

8 Epidemic Data

9 Epidemic Data II



Mathematics
and Statistics

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

Mathematics 4MB3/6MB3 Mathematical Biology

Instructor: David Earn

Lecture 8
Epidemic Data
Wednesday 24 January 2018

Announcements

- Thanks everyone for doing the contributions survey for Assignment 1.
- Don't stress about the ratings about each other's contributions. The issue is whether some group members did not pull their weight. If somebody didn't try and others had to pick up the slack, that person should be penalized. I will not penalize somebody because they tried but felt they didn't contribute as much to the final document as they could have. Do try to even out the work across the assignments.
- Make sure everyone in your group gets a chance to be in control of the \LaTeX for one assignment.

More Announcements!

- **Assignment 2:**

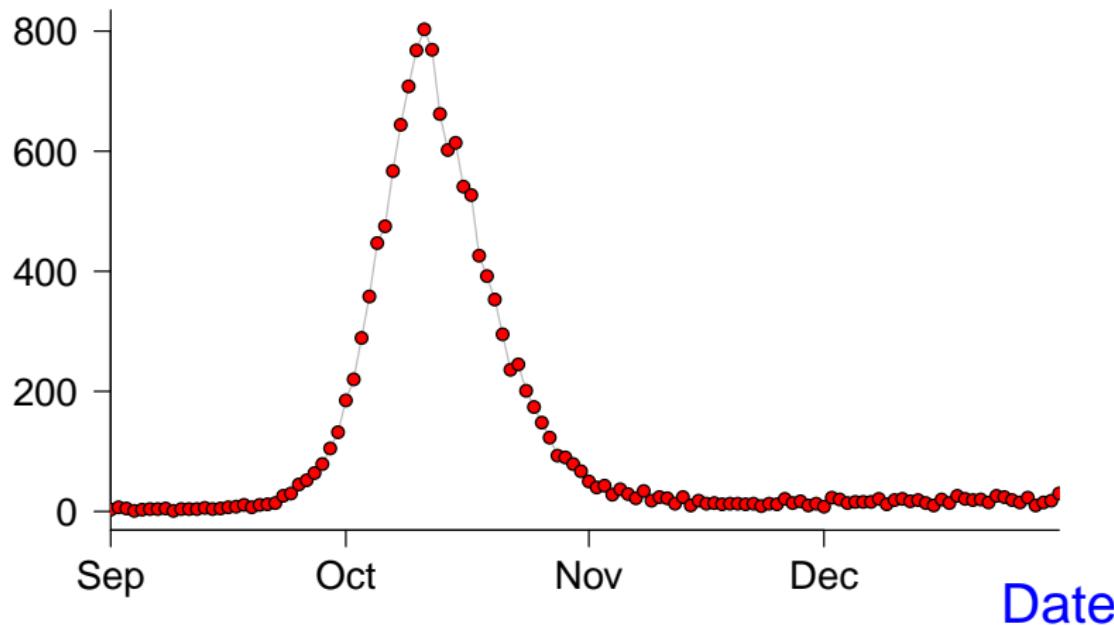
Due Monday 5 February 2018 in class (and by e-mail) at 11:30am.

- **Midterm test:**

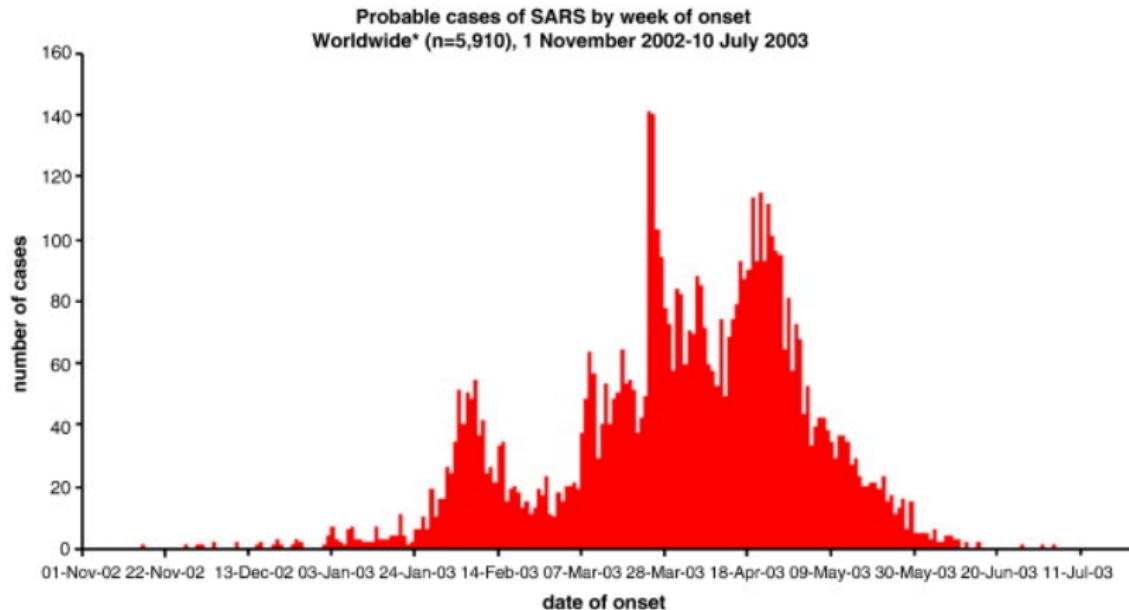
- *Date:* week of 5–9 March? or 12–16 March?
- *Time:* TBA
- *Location:* TBA

