



Mathematics
and Statistics

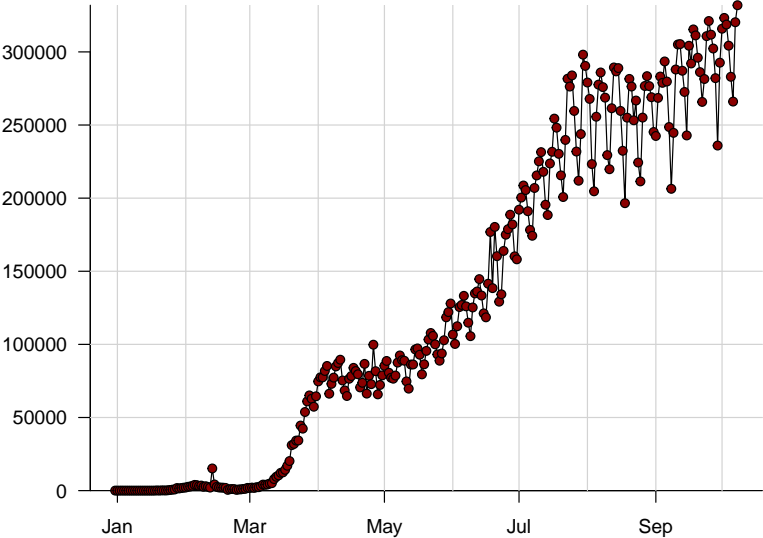
$$\int_M d\omega = \int_{\partial M} \omega$$

Mathematics 747 / 5GT3 Topics in Mathematical Biology

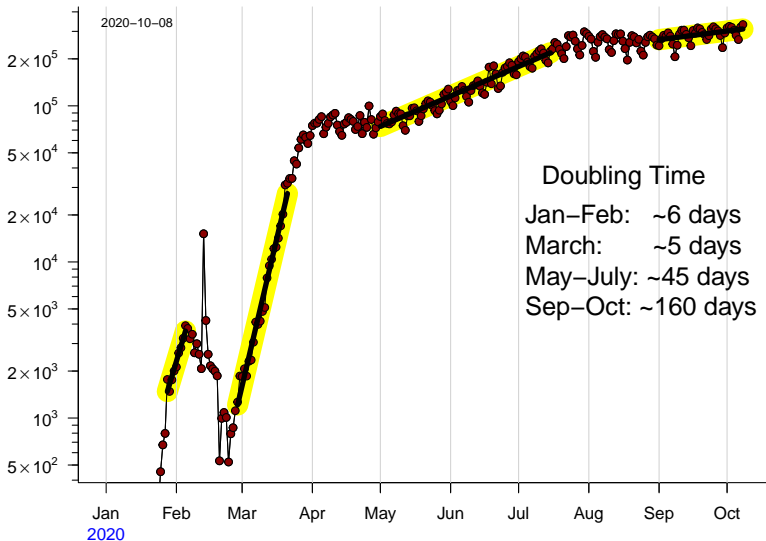
Instructor: David Earn

Lecture 4
Plague Pandemics
Thursday 8 October 2020

Daily SARS-CoV-2 in 2020 (Worldwide)



Daily SARS-CoV-2 (Worldwide) exponential growth fits



What does
“plague”
mean?

plague



plague

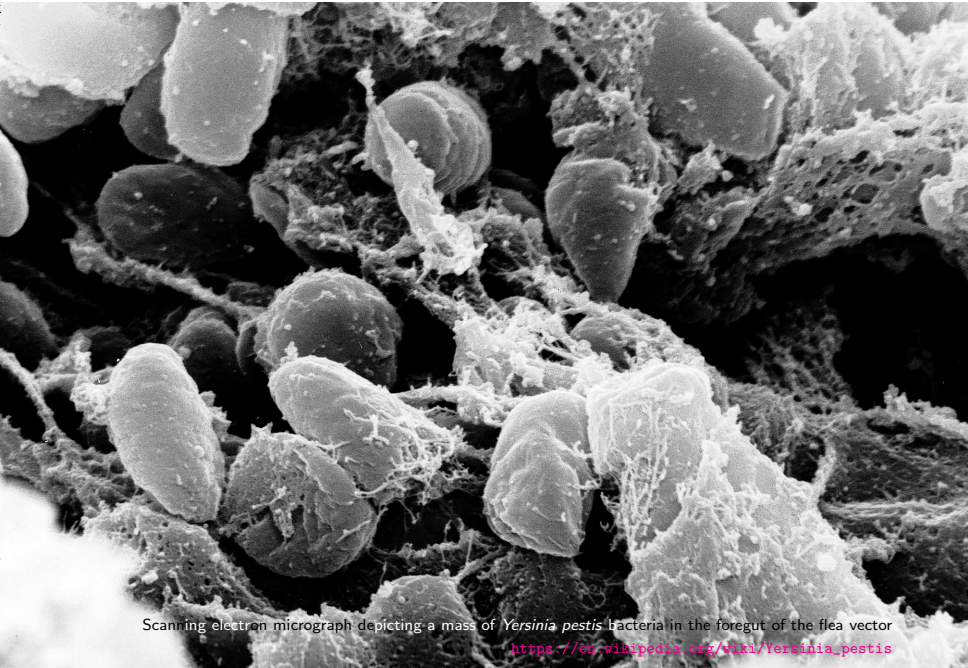
NOUN

- 1 (usually **the plague**) A contagious bacterial disease characterized by fever and delirium, typically with the formation of buboes (see bubonic plague) and sometimes infection of the lungs (pneumonic plague).
See also **bubonic plague**

+ Example sentences

- 1.1 Any contagious disease that spreads rapidly and kills many people.

Plague is caused by the bacterium *Yersinia pestis*



Scanning electron micrograph depicting a mass of *Yersinia pestis* bacteria in the foregut of the flea vector

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

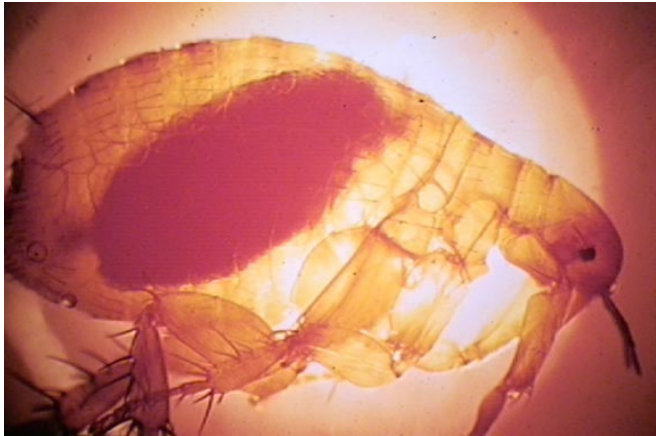
Transmission of Plague

How do humans get plague?

- ▶ Normally present at low levels in rodents
(e.g., rats, prairie dogs)
- ▶ Occasional large outbreaks
- ▶ Spread by insect vector (typically fleas)
- ▶ Infected fleas may bite humans
- ▶ If it enters the lungs, can spread human-to-human \implies pneumonic



How *Y. pestis* manipulates the flea



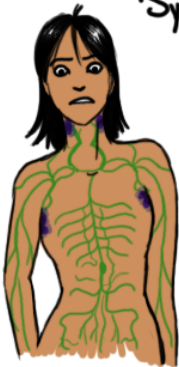
- ▶ Bacteria plug up the stomach of the flea.
- ▶ It starves and constantly tries to feed.
- ▶ When it tries to swallow, it regurgitates *Y. pestis* into the wound of the host.

Clinical Nature of Disease

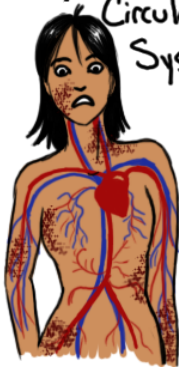
Clinical nature of disease depends on parts of body infected

Normally begins with flu-like symptoms: high fever, chills, malaise

Bubonic: Lymphatic System



Septicemic: Circulatory System



Pneumonic: Lungs



► buboes

► coughing blood

Clinical nature of disease depends on parts of body infected

Symptoms of Septicemic Plague



Hence “black death” . . .

Probability of death from plague infection

- ▶ Bubonic: $\sim 66\%$ if untreated
 $\sim 11\%$ with antibiotics
- ▶ Pneumonic: $\sim 100\%$ if untreated
- ▶ Bubonic $<$ Septicemic $<$ Pneumonic

Plague in of History

Plague in History



- ▶ Plague of Justinian
 - ▶ Began 541 CE
 - ▶ Continued ~ 200 years
 - ▶ ~ 25 million deaths
- ▶ Black Death
 - ▶ Began 1334, China
 - ▶ Continued ~ 350 years
 - ▶ ~ 60% Europe killed in 1300s
- ▶ Modern Plague
 - ▶ Began ca. 1860, China
 - ▶ 2–10 million deaths
- ▶ Causative agent identified by Alexander Yersin in 1894 (bacterium later named *Yersinia pestis*).

How do we know historical outbreaks were caused by *Y. pestis* ?

Actually, *do we know* historical “plagues” were caused by *Y. pestis* ???



Hendrik Poinar

a.k.a. “Indiana Bones”

Bos *et al.* 2011, *Nature* **478**:506

The Nature of Things
Season 2013–14, Episode 12

BLACK DEATH GENOME

Reconstruction from fourteenth-century DNA is
close match to modern pathogen **PAGES 444, XXX & 506**

Do we know historical “plagues” were caused by *Y. pestis* ?

- ▶ **Second pandemic:** Black Death: **YES**

Bos *et al.* 2011, *Nature* **478**:506

- ▶ Plagues following the starts of these pandemics?
Probably! (Many now confirmed.)

- ▶ **First pandemic:** Plague of Justinian: **YES**

Wagner *et al.* 2014, *Lancet Infectious Diseases* **14**:319–326

- ▶ **Third pandemic:** Modern Plague: **YES**

What data exist that allow us to quantify the temporal and spatial patterns of plague outbreaks?

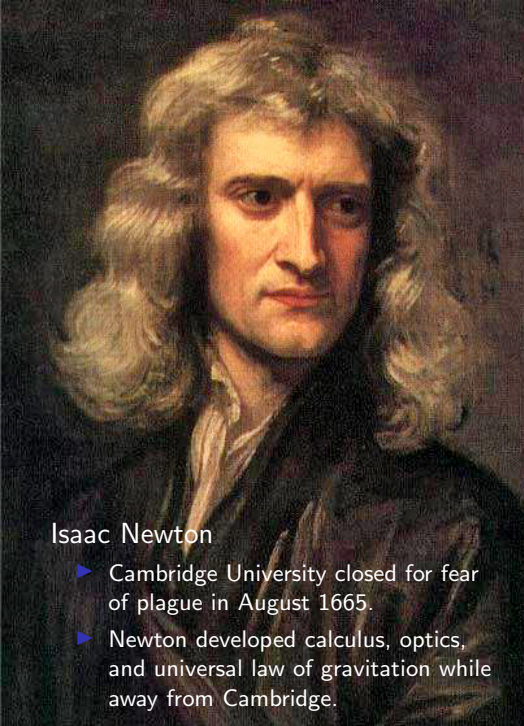
A variety of sources for the second pandemic.



