AND** testing positive for cancer?



$$P(A,B) = \frac{|AB|}{|U|}$$

Joint probability

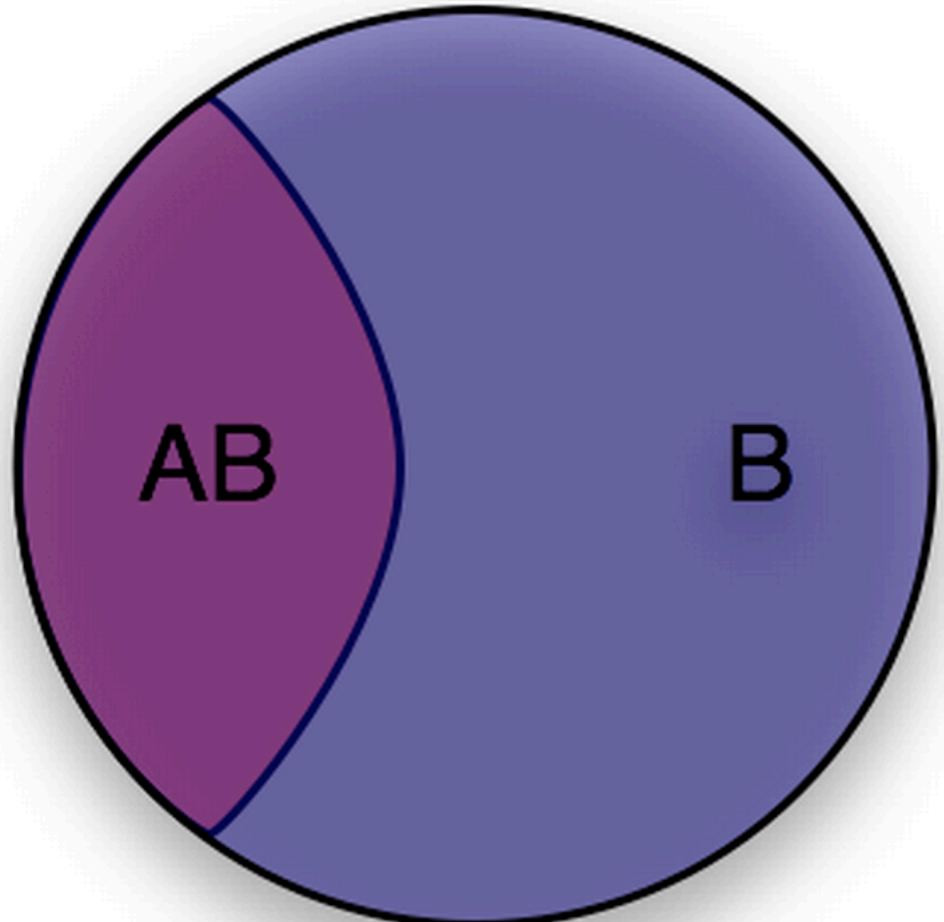
If I picked a random person **that tested positive**, what is the prob. of him/her actually having cancer?



$$P(A \mid B) = \frac{|AB|}{|B|}$$

Conditional probability

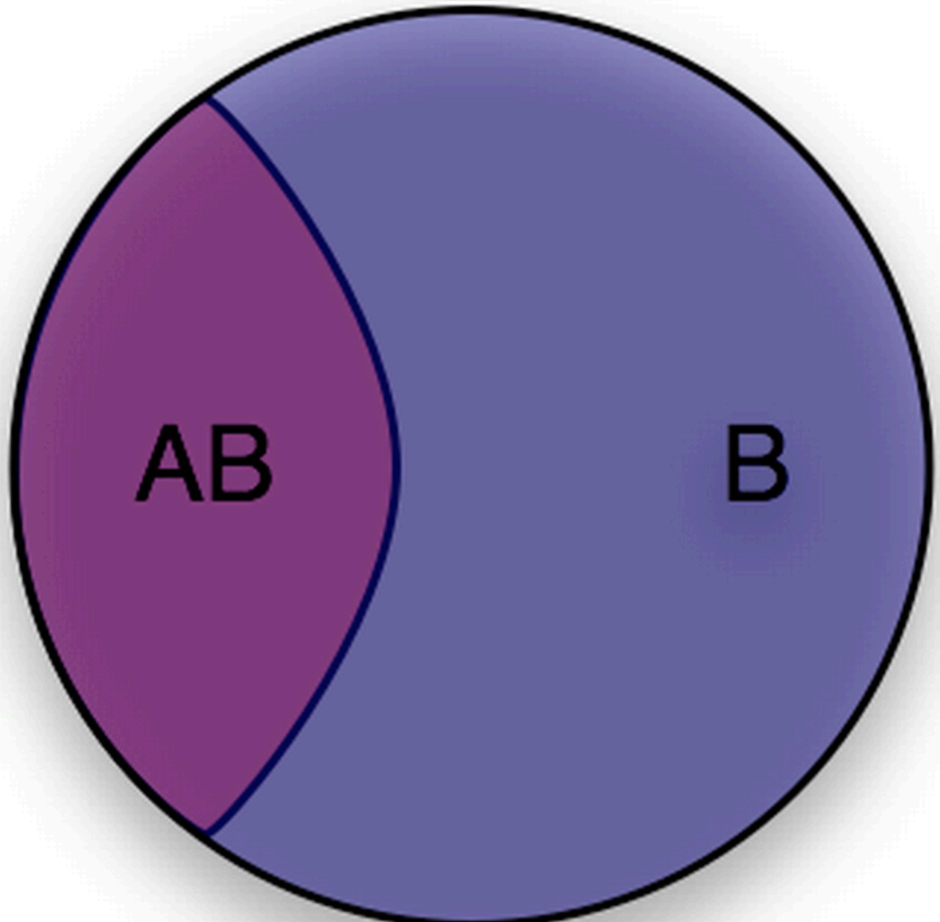
If I picked a random person **that tested positive**, what is the prob. of him/her actually having cancer?



$$P(A \mid B) = \frac{|AB|}{|B|}$$

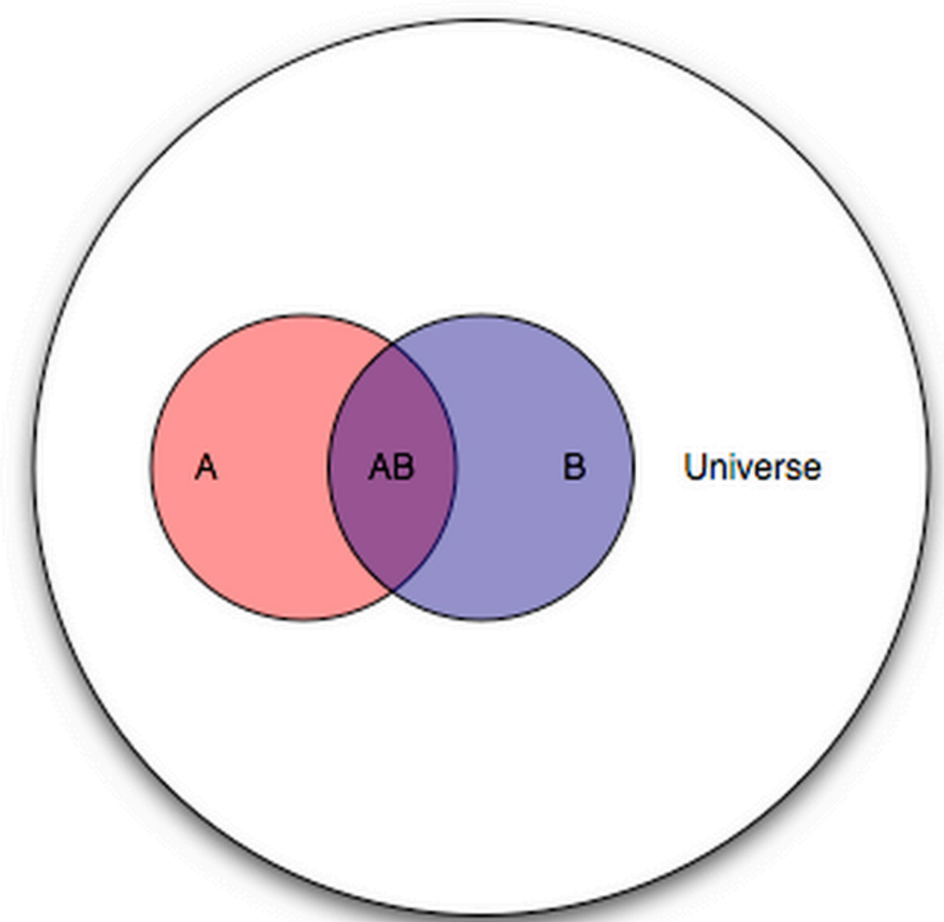
Conditional probability

If I picked a random person **that tested positive**, what is the prob. of him/her actually having cancer?



$$P(A \mid B) = \frac{|AB|}{|B|} = \frac{|AB|/|U|}{|B|/|U|} = \frac{P(A,B)}{P(B)}$$

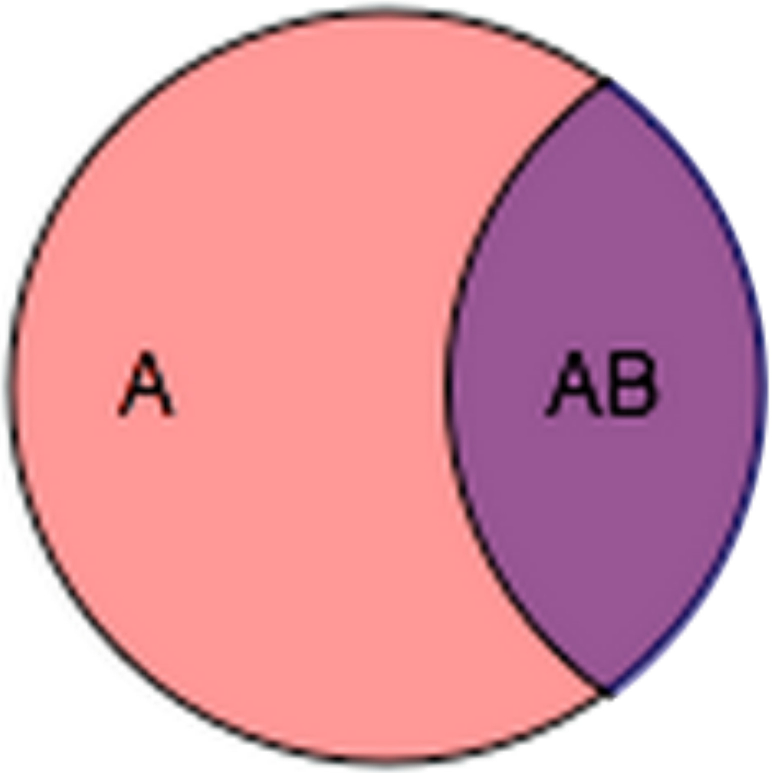
If I picked a random person **that has cancer**, what is the prob. of him/her testing positive?



$$P(B \mid A) = \frac{|AB|}{|A|}$$

Conditional probability

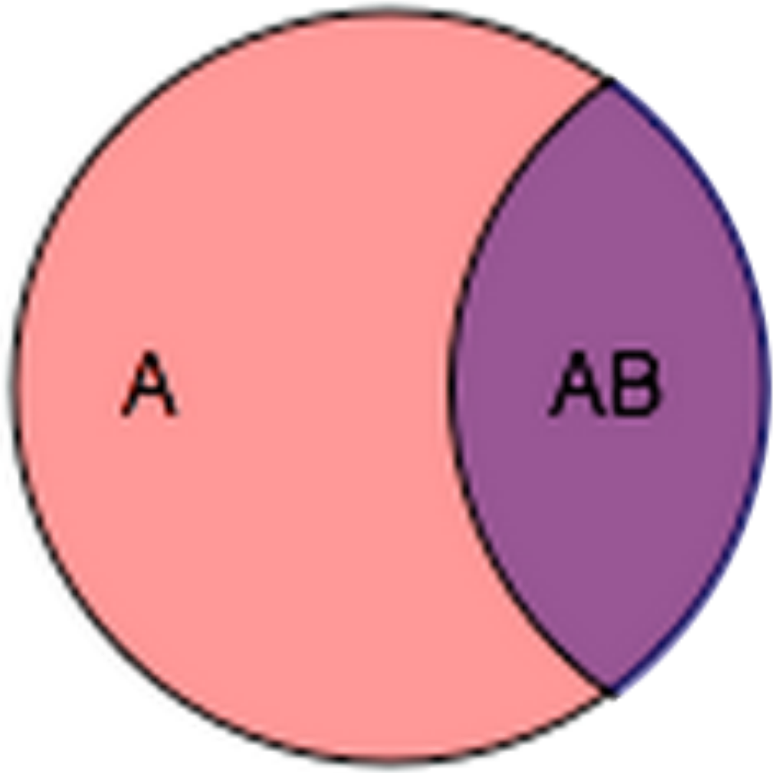
If I picked a random person **that has cancer**, what is the prob. of him/her testing positive?



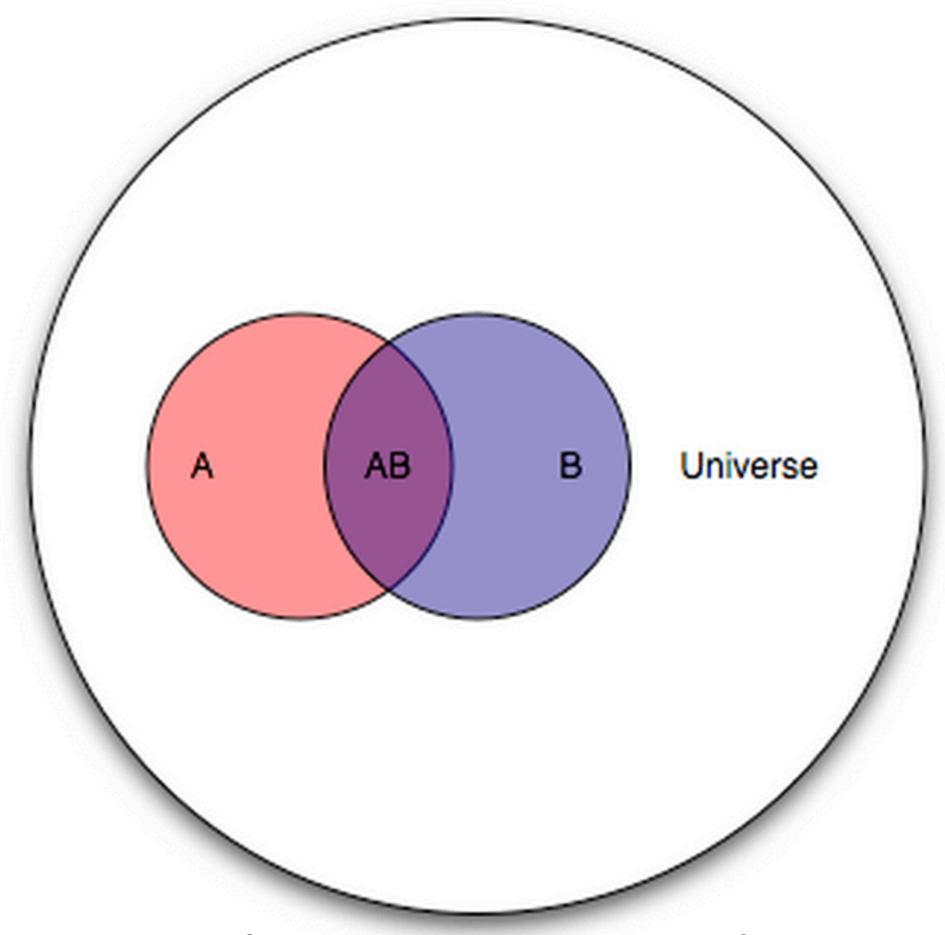
$$P(B \mid A) = \frac{|AB|}{|A|}$$

Conditional probability

If I picked a random person **that has cancer**, what is the prob. of him/her testing positive?



$$P(B \mid A) = \frac{|AB|}{|A|} = \frac{|AB|/|U|}{|A|/|U|} = \frac{P(A,B)}{P(A)}$$