P&I Mortality, Philadelphia, 1918

P&I Deaths

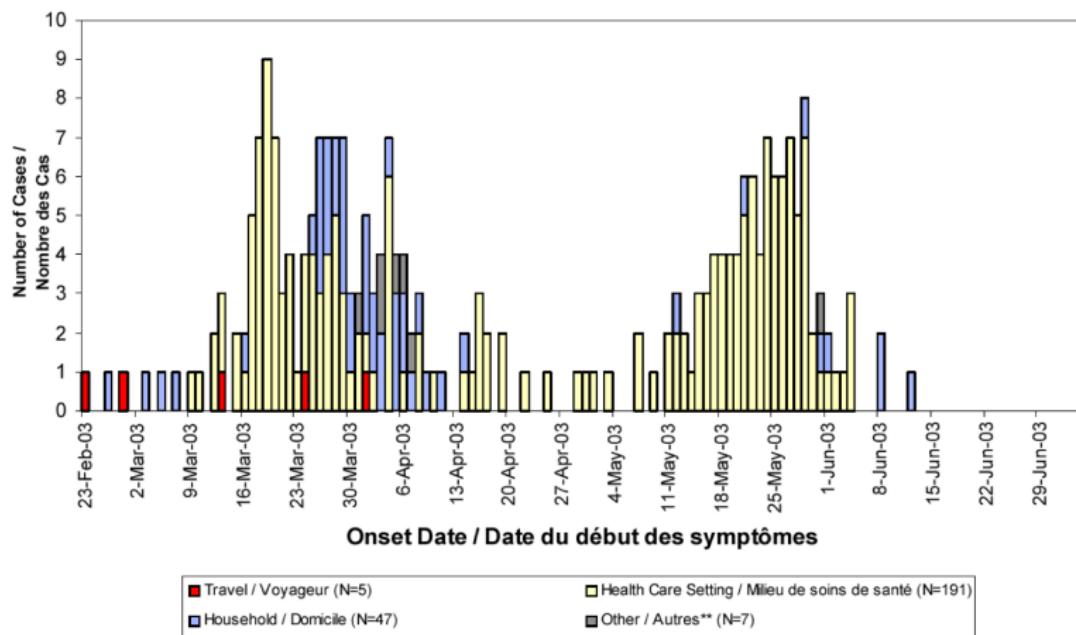


SARS in 2003 (Worldwide)



*This graph does not include 2,527 probable cases of SARS (2,521 from Beijing, China), for whom no dates of onset are currently available.

SARS in 2003 (Toronto)