The
Black
Death
1348



Plague in 1665.



Isaac Newton

- ▶ Cambridge University closed for fear of plague in August 1665.
- ▶ Newton developed calculus, optics, and universal law of gravitation while away from Cambridge.



Plague Science

To describe the spread of plague in a human population, we need:

- ▶ Written records that survive in archives today
- ▶ Systematic record keeping over the course of an epidemic
- ▶ Ideally, death certificate for each person who died of plague
- ▶ What can we obtain in practice?

Where should
we look for
useful data?

London, England



London, England, 1630



3. S. Magnes

2. Gray Church

S. Dunston in the East

J. Alhallowe barking



London, England 1670

Data Source

Weekly Bills of Mortality (London, England)

London, 1630



London, 2012



The Diseases and Casualties this Week.



A Bortive	6
A Aged	50
Ague	1
Apoplexie	2
Childbed	42
Chirromes	11
Cold	1
Consumption	99
Convulsion	63
Cough	1
Droptic	22
Drown'd at St. Martin in the Fields	1
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Flox and Small-pox	4
Flux	1
Found dead in the Fields at St. Mary Iflington	1
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Scurvy	5
Spotted Feaver	65
Stilborn	10
Stone	3
Stopping of the stomach	6
Suddenly	1
Surfeit	36
Teeth	112
Thrush	3
Tiffick	5
Vomiting	4
Winde	1
Wormes	12

Christned	Males	68	Buried	Males	3212	Plague	5533
	Females	78		Females	3248		
	In all	146		In all	6460		
Decreased in the Burials this Week				1837			
Parishes clear of the Plague				7 Parishes Infected 123			

The Assize of Bread set forth by Order of the Lord Mayor and Counc of Aldermen, A penny Wheatn Loaf to contain Nine Ounces and a half, and three half-penny White Loaves the like weight.

	Bur.	Plag.		Bur.	Plag.
S ^t Alban Woodstreet	16	12	S ^t George Botolphane	1	1
S ^t Albawles Barking	40	34	S ^t Gregory by S ^t Pauls	26	25
S ^t Albawles Breadstreet	1	1	S ^t Hellen	6	5
S ^t Albawles Greac	42	41	S ^t James Dukes place	17	23
S ^t Albawles Hovias	20	24	S ^t James Garlickhithe	10	12
S ^t Albawles Letic	17	17	S ^t John Baptist	11	10
S ^t Albawles Lumbarstreet	5	5	S ^t John Evangelist	1	1
S ^t Albawles Steining	21	18	S ^t John Zachary	12	9
S ^t Albawles the Wall	33	28	S ^t Katharine Coleman	20	16
S ^t Alpheage	13	5	S ^t Katharine Creechurch	34	29
S ^t Andrew Hubbard	4	5	S ^t Lawrence Jewry	6	5
S ^t Andrew Underhafe	16	14	S ^t Lawrence Pounney	14	10
S ^t Andrew Wardrobe	23	24	S ^t Leonard Fishers	3	3
S ^t Ann Alderstreet	28	27	S ^t Leonard Fotherlane	16	13
S ^t Ann Blackyeres	57	50	S ^t Margarets Parish	5	4
S ^t Anthonis Parish	7	4	S ^t Margarets Lothbury	7	6
S ^t Austins Parish	4	3	S ^t Margarets Newfillstreet	13	13
S ^t Bartholomew Exchange	7	7	S ^t Margarets Patton	4	3
S ^t Bennet Fynack	4	2	S ^t Mary Abchurch	7	5
S ^t Bennet Gracechurch	4	2	S ^t Mary Aldermanbury	14	14
S ^t Bennet Paulwharfe	15	7	S ^t Mary Aldermay	4	4
S ^t Bennet Sherehog	2	8	S ^t Mary le Bow	1	1
S ^t Boroloh Billinggate	8	8	S ^t Mary Bothaw	6	4
S ^t Christs Church	44	39	S ^t Mary Colechurch	3	1
S ^t Christophers	4	4	S ^t Mary Hill	11	8
S ^t Clement Eastcheap	1	1	S ^t Mary Mounshaw	4	3
S ^t Dionis Backchurch	9	2	S ^t Mary Sommerset	44	38
S ^t Dunstan East	28	24	S ^t Mary Swayning	3	3
S ^t Edmund Lumbarstreet	3	1	S ^t Mary Woolchurch	7	4
S ^t Ethelborough	7	4	S ^t Mary Woolnoth	7	5
S ^t Faich	8	6	S ^t Martin Ironmongerlane	2	2
S ^t F.ter	8	6			
S ^t Gabeiel Fenchurch	3	3			

Christned in the 97 Parishes within the Walls 39 Buried 1149 Plague 99

S ^t Andrew Holborn	173	151	S ^t Boroloh Aldgate	374	338	S ^t aviours Southwark	364
S ^t Bartholomew Greac	17	15	S ^t Boroloh Bishopsgate	153	121	S ^t Sepulchres Parish	147
S ^t Bartholomew Lette	7	7	S ^t Dunstan West	63	59	S ^t Thomas Southwark	2
S ^t Bridge	92	67	S ^t George Southwark	140	133	Trinity Minorities	24
Bidwell Precinct	23	23	S ^t Giles Cripplegate	196	151	at the Pesthouse	8
S ^t Boroloh Aldergate	71	64	S ^t Olave Southwark	378	281		

Christned in the 16 Parishes without the Walls 45 Buried, and at the Pesthouse 2358 Plague 1

S ^t Giles in the fields	95	78	Lambeth Parish	49	39	S ^t Mary Abington	35
Hackney Parish	14	12	S ^t Leonard Shoreditch	95	94	S ^t Mary Wharfedale	32
S ^t James Clerkenwell	48	42	S ^t Magdalen Newmenny	138	106	Rothsith Parish	21
S ^t Kath near the Tower	55	49	S ^t Mary Newington	31	21	Scepnay Parish	67

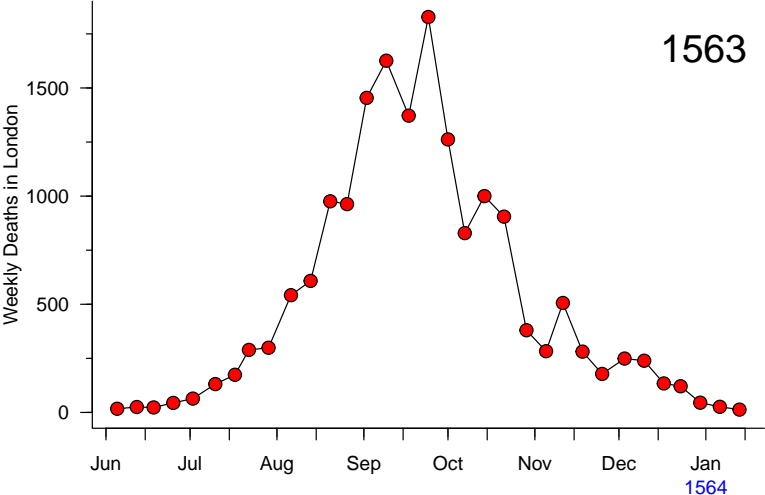
Christned in the 12 out Parishes in Middlesex and Surry 40 Buried 1623 Plague 1

S ^t Clement Danes	1	1	S ^t Martin in the fields	209	143	S ^t Margarets Westminster	30
S ^t Paul Covent Garden	35	24	S ^t Mary Savoy	19	16	at the Pesthouse	

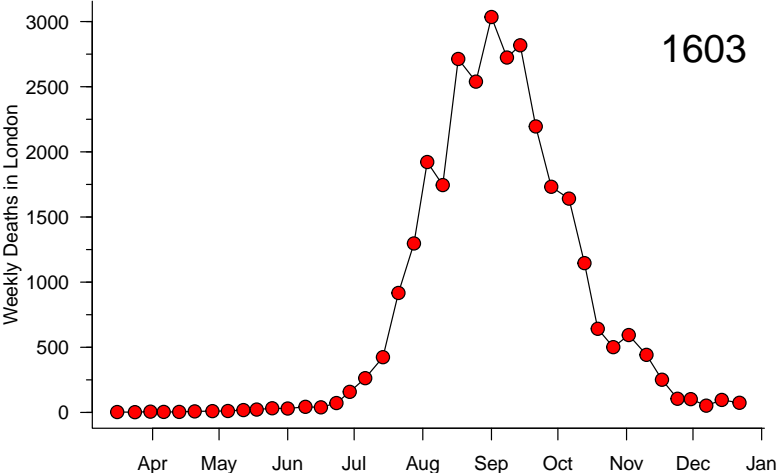
Christned in the 5 Parishes in the City and Liberties of Westminster 18 Buried 690 Plague 1

<u>Frighted</u>	1
Gowt	1
<u>Grief</u>	3
Griping in the Guts	35
Jaundies	2
Imposthume	8
Infants	9
Kingsevil	2
Meagrome	2
<u>Plague</u>	5533
Purples	2
Rickets	10
Rif	(the Light)

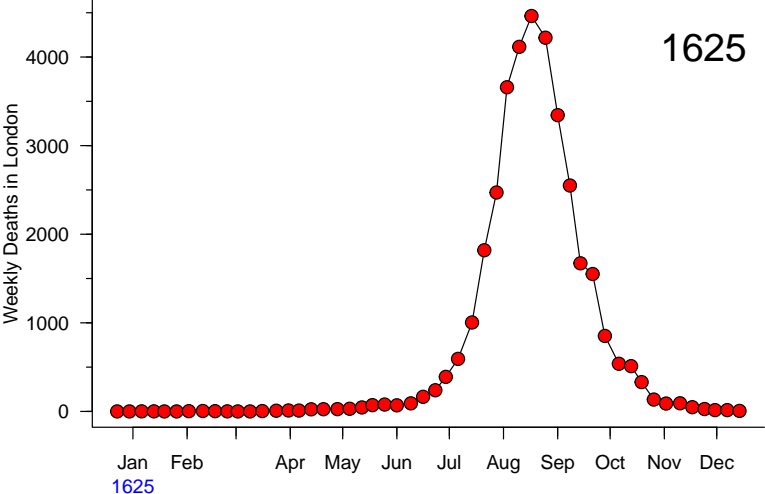
Plague in London



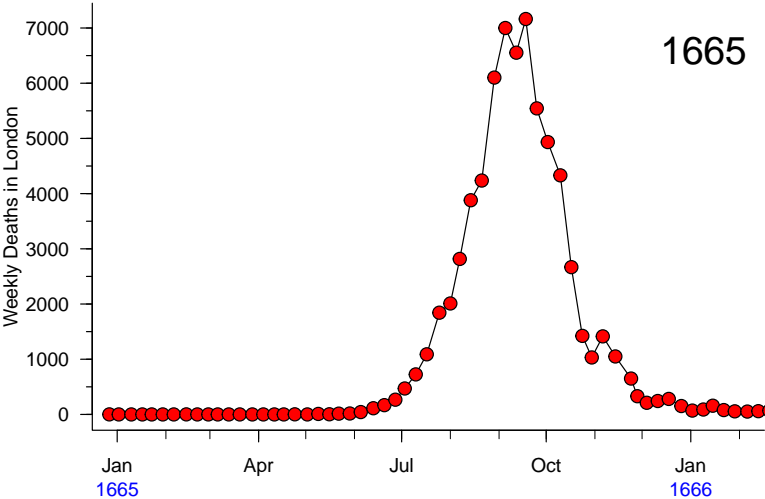
Plague in London



Plague in London



Plague in London



Plague in London

~ 20% of the total population
is reported to have died in each
of these 16th and 17th century
plague epidemics

Plague in London

Registration of baptisms,
weddings and burials began in
London in 1538.