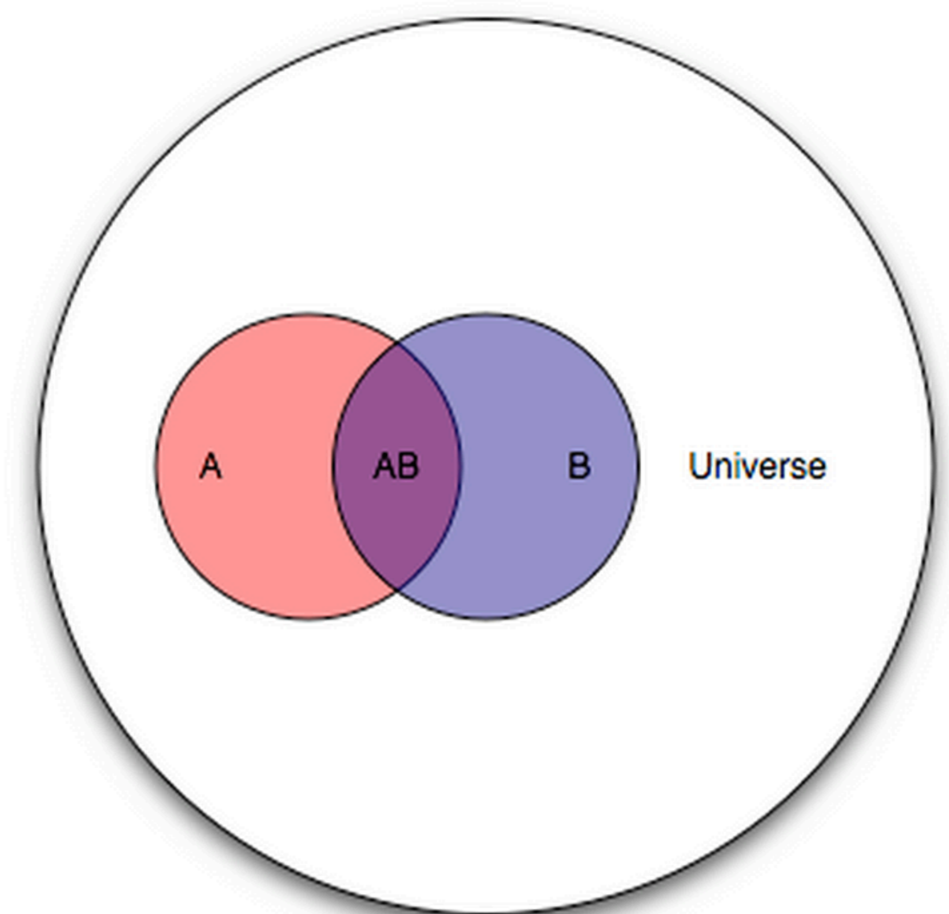


P(test positive | has cancer)

$$P(B \mid A) = \frac{P(A,B)}{P(A)}$$

P(has cancer | test positive)

$$P(A \mid B) = \frac{P(A,B)}{P(B)}$$

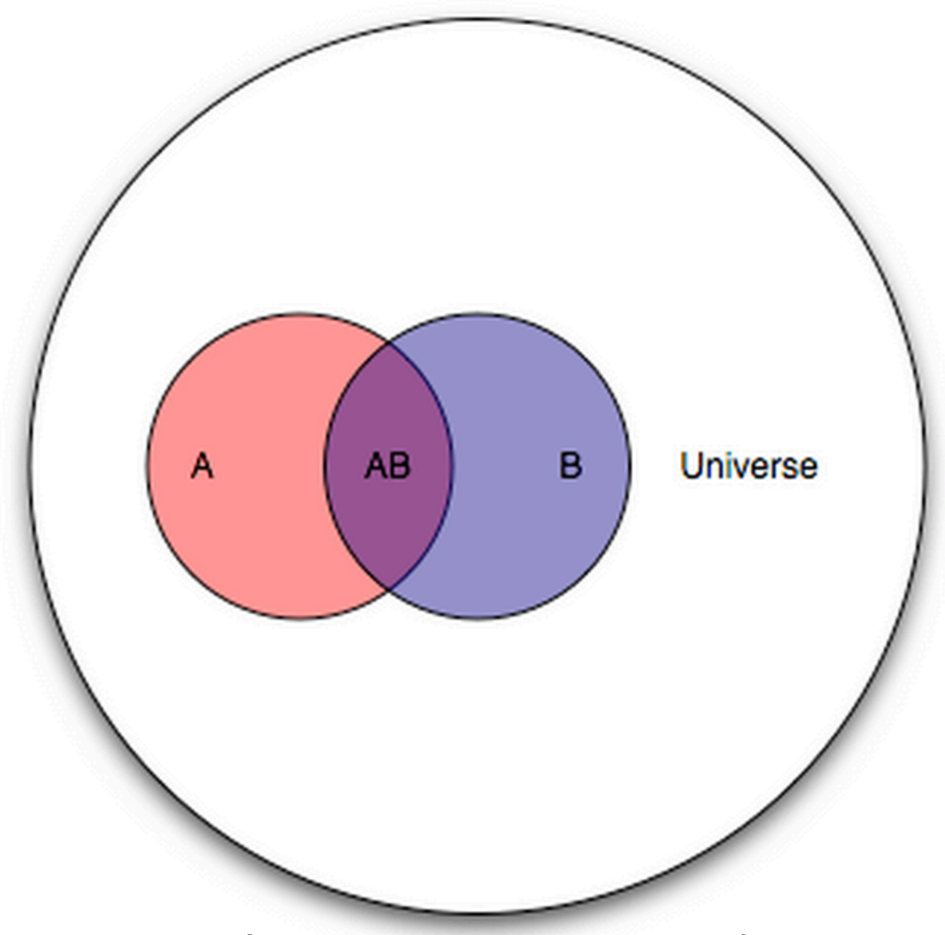


P(test positive | has cancer)

P(has cancer | test positive)

$$P(B \mid A)P(A) = P(A,B)$$

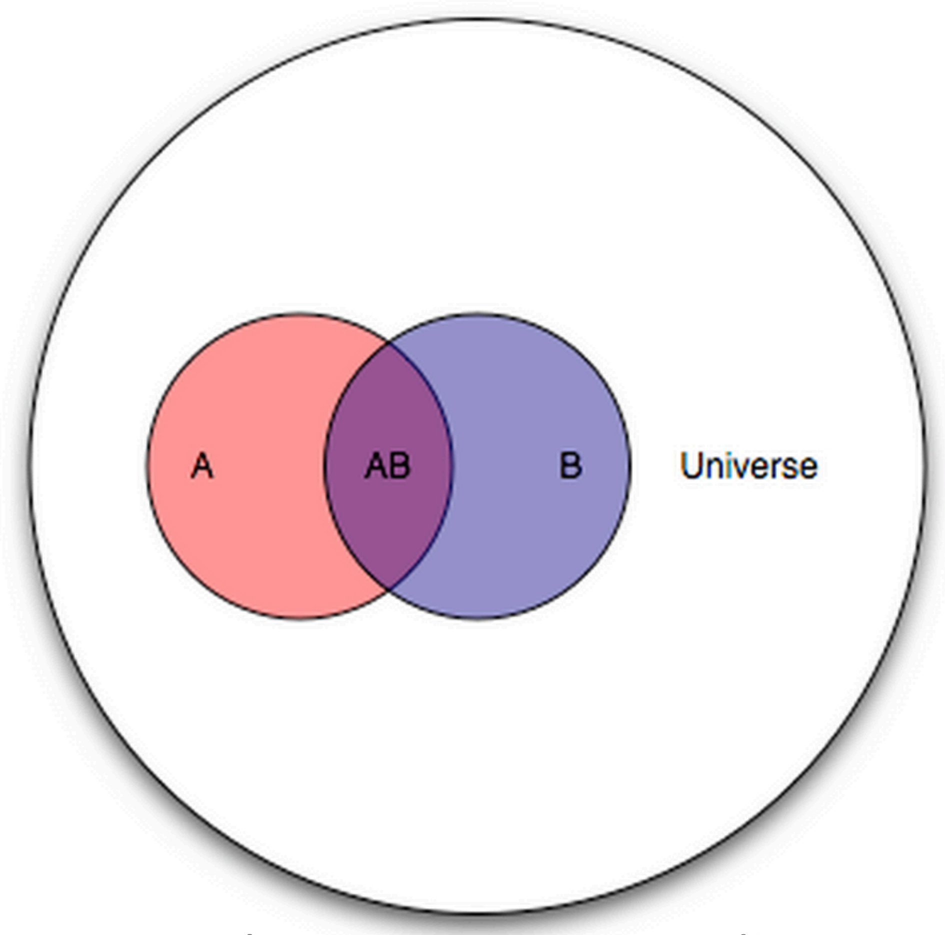
$$P(A,B) = P(A \mid B)P(B)$$



P(test positive | has cancer)

P(has cancer | test positive)

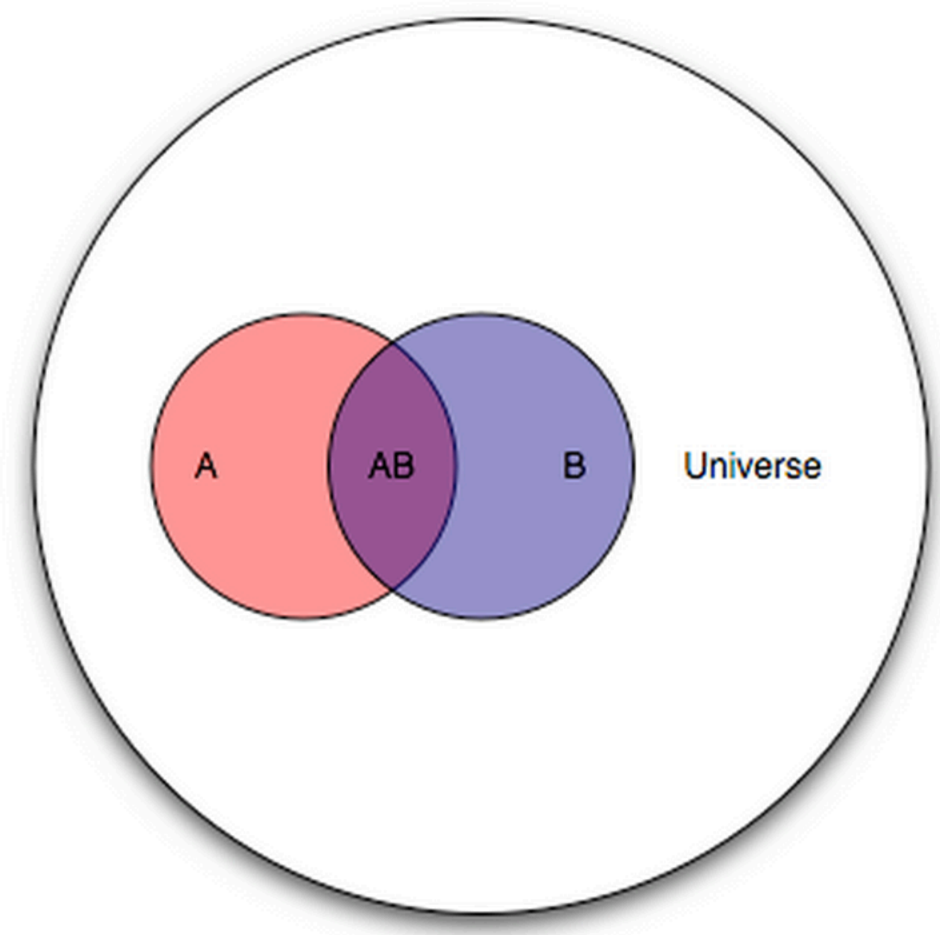
$$P(B \mid A)P(A) = \qquad P(A,B) \qquad = P(A \mid B)P(B)$$



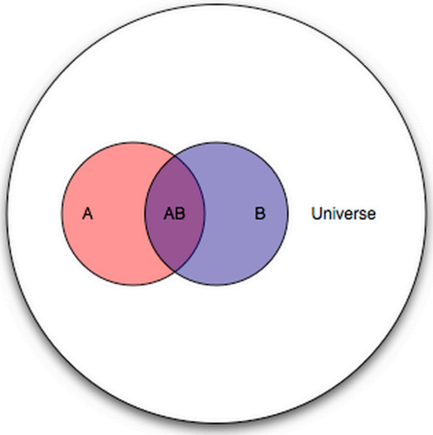
P(test positive | has cancer)

P(has cancer | test positive)

$$P(B \mid A)P(A) = P(A \mid B)P(B)$$



$$\overbrace{P(B \mid A)}^{P(\text{test positive} \mid \text{has cancer})}\underbrace{P(A)}_{P(\text{has cancer})} = \overbrace{P(A \mid B)}^{P(\text{has cancer} \mid \text{test positive})}\underbrace{P(B)}_{P(\text{test positive})}$$



$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

$$P(A \mid B) = \frac{P(B \mid A) P(A)}{P(B)}$$

1% of women at age forty who participate in routine screening have breast cancer. 80% of women with breast cancer will get positive mammograms. 9.6% of women without breast cancer will also get positive mammograms. A woman in this age group had a positive mammography in a routine screening. What is the probability that she actually has breast cancer?

$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

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$$P(\text{has cancer}) = 0.01$$

$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

1% of women at age forty who participate in routine screening have breast cancer. 80% of women with breast cancer will get positive mammograms. 9.6% of women without breast cancer will also get positive mammograms. A woman in this age group had a positive mammography in a routine screening. What is the probability that she actually has breast cancer?

$P(\text{has cancer}) = 0.01$

$P(\text{test positive} \mid \text{has cancer}) = 0.80$

$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

1% of women at age forty who participate in routine screening have breast cancer. 80% of women with breast cancer will get positive mammograms. 9.6% of women without breast cancer will also get positive mammograms. A woman in this age group had a positive mammography in a routine screening. What is the probability that she actually has breast cancer?

P(has cancer) = 0.01

P(test positive | has cancer) = 0.80

$$
\begin{aligned}
P(\text{test positive}) &= P(\text{test positive}, \text{has cancer}) \\
&\quad + P(\text{test positive}, \text{not cancer})
\end{aligned}
$$

$$
P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}
$$

1% of women at age forty who participate in routine screening have breast cancer. 80% of women with breast cancer will get positive mammograms. 9.6% of women without breast cancer will also get positive mammograms. A woman in this age group had a positive mammography in a routine screening. What is the probability that she actually has breast cancer?

P(has cancer) = 0.01

P(test positive | has cancer) = 0.80

$$P(\text{test positive}) = P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer}) + P(\text{test positive} \mid \text{not cancer})\, P(\text{not cancer})$$

$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

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$$P(\text{has cancer}) = 0.01$$

$$P(\text{test positive} \mid \text{has cancer}) = 0.80$$

$$\begin{aligned} P(\text{test positive}) &= P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer}) \\ &\quad + P(\text{test positive} \mid \text{not cancer})\, P(\text{not cancer}) \\ &= 0.80\, P(\text{has cancer}) + 0.096\, P(\text{not cancer}) \end{aligned}$$

$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

1% of women at age forty who participate in routine screening have breast cancer. 80% of women with breast cancer will get positive mammograms. 9.6% of women without breast cancer will also get positive mammograms. A woman in this age group had a positive mammography in a routine screening. What is the probability that she actually has breast cancer?

P(has cancer) = 0.01

P(test positive | has cancer) = 0.80

P(test positive) = P(test positive | has cancer) P(has cancer)
+ P(test positive | not cancer) P(not cancer)
= 0.80 P(has cancer) + 0.096 P(not cancer)
= 0.80 * 0.01 + 0.096*(1 – 0.01)

$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

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$$\begin{aligned} P(\text{test positive}) &= P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer}) \\ &\quad + P(\text{test positive} \mid \text{not cancer})\, P(\text{not cancer}) \\ &= 0.80\, P(\text{has cancer}) + 0.096\, P(\text{not cancer}) \\ &= 0.80 * 0.01 + 0.096 * (1 - 0.01) \end{aligned}$$

$$P(\text{test positive}) = 0.103$$

$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

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$P(\text{has cancer}) = 0.01$

$P(\text{test positive} \mid \text{has cancer}) = 0.80$

$P(\text{test positive}) = 0.103$

$P(\text{has cancer} \mid \text{test positive}) = ?$

$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

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$$P(\text{has cancer}) = 0.01$$

$$P(\text{test positive} \mid \text{has cancer}) = 0.80$$

$$P(\text{test positive}) = 0.103$$

$$P(\text{has cancer} \mid \text{test positive}) = \frac{0.80 \; * \; 0.01}{0.103} = 0.078$$

$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

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P(has cancer) = 0.01

P(test positive | has cancer) = 0.80

P(test positive) = 0.103

$$P(\text{has cancer} \mid \text{test positive}) = \frac{0.80 \,*\, 0.01}{0.103} = 0.078$$

ONLY 7.8%

1% of women at age forty who participate in routine screening have breast cancer. 80% of women with breast cancer will get positive mammograms. 9.6% of women without breast cancer will also get positive mammograms. A woman in this age group had a positive mammography in a routine screening. What is the probability that she actually has breast cancer?

