

The background of the slide features a large, faint, circular seal of the State of Oregon. The seal contains an eagle with wings spread at the top, a plow and sheaf of wheat at the bottom, and a central scene with a cow and a covered wagon. The text "STATE OF OREGON" is written around the top inner edge, and "1859" is at the bottom. The words "THE UNION" and "ORIGINS" are also visible within the seal's design.

# **The Use of Binomial Probabilities in Outbreak Investigations**

**Bill Keene, Oregon**

The background features a large, faint, circular seal of the Oregon State Board of Health. The seal contains an eagle with spread wings at the top, a plow and sheaf of wheat in the center, and a cow and a horse on the left. The text "SEAL OF THE BOARD OF HEALTH OF THE STATE OF OREGON" is written around the perimeter, with "1859" at the bottom.

# The Use of Binomial Probabilities in Outbreak Investigations

*Are case-control studies obsolete?*

Bill Keene, Oregon

# Binomial (aka Bernoulli) Trials

- 2 possible outcomes for each “trial”
  - heads or tails*
  - male or female*
  - under age 5 or not*
  - ate cantaloupe or didn't*
- Probability of “success” =  $p$
- Probability of “failure” =  $1 - p$
- $p$  is constant for all trials (independence)





Probability of getting at least 7 tails = 0.375







Probability of getting at least 11 tails = 0.0032

# Assessing Exposure Histories

- By chance alone, how likely are we to find  $x$  of  $n$  people (or more) eating a given product?

$$\sum_{y=x}^n \left( \frac{n!}{y!(n-y)!} \right) p^y (1-p)^{n-y}$$

*$n$  = number of cases*

*$x$  = number of cases who ate product*

*$p$  = background consumption rate*



## ***E. coli* O157 — 1993**

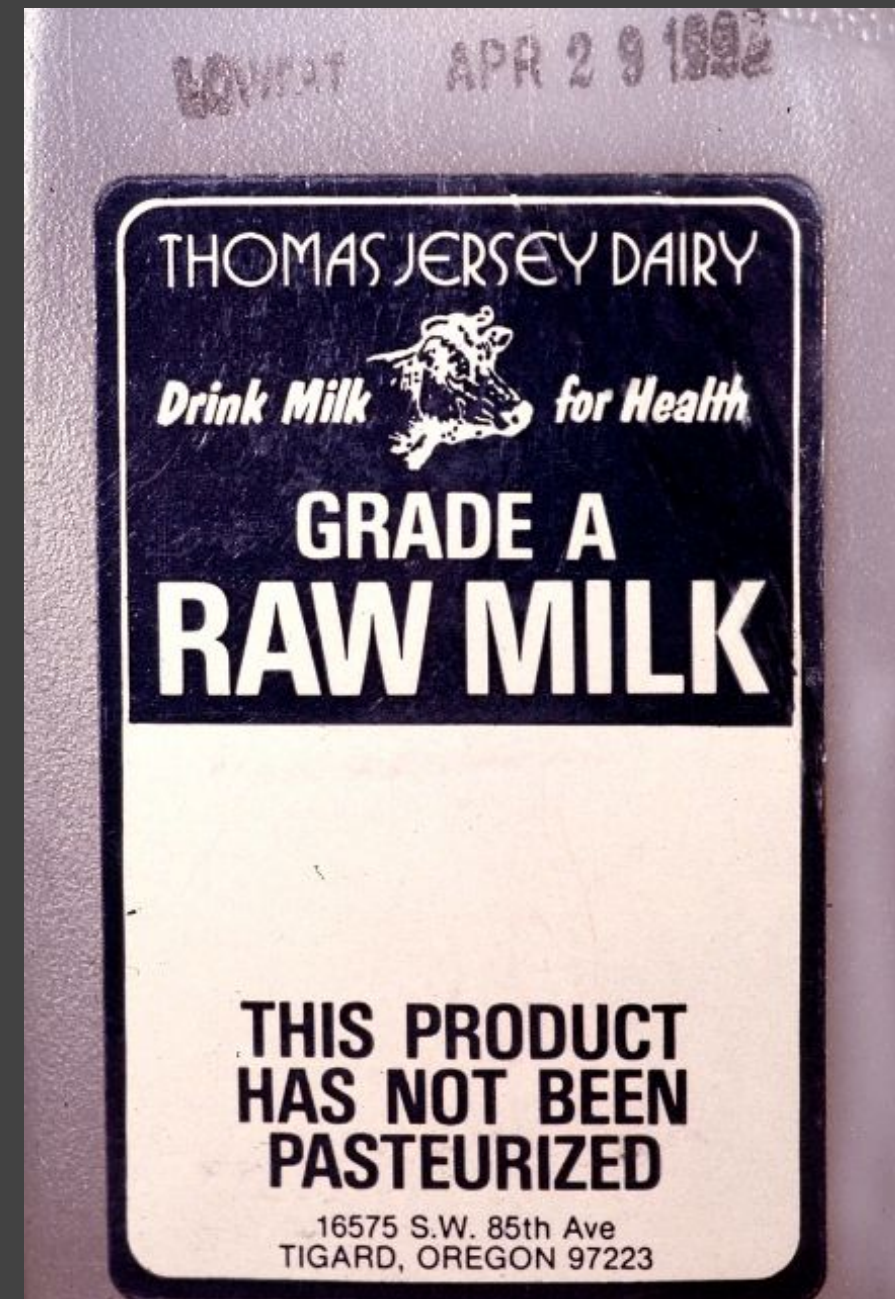
- LHD reported raw milk consumption by 2 recent cases in April
- Review of previous 16 cases (Dec 1992–April 1993)
- No PFGE subtyping
- 6/16 (37%) reported drinking raw milk