*How can we quantify earlier
epidemic patterns?*

Data Source

Last Wills and Testments
(London, England)

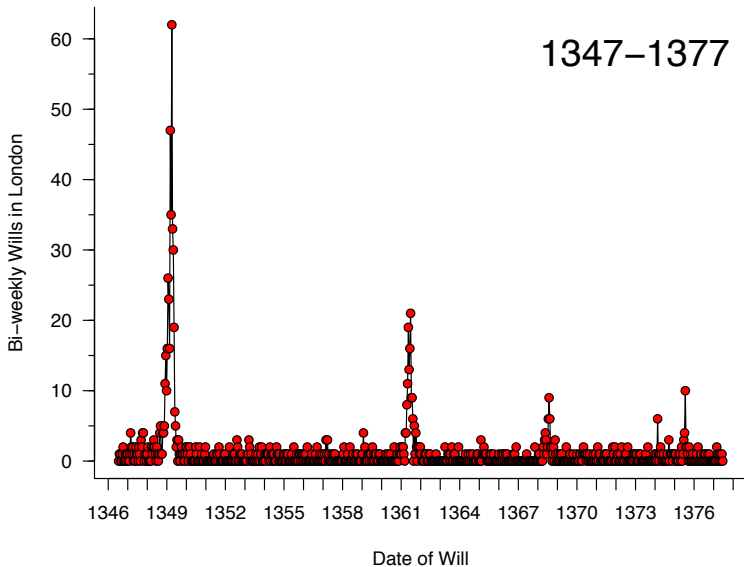
Data from Last Wills and Testaments in London

- ▶ We assume the *temporal pattern* of wills written reflects *deaths from plague* throughout the population
 - ▶ Similar to how Google searches for flu symptoms can predict the patterns of flu epidemics today Ginsberg et al (2009, *Nature* 457:1012)
- ▶ Google recently scanned a 19th century “calendar” of wills probated by the Court of Husting and made pdfs freely available online.
 - ▶ In the summer of 2017 I entered the dates of 1113 wills that were probated between 1346 and 1378.

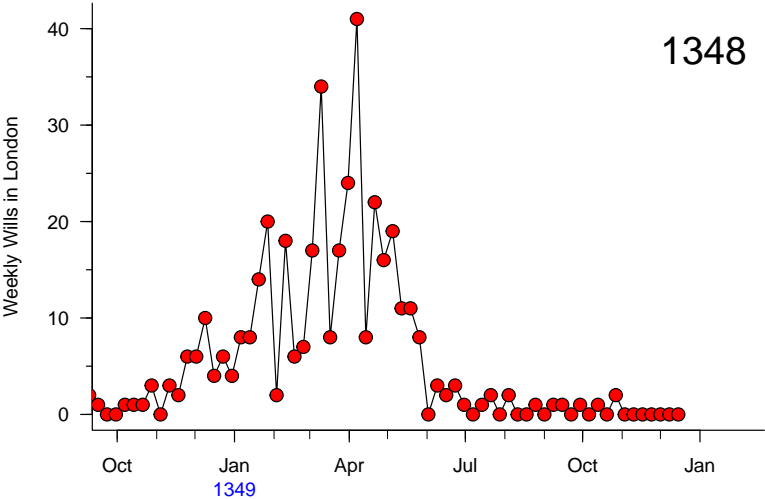
Much further work on Husting wills in Alex Bushby's 2019 McMaster MSc thesis

Plague in London

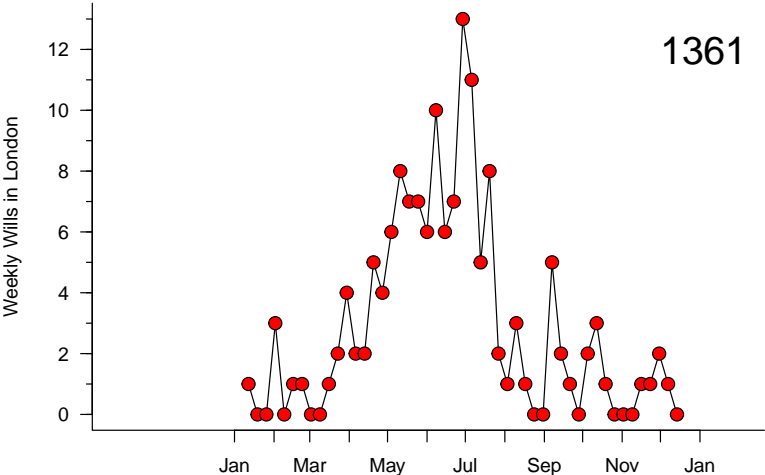
Wills Probated in the Court of Husting, London



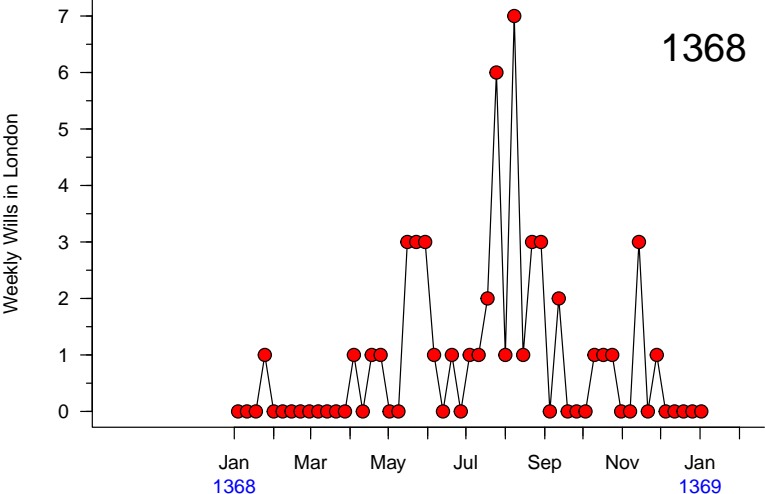
Plague in London



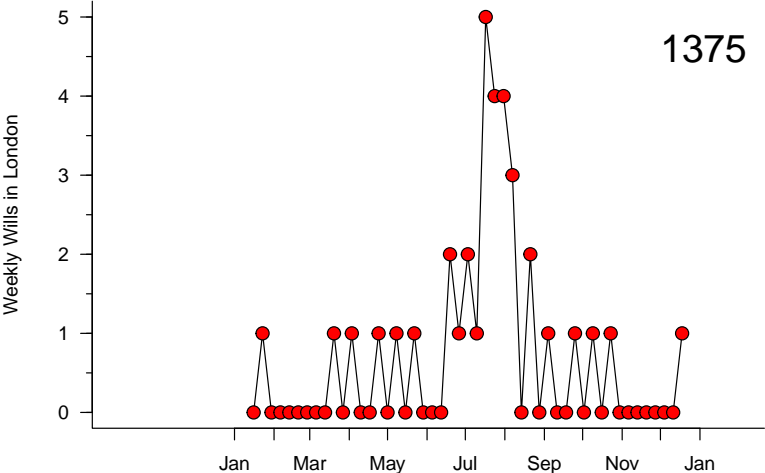
Plague in London



Plague in London



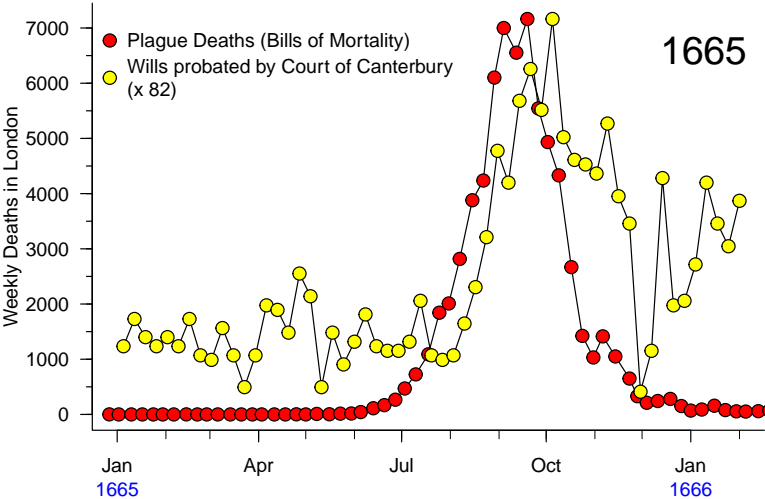
Plague in London



Is it OK to compare
results based on wills
with results from
mortality data?

*The London Metropolitan archives has
created an [online index](#) of wills probated by
the Court of Canterbury since 1384...*

Plague in London



How can we use these time series to learn about the disease?

A mathematical model will help...