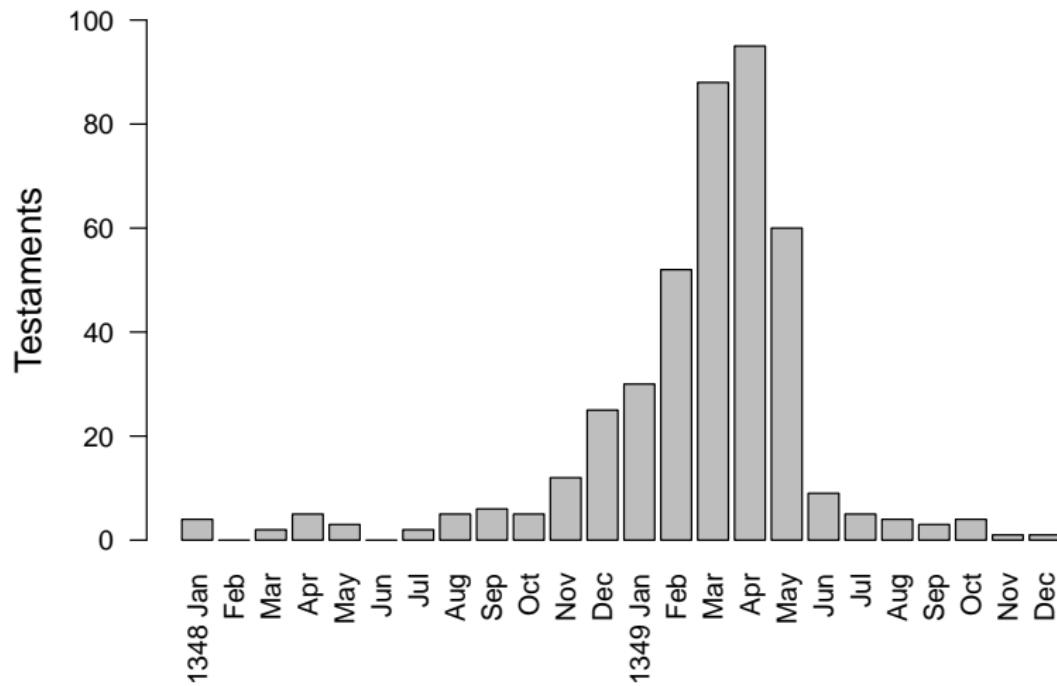


$N = 249$ (of 250 reported)

Some SARS Facts

- High case fatality
 - 1918 flu < 3%
 - SARS > 10%
- Long hospital stays
 - Mean time from admission to discharge or death:
~ 25 days in Hong Kong
- 8098 probable cases, 774 deaths
- How bad would it have been if it had not been controlled?

The Black Death in London, England, 1348–1349



London Bill of Mortality, 26 Sept to 3 Oct 1665

The Diseases and Casualties this Week,



Bortive	1
Aged	6
Ague	50
Apoxyxie	1
Chilblains	42
Chirfomes	11
Cold	1
Consumption	99
Convallion	63
Cough	1
Dropyle	22
Drown'd at St. Martin in the Fields	1
Feaver	268
Fiftula	2
Flor and Small-pox	4
Flux	1
Found dead in the Fields at St. Mary Iffington	1
Males	687
Christned Females	78
In all	146
Decreased in the Burials this Week	1837
Parishes clear of the Plague	7
Males	3212
Baried Females	3248
In all	6460
Plague	5533