P(has cancer) = 0.01

P(test positive | has cancer) = 0.80

P(test positive) = 0.103

$$P(\text{has cancer} \mid \text{test positive}) = \frac{0.80 \; * \; 0.01}{0.103} = 0.078$$

ONLY 7.8%

Most doctors guessed ~80%

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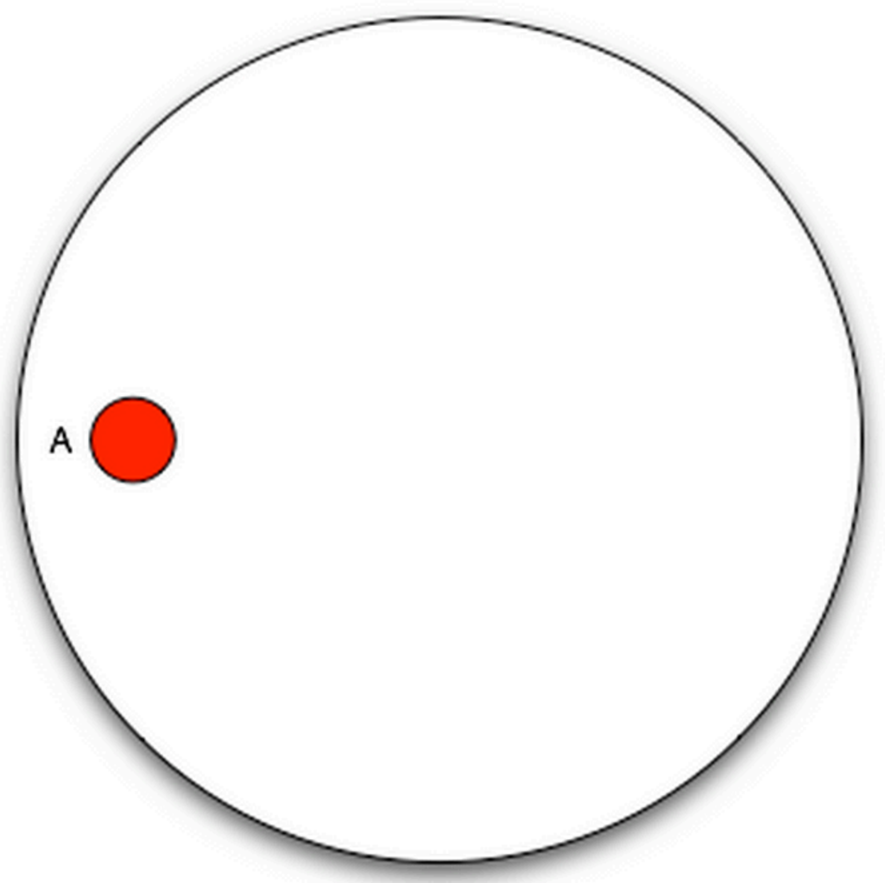

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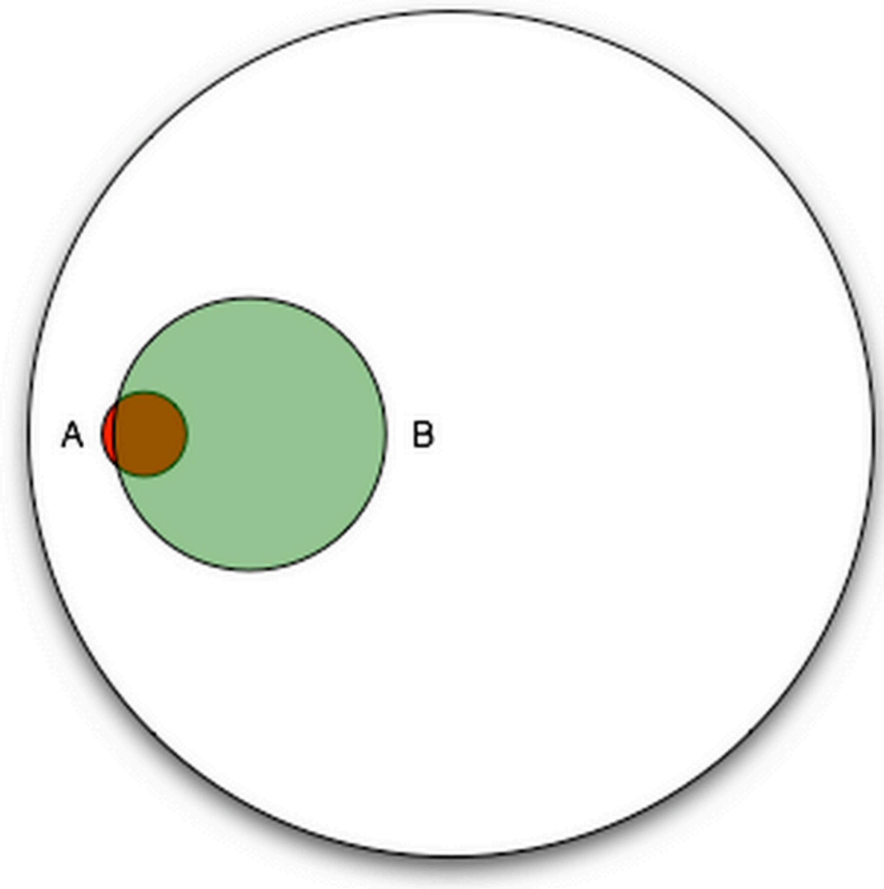

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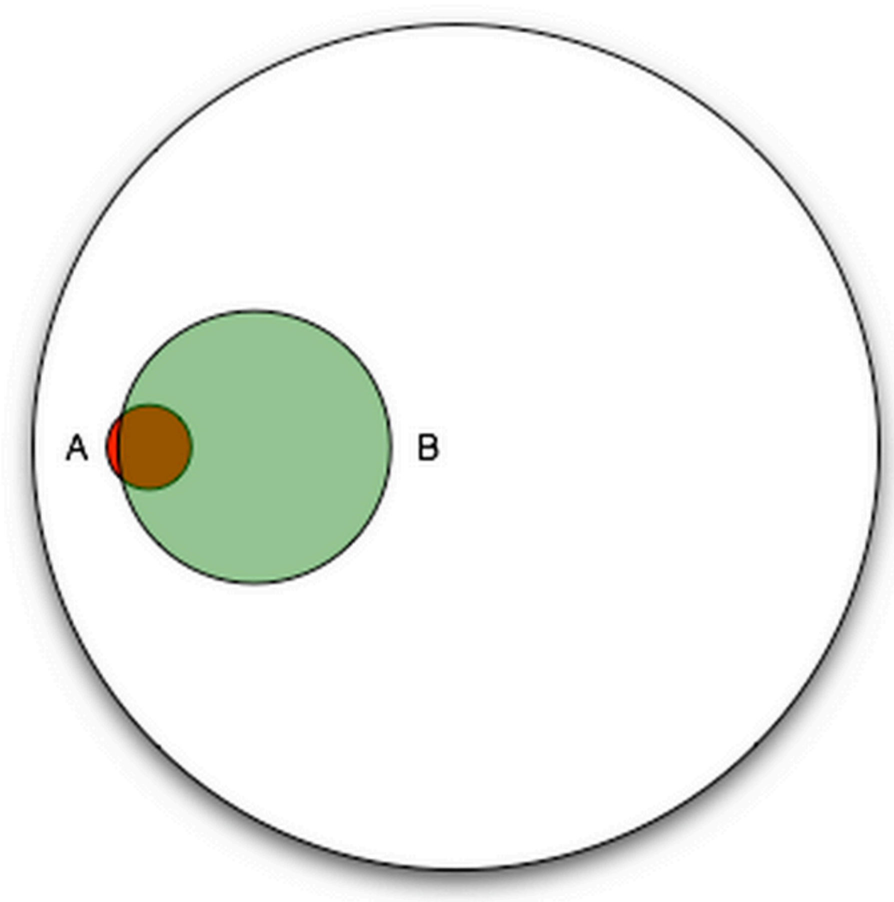
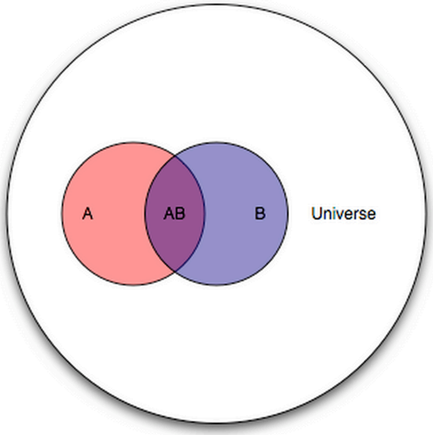


$|A|/|U| = 1\%$

$|AB|/|A| = 80\%$

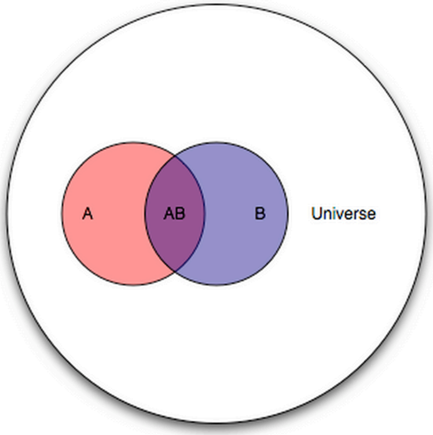
$(|B|-|AB|)/|U| = 9.6\%$

$|AB|/|B| = 7.8\%$



$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\,P(\text{has cancer})}{P(\text{test positive})}$$

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$



$$P(\text{has cancer} \mid \text{test positive}) = \frac{P(\text{test positive} \mid \text{has cancer})\, P(\text{has cancer})}{P(\text{test positive})}$$

$$\overset{\text{posterior}}{P(A \mid B)} = \frac{\overset{\text{likelihood}}{P(B \mid A)}\,\overset{\text{prior}}{P(A)}}{\underset{\text{evidence}}{P(B)}}$$

P(oscar nomination | Meryl Streep in the movie) = ?

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) = # nominated / # released

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

oscar.go.com/nominees

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NOMINEES

The 87th Academy Award Nominations for the 2015 Oscars

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BEST PICTURE

American Sniper
Clint Eastwood, Robert Lorenz, Andrew Lazar, Bradley Cooper and Peter Morgan

View Trailer / ▶

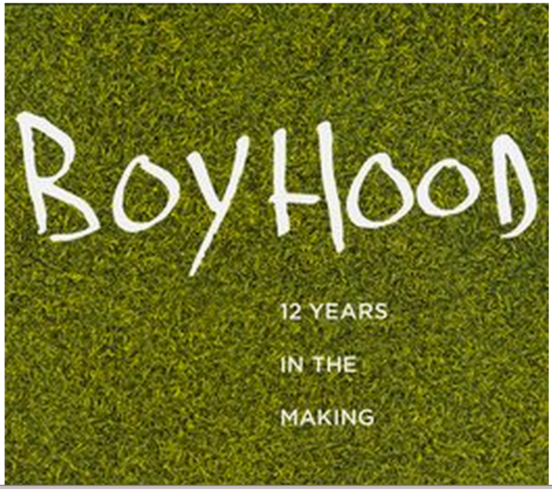
More Information

The Imitation Game
Nora Grossman, Ido Ostrowsky and Teddy Schwarzman

View Trailer / ▶

More Information

Selma



ACTRESS
in a Supporting Role

Patricia Arquette
Boyhood

View Trailer / ▶

More Information

Laura Dern
Wild

View Trailer / ▶

More Information

Keira Knightley
The Imitation Game

View Trailer / ▶

More Information

Emma Stone
Birdman or (The Unexpected Virtue of Ignorance)

View Trailer / ▶

More Information

Meryl Streep
Into the Woods

View Trailer / ▶

More Information

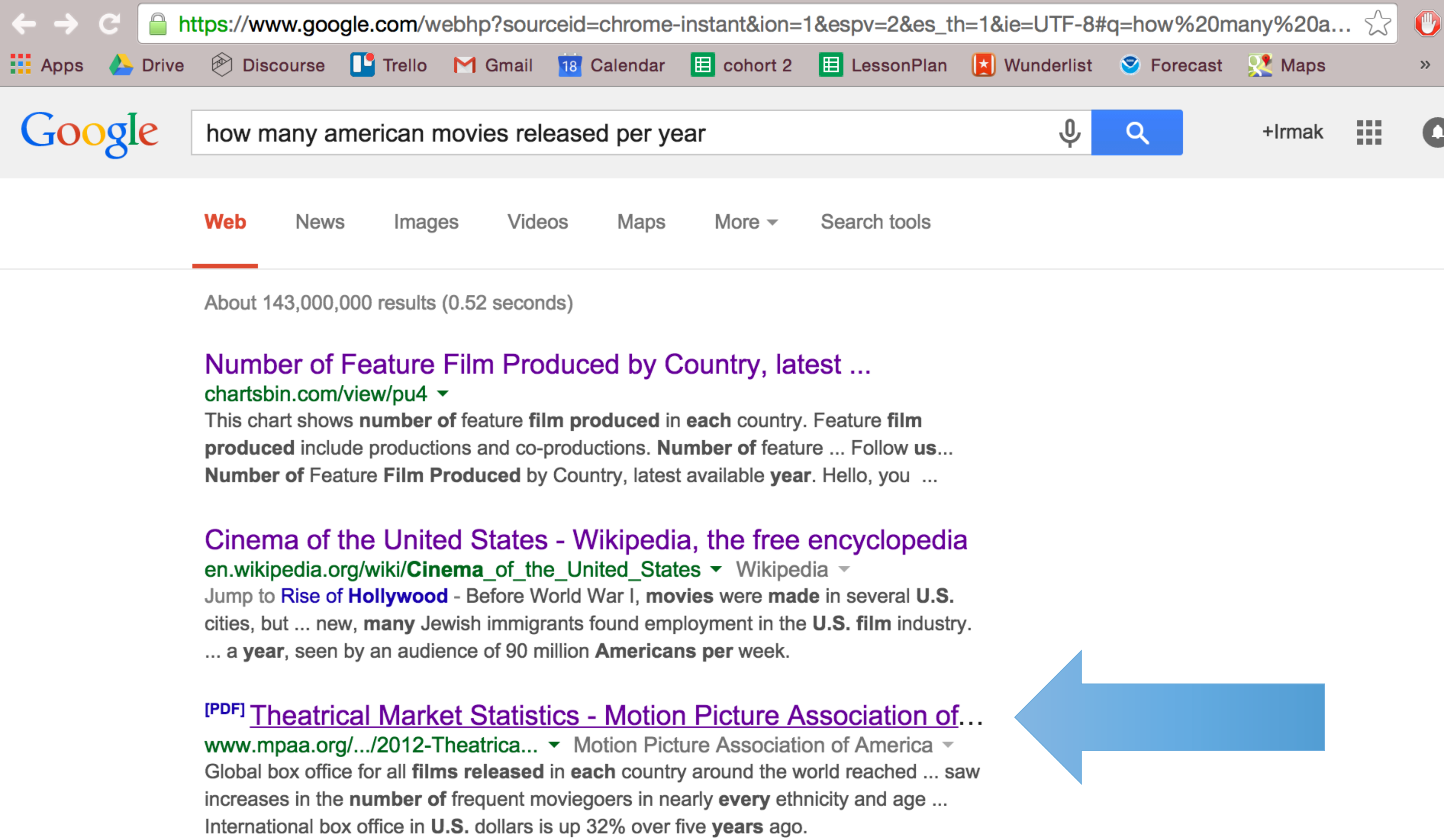
Make Your Pick

- Meryl Streep

P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / # released

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$


https://www.google.com/webhp?sourceid=chrome-instant&ion=1&espv=2&es_th=1&ie=UTF-8#q=how%20many%20a...
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Discourse
Trello
Gmail
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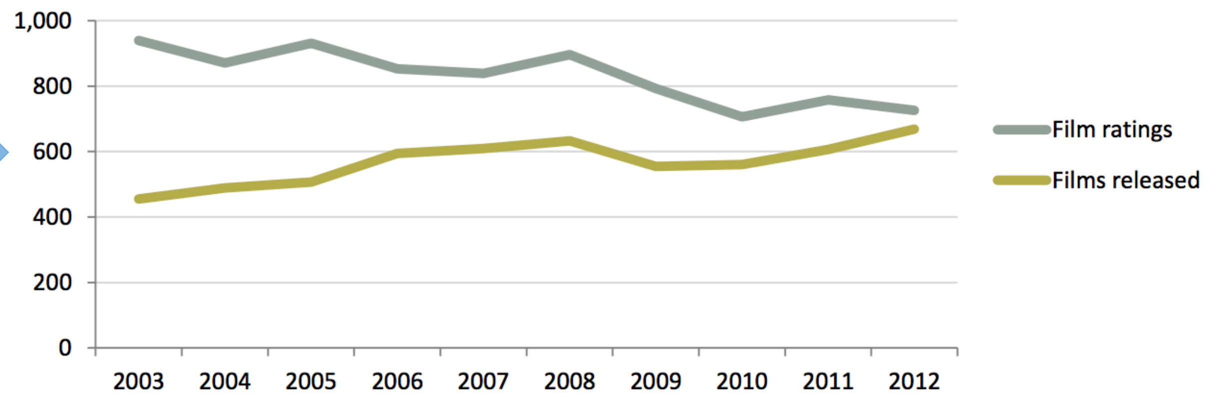
cohort 2
LessonPlan
Wunderlist
Forecast
Maps
Google
how many american movies released per year
+Irmak
Web
News
Images
Videos
Maps
More
Search tools
About 143,000,000 results (0.52 seconds)
Number of Feature Film Produced by Country, latest ...
chartsbin.com/view/pu4
This chart shows number of feature film produced in each country. Feature film produced include productions and co-productions. Number of feature ... Follow us... Number of Feature Film Produced by Country, latest available year. Hello, you ...
Cinema of the United States - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Cinema_of_the_United_States
Wikipedia
Jump to Rise of Hollywood - Before World War I, movies were made in several U.S. cities, but ... new, many Jewish immigrants found employment in the U.S. film industry. ... a year, seen by an audience of 90 million Americans per week.
[PDF] Theatrical Market Statistics - Motion Picture Association of...
www.mpaa.org/.../2012-Theatrica...
Motion Picture Association of America
Global box office for all films released in each country around the world reached ... saw increases in the number of frequent moviegoers in nearly every ethnicity and age ... International box office in U.S. dollars is up 32% over five years ago.

Films rated, released and produced

In 2012, the number of films rated by the Classification and Ratings Administration (CARA) was down 4% compared to 2011. The number of films released in theaters in U.S./Canada was up 10% compared to 2011, and up 5% from the previous historic high in 2008 .

Films Rated by CARA and Films Released in Domestic Theaters

Sources: CARA (Film ratings), Rentrak Corporation (Films released)



Films rated, including non-theatrical films, decreased to 726 films in 2012, with a 4% drop in both member and non-member films rated. MPAA member films rated have been in decline since 2004, mirroring the decline in MPAA member films released in domestic theaters over the same period (see below).