The SIR model



Rates of change of numbers of individuals who are:

Susceptible $\frac{dS}{dt} = -\beta SI$

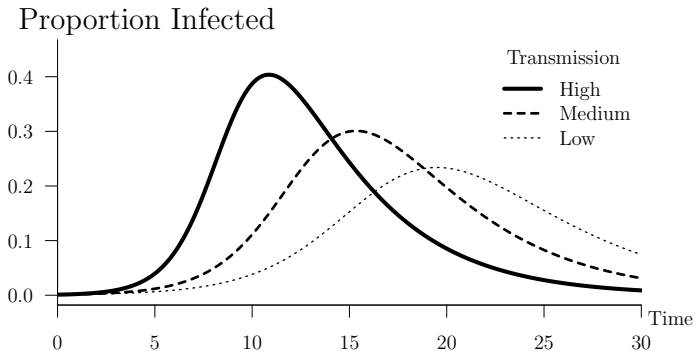
$\beta =$ transmission rate

Infectious $\frac{dI}{dt} = \beta SI - \gamma I$

$\gamma =$ recovery/removal rate

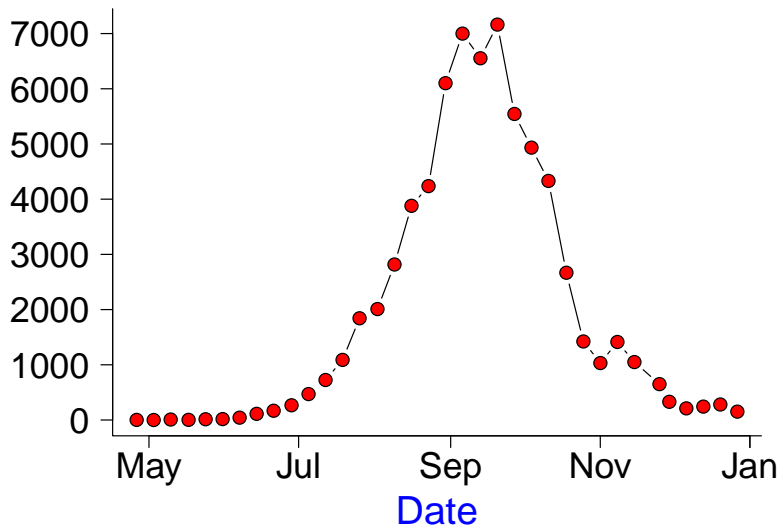
Removed $\frac{dR}{dt} = \gamma I$

The SIR model



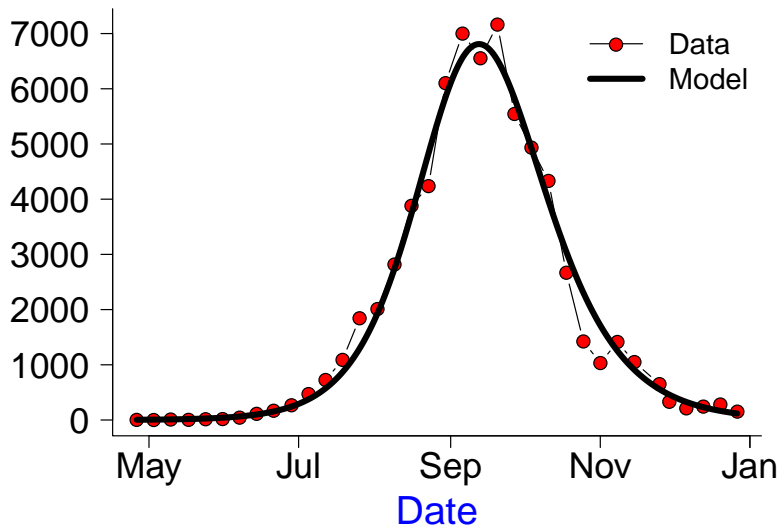
The Great Plague of London, 1665

Weekly Deaths from Plague




SIR Model Fit to the Great Plague of London

Weekly Deaths from Plague

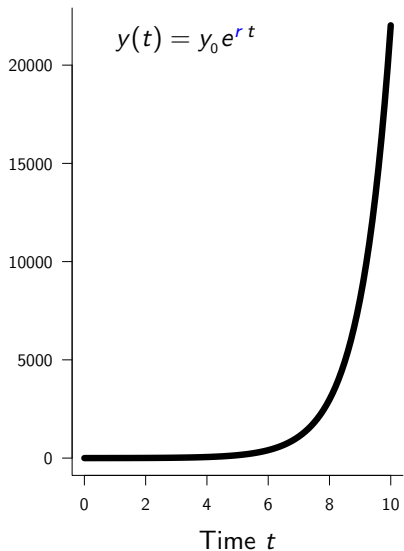


What can we estimate confidently from the data?

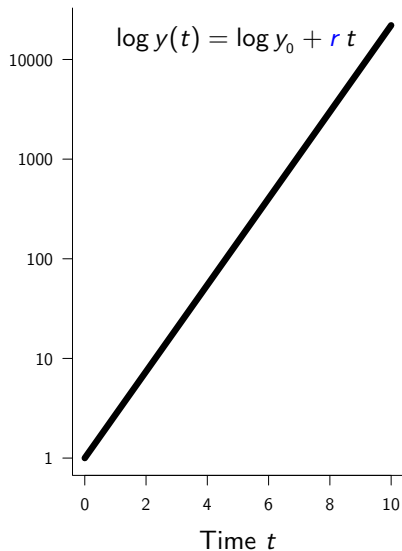
- ▶ Fitting an SIR model to these data yields:
 - ▶ transmission rate
 - ▶ recovery ratebut implicitly assumes human-to-human transmission.
 - ▶ Hard to justify SIR fit given:
 - ▶ All we have is mortality time series.
 - ▶ We do not know the precise transmission process that generated these data (e.g., bubonic vs. pneumonic).
 - ▶ What can we estimate from *the data alone* that will facilitate *meaningful comparisons of epidemics* ?
 - ▶ Initial epidemic growth rate?
 - ▶ This is a property of the epidemic curve.
 - ▶ We can estimate it without making assumptions about the processes that generated the data.
- 

Exponential growth at rate r

Linear scale

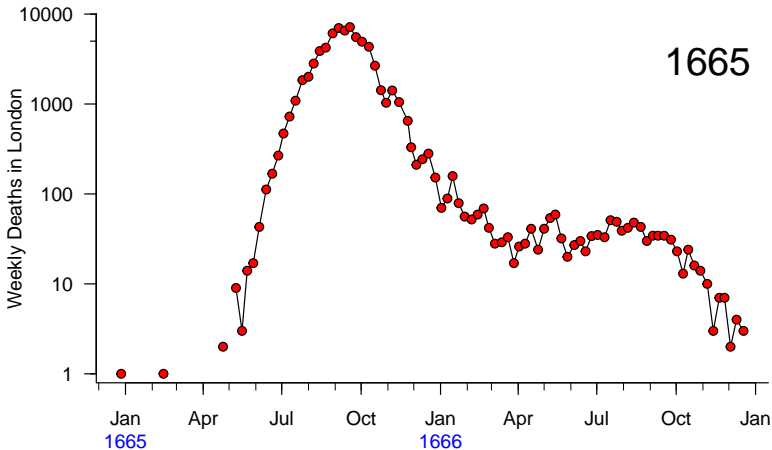


Log scale



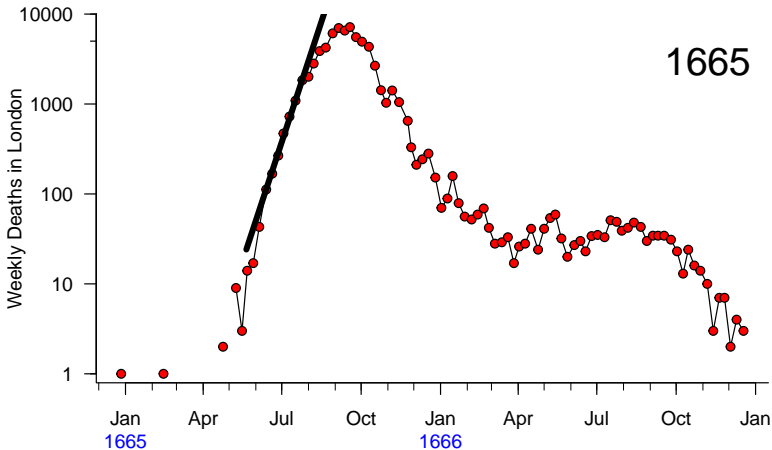
Estimating the initial growth rate of an epidemic

- ▶ Naïvely, we just fit a straight line to the log of the mortality time series.



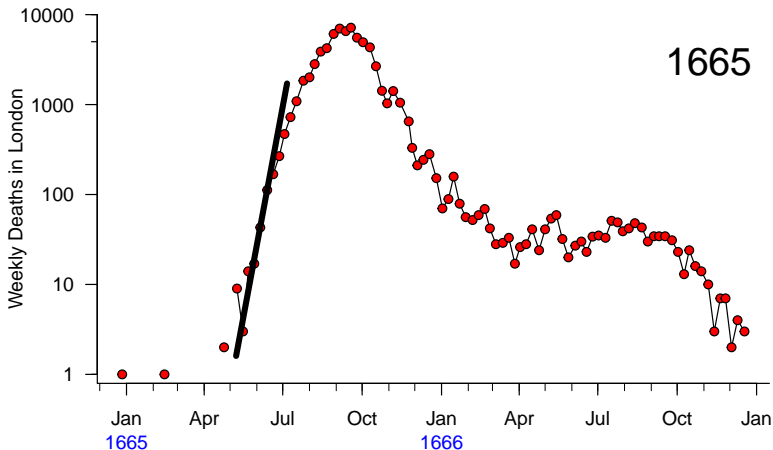
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Estimating the initial growth rate of an epidemic

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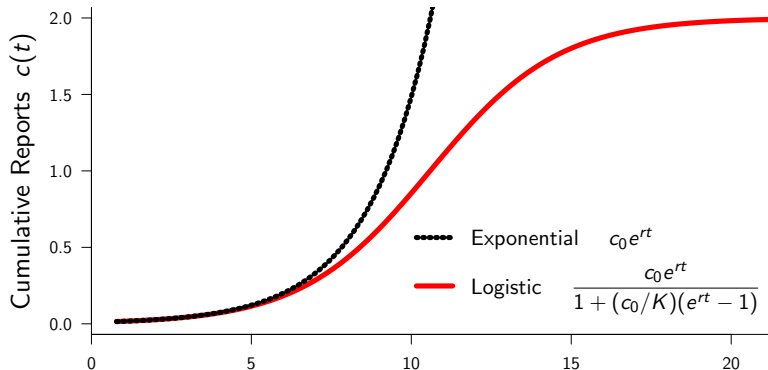
Estimating the initial growth rate of an epidemic

A number of *thorny issues*:

- ▶ How do we determine the *time window* during which growth was exponential?
 - ▶ “By eye” is not robust: different people choose different windows, yielding very different growth rates.
- ▶ How does *saturation* (“running out of susceptibles”) affect our estimates? *Growth is truly exponential only briefly.*
- ▶ How do we estimate a meaningful *confidence interval* (CI) for an estimated growth rate?
 - ▶ To compare different epidemics, we need to have CIs for each epidemic individually.