London 41		From the 26 of September to the 3 of October.										1665	
	Bur. Reg.											Bur. Reg.	
S ^t Andrew Holborn	16 15	S ^t George Bosophilus—					S ^t Martin Ludgate—					1 10	
S ^t Bartholomew Great—	40 34	S ^t George in S ^t Paul's—					S ^t Martin Orgar—					3 3	
S ^t Bartholomew Less—	7 75	S ^t James Duke place—					S ^t Martin Outwich—					6 5	
S ^t Bridge—	92 67	S ^t James Garlickhithe—					S ^t Martin Vintry—					44 44	
Bridewell Precinct—	33 23	S ^t John Bowes—					S ^t Michael Fridayfayre—					4 4	
S ^t Botolph Bishopsgate—	3 35	S ^t John Evangelist—					S ^t Michael Oldholtre—					4 4	
S ^t Botolph Wal—	33 28	S ^t John Fishmonger—					S ^t Michael Buffawen—					10 7	
S ^t Cuthbert—	13 55	S ^t Katharine Creechard—					S ^t Michael Cornhill—					4 3	
S ^t Andrew Undershaft—	16 14	S ^t Lawrence Jewry—					S ^t Michael Queenhithe—					15 12	
S ^t Andrew Undershaft—	30 24	S ^t Mary Aldermanbury—					S ^t Michael Queenhithe—					15 12	
S ^t Benet Finsbury—	18 22	S ^t Mary Aldermoorney—					S ^t Michael Royal—					4 3	
S ^t Benet Blackfriars—	57 30	S ^t Mary Fenchurche—					S ^t Michael Woodlark—					10 9	
S ^t Antholme Paroch—	7 45	S ^t Margaret Pavill—					S ^t Michael Woodlark—					6 3	
S ^t Antholme Paroch—	14 59	S ^t Margarete Lothbury—					S ^t Michael Woodlark—					4 4	
S ^t Barresby Exchange—	12 72	S ^t Margarete Mofes—					S ^t Nicholas Acon—					4 2	
S ^t Benet Finsbury—	12 72	S ^t Margarete Newfaze—					S ^t Nicholas Colehale—					2 2	
S ^t Benet Gracechurch—	4 2	S ^t Mary Abchurch—					S ^t Nicholas Olaves—					9 8	
S ^t Benet Paulwharf—	15 7	S ^t Mary Aldermanbury—					S ^t Olave Hartfoure—					13 14	
S ^t Benet Shereches—	8 13	S ^t Mary Aldemorey—					S ^t Olave Jewry—					7 4	
S ^t Bouth Billinggate—	8 18	S ^t Mary le Bow—					S ^t Olave Newfaze—					4 4	
S ^t Cuthbert—	14 59	S ^t Mary le Bow—					S ^t Pancras Soperiane—					1 1	
S ^t Clement Eastchurche—	7 45	S ^t Mary le Bow—					S ^t Peter Cheape—					1 1	
S ^t Dionis Backborow—	9 2	S ^t Mary le Bow—					S ^t Peter Cornhill—					6 6	
S ^t Dunstan East—	18 24	S ^t Mary Mountayne—					S ^t Peter Paulwharf—					10 10	
S ^t Edmund Lambrechts—	3 1	S ^t Mary Somerses—					S ^t Peter Pover—					2 2	
S ^t Ethelburgh—	7 45	S ^t Mary Steynning—					S ^t Steven Colemanfie—					33 28	
S ^t Faith—	8 65	S ^t Mary Woolchurche—					S ^t Steven Wallbroke—					3 2	
S ^t Fister—	8 65	S ^t Mary Woolnoth—					S ^t Thomas Beale—					6 5	
S ^t Gabriel Finchurche—	3 3	S ^t Martin Iwengengiane—					S ^t Thomas Finche—					10 9	
<i>Certified in the 12 Parishes within the walls—39 Buried, 1149 Plague—948</i>												Trinity Paroch.	
<i>Certified in the 16 Parishes without the walls—45 Buried, and in the 2 Parishes—2258 Plague—1913</i>												M	
S ^t Giles in the Fields—	95 78	S ^t Bowbelle Aldgate—					S ^t Swithin Southwark—					364 352	
S ^t Hencote Paroch—	14 12	S ^t Bowbelle Billingsgate—					S ^t Sepulchre Paroch—					117 95	
S ^t James Clerkenwell—	48 42	S ^t Dunstan West—					S ^t Thomas Southwark—					40 20	
S ^t Kath. near the Tower—	15 39	S ^t George Southwark—					S ^t Trinity Minories—					24 20	
<i>Certified in the 12 Parishes in Middlesex and Surry—40 Buried—1623 Plague—1469</i>												M	
S ^t Clement Danes—	13 810	S ^t Martin in the fields—					S ^t Margaret Wellingtem—					309 147	
S ^t Paul Covent Garden—	164 144	S ^t Mary Savoy—					S ^t Mary Whitechurche—					38 301	
<i>Certified in the 5 Parishes in the City and Liberties of Wellingtem—18 Buried—690 Pla—590</i>												M	

Mortality Bills are typically handwritten

London 29: From the 4 th of July to the 11 th of the same 1665																	
Buried			Plag.			Buried			Plag.			Buried			Plag.		
St Alban Woodstreet	2		St Clement Eastchapp-			St Margaret Newfisht			St Michael Crookedla.			St Michael Queenhithe	4		3		
Alhallows Bark-	2		St Dionys Backchurch	1		St Margret Patrons			St Michael Quern	7		St Michael Royal					
Alhallows Breadfreet			St Dunstans East	2		St Mary Abchurch			St Michael Woodstreet			St Mildred Breadfreet					
Alhallows Great	1		St Edmund Lumbardis	2		St Mary Aldermanbury			St Mildred Poultrey			St Nicholas Acons					
Alhallows Honilane			St Ethelborough	2		St Mary Aldemary			St Nicholas Coleabbi-			St Nicholas Olaves					
Alhal ows Less	1		St Faiths	1		St Mary le Bow			St Olave Hartfreet			St Olave Jewry					
Alhallows Lombardstr			St Gabriel Fenchurch			St Mary Bothaw			St Olave Silverstreet			St Pancras Soperlane	+		1		
Alhallows Staining	1		St George Botolphane			St Mary Colechurch			St Peter Cheap			St Peter Cornhill					
Alhallows the Wall	4	3	St Gregories by St. Paul			St Mary Hill			St Peter Paulisharf			St Peter Paullwharf					
St Alphege			St Hellen	2		St Mary Mag. Milkstr.			St Peter Poor			St Steven Colemanstr.	2		1		
St Andrew Hubbard			St James Dukes place	1		St Mary Mag. Oldfish			St Steven Walbrook			St Steven Walbrook					
St Andrew Underhafe	3		St James Garlickhithe			St Mary Mounthaw			St Swithin			St Thomas Apostle	1		1		
St Andrew Wardrobe			St John Baptis			St Mary Summercer			Trinity Parish			Trinity Parish					
St Anne Alderfae			St John Evangelist			St Mary Straining			St Vedast alias Fosters								
St Anne Blackfriars	7		St John Zichary			St Mary Woolchurch											