Film Ratings[16]

Source: CARA (Film ratings), MPAA (Subtotals)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	12 vs. 11	12 vs. 03
Film ratings	939	867	928	853	840	897	793	706	758	726	-4%	-23%
-MPAA members[17]	339	325	322	296	233	201	177	174	169	162	-4%	-52%

P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) = 10 / 600

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / 600 = 1.67%

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / 600 = 1.67%

P(Meryl Streep in the movie) = # MS movies / # all

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / 600 = 1.67%

P(Meryl Streep in the movie) = # MS movies / 600

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$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Meryl Streep
74
Actress | Soundtrack | Producer
Considered by many critics to be the greatest living actress, Meryl Streep has been nominated for the Academy Award an astonishing 19 times, and has won it three times. Meryl was born Mary Louise Streep in 1949 in Summit, New Jersey, to Mary Wolf (Wilkinson), a commercial artist, and Harry William Streep, Jr., a pharmaceutical executive. Her ...
See full bio »
Born: Mary Louise Streep
June 22, 1949 in Summit, New Jersey, USA
More at IMDbPro »
Contact Info: View agent, publicist and legal
Represent Meryl Streep? Add or change photos
746 photos | 143 videos | 12608 news articles »
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IMDb What to Watch: Cak
In this episode of What to W
Keith Simanton chats with Je
Aniston about the drama Cak
opens in the U.S. on January
IMDb What to Watch: Cake

www.imdb.com/name/nm0000658/

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Filmography

Show all | Show by... | Edit

Jump to: Actress | Soundtrack | Producer | Thanks | Self | Archive footage

Actress (74 credits)

Hide

Florence Foster Jenkins (*pre-production*) Florence Foster Jenkins	2015
Suffragette (*post-production*) Emmeline Pankhurst	2015
Ricki and the Flash (*post-production*) Ricki	2015
Into the Woods Witch	2014
The Giver Chief Elder	2014
The Homesman Altha Carter	2014
August: Osage County Violet Weston	2013
Hope Springs Kay	2012
Web Therapy (TV Series) Camilla Bowner - Blindsides and Backslides (2012) ... Camilla Bowner - Getting It Straight (2012) ... Camilla Bowner	2012
The Iron Lady Margaret Thatcher	2011

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Prime
Fri Jan. 23 1:45 PM CST on HBO (444)

August: Osage County
Sat Jan. 24 9:00 AM CST on TMC (488

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Projects In Developmen

Master Class

The Good House

The Senator's Wife

www.imdb.com/name/nm0000658/

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Kramer vs. Kramer Joanna Kramer	1979
The Seduction of Joe Tynan Karen Traynor	1979
Great Performances (TV Series) Leilah / Edith Varney - Uncommon Women... and Others (1979) ... Leilah - Secret Service (1977) ... Edith Varney	1977-1979
Manhattan Jill	1979
The Deer Hunter Linda	1978
Holocaust (TV Mini-Series) Inga Helms Weiss - Part 4 (1978) ... Inga Helms Weiss - Part 2 (1978) ... Inga Helms Weiss - Part I: The Gathering Darkness (1978) ... Inga Helms Weiss	1978
Julia Anne Marie	1977
The Deadliest Season (TV Movie) Sharon Miller	1977
Everybody Rides the Carousel Stage 6 (voice)	1975

Soundtrack (13 credits) Show

Producer (1 credit) Show

Thanks (5 credits) Show

Self (223 credits) Show

MS movies

74 movies
In 40 years

1.85
Meryl
Movies
per year
on average

P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / 600 = 1.67%

P(Meryl Streep in the movie) ≈ 1.85 / 600 = 0.3%

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P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / 600 = 1.67%

P(Meryl Streep in the movie) ≈ 1.85 / 600 = 0.3%

P(Meryl Streep in the movie|oscar nomination) =

nominated MS movies / all nominated movies

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / 600 = 1.67%

P(Meryl Streep in the movie) ≈ 1.85 / 600 = 0.3%

P(Meryl Streep in the movie | oscar nomination) =

\# nominated MS movies / 10

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

en.wikipedia.org/wiki/Meryl_Streep

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Meryl Streep

From Wikipedia, the free encyclopedia

Meryl Streep (born **Mary Louise Streep**; June 22, 1949) is an American actress and producer. A three-time Academy Award winner, she is widely regarded as one of the greatest film actors of all time.[1][2][3] Streep made her professional stage debut in *The Playboy of Seville* in 1971, and went on to receive a 1976 Tony Award nomination for Best Featured Actor in a Play for *A Memory of Two Mondays/27 Wagons Full of Cotton*. She made her screen debut in the 1977 television film *The Deadliest Season*, and made her film debut later that same year in *Julia*. In 1978, she won an Emmy Award for her role in the miniseries *Holocaust*, and received the first of her 19 Academy Award nominations for *The Deer Hunter*. She has more Academy Award nomina… …an any actor or actress in history, winning Best Supporting Actress for *Krame… …er* (1979) and Best Actress for *Sophie's Choice* (1982) and *The Iron Lady* (2011).

Streep is one of only six actors who have won three or m… …petitive Academy Awards for acting. Her other nominated roles include *The French L… …'s Woman* (1981), *Silkwood* (1983), *Out of Africa* (1985), *A Cry in the Dark* (198… …ards From the Edge* (1990), *The Bridges of Madison County* (1995), *Adaptation* (20… …*Devil Wears Prada* (2006), *Doubt* (2008), *Julie & Julia* (2009), *August: Osage Count…* …and *Into the Woods* (2014). She returned to the stage for the first time in over 2… …n The Public Theater's 2002 revival of *The Seagull*, won a second Emmy Award i… …r the HBO miniseries *Angels in America* (2003), and starred in the Public Theater… …roduction of

Meryl Streep
Ordre des Arts et des Lettres

Streep at the 2014 SAG Awards.

Born	Mary Louise Streep June 22, 1949 (age 65) Summit, New Jersey, U.S.
Occupation	Actress, producer
Years active	1971–present
Spouse(s)	Don Gummer (1978–present)

19 nominations 40 years → 0.475 nominations per year!

P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / 600 = 1.67%

P(Meryl Streep in the movie) ≈ 1.85 / 600 = 0.3%

P(Meryl Streep in the movie | oscar nomination) =

nominated MS movies / 10

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

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0.475 / 10

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P(Meryl Streep in the movie) ≈ 1.85 / 600 = 0.3%

P(Meryl Streep in the movie | oscar nomination)=4.8%

0.475 / 10

$$P(A \mid B) = \frac{P(B \mid A) P(A)}{P(B)}$$

P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / 600 = 1.67%

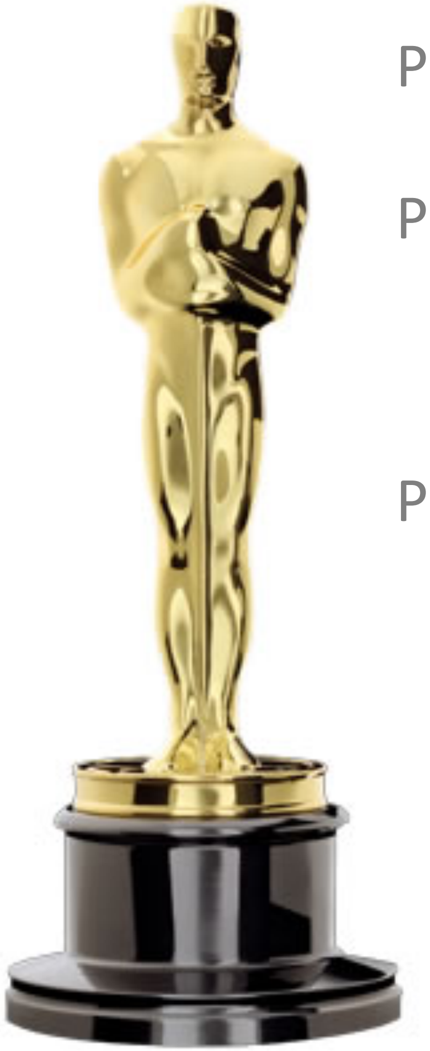
P(Meryl Streep in the movie) ≈ 1.85 / 600 = 0.3%

P(Meryl Streep in the movie|oscar nomination)=4.8%

0.475 / 10

P(nom|MS) = P(MS|nom)P(nom) / P(MS)

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$



P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / 600 = 1.67%

P(Meryl Streep in the movie) ≈ 1.85 / 600 = 0.3%

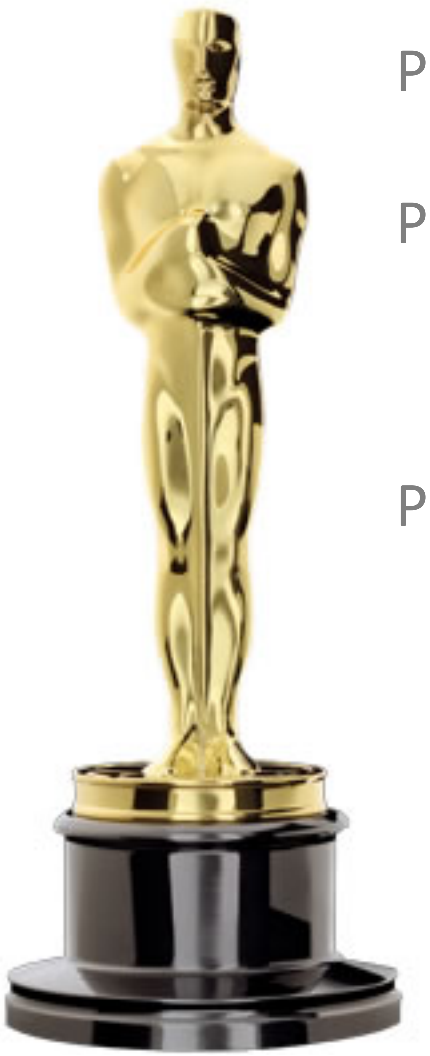
P(Meryl Streep in the movie|oscar nomination)=4.8%

0.475 / 10

P(nom|MS) = P(MS|nom)P(nom) / P(MS)

= 4.8% * 1.67% / 0.3%

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$



P(oscar nomination | Meryl Streep in the movie) = ?

P(oscar nomination) ≈ 10 / 600 = 1.67%

P(Meryl Streep in the movie) ≈ 1.85 / 600 = 0.3%

P(Meryl Streep in the movie|oscar nomination)=4.8%

0.475 / 10

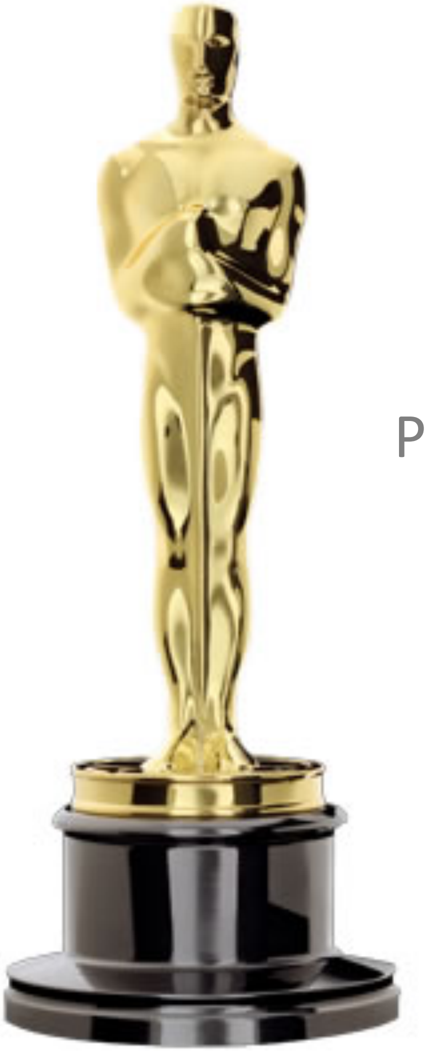
P(nom|MS) = P(MS|nom)P(nom) / P(MS)

= 4.8% * 1.67% / 0.3%

= 25.7%

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

P(oscar nomination | Meryl Streep in the movie) = ?



P(nom|MS) = P(MS|nom)P(nom) / P(MS)

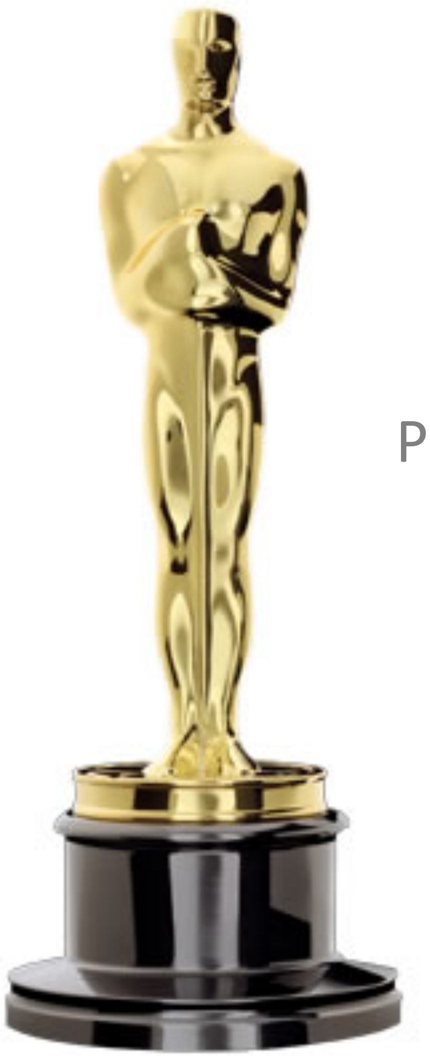
= 4.8% * 1.67% / 0.3%

= 25.7%

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

P(oscar nomination | Meryl Streep in the movie) = ?

= # nominated MS movies / # MS movies

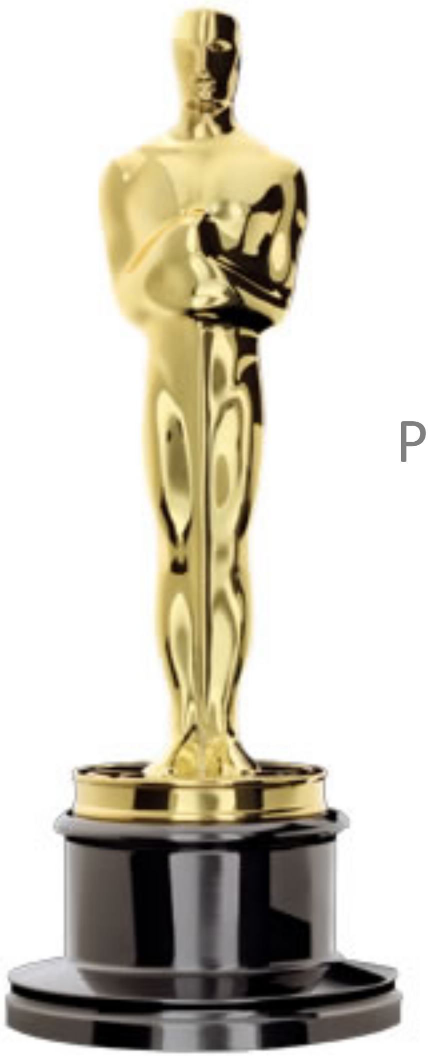


P(nom|MS) = P(MS|nom)P(nom) / P(MS)

= 4.8% * 1.67% / 0.3%

= 25.7%

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$



P(oscar nomination | Meryl Streep in the movie) = ?

= # nominated MS movies / # MS movies

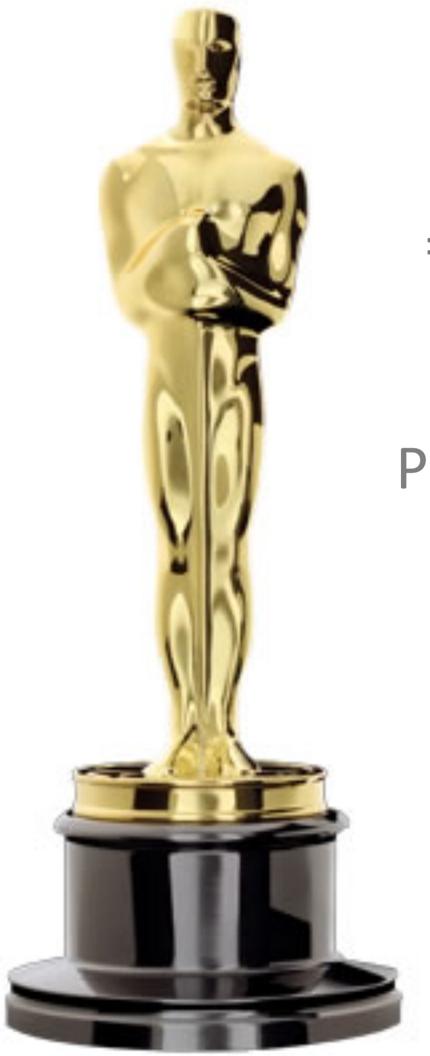
= (0.475 nom per year) / (1.85 MS movies per year)

P(nom|MS) = P(MS|nom)P(nom) / P(MS)

= 4.8% * 1.67% / 0.3%

= 25.7%

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$



P(oscar nomination | Meryl Streep in the movie) = ?