Estimating the initial growth rate of an epidemic

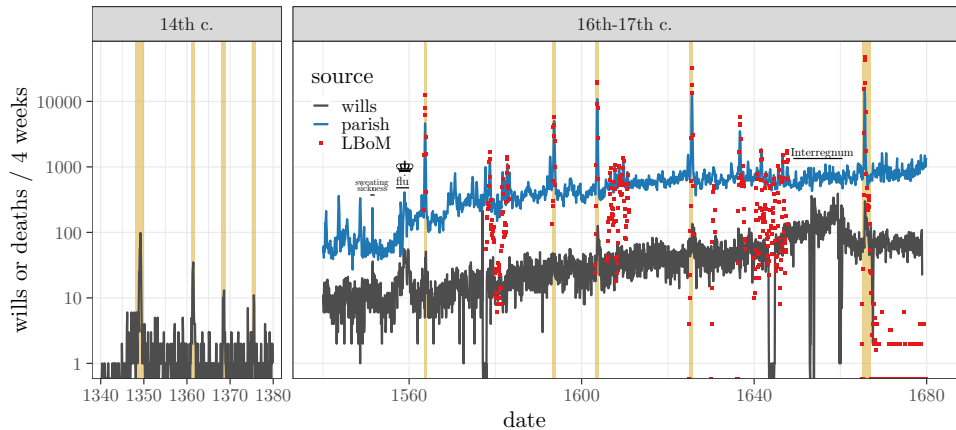
All these thorny issues can be addressed by fitting a **satürating** rather than a **purely exponential** curve.



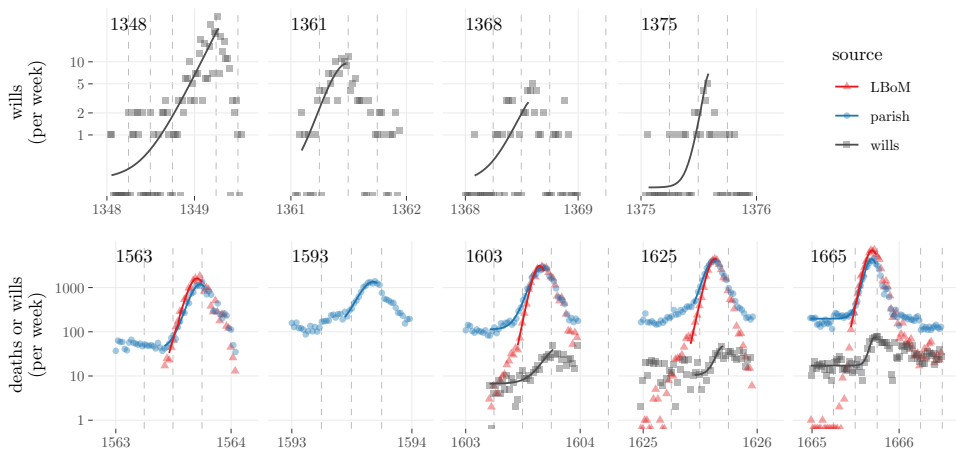
- ▶ Both curves have same initial exponential growth rate r .
- ▶ Test extensively using **simulated epidemics** for which we know the correct answer.

Application to Plague

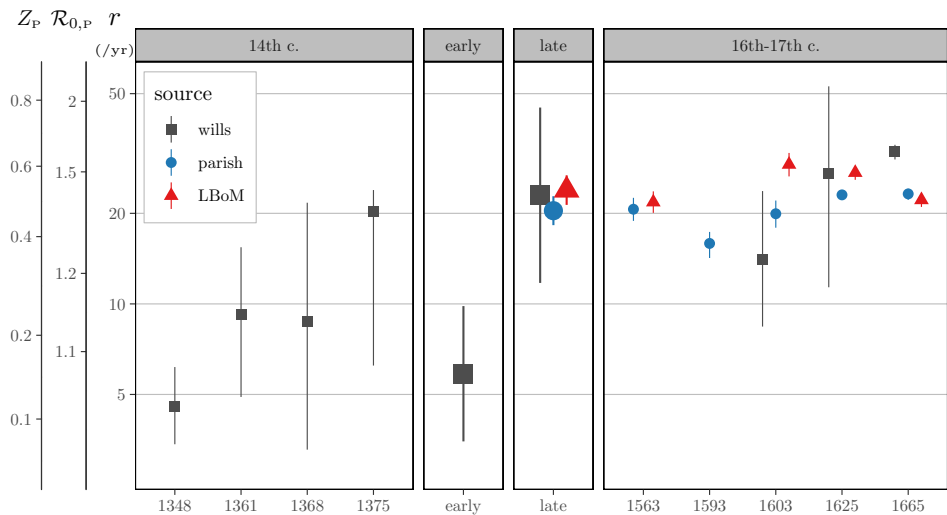
Plague Epidemics in London, 1348–1665



Fits to Plague Epidemics in London, 1348–1665



Initial growth rates for plague in London, 1348–1665



Earn, Ma, Poinar, Dushoff, Bolker (2020, *PNAS*, in press)

Initial growth rates for plague in London, 1348–1665

- ▶ Later plagues grew 4× faster than early plagues!

Proportional change in growth rate from 14th to 16th–17th centuries:

3.9× (95% CI: 1.5× to 10.3×)

p -value (permutation test): $2/126 = 0.016$

- ▶ Intuition is better for *doubling time* than growth rate.

First vs. last outbreak:

- ▶ 1348: ~ 56 days (95% CI: 41–74 days)
- ▶ 1665: ~ 11.4 days (95% CI: 10.8–12.0 days)

Early vs. late epoch:

- ▶ 14th c. wills: ~ 43 days (95% CI: 26–73 days)
- ▶ 17th c. wills: ~ 11 days (95% CI: 5.6–21.5 days)

Puzzles in the Patterns of Plagues. . .

- ▶ Why were plague epidemics in London *four times faster* in the 16th and 17th centuries than in the 14th century?
 - ▶ Pathogen evolution?
 - ▶ increased infectiousness?
 - ▶ longer infectious period?
 - ▶ Host population changes?
 - ▶ increased population density?
 - ▶ different social structure / contact patterns?
 - ▶ effects of selection on hosts in 1300s?
 - ▶ Weather or other environmental changes?
 - ▶ “Little Ice Age” *circa* 1300–1850 (minimum in 1600s)
 - ▶ Bubonic vs pneumonic plague?
 - ▶ Other ideas?

Bubonic or pneumonic plague?

Suppose pneumonic plague during second pandemic was exactly like modern pneumonic plague.

- ▶ Pneumonic in 14th century London?
 - ⇒ $\lesssim 20\%$ of population infected
 - BUT $\sim 30\text{--}50\%$ of total population died in 1348
 - ⇒ early plagues probably not (primarily) pneumonic
- ▶ A remarkable inference to be able to make based on counting wills! (and a little mathematical modelling)

Spatial Dynamics of Plague

in London, England

Why study spatial dynamics of plague?

- ▶ Is there evidence of spatial spread? or did plague enter the whole city roughly simultaneously?
- ▶ Fitting spatial transmission models to observed data may allow us to estimate:
 - ▶ disease properties (*e.g.*, latent and infectious periods);
 - ▶ patterns of contact within host population;
 - ▶ plausibility of bubonic vs pneumonic plague.

Some preliminary work in Karsten Hempel's 2018 PhD thesis

The Diseases and Casualties this Week.



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Albhallows Greac	42	41	S ^t James Dukes place	17	13	S ^t Martin Vintry	4	4
Albhallows Hovias	30	24	S ^t James Garlickhithe	10	12	S ^t Marlowe Fridaystreet	4	5
Albhallows Letic	17	17	S ^t John Baptist	11	10	S ^t Margit Milners	4	5
Albhallows Lumbardstreet	5	5	S ^t John Evangelist	1	0	S ^t Martin in the Fields	5	0
Albhallows Staining	21	18	S ^t John Zachary	12	9	S ^t Michael Aldersgate	5	0
Albhallows the Wall	33	28	S ^t Katharine Coleman	20	16	S ^t Michael Baitshaw	10	7
S ^t Alphege	13	5	S ^t Katharine Creechurch	34	29	S ^t Michael Cornhill	4	3
S ^t Andrew Hubbard	4	5	S ^t Lawrence Jewry	6	5	S ^t Michael Crookedlane	15	1
S ^t Andrew Underhaft	16	14	S ^t Lawrence Pountney	14	10	S ^t Michael Quenehithe	25	2
S ^t Andrew Wardrobe	3	2	S ^t Leonard Eastcheap	3	3	S ^t Michael Quenhithe	4	3
S ^t Ann Alderfer	28	27	S ^t Leonard Fenchurch	16	13	S ^t Michael Royal	20	1
S ^t Ann Blackyeres	57	50	S ^t Margaret Parish	5	4	S ^t Michael Woodstreet	6	3
S ^t Anthonis Parich	7	4	S ^t Margaret Louthbury	7	6	S ^t Mildred Breadstreet	4	3
S ^t Austins Parich	4	3	S ^t Margarec Mofes	5	4	S ^t Mildred Poultry	4	3
S ^t Bartholomew Exchange	7	7	S ^t Margarec New fillstreet	13	13	S ^t Nicholas Acon	4	3
S ^t Bennet Fynack	4	2	S ^t Margarec Patton	4	3	S ^t Nicholas Coleaby	8	3
S ^t Bennet Gracechurch	4	2	S ^t Mary Abchurch	7	5	S ^t Nicholas Olaves	8	8
S ^t Bennet Paulwharfe	15	7	S ^t Mary Aldermanbury	14	14	S ^t Olave Hartstreet	13	1
S ^t Bennet Sherehog	2	2	S ^t Mary Aldermay	4	4	S ^t Olave Jewry	5	4
S ^t Boroloh Billinggate	8	8	S ^t Mary le Bow	1	1	S ^t Olave Silverstreet	5	4
Chrifs Church	44	39	S ^t Mary Bothaw	6	4	S ^t Pancras Soperlane	1	1
S ^t Christophers	4	4	S ^t Mary Colechurch	3	1	S ^t Peter Cheap	4	3
S ^t Clement Eastcheap	1	1	S ^t Mary Hill	11	8	S ^t Peter Cornhill	8	8
S ^t Dionis Backchurch	9	2	S ^t Mary Mounchaw	4	3	S ^t Peter Paulwharf	10	8
S ^t Dunstan East	28	24	S ^t Mary Sommefer	44	38	S ^t Peter Poor	4	3
S ^t Edmund Lumbardst	3	1	S ^t Mary Swayning	3	3	S ^t Steven Colemanstreet	4	3
S ^t Ethelborough	7	4	S ^t Mary Woolchurch	7	4	S ^t Steven Walbrook	2	2
S ^t Faich	8	6	S ^t Mary Woolnoth	7	5	S ^t Swithin	6	6
S ^t F.ter	8	6	S ^t Martin Ironmongerlane	2	2	S ^t Thomas Apostle	2	2
S ^t Gabeiel Fenchurch	3	3				Trinity Parich	10	8

Christned in the 97 Parishes within the Walls 39 Buried 1149 Plague 99

S ^t Andrew Holborn	173	151	S ^t Boroloh Aldgate	374	338	S ^t aviours Southwark	364
S ^t Bartholomew Greac	17	15	S ^t Boroloh Bishopsgate	153	121	S. Sepulchres Parich	147
S ^t Bartholomew Lette	7	7	S ^t Dunstan West	63	59	S ^t Thomas Southwark	2
S ^t Bridge	92	67	S ^t George Southwark	140	133	Trinity Minorities	8
Bidwell Precinct	23	23	S ^t Giles Cripplegate	196	151	at the Pesthouse	24
S ^t Boroloh Alderigate	71	64	S ^t Olave Southwark	378	281		