# *E. coli* O157 — 1993

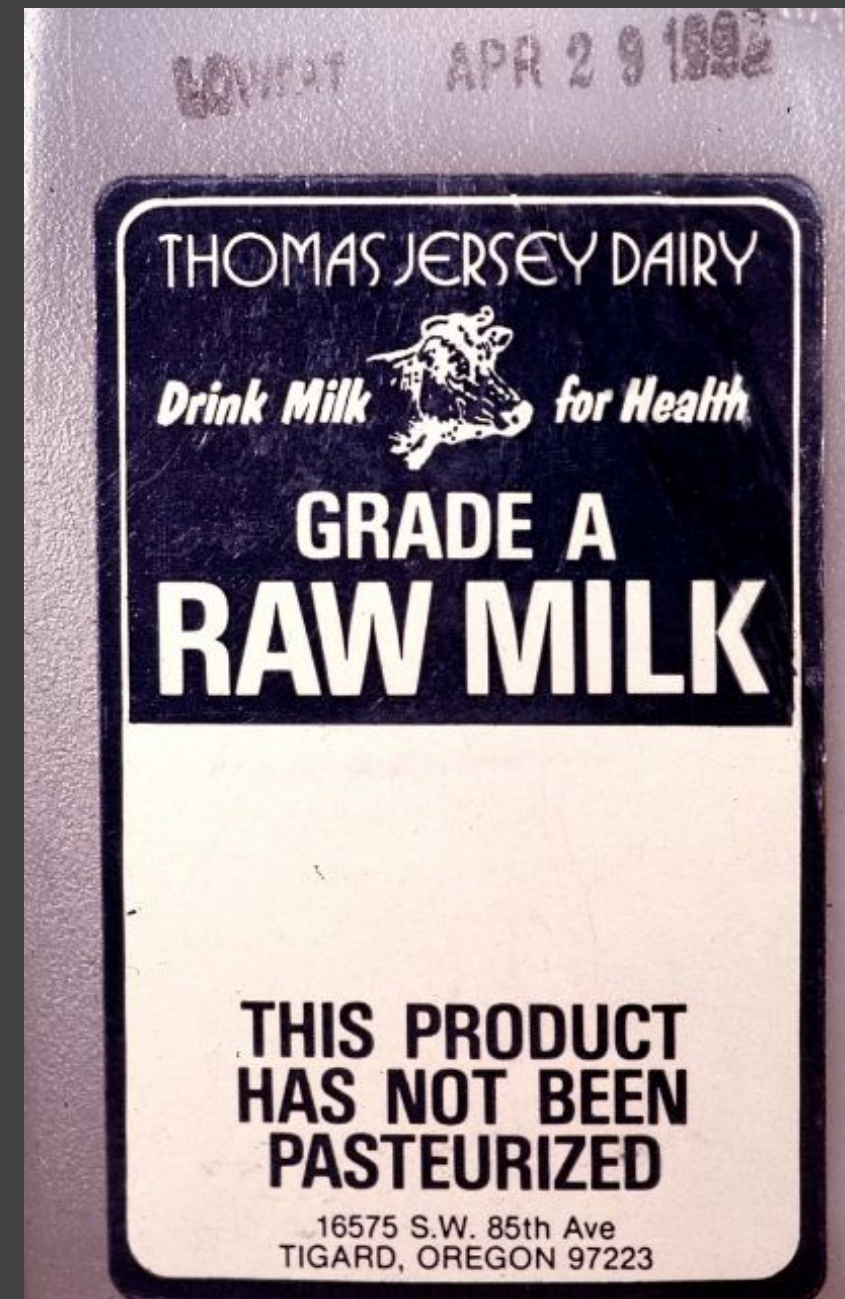
- 6/16 (37%) reported exposure
- Background prevalence of consumption unknown, but had to be <1%