= # nominated MS movies / # MS movies

= (0.475 nom per year) / (1.85 MS movies per year)

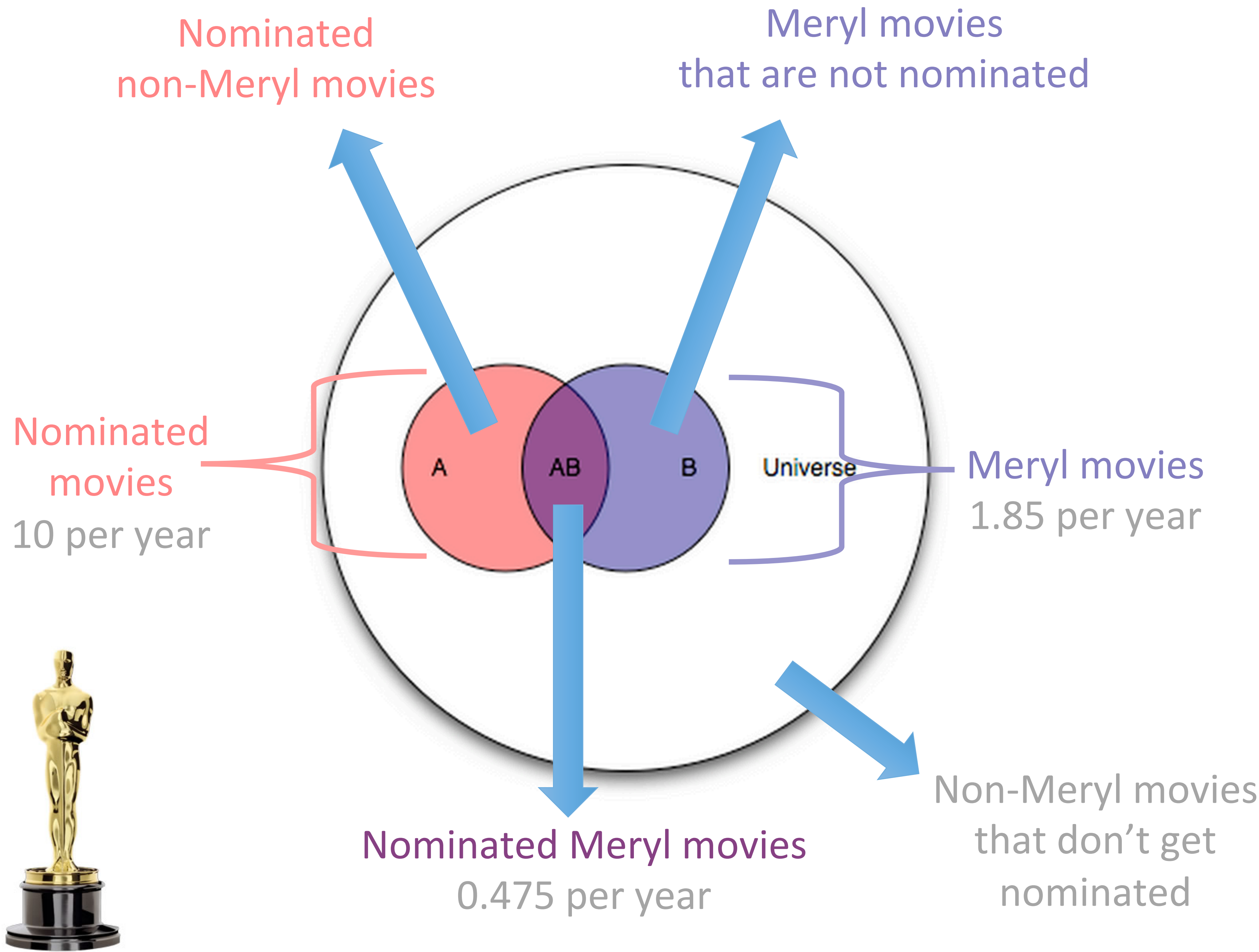
= 0.475 / 1.85 = 25.7%

P(nom|MS) = P(MS|nom)P(nom) / P(MS)

= 4.8% * 1.67% / 0.3%

= 25.7%

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$



Nominated
non-Meryl movies
Meryl movies
that are not nominated
Nominated
movies
10 per year
A
AB
B
Universe
Meryl movies
1.85 per year
Nominated Meryl movies
0.475 per year
Non-Meryl movies
that don't get
nominated

Updating the state of knowledge

step by step

with new information

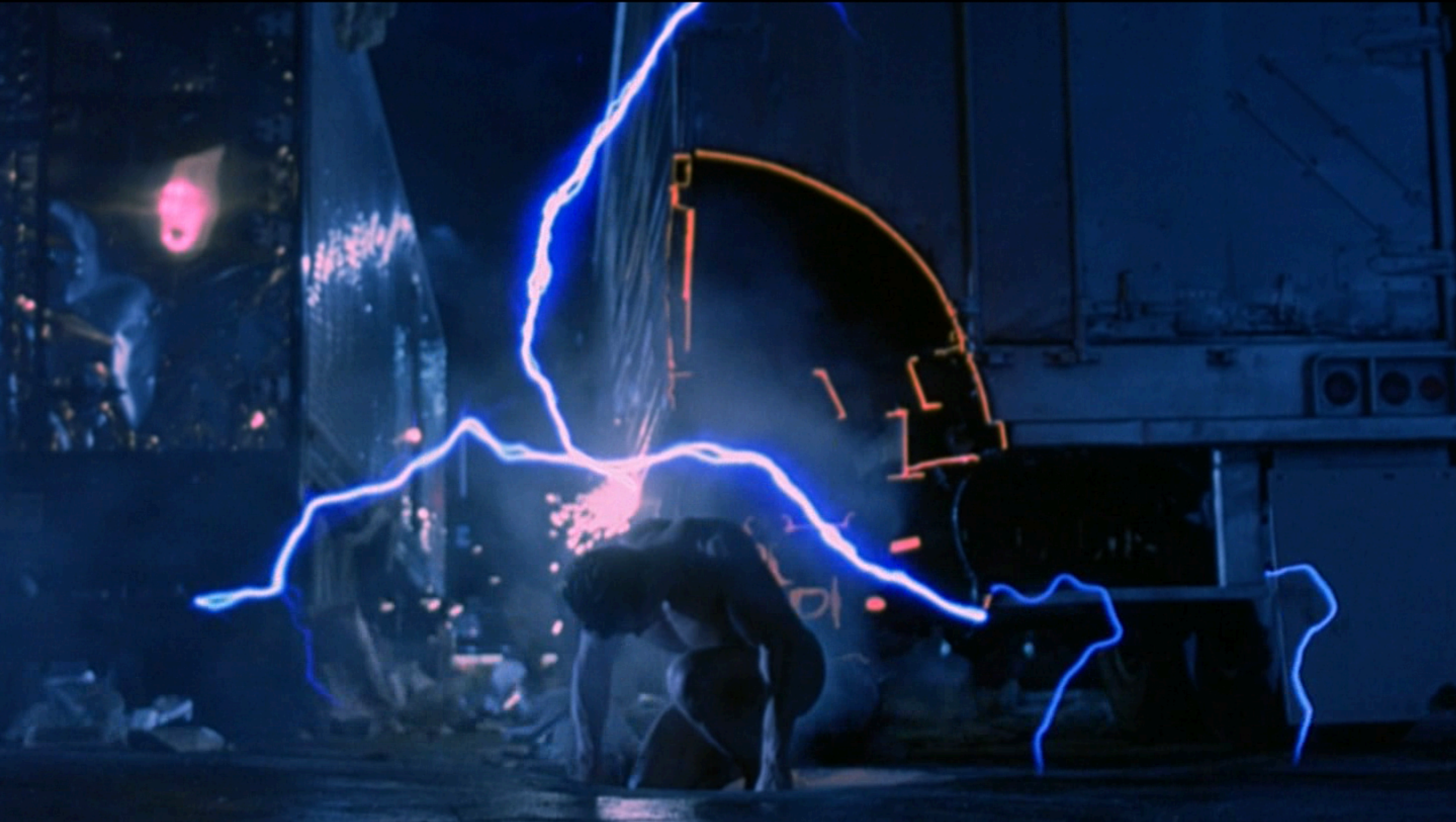
Updating the state of knowledge

step by step

with new information

or

An Introduction to Time Travel



Date Apr. 16, 2015.
Time Unknown.

Date Apr. 16, 2015.
Time Unknown.

I arrived from 2055,
in Union Square subway station.

Date Apr. 16, 2015.
Time Unknown.

I arrived from 2055,
in Union Square subway station.

Between 9 AM and 10 AM today, a scientist will perform an experiment, starting a chain of events resulting in a black hole in NYC.

Date Apr. 16, 2015.
Time Unknown.

I arrived from 2055,
in Union Square subway station.

Between 9 AM and 10 AM today, a scientist will perform an experiment, starting a chain of events resulting in a black hole in NYC.

I've been sent back to stop her.

What time is it? Is it 9 AM?

What time is it? Is it 9 AM?

Time travel technology is only precise enough to target a 24 hour window.

What time is it? Is it 9 AM?

Time travel technology is only precise enough to target a 24 hour window.

Any hour in that 24-hour window is equally likely.

What time is it? Is it 9 AM?

Time travel technology is only precise enough to target a 24 hour window.

Any hour in that 24-hour window is equally likely.

What is my current certainty that it is 9 AM?

What time is it? Is it 9 AM?

Time travel technology is only precise enough to target a 24 hour window.

What is my current certainty that it is 9 AM?

Any hour in that 24-hour window is equally likely.
$P(9AM) = 1/24 = 0.0416$

4.16%
Right
Time

What time is it? Is it 9 AM?

Time travel technology is only precise enough to target a 24 hour window.

What is my current certainty that it is 9 AM?

Any hour in that 24-hour window is equally likely.
P(9AM) = 1/24 = 0.0416

4.16%
Right
Time

What time is it? Is it 9 AM?

Time travel technology is only precise enough to target a 24 hour window.

What is my current certainty that it is 9 AM?

Any hour in that 24-hour window is equally likely.
P(9AM) = 1/24 = 0.0416

I need to gather more information.

4.16%
Right
Time

4.16%
Right
Time

What time is it? Is it 9 AM?

Time travel technology is only precise enough to target a 24 hour window.

What is my current certainty that it is 9 AM?

Any hour in that 24-hour window is equally likely.
P(9AM) = 1/24 = 0.0416

I need to gather more information.

5-Train is approaching. I can see that it is full.
Checking my databanks.....

4.16%
Right
Time

Checking my databanks.....Records found:

4.16% Right Time

Checking my databanks.....Records found:

Between 9 and 10 AM, 5-train is full 70% of the time

4.16%
Right
Time

Checking my databanks.....Records found:

Between 9 and 10 AM, 5-train is full 70% of the time

Other times, it is full 20% of the time on average

4.16%
Right
Time

Checking my databanks.....Records found:
Between 9 and 10 AM, 5-train is full 70% of the time
Other times, it is full 20% of the time on average
$P(\text{5-train full} \mid \text{9AM}) = 0.7$

4.16%
Right
Time

Checking my databanks.....Records found:
Between 9 and 10 AM, 5-train is full 70% of the time
Other times, it is full 20% of the time on average
P(5-train full | 9AM) = 0.7

My current certainty, **prior** to the new information, is
P(9AM) = 0.0416

4.16%
Right
Time

Checking my databanks.....Records found:
Between 9 and 10 AM, 5-train is full 70% of the time
Other times, it is full 20% of the time on average

$P(\text{5-train full} \mid \text{9AM}) = 0.7$

My current certainty, **prior** to the new information, is

$P(\text{9AM}) = 0.0416$

$$P(\text{5-train full}) = P(\text{5-train full} \mid \text{9AM})\, P(\text{9AM}) + P(\text{5-train full} \mid \text{not 9AM})\, P(\text{not 9AM})$$

4.16%
Right
Time

Checking my databanks.....Records found:
Between 9 and 10 AM, 5-train is full 70% of the time
Other times, it is full 20% of the time on average

$P(\text{5-train full} \mid \text{9AM}) = 0.7$

My current certainty, **prior** to the new information, is

$P(\text{9AM}) = 0.0416$

$$
\begin{aligned}
P(\text{5-train full}) &= P(\text{5-train full} \mid \text{9AM})\, P(\text{9AM}) \\
&\quad + P(\text{5-train full} \mid \text{not 9AM})\, P(\text{not 9AM}) \\
&= 0.7 * 0.0416 + 0.2 * (1 - 0.0416) \\
&= 0.2208
\end{aligned}
$$

4.16% Right Time

$P(\text{5-train full} \mid \text{9AM}) = 0.7$

$P(\text{5-train full}) = 0.2208$

$P(\text{9AM}) = 0.0416$

4.16%
Right
Time

$P(\text{5-train full} \mid \text{9AM}) = 0.7$
$P(\text{5-train full}) = 0.2208$
$P(\text{9AM}) = 0.0416$

$$P(\text{9AM} \mid \text{5-train full}) = \frac{P(\text{5-train full} \mid \text{9AM})\ P(\text{9AM})}{P(\text{5-train full})}$$

4.16%
Right
Time

$P(\text{5-train full} \mid \text{9AM}) = 0.7$

$P(\text{5-train full}) = 0.2208$

$P(\text{9AM}) = 0.0416$

$$\underbrace{P(\text{9AM} \mid \text{5-train full})}_{\text{updated}} = \frac{P(\text{5-train full} \mid \text{9AM})\ \overbrace{P(\text{9AM})}^{\text{current}}}{P(\text{5-train full})}$$

4.16%
Right
Time

$P(\text{5-train full} \mid \text{9AM}) = 0.7$
$P(\text{5-train full}) = 0.2208$
$P(\text{9AM}) = 0.0416$

$$P(\text{9AM} \mid \text{5-train full}) = \frac{0.7 \quad * \quad 0.0416}{0.2208}$$

13.19%
Right
Time

$P(\text{5-train full} \mid \text{9AM}) = 0.7$

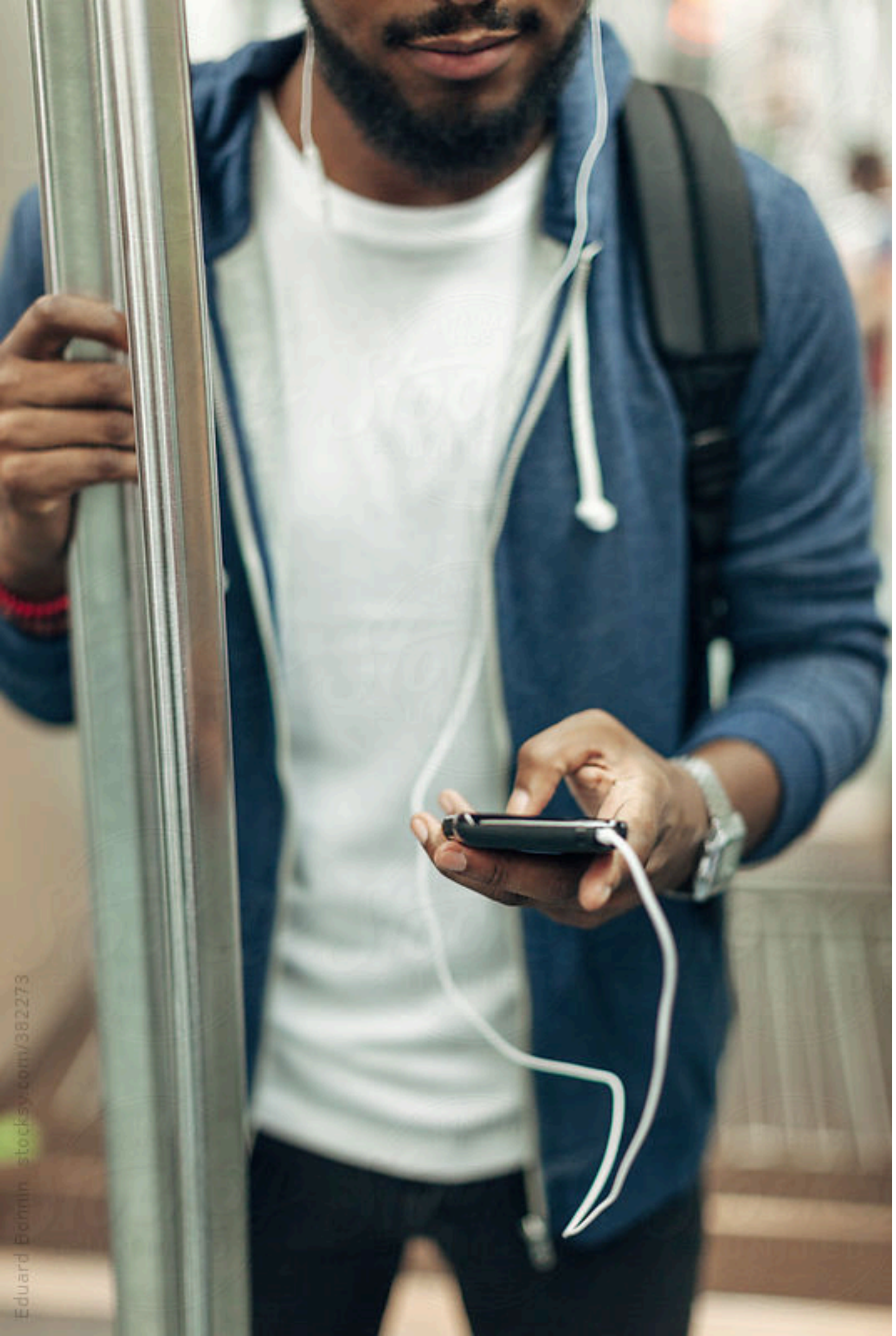
$P(\text{5-train full}) = 0.2208$

$P(\text{9AM}) = 0.0416$

$P(\text{9AM} \mid \text{5-train full}) = 0.1319$

13.19%
Right
Time

My current certainty is 13.19%.
I need to gather more information.