Christned in the 16 Parishes without the Walls 45 Buried, and at the Pesthouse 2358 Plague 1

S ^t Giles in the fields	95	78	Lambeth Parich	49	39	S ^t Mary Abington	35
Hackney Parich	14	12	S ^t Leonard Shoreditch	95	94	S ^t Mary Wharfedale	32
S ^t James Clerkenwell	48	42	S ^t Magdalen Beemenley	138	106	Rothsith Parich	21
S ^t Kath near the Tower	55	49	S ^t Mary Newington	31	21	Scepney Parich	67

Christned in the 12 out Parishes in Middlesex and Surry 40 Buried 1623 Plague 1

S ^t Clement Danes	1	1	S ^t Martin in the fields	209	143	S ^t Margarec Westminster	30
S ^t Paul Covent Garden	35	24	S ^t Mary Savoy	19	16	at the Pesthouse	

Christned in the 5 Parishes in the City and Liberties of Westminster 18 Buried 690 Plague

	Bur.	Plag.	
S^t Alban Woodstreet	16	12	S^t George Botolph
Alhallows Barking	46	34	S^t Gregory by S^t
Alhallows Breadstreet	1	1	S^t Hellen
Alhallows Great	42	41	S^t James Dukes
Alhallows Honylane			S^t James Garlick
Alhallows Lesse	17	17	S^t John Baptist
Alhallows Lumbardstreet	5	5	S^t John Evangeli
Alhallows Staining	21	18	S^t John Zachary
Alhallows the Wall	33	28	S^t Katharine Col
S^t Alphage	13	5	S^t Katharine Cre
S^t Andrew Hubbard	4		S^t Lawrence Jew
S^t Andrew Undershaft	16	14	S^t Lawrence Pou
S^t Andrew Wardrobe	30	24	S^t Leonard East

LONNDR 29^o From the 4^o of July to the 11^o of Aug. same 1665

Buried.		Plag.	Buried.		Plag.	Buried.		Plag.	Buried.		Plag.
St Alban Woodstreet	2	1	St Clement Eastcheap	1	St Margaret Newfish		St Michael Crookedla.	4	3		
Alhallows Bark-	2		St Dionis Backchurch	1	St Margaret Pattons		St Michael Queenhith	4			
Alhallows Breadstreet			St Dunstons East	2	St Mary Abchurch	1	St Michael Quern	7			
Alhallows Great	1		St Edmund Lumbardst.	1	St Mary Aldermanbury		St Michael Royal				
Alhallows Honilanc			St Ethelborough	2	St Mary Alde mary		St Michael Woodstreet				
Alhallows Lef	1		St Faiths	1	St Mary le Bow		St Mildred Breadstreet				
Alhallows Lumbardstr.			St Gabriel Fenchurch		St Mary le Bow		St Mildred Poultry				
Alhallows Staining	1		St George Botolphlane		St Mary Colechurch		St Nicholas Acons				
Alhallows the Wall	4	3	St Gregories by St. Paul		St Mary Hill		St Nicholas Coleabby				
St Alphege	1		St Hellen	2	St Mary Mag. Milkstr.		St Nicholas Olaves				
St Andrew Hubbard			St James Dukes place	1	St Mary Mag. Oldfishst		St Olave Hartstreet				
St Andrew Undershaft	3		St James Garlickhith	1	St Mary Mounthaw		St Olave Jewry				
St Andrew Wardrobe			St John Baptist		St Mary Summersec	2	St Olave Silverstreet		4	1	
St Anne Aldersgate	1	6	St John Evangelist		St Mary Staining		St Pancras Soperlane				
St Anne Blackfryers	7		St John Zachary		St Mary Woolchurch		St Peter Cheap				
St Antholins Parish	1		St Katharine Coleman	1	St Mary Woolnoth		St Peter Cornhil				
St Austins Parish			St Katharine Creechur.		St Martins Iremongerl.		St Peter Paulswharf				
St Barthol. Exchange	1		St Lawrence Jewry		St Martins Ludgate	2	St Peter Poor		1		
St Bennet Fynck			St Lawrence Pountney		St Martins Orgars		St Steven Colemanstr.		2	1	
St Bennet Gracechurch	2		St Leonard Eastcheap		St Martins Outwich	1	St Steven Walbrook				
St Bennet Paulswharf	7		St Leonard Fosterlane		St Martins Vintrey	1	St Swithin		2	1	
St Bennet Sherehog			St Magnus Parish	1	St Matthew Frydaystr.		St Thomas Apostle		1	1	
St Borolp Billingfgate			St Margaret Lothbury		St Michael Bassishaw	5	Trinity Parish		1		
Christ Church	5	3	St Margaret Moses		St Michael Cornhil		St Vedast alias Fosters				
St Christophers											
Christned in 9 the Parishes within the walls			Buried			36		Plague		28	

St Andrew Holborn	06	40	St Borolp Aldersgate	11	9	St George Southwark	13	4	St Sepulchres Parish	117	81
St Bartholomew Great	7	4	St Borolp Aldgate	24	4	St Giles Cripplegate	105	49	St Thomas Southwark	7	5
St Bartholomew Lef			St Borolp Bishopsgate	37	20	St Olave Southwark	20	6	Trinity Minories		
St Bridget	24	17	St Dunstan West	19	9	St Saviour Southwark	21	1	At the Pesthouse	6	6
Bridewel Precinct	1	1									
Christned in the 16 Parishes without the walls			Buried			473		Plague		253	

Christs Church			St Kath. near the Tower	5	1	St Mary Issington	3	2	St Paul Shadwel		
St John at Hackney	1		Lambeth Parish	7		St Mary Newington	7		Rotherhith Parish	7	3
St Giles in the Fields	208	213	St Leonard Shoreditch	21	13	St Mary Whitechappel	16	5	Stepney Parish	47	1
St James Clerkenwel	55	73	St Magdalen Bermond.	14							
Christned in the 12 Out-Parishes in Middlesex and Surrey			Buried			455		Plague		286	

St Clement Danes	29	15	St Martins in the fields	153	101	St Mary Savoy	8	6	St Margaret Westminster	28	34
St Paul Covent Garden	4							whereof at the Pesthouse		3	

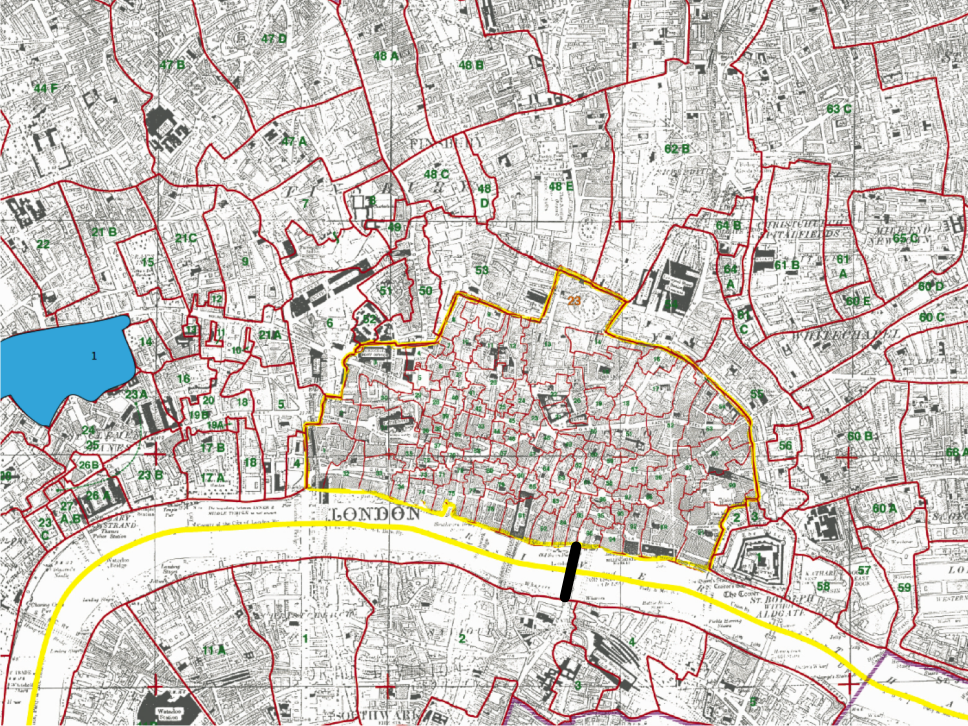
St Andrew Holborn—	66	40	St B
St Bartholomew Great	7	7	St B
St Bartholomew Less—			St B
St Bridget—	24	14	St D
Bridewel Precinct—	1	1	