# *E. coli* O157 — 1993

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0.0000000073



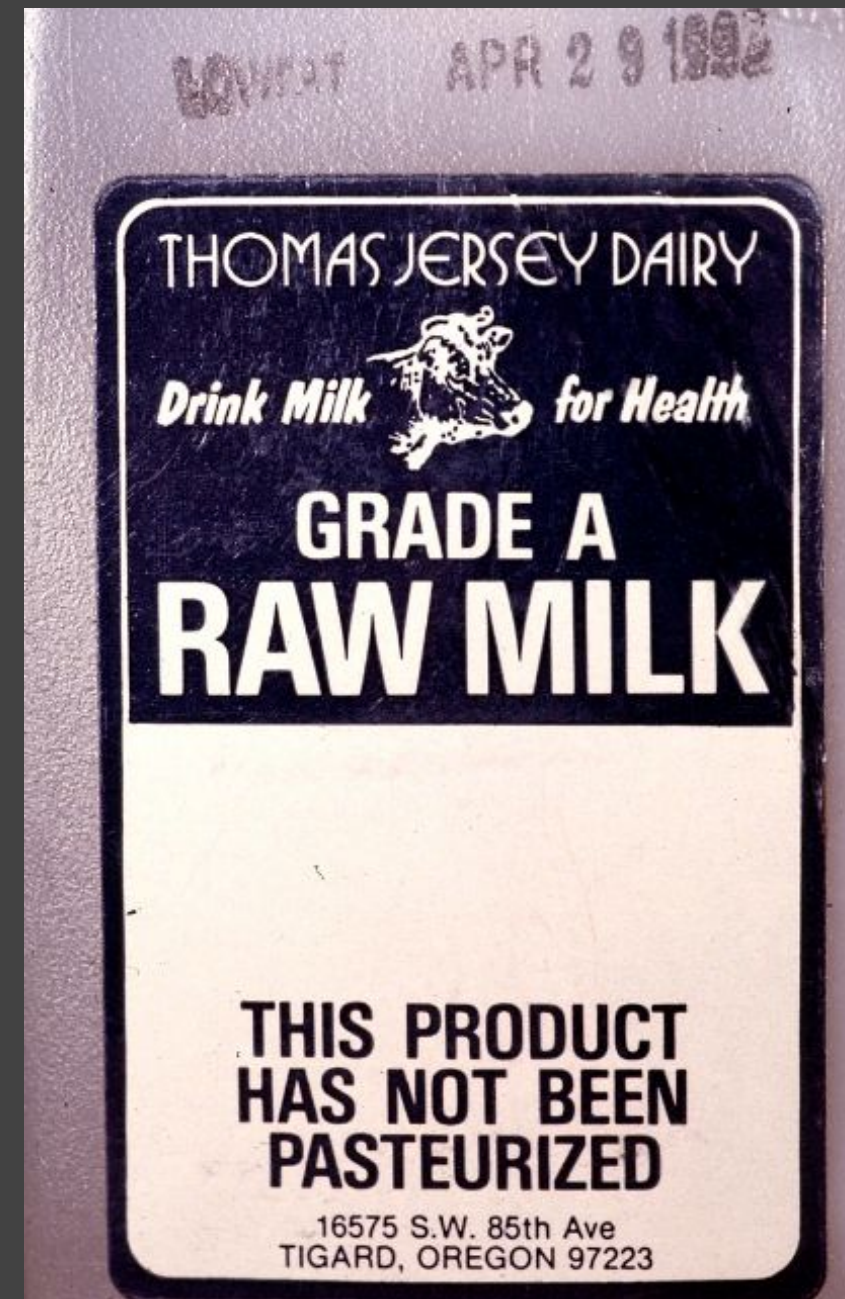


## ***E. coli* 0157 — 1993**

- 6/16 (37%) reported exposure
- Background prevalence of consumption unknown, but had to be <1%

0.0000000073

for 6/6,  $10^{-12}$



# ***Salmonella* Enteritidis — 2004**

- 5 PFGE-matching cases
- 5/5 (100%) reported Costco almonds
- background = ??????