13.19%
Right
Time

13.19%
Right
Time

My current certainty is 13.19%.
I need to gather more information.

Train doors open. I can hear someone's radio.
It's NPR News, live.

My current certainty is 13.19%.
I need to gather more information.

Train doors open. I can hear someone's radio.
It's NPR News, live.
Checking database……

13.19%
Right
Time

My current certainty is 13.19%.
I need to gather more information.

Train doors open. I can hear someone's radio.
It's NPR News.
Checking database……Records found:
NPR News is broadcast 3 times during the day:
9AM-10AM, 1PM-2PM, 7PM-8PM.

13.19%
Right
Time

My current certainty is 13.19%.
I need to gather more information.

Train doors open. I can hear someone's radio.
It's NPR News.
Checking database......Records found:
NPR News is broadcast 3 times during the day:
9AM-10AM, 1PM-2PM, 7PM-8PM.
P(News | 9AM) = 1.0
P(News | not 9AM) = 2 / 23 = 0.087

13.19%
Right
Time

My current certainty is 13.19%.
I need to gather more information.

Train doors open. I can hear someone's radio.
It's NPR News.
Checking database……Records found:
NPR News is broadcast 3 times during the day:
9AM-10AM, 1PM-2PM, 7PM-8PM.
P(News | 9AM, 5tf) = 1.0
P(News | not 9AM, 5tf) = 2 / 23 = 0.087

13.19%
Right
Time

My current certainty is 13.19%.
I need to gather more information.

Train doors open. I can hear someone's radio.
It's NPR News.
Checking database......Records found:
NPR News is broadcast 3 times during the day:
9AM-10AM, 1PM-2PM, 7PM-8PM.

P(News | 9AM, 5tf) = 1.0

P(News | not 9AM, 5tf) = 2 / 23 = 0.087

P(9AM | 5tf) = 0.1319

13.19%
Right
Time

My current certainty is 13.19%.
I need to gather more information.

Train doors open. I can hear someone's radio.
It's NPR News.
Checking database……Records found:
NPR News is broadcast 3 times during the day:
9AM-10AM, 1PM-2PM, 7PM-8PM.

$P(\text{News} \mid \text{9AM}, \text{5tf}) = 1.0$

$P(\text{News} \mid \text{not 9AM}, \text{5tf}) = 2 / 23 = 0.087$

$P(\text{9AM} \mid \text{5tf}) = 0.1319$

$$P(\text{News} \mid \text{5tf}) = P(\text{News}, \text{9AM} \mid \text{5tf}) + P(\text{News}, \text{not 9AM} \mid \text{5tf})$$

13.19%
Right
Time

My current certainty is 13.19%.
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Train doors open. I can hear someone's radio.
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$P(\text{News} \mid \text{9AM, 5tf}) = 1.0$

$P(\text{News} \mid \text{not 9AM, 5tf}) = 2 / 23 = 0.087$

$P(\text{9AM} \mid \text{5tf}) = 0.1319$

$$P(\text{News} \mid \text{5tf}) = P(\text{News} \mid \text{9AM, 5tf})P(\text{9AM} \mid \text{5tf}) + P(\text{News} \mid \text{not 9AM, 5tf})P(\text{not 9AM} \mid \text{5tf})$$

13.19%
Right
Time

My current certainty is 13.19%.
I need to gather more information.

Train doors open. I can hear someone's radio.
It's NPR News.
Checking database......Records found:
NPR News is broadcast 3 times during the day:
9AM-10AM, 1PM-2PM, 7PM-8PM.

$P(\text{News} \mid 9\text{AM}, 5\text{tf}) = 1.0$

$P(\text{News} \mid \text{not } 9\text{AM}, 5\text{tf}) = 2 / 23 = 0.087$

$P(9\text{AM} \mid 5\text{tf}) = 0.1319$

$$\begin{aligned} P(\text{News} \mid 5\text{tf}) &= P(\text{News} \mid 9\text{AM}, 5\text{tf}) P(9\text{AM} \mid 5\text{tf}) \\ &\quad + P(\text{News} \mid \text{not } 9\text{AM}, 5\text{tf}) P(\text{not } 9\text{AM} \mid 5\text{tf}) \\ &= 1.0 * 0.1319 + 0.087 * (1 - 0.1319) \\ &= 0.2074 \end{aligned}$$

13.19%
Right
Time

$P(\text{News} \mid \text{5tf}) = 0.2074$

$P(\text{News} \mid \text{9AM}, \text{5tf}) = P(\text{News} \mid \text{9AM}) = 1.0$

$P(\text{9AM} \mid \text{5tf}) = 0.1319$

13.19%
Right
Time

$P(News|5tf) = 0.2074$

$P(News\ |9AM,5tf) = P(News\ |9AM) = 1.0$

$P(9AM|5tf) = 0.1319$

$$P(9AM|News,5tf) = \frac{P(News|9AM,5tf)\ P(9AM|5tf)}{P(News|5tf)}$$

13.19%
Right
Time

$P(\text{News} \mid \text{5tf}) = 0.2074$
$P(\text{News} \mid \text{9AM}, \text{5tf}) = P(\text{News} \mid \text{9AM}) = 1.0$
$P(\text{9AM} \mid \text{5tf}) = 0.1319$

$$P(\text{9AM} \mid \text{News}, \text{5tf}) = \frac{1.0 \quad * \quad 0.1319}{0.2074}$$

63.59%
Right Time

$P(\text{News} \mid \text{5tf}) = 0.2074$

$P(\text{News} \mid \text{9AM}, \text{5tf}) = P(\text{News} \mid \text{9AM}) = 1.0$

$P(\text{9AM} \mid \text{5tf}) = 0.1319$

$P(\text{9AM} \mid \text{News}, \text{5tf}) = 0.6359$

63.59%
Right
Time

My current certainty is 63.59%.
I need to gather more information.

63.59%
Right
Time

My current certainty is 63.59%.
I need to gather more information.

I'll ask this person. "What time is it?"

63.59%
Right
Time

63.59%
Right
Time

My current certainty is 63.59%.
I need to gather more information.

I'll ask this person. "What time is it?"
He says "It's nine."

63.59%
Right
Time

My current certainty is 63.59%.
I need to gather more information.

I'll ask this person. "What time is it?"
He says "It's nine."
Loading human interactions model……..

63.59%
Right
Time

My current certainty is 63.59%.
I need to gather more information.

I'll ask this person. "What time is it?"
He says "It's nine."
Loading human interactions model........
$P(\text{"Nine"} \mid 9AM) = 0.96$ (watch may be broken, etc.)

63.59%
Right
Time

My current certainty is 63.59%.
I need to gather more information.

I'll ask this person. "What time is it?"
He says "It's nine."
Loading human interactions model........
P("Nine" | 9AM) = 0.96 (watch may be broken, etc.)
P("Nine" | not 9AM) = 1/23 = 0.043 (9 PM -> "Nine")

63.59%
Right
Time

My current certainty is 63.59%.
I need to gather more information.

I'll ask this person. "What time is it?"
He says "It's nine."
Loading human interactions model........
P("Nine"|9AM,N,5tf) = 0.96 (watch may be broken, etc.)
P("Nine"|not 9AM,N,5tf) = 1/23 = 0.043 (9 PM -> "Nine")

63.59%
Right
Time

My current certainty is 63.59%.
I need to gather more information.

I'll ask this person. "What time is it?"
He says "It's nine."
Loading human interactions model........
P("Nine"|9AM, N,5tf) = 0.96 (watch may be broken, etc.)
P("Nine"|not 9AM, N,5tf) = 1/23 = 0.043 (9 PM -> "Nine")

P(9AM|N,5tf)= 0.6359

63.59%
Right
Time

My current certainty is 63.59%.
I need to gather more information.

I'll ask this person. "What time is it?"
He says "It's nine."
Loading human interactions model........

P("Nine"|9AM, N,5tf) = 0.96 (watch may be broken, etc.)

P("Nine"|not 9AM, N,5tf) = 1/23 = 0.043 (9 PM -> "Nine")

P(9AM|N,5tf)= 0.6359

P("Nine"|N,5tf) = P("Nine"|9AM,N,5tf)P(9AM|N,5tf)
+ P("Nine"|not 9AM,N,5tf)P(not 9AM|N,5tf)

63.59%
Right
Time

My current certainty is 63.59%.
I need to gather more information.

I'll ask this person. "What time is it?"
He says "It's nine."
Loading human interactions model........

P("Nine"|9AM, N,5tf) = 0.96 (watch may be broken, etc.)

P("Nine"|not 9AM, N,5tf) = 1/23 = 0.043 (9 PM -> "Nine")

P(9AM|N,5tf)= 0.6359

P("Nine"|N,5tf) = P("Nine"|9AM,N,5tf)P(9AM|N,5tf)
+ P("Nine"|not 9AM,N,5tf)P(not 9AM|N,5tf)
= 0.96 * 0.6359 + 0.043 * (1 - 0.6359)
= 0.6261

63.59%
Right
Time

$P(\text{"Nine"} \mid N, 5tf) = 0.6261$

$P(\text{"Nine"} \mid 9AM, N, 5tf) = P(\text{"Nine"} \mid 9AM) = 0.96$

$P(9AM \mid N, 5tf) = 0.6359$

63.59%
Right
Time

$P(\text{“Nine”} \mid N, 5tf) = 0.6261$

$P(\text{“Nine”} \mid 9AM, N, 5tf) = P(\text{“Nine”} \mid 9AM) = 0.96$

$P(9AM \mid N, 5tf) = 0.6359$

$$P(9AM \mid \text{“Nine”}, N, 5tf) = \frac{P(\text{“Nine”} \mid 9AM, N, 5tf)\, P(9AM \mid N, 5tf)}{P(\text{“Nine”} \mid N, 5tf)}$$

63.59%
Right
Time

$P(\text{"Nine"} \mid N, 5tf) = 0.6261$

$P(\text{"Nine"} \mid 9AM, N, 5tf) = P(\text{"Nine"} \mid 9AM) = 0.96$

$P(9AM \mid N, 5tf) = 0.6359$

$$P(9AM \mid \text{"Nine"}, N, 5tf) = \frac{0.96 \quad * \quad 0.6359}{0.6261}$$

97.5%
Right
Time

$P(\text{"Nine"} \mid N, 5tf) = 0.6261$

$P(\text{"Nine"} \mid 9AM, N, 5tf) = P(\text{"Nine"} \mid 9AM) = 0.96$

$P(9AM \mid N, 5tf) = 0.6359$

$P(9AM \mid \text{"Nine"}, N, 5tf) = 0.975$

97.5%
Right
Time

My latest posterior is 97.5%.

My latest posterior is 97.5%.

I am now sufficiently certain that I arrived at the right time.

97.5%
Right
Time

97.5%
Right
Time

My latest posterior is 97.5%.

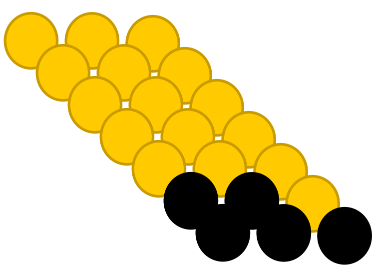
I am now sufficiently certain that I arrived at the right time.

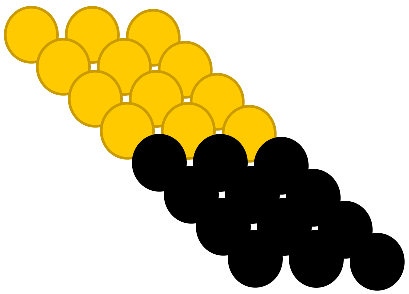
Time to kill a scientist.

The Cookie Problem

Bowl 1

Bowl 2






Which
Bowl?

Our time traveler had two hypotheses

H_1 : It is 9 AM (9 to 10)
H_2 : It is **not** 9 AM

Our time traveler had two hypotheses

H_1 : It is 9 AM (9 to 10)
H_2 : It is **not** 9 AM

At first,
$P(H_1) = P(9AM) = 4.16\%$
$P(H_2) = P(\text{not } 9AM) = 95.83\%$

Our time traveler had two hypotheses

H_1 : It is 9 AM (9 to 10)

H_2 : It is **not** 9 AM

At first,

$P(H_1) = P(9AM) = 4.16\%$

$P(H_2) = P(\text{not } 9AM) = 95.84\%$

Updates with new information

Our time traveler had two hypotheses

H_1 : It is 9 AM (9 to 10)
H_2 : It is **not** 9 AM

At first,
$P(H_1) = P(9AM) = 4.16\%$
$P(H_2) = P(\text{not } 9AM) = 95.84\%$

Updates with new information

In the end,
$P(H_1) = P(9AM \mid \text{“Nine”}, N, 5tf) = 97.5\%$
$P(H_2) = P(\text{not } 9AM \mid \text{“Nine”}, N, 5tf) = 2.5\%$

Cookie problem also has two hypotheses

H_1 : It is Bowl 1

H_2 : It is Bowl 2

Cookie problem also has two hypotheses

H_1 : It is Bowl 1
H_2 : It is Bowl 2

At first,
$P(H_1) = P(\text{Bowl 1}) = 50\%$
$P(H_2) = P(\text{Bowl 2}) = 50\%$

Cookie problem also has two hypotheses

H_1 : It is Bowl 1

H_2 : It is Bowl 2

At first,

P(H_1) = P(Bowl 1) = 50%

P(H_2) = P(Bowl 2) = 50%

Update with one cookie information: **Vanilla**

P(Bowl 1 | Vanilla) = ?

Cookie problem also has two hypotheses

H_1 : It is Bowl 1

H_2 : It is Bowl 2

At first,

P(H_1) = P(Bowl 1) = 50%

P(H_2) = P(Bowl 2) = 50%

Update with one cookie information: **Vanilla**

P(Bowl 1 | Vanilla) = ?

P(Bowl 2 | Vanilla) = 1 - P(Bowl 1 | Vanilla) = ?

Prior:

P(Bowl 1) = 50%

Prior:

P(Bowl 1) = 50%

Likelihood:

P(Vanilla | Bowl 1) = # vanilla / # all bowl 1

Prior:

P(Bowl 1) = 50%

Likelihood:

P(Vanilla | Bowl 1) = 30 / 40 = 0.75

Prior:

P(Bowl 1) = 50%

P(Bowl 2) = 50%

Likelihood:

P(Vanilla | Bowl 1) = 30 / 40 = 0.75

P(Vanilla | Bowl 2) = 20 / 40 = 0.50

Prior:

P(Bowl 1) = 50%

P(Bowl 2) = 50%

Likelihood:

P(Vanilla | Bowl 1) = 30 / 40 = 0.75

P(Vanilla | Bowl 2) = 20 / 40 = 0.50

Evidence:

P(Vanilla) = P(Vanilla|Bowl 1)P(Bowl 1)
+ P(Vanilla|Bowl 2)P(Bowl 2)

Prior:

P(Bowl 1) = 50%

P(Bowl 2) = 50%

Likelihood:

P(Vanilla | Bowl 1) = 30 / 40 = 0.75

P(Vanilla | Bowl 2) = 20 / 40 = 0.50

Evidence:

P(Vanilla) = P(Vanilla|Bowl 1)P(Bowl 1)

+ P(Vanilla|Bowl 2)P(Bowl 2)

= 0.75 * 0.50 + 0.50 * 0.50

= 0.625

P(Bowl 1) = 0.50

P(Vanilla | Bowl 1) = 0.75

P(Vanilla) = 0.625

$P(\text{Bowl 1}) = 0.50$
$P(\text{Vanilla} \mid \text{Bowl 1}) = 0.75$
$P(\text{Vanilla}) = 0.625$

$$P(\text{Bowl 1} \mid \text{Vanilla}) = \frac{P(\text{Vanilla} \mid \text{Bowl 1})\ P(\text{Bowl 1})}{P(\text{Vanilla})}$$

$P(\text{Bowl 1}) = 0.50$

$P(\text{Vanilla} \mid \text{Bowl 1}) = 0.75$

$P(\text{Vanilla}) = 0.625$

$$P(\text{Bowl 1} \mid \text{Vanilla}) = \frac{0.75 \quad * \quad 0.50}{0.625}$$

$P(\text{Bowl 1}) = 0.50$

$P(\text{Vanilla} \mid \text{Bowl 1}) = 0.75$

$P(\text{Vanilla}) = 0.625$

$$P(\text{Bowl 1} \mid \text{Vanilla}) = 0.6$$

$P(\text{Bowl 1}) = 0.50$

$P(\text{Vanilla} \mid \text{Bowl 1}) = 0.75$

$P(\text{Vanilla}) = 0.625$

$P(\text{Bowl 1} \mid \text{Vanilla}) = 0.6$

$P(\text{Bowl 2} \mid \text{Vanilla}) = 1 - 0.6 = 0.4$

$P(\text{Bowl 1}) = 0.50$

$P(\text{Vanilla} \mid \text{Bowl 1}) = 0.75$

$P(\text{Vanilla}) = 0.625$

$P(\text{Bowl 1} \mid \text{Vanilla}) = 0.6$

$P(\text{Bowl 2} \mid \text{Vanilla}) = 0.4$

I can get more information by eating another cookie!