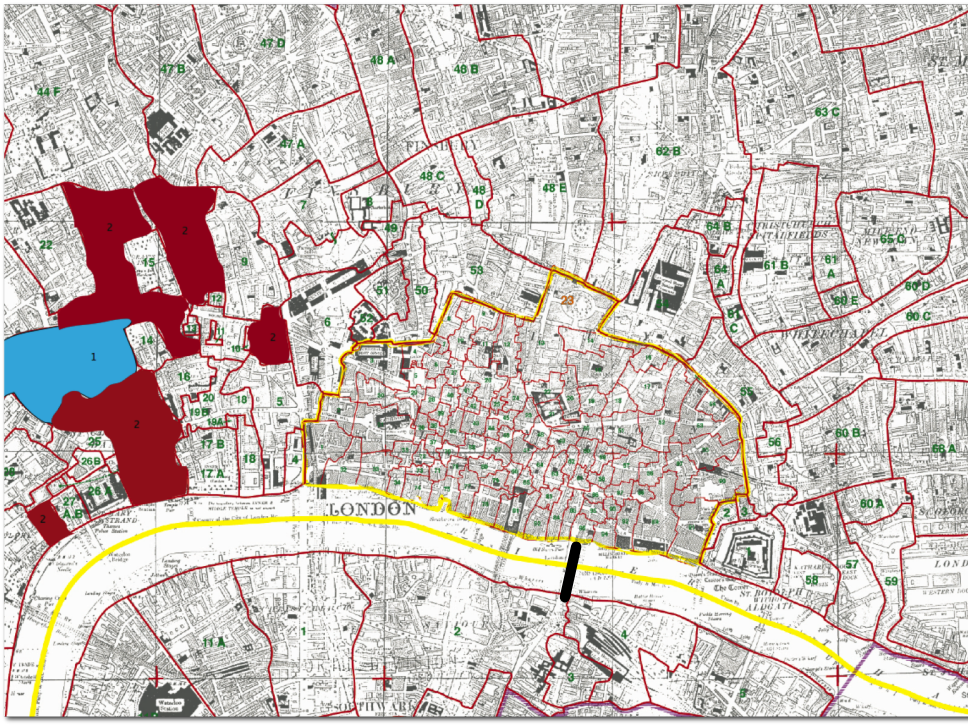
Christned in the 16 Parishes wit

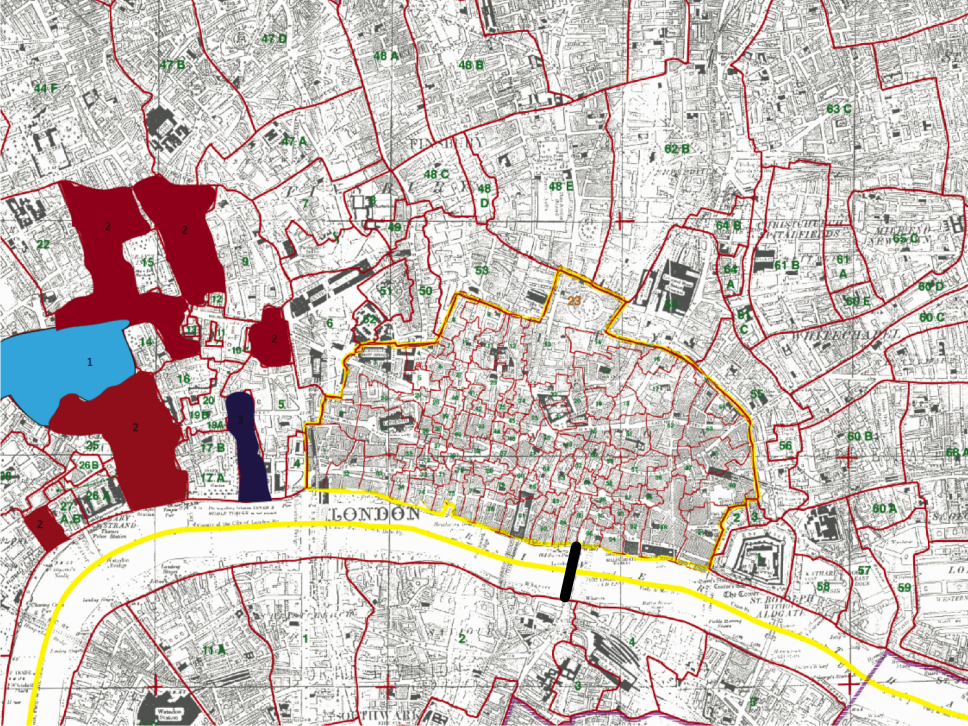
Christs Church—			St K
St John at Hackney—	1		Lan
St Giles in the Fields—	268	215	St L
St James Clerkenwel—	67	50	St M