# Salmonella Enteritidis — 2004

- 5 PFGE-matching cases
- 5/5 (100%) reported Costco almonds
- background = ??????

Rate	P
1%	0.000000000011
5%	0.00000003
10%	0.000001
25%	0.001
50%	0.03



# ***E. coli* 0157 — 2006**

- 6 PFGE-matching cases in Oregon
- 5/6 (83%) reported eating bagged spinach
- 17% background for any spinach





# *E. coli* O157 — 2006

- 6 PFGE-matching cases in Oregon
- 5/6 (83%) reported eating bagged spinach
- 17% background for any spinach

0.00073



# ***Salmonella* Braenderup — 2010**

- 23 PFGE matching Braenderup cases
- 20/21 (95%) reported drinking pasteurized milk
- 87% background rate





# ***Salmonella* Braenderup — 2010**

- 23 PFGE matching Braenderup cases
- 20/21 (95%) reported drinking pasteurized milk
- 87% background rate

0.155



# Free Excel worksheet available

	A	B	C	D	E	F	G
1		<i># cases with exposure</i>	<i>% cases with exposure</i>	<i>Cumulative Probability</i>		<i>Cumulative Probability (exponential)</i>	<i>P (exactly that many hits)</i>
2		12	100%	0.000000		1.297E-10	0.00000
3	sample size	11	92%	0.000000		8.952E-09	0.00000
4	12	10	83%	0.000000		2.839E-07	0.00000
5		9	75%	0.000005		5.478E-06	0.00001
6		8	67%	0.000072		7.170E-05	0.00007
7	background rate	7	58%	0.000672		6.721E-04	0.00060
8	15.0%	6	50%	0.004642		4.642E-03	0.00397
9		5	42%	0.023922		2.392E-02	0.01928
10		4	33%	0.092206		9.221E-02	0.06828
11		3	25%	0.264182		2.642E-01	0.17198
12		2	17%	0.556540		5.565E-01	0.29236
13		1	8%	0.857758		8.578E-01	0.30122
14		0	0%	1.000000		1.000E+00	0.14224



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“keene binomial outbreak”

# **Salmonella Heidelberg (etc.) — 2011**

- July 21: 73 cases
- 8/13 reported eating ground turkey
- ~11% in FoodNet Pop Survey reported ground turkey consumption





# *Salmonella* Heidelberg (etc.) — 2011

- July 21: 73 cases
- 8/13 reported eating ground turkey
- ~11% in FoodNet Pop Survey reported ground turkey consumption

0.000016





# Salmonella Heidelberg — 2011

- July 27: 77 cases
- 25/51 (49%) reported eating ground turkey
- ~11% background



# Salmonella Heidelberg — 2011

- July 27: 77 cases
- 25/51 (49%) reported eating ground turkey
- ~11% background

0.000000000015



# Sources of Exposure Data

[12]	Y	?	N	FRESH VEGETABLES 2
A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	white or yellow onions
B	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	green onions (scallions)
C	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	leeks
D	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	eggplant
E	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	commercially made guacamole
F	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	other avocado
G	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	cabbage
H	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	bean sprouts
I	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	any stir-fry that might have included bean sprouts
J	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	alfalfa sprouts
K	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	any other sprouts (clover, mixed, broccoli, daikon radish, ...)
L	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Did you handle any sprouts, even if you didn't eat them?
M	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	any bagged, pre-washed lettuce or salad mix
N	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	any other iceberg lettuce
O	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	any romaine lettuce
P	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	any other leafy lettuce (red, green, butter, radicchio ...)
Q	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	any mesclun, "spring mix", or "baby" salad items
R	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	any lettuce on sandwiches or burgers
S	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	any tomatoes on sandwiches or burgers
T	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	bagged, pre-washed spinach or spinach mix
U	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	fresh spinach ("loose"; not frozen)
V	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	arugula, endive, chard, watercress, other salad greens
W	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	other greens (kale, collard, mustard, etc)
X	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	fresh basil or pesto (at home or away)
Y	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	fresh parsley (regular or Italian)
Z	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	fresh cilantro

# Sources of Background Rate Estimates

- FoodNet Population Survey Data
- USDA nutrition surveys
- Market share data
- Educated guesses
- Restaurant sales records



Foodborne Diseases Active Surveillance Network (FoodNet)  
Population Survey  
Atlas of Exposures, 2006-2007



U.S. Department of Health & Human Services  
Centers for Disease Control and Prevention



## Fresh Fruit Consumed in the Past 7 Days, by FoodNet Site (Food Exposures A)

Exposure	California N=564		Colorado N=904		Connecticut N=915		Georgia N=931		Maryland N=929		Minnesota N=928		New Mexico N=904		New York N=933		Oregon N=898		Tennessee N=923		Total N=8,829	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Apples	359	63.7	586	64.8	587	64.2	557	59.8	528	56.8	599	64.5	550	60.8	588	63.0	600	66.8	536	58.1	5,490	62.2
Oranges	288	51.1	456	50.4	407	44.5	381	40.9	356	38.3	455	49.0	454	50.2	409	43.8	437	48.7	354	38.4	3,997	45.3
Strawberries	267	47.3	401	44.4	410	44.8	416	44.7	461	49.6	422	45.5	399	44.1	393	42.1	388	43.2	417	45.2	3,974	45.0
Lemon	243	43.1	263	29.1	275	30.1	247	26.5	250	26.9	155	16.7	315	34.8	170	18.2	266	29.6	263	28.5	2,447	27.7
Blueberries	142	25.2	229	25.3	256	28.0	190	20.4	247	26.6	176	19.0	153	16.9	197	21.1	228	25.4	149	16.1	1,967	22.3
Pears	141	25.0	218	24.1	223	24.4	154	16.5	174	18.7	191	20.6	169	18.7	170	18.2	178	19.8	139	15.1	1,757	19.9
Peaches	119	21.1	157	17.4	160	17.5	208	22.3	206	22.2	133	14.3	229	25.3	154	16.5	165	18.4	220	23.8	1,751	19.8
Grapefruit	92	16.3	136	15.0	141	15.4	94	10.1	128	13.8	114	12.3	123	13.6	117	12.5	129	14.4	84	9.1	1,158	13.1
Lime	97	17.2	179	19.8	120	13.1	92	9.9	116	12.5	90	9.7	187	20.7	69	7.4	131	14.6	76	8.2	1,157	13.1
Raspberries	77	13.7	159	17.6	107	11.7	54	5.8	95	10.2	164	17.7	81	9.0	120	12.9	145	16.1	55	6.0	1,057	12.0
Tangerines	95	16.8	102	11.3	99	10.8	120	12.9	76	8.2	68	7.3	82	9.1	82	8.8	85	9.5	86	9.3	895	10.1
Nectarines	78	13.8	77	8.5	91	9.9	78	8.4	89	9.6	85	9.2	125	13.8	86	9.2	107	11.9	62	6.7	878	9.9
Blackberries	62	11.0	82	9.1	57	6.2	52	5.6	71	7.6	46	5.0	53	5.9	45	4.8	110	12.2	70	7.6	648	7.3
Apricots	39	6.9	39	4.3	29	3.2	22	2.4	27	2.9	33	3.6	91	10.1	25	2.7	56	6.2	18	2.0	379	4.3

*e.g., strawberries, 45%*



# Listeriosis — 2011

- Sept 8: 13 cases in Colorado
- 11/12 (92%) ate cantaloupe
- 32% background rate



# Listeriosis — 2011

- Sept 8: 13 cases in Colorado
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0.00003



# Listeriosis — 2011

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# Listeriosis — 2011

- Sept 8: 13 cases in Colorado
- 11/12 (92%) ate cantaloupe
- 32% background rate

0.00003

- 9/12 (75%) ate ham
- 36% background rate



# Listeriosis — 2011

- Sept 8: 13 cases in Colorado
- 11/12 (92%) ate cantaloupe
- 32% background rate

0.00003

- 9/12 (75%) ate ham
- 36% background rate

0.007





















# Reasons for Associations

- Chance
- Bias
- Confounding
- Causality

**Hypothesis Generation**

**vs.**

**Hypothesis Testing**

The Illusion of Separation

# Epi Evidence: More than 2x2 Tables

- Past history and general knowledge
- Descriptive epi (person, place, time)
- Product testing
- Traceback / traceforward