Update 2

(An excuse to eat more cookies)

Prior:

P(Bowl 1) = 0.6

Prior:

P(Bowl 1) = 0.6

Likelihood:

P(Vanilla | Bowl 1) = 29 / 39 = 0.7436

Prior:

P(Bowl 1) = 0.6

P(Bowl 2) = 0.4

Likelihood:

P(Vanilla | Bowl 1) = 29 / 39 = 0.7436

P(Vanilla | Bowl 2) = 19 / 39 = 0.4872

Prior:

P(Bowl 1) = 0.6

P(Bowl 2) = 0.4

Likelihood:

P(Vanilla | Bowl 1) = 29 / 39 = 0.7436

P(Vanilla | Bowl 2) = 19 / 39 = 0.4872

Evidence:

P(Vanilla) = P(Vanilla|Bowl 1)P(Bowl 1)

+ P(Vanilla|Bowl 2)P(Bowl 2)

= 0.7436 * 0.6 + 0.4872 * 0.4

= 0.641

$P(\text{Bowl 1}) = 0.6$

$P(\text{Vanilla} \mid \text{Bowl 1}) = 0.7436$

$P(\text{Vanilla}) = 0.641$

P(Bowl 1) = 0.6
P(Vanilla | Bowl 1) = 0.7436
P(Vanilla) = 0.641

$$P(\text{Bowl 1} \mid \text{Vanilla}) = \frac{P(\text{Vanilla} \mid \text{Bowl 1})\ P(\text{Bowl 1})}{P(\text{Vanilla})}$$

P(Bowl 1) = 0.6
P(Vanilla | Bowl 1) = 0.7436
P(Vanilla) = 0.641

$$P(\text{Bowl 1} \mid \text{Vanilla}) = \frac{0.7436 \quad * \quad 0.6}{0.641}$$

P(Bowl 1) = 0.6
P(Vanilla | Bowl 1) = 0.7436
P(Vanilla) = 0.641

P(Bowl 1 | Vanilla) = 0.696

$P(\text{Bowl 1}) = 0.6$

$P(\text{Vanilla} \mid \text{Bowl 1}) = 0.7436$

$P(\text{Vanilla}) = 0.641$

$P(\text{Bowl 1} \mid \text{Vanilla}) = 0.696$

$P(\text{Bowl 2} \mid \text{Vanilla}) = 0.304$

Update 3
(MOAR COOKIEEEEES)

Prior:

$P(\text{Bowl 1}) = 0.696$

$P(\text{Bowl 2}) = 0.304$

Likelihood:

$P(\text{Chocolate} \mid \text{Bowl 1}) = 10 / 38 = 0.2632$

$P(\text{Chocolate} \mid \text{Bowl 2}) = 20 / 38 = 0.5263$

Evidence:

$$\begin{aligned} P(\text{Chocolate}) &= P(\text{Chocolate} \mid \text{Bowl 1})P(\text{Bowl 1}) \\ &\quad + P(\text{Chocolate} \mid \text{Bowl 2})P(\text{Bowl 2}) \\ &= 0.2632 * 0.696 + 0.5263 * 0.304 \\ &= 0.343 \end{aligned}$$

P(Bowl 1) = 0.696
P(Chocolate | Bowl 1) = 0.2632
P(Chocolate) = 0.343

$$P(\text{Bowl 1} \mid \text{Chocolate}) = \frac{P(\text{Chocolate} \mid \text{Bowl 1})\ P(\text{Bowl 1})}{P(\text{Chocolate})}$$

P(Bowl 1) = 0.696

P(Chocolate | Bowl 1) = 0.2632

P(Chocolate) = 0.343

$$P(\text{Bowl 1} \mid \text{Chocolate}) = \frac{0.2632 \ * \ 0.696}{0.343}$$

$P(\text{Bowl 1}) = 0.696$

$P(\text{Chocolate} \mid \text{Bowl 1}) = 0.2632$

$P(\text{Chocolate}) = 0.343$

$P(\text{Bowl 1} \mid \text{Chocolate}) = 0.5338$

$P(\text{Bowl 1}) = 0.696$

$P(\text{Chocolate} \mid \text{Bowl 1}) = 0.2632$

$P(\text{Chocolate}) = 0.343$

$P(\text{Bowl 1} \mid \text{Chocolate}) = 0.5338$

$P(\text{Bowl 2} \mid \text{Chocolate}) = 0.4662$

P(Bowl 1) = 0.696
P(Chocolate | Bowl 1) = 0.2632
P(Chocolate) = 0.343

P(Bowl 1 | Chocolate) = 0.5338
P(Bowl 2 | Chocolate) = 0.4662

After eating Vanilla, Vanilla, Chocolate,
I am **53.38%** certain that this is Bowl 1.
(So basically I have no idea, I'll have to eat all cookies)

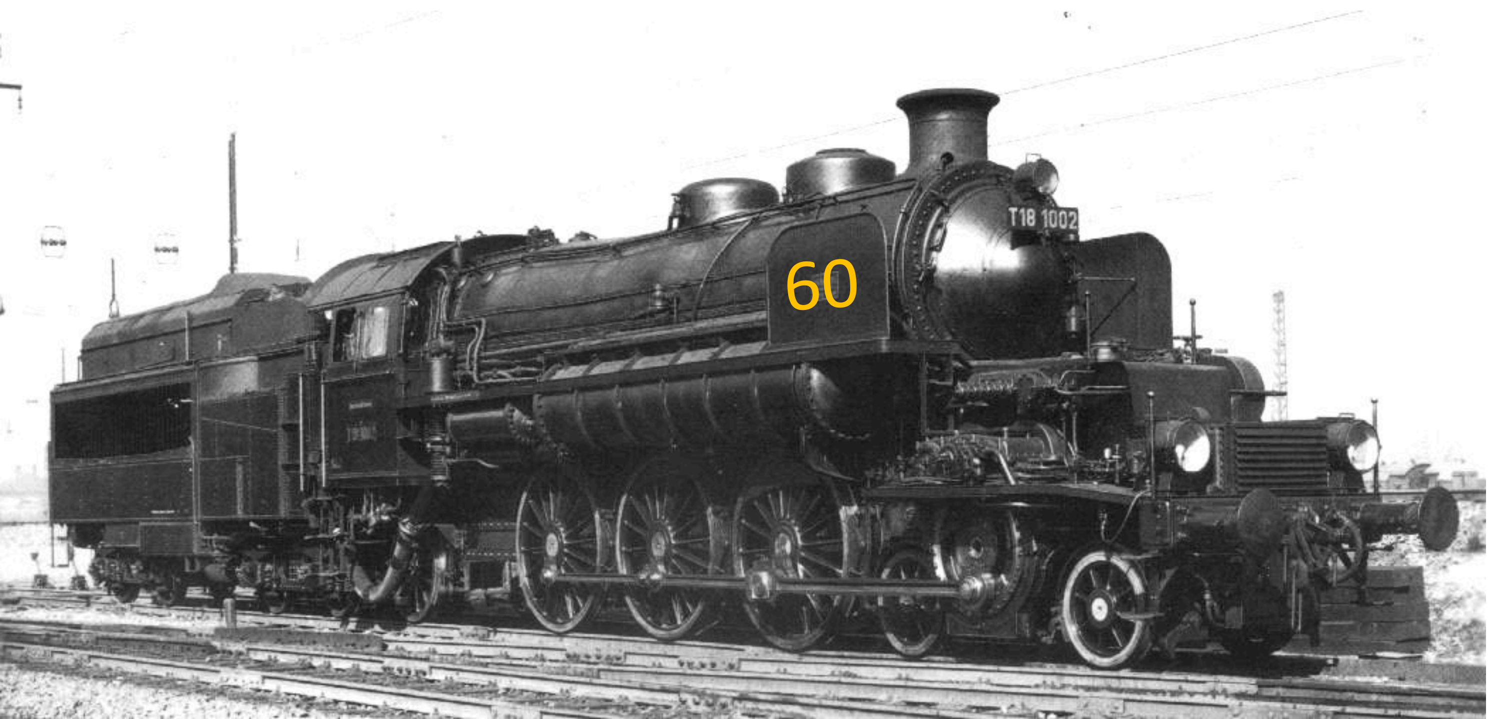
The Locomotive Problem

Choo choo, baby

A railroad numbers its locomotives in order 1......N.

One day you see a locomotive with the number 60.

Estimate how many locomotives the railroad has.



H_1 : There is 1 train

H_2 : There are 2 trains

H_3 : There are 3 trains

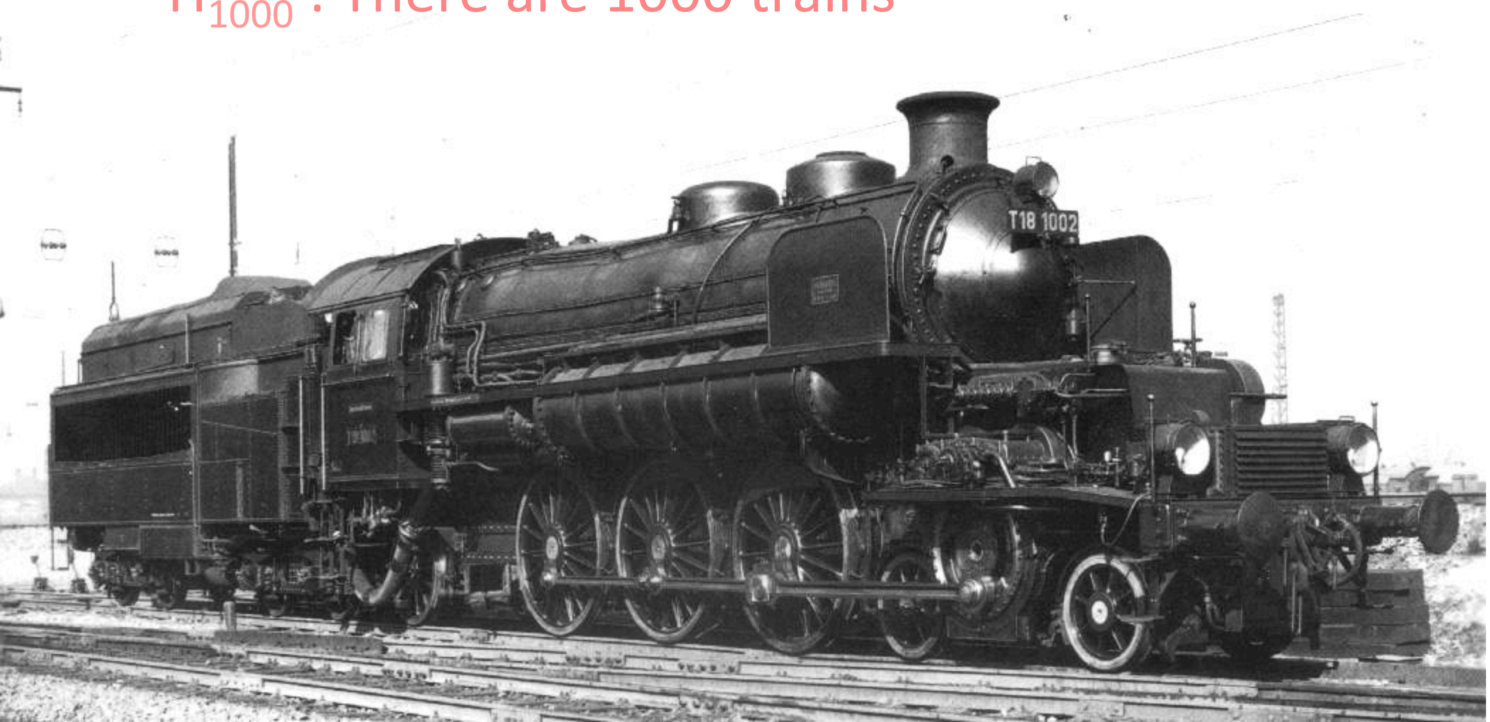
H_4 : There are 4 trains

.

.

.