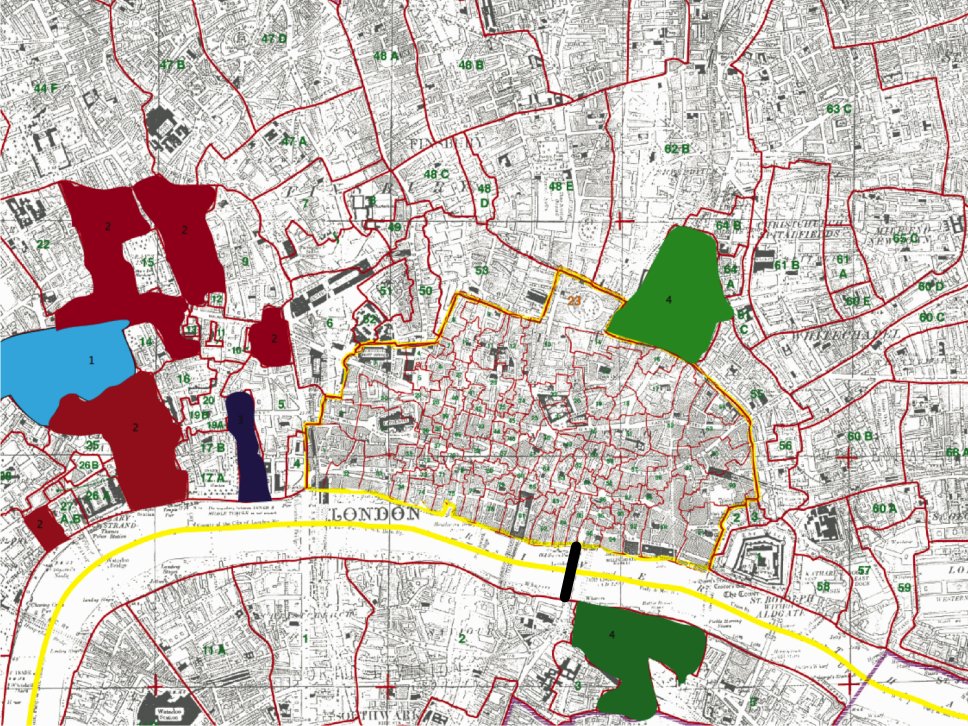
Christned in the 12 Out-Parishes in M

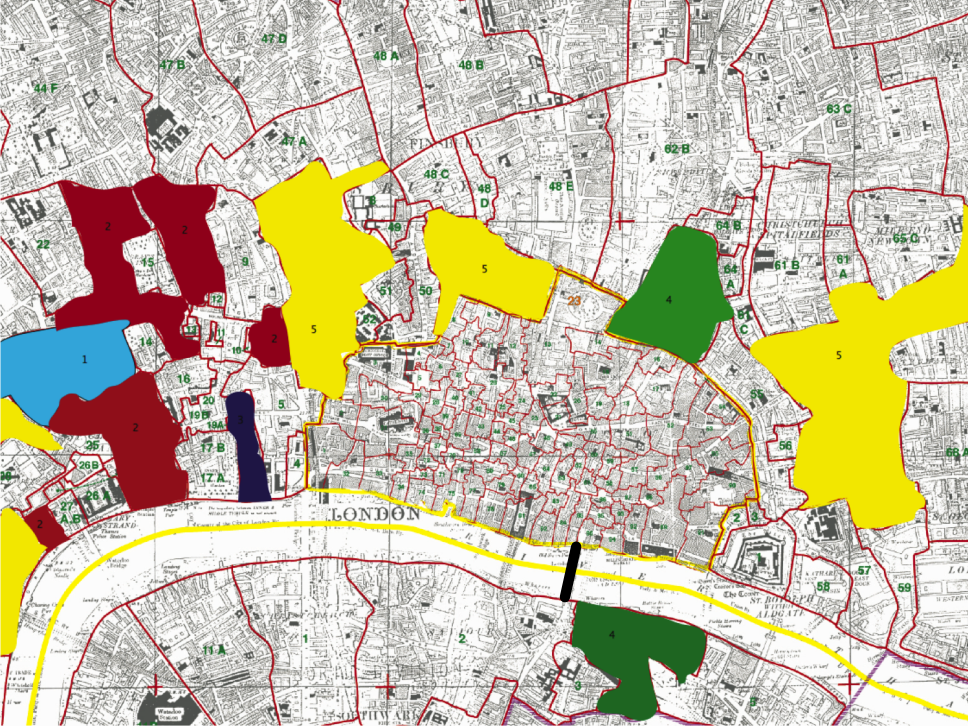


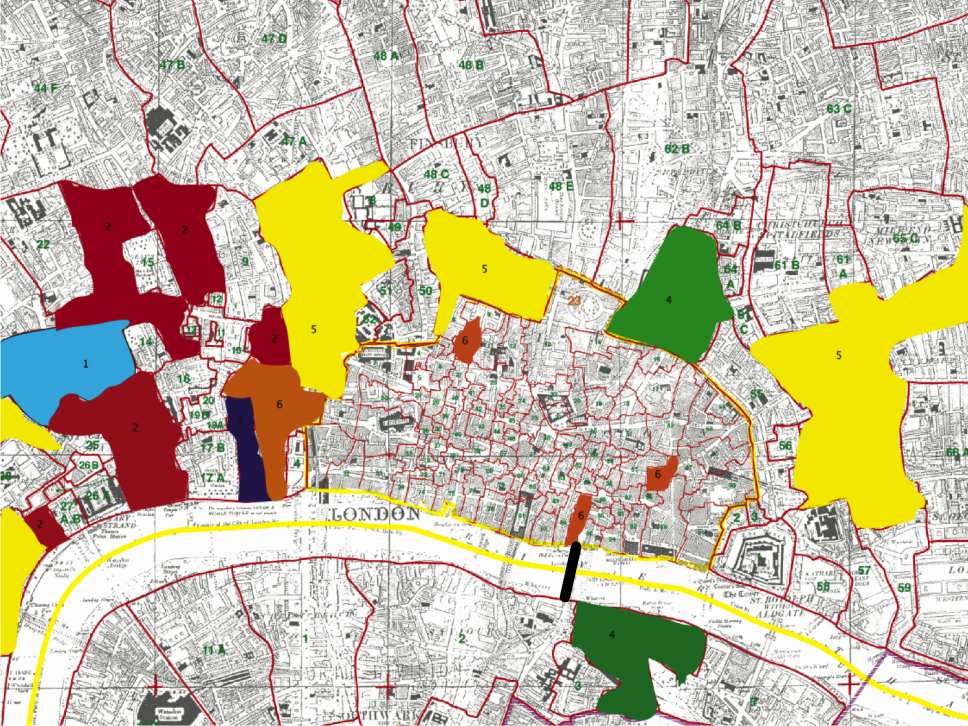


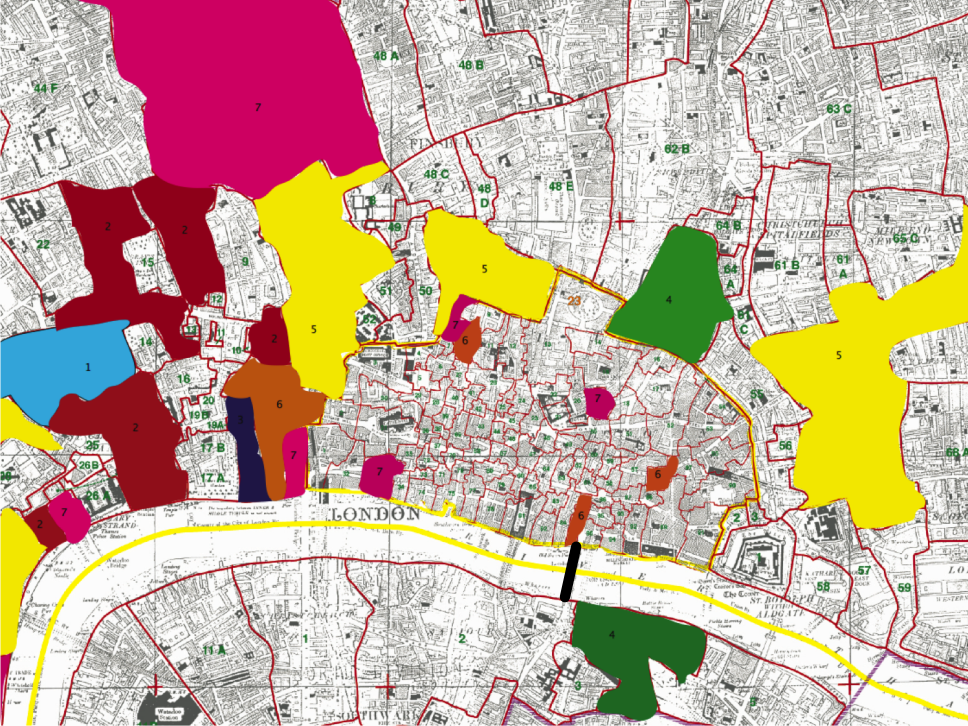


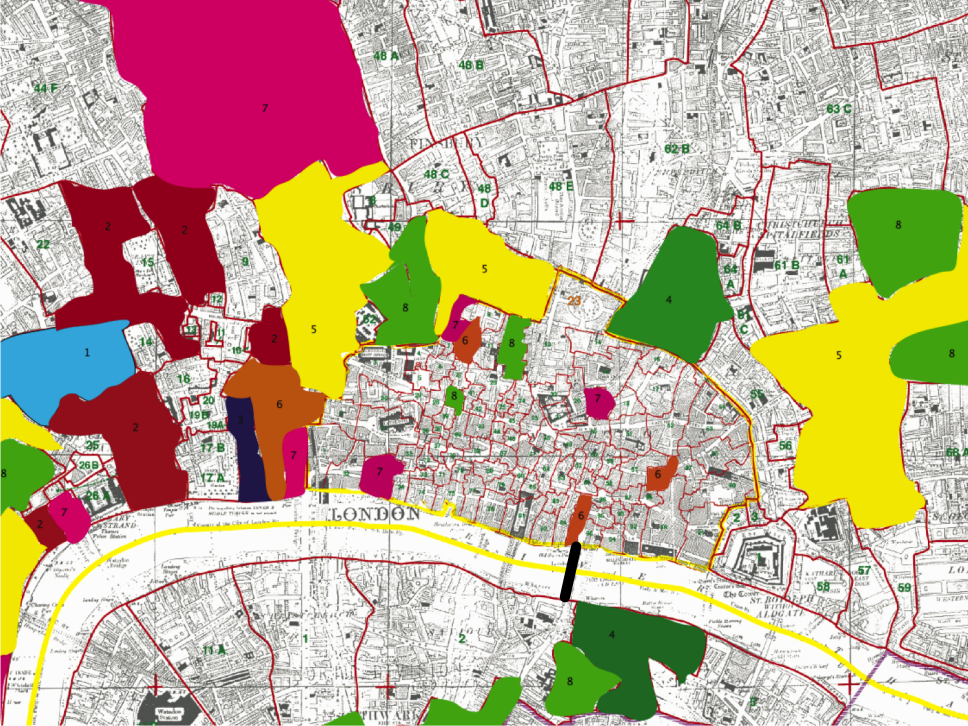


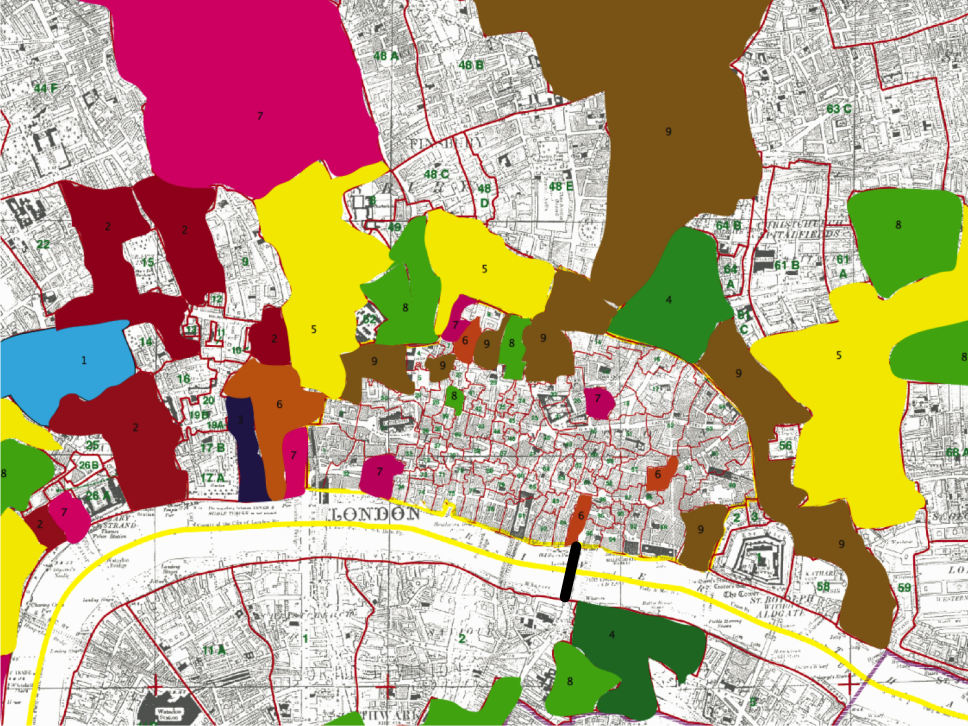




























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When graphics professionals get involved. . .

- ▶ CBC was not satisfied with that animation. . .
- ▶ So they made their own version:

The Nature of Things Animation

EpiVis Animation



Another Plague Puzzle. . .

- ▶ Why did plague disappear in London after 1666?
- ▶ We can speculate that the distance between humans and rats generally increased. For example:

. . . Thatch roofs, in particular, offered ready refuge for rats; and it was easy for a flea to fall from such a roof onto someone beneath. When thatch roofs were replaced by tiles, as happened generally in London after the Great Fire of 1666, opportunities for this kind of transfer of infection drastically diminished. Hence the popular notion that the Great Fire somehow drove the plague from the city probably had a basis in fact.

– McNeill 1978, “Plagues and Peoples”, p. 153

Plague in Our Time

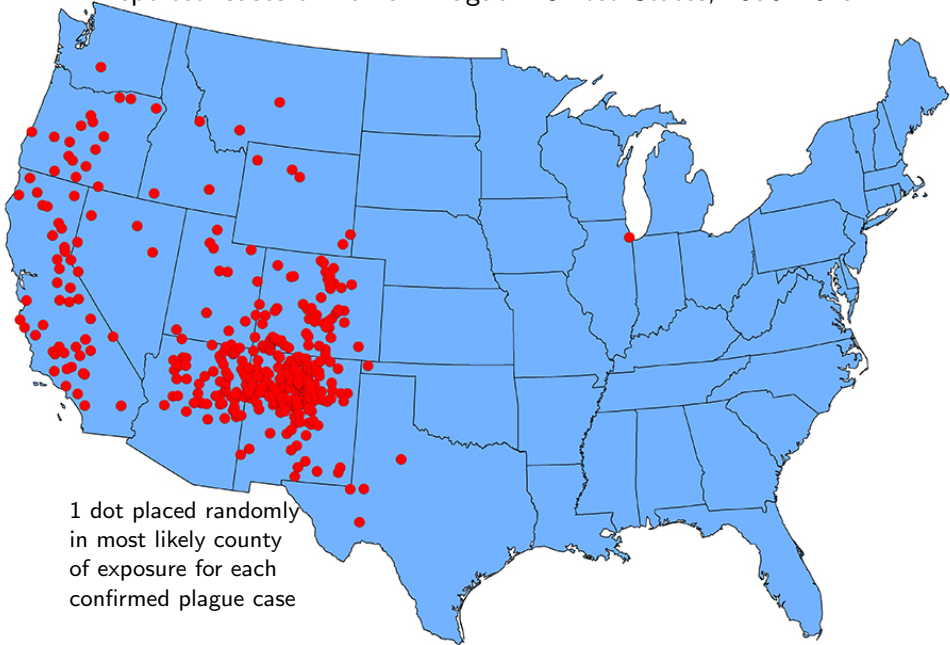
The Global Distribution of Plague

Reported* Plague Cases by Country, 2010–2015



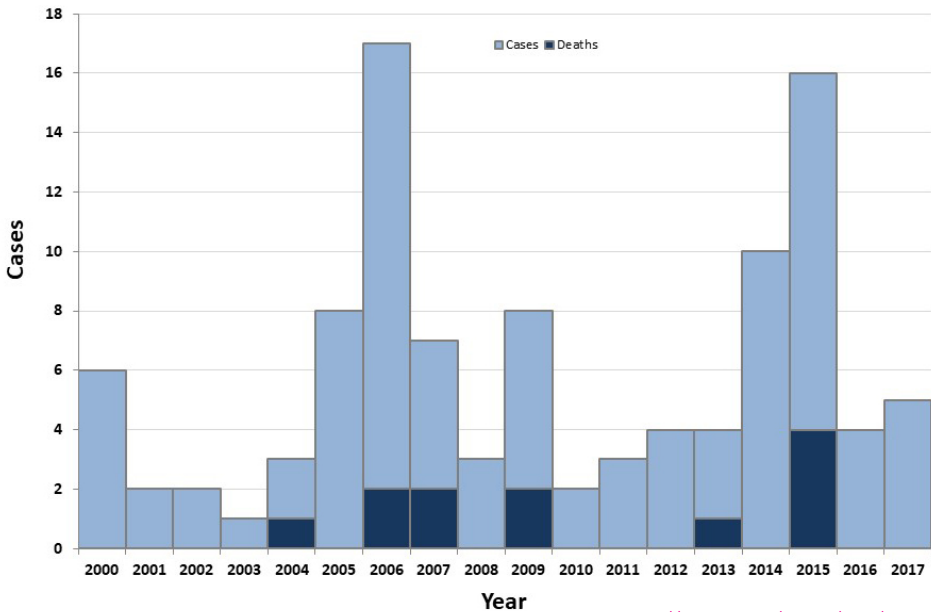
<https://www.cdc.gov/plague/maps/>

Reported Cases of Human Plague – United States, 1970–2017



1 dot placed randomly
in most likely county
of exposure for each
confirmed plague case

Human Plague Cases and Deaths – United States, 2000–2017



plague



plague

NOUN

- 1 (usually **the plague**) A contagious bacterial disease characterized by fever and delirium, typically with the formation of buboes (see bubonic plague) and sometimes infection of the lungs (pneumonic plague).
See also **bubonic plague**

+ Example sentences

- 1.1 Any contagious disease that spreads rapidly and kills many people.



plague



– Example sentences

‘The pneumonic plague would be the form most likely implicated in the event of an intentional attack.’

‘At first, bioterrorism – whether it's inhalation anthrax, smallpox, pneumonic plague or something else entirely – will probably feel like the flu.’