H_{1000} : There are 1000 trains



H_1 : There is 1 train 0.1%

H_2 : There are 2 trains 0.1%

H_3 : There are 3 trains 0.1%

…

H_{200} : There are 200 trains 0.1%

…

H_{1000} : There are 1000 trains 0.1%

H_1 : There is 1 train 0.1%

H_2 : There are 2 trains 0.1%

H_3 : There are 3 trains 0.1%

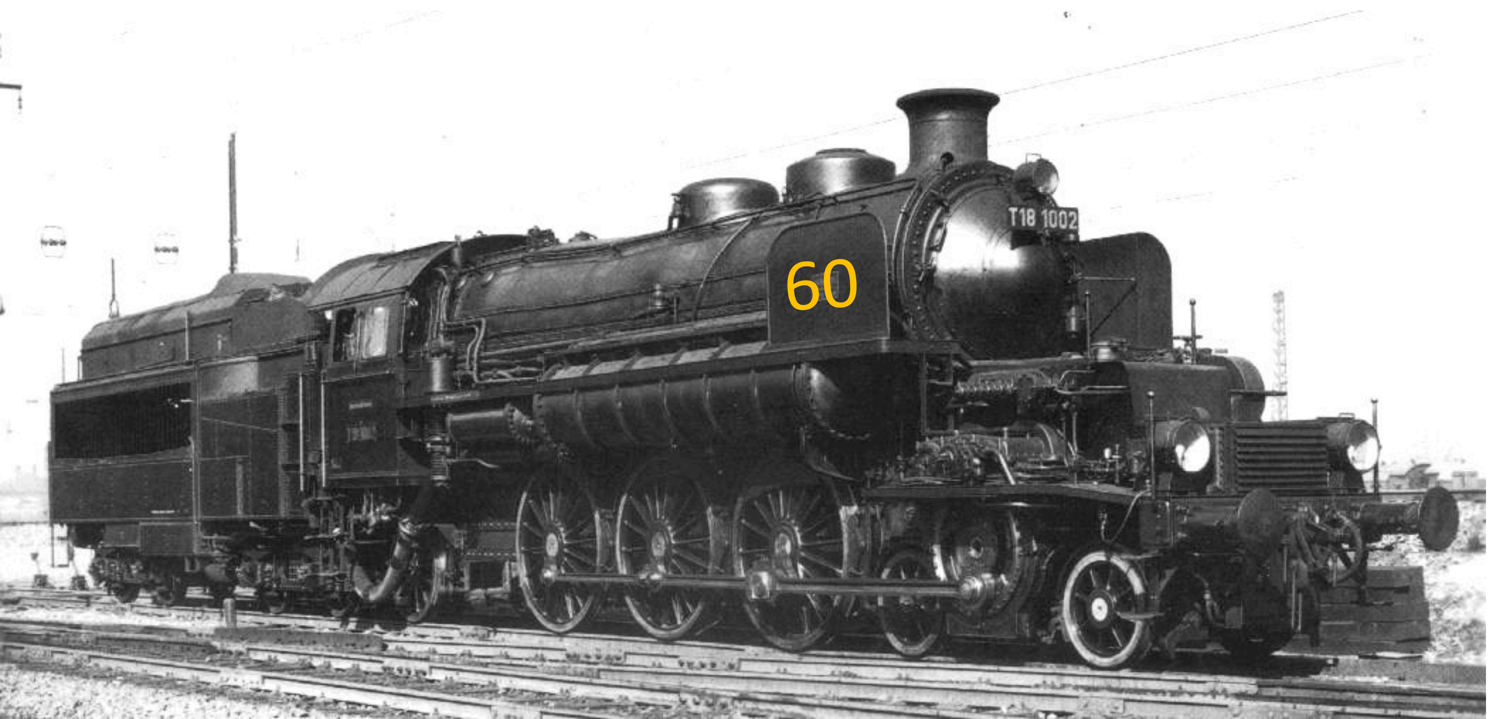
…

H_{200} : There are 200 trains 0.1%

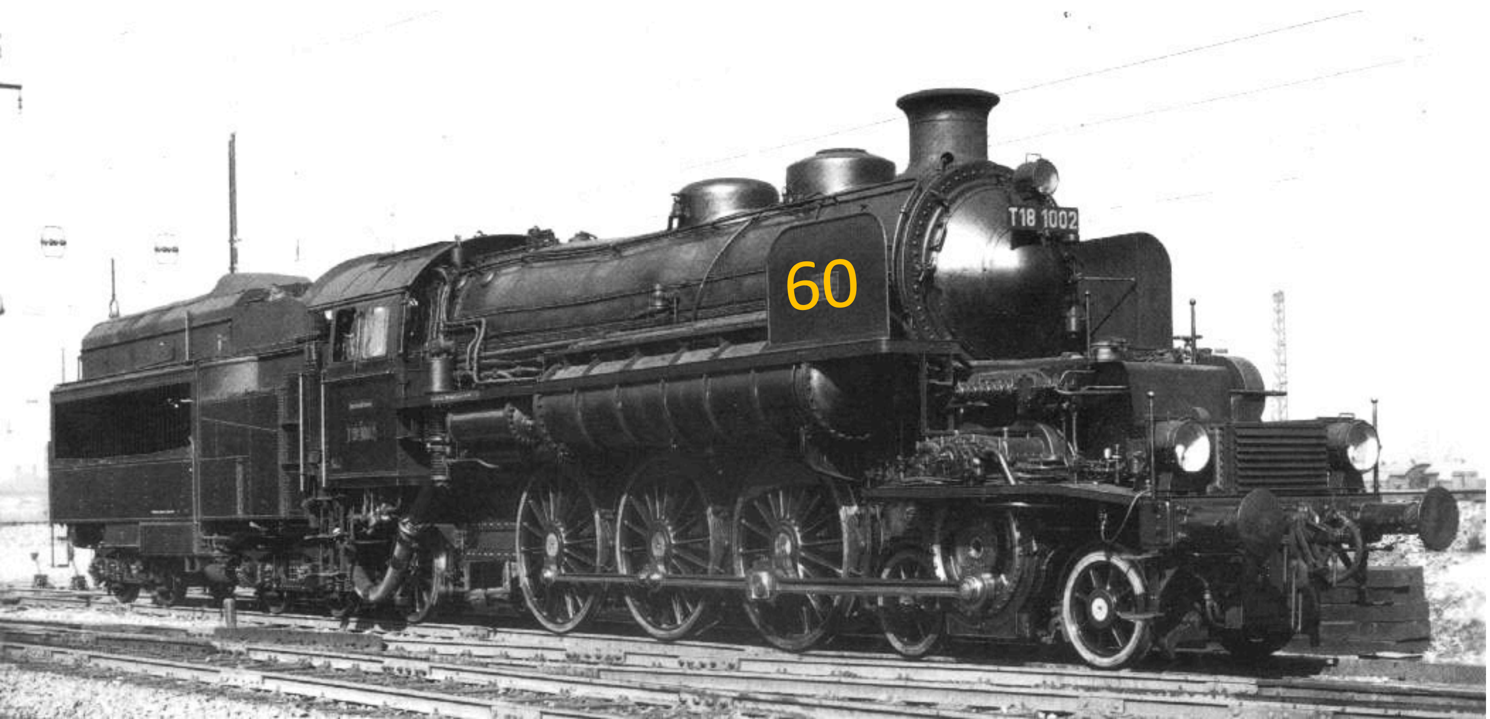
…

H_{1000} : There are 1000 trains 0.1%

Update



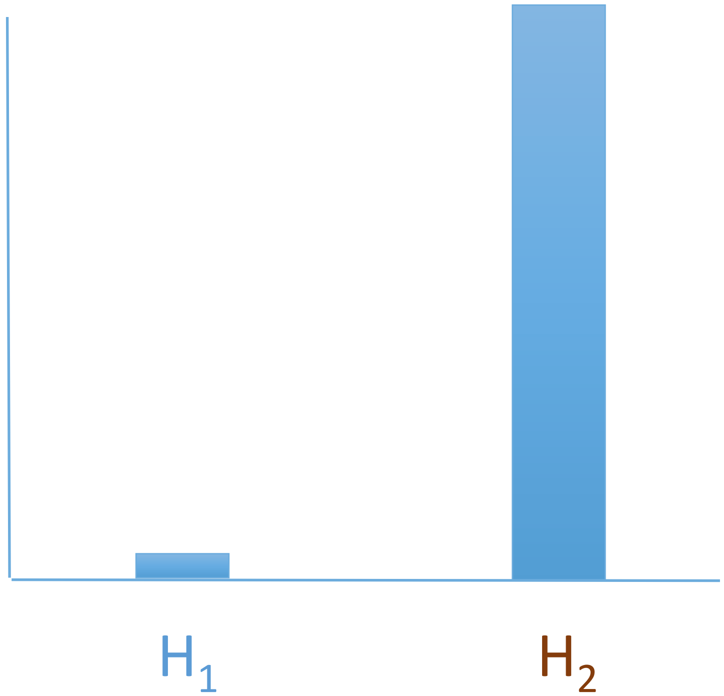
H_1 : There is 1 train	0.1%		0%
H_2 : There are 2 trains	0.1%		0%
H_3 : There are 3 trains	0.1%	Update	0%
…			
H_{200} : There are 200 trains	0.1%		>0.1%
…			
H_{1000} : There are 1000 trains	0.1%		>0.1%



Our time traveler had two hypotheses

H_1 : It is 9 AM (9 to 10)

H_2 : It is **not** 9 AM



prior dist.

At first,

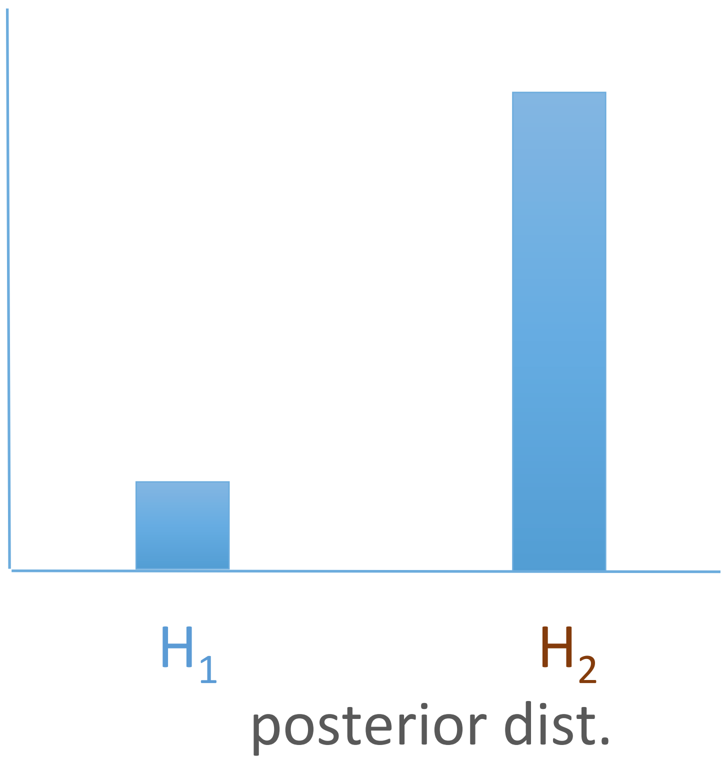
$P(H_1) = P(9AM) = 4.16\%$

$P(H_2) = P(\text{not } 9AM) = 95.84\%$

Our time traveler had two hypotheses

H_1 : It is 9 AM (9 to 10)

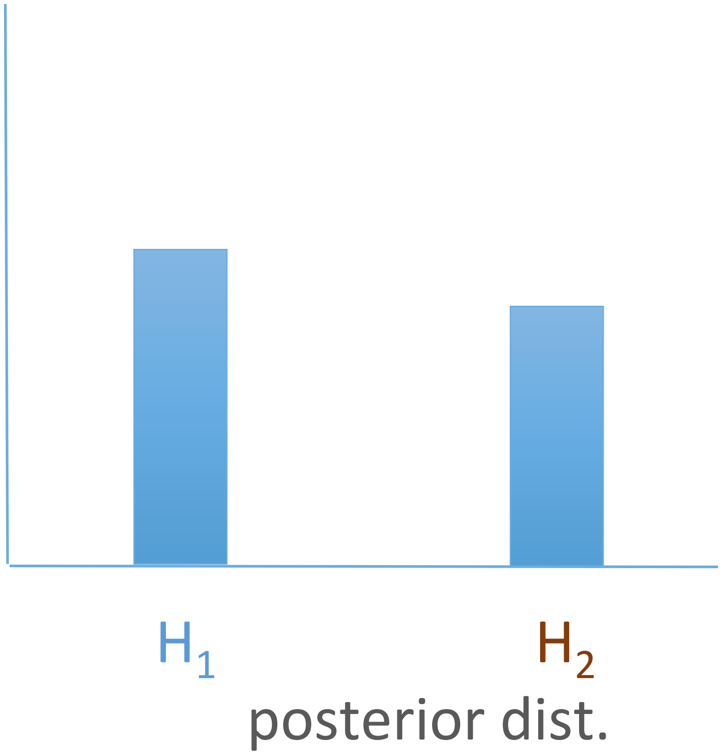
H_2 : It is **not** 9 AM



Our time traveler had two hypotheses

H_1 : It is 9 AM (9 to 10)

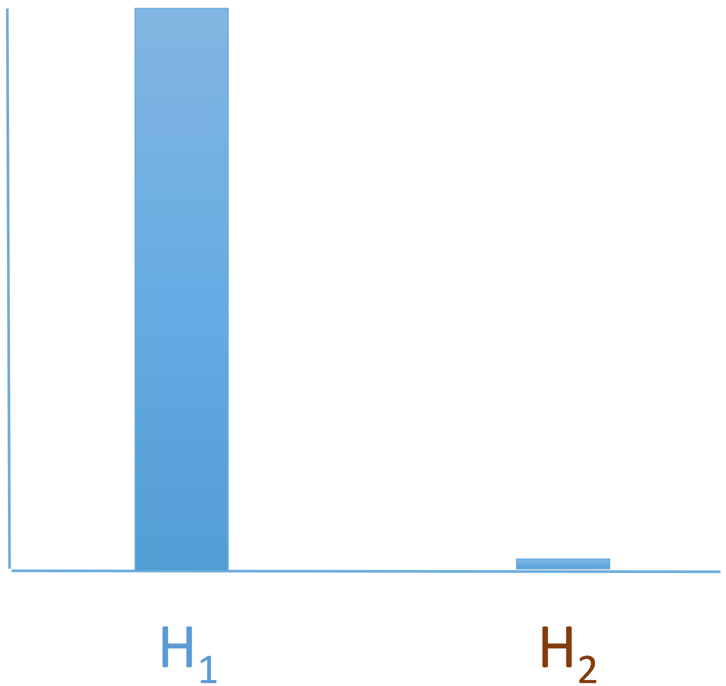
H_2 : It is **not** 9 AM



Our time traveler had two hypotheses

H_1 : It is 9 AM (9 to 10)

H_2 : It is **not** 9 AM

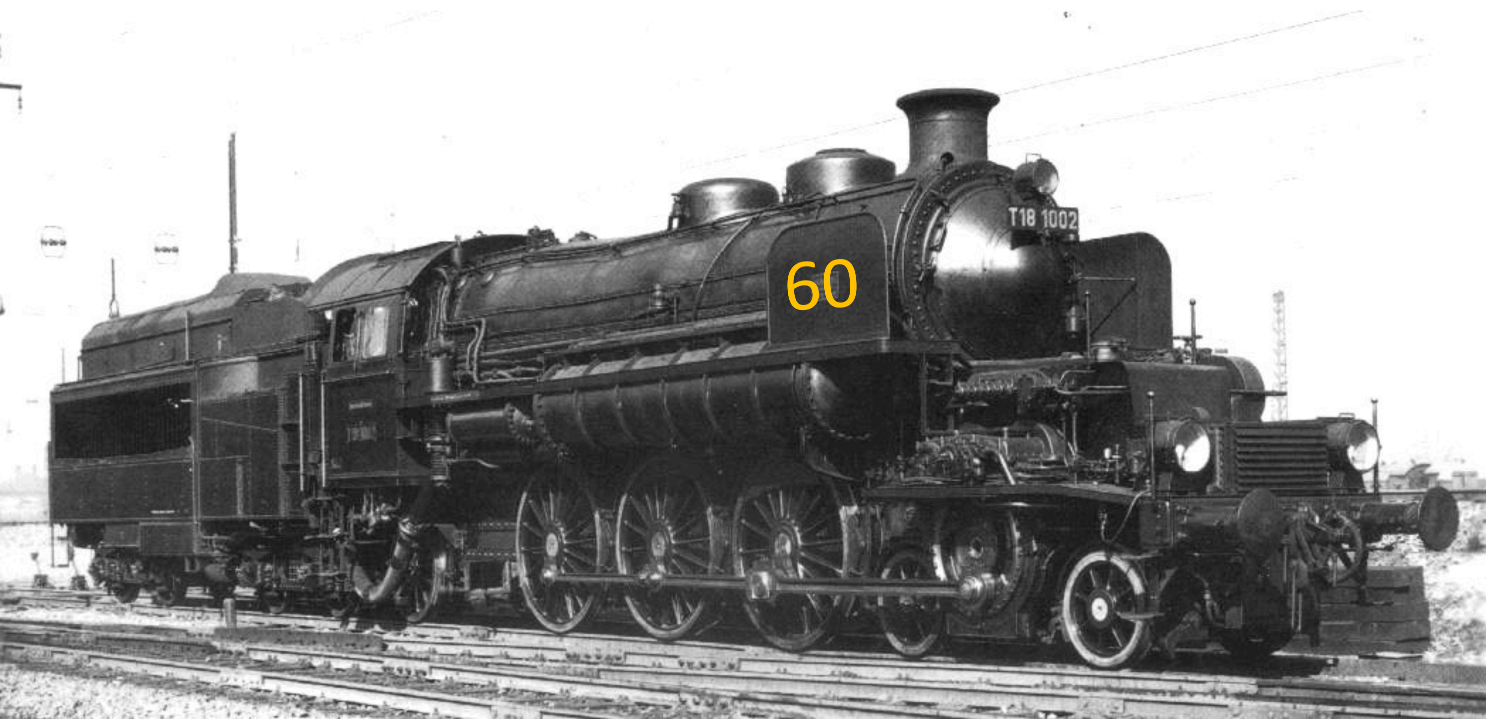


In the end,

P(H_1) = P(9AM | "Nine", N, 5tf) = 97.5%

P(H_2) = P(not 9AM | "Nine", N, 5tf) = 2.5%

H_1 : There is 1 train	0.1%		0%
H_2 : There are 2 trains	0.1%		0%
H_3 : There are 3 trains	0.1%	Update	0%
…			
H_{200} : There are 200 trains	0.1%		>0.1%
…			
H_{1000} : There are 1000 trains	0.1%		>0.1%



H_1 : There is 1 train 0.1%

H_2 : There are 2 trains 0.1%

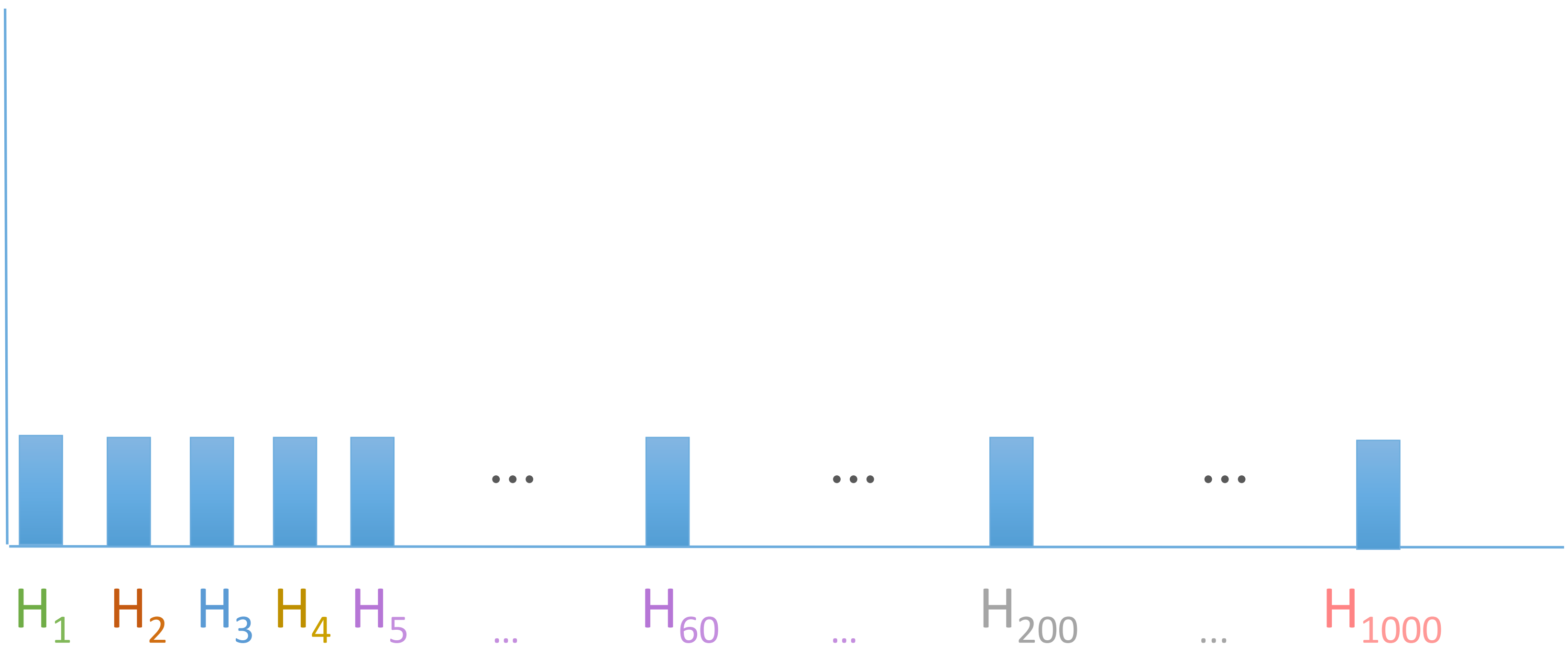
H_3 : There are 3 trains 0.1%

...

H_{200} : There are 200 trains 0.1%

...

H_{1000} : There are 1000 trains 0.1%



H_1 : There is 1 train	0.1%		0%
H_2 : There are 2 trains	0.1%		0%
H_3 : There are 3 trains	0.1%	Update	0%
…			
H_{200} : There are 200 trains	0.1%		>0.1%
…			
H_{1000} : There are 1000 trains	0.1%		>0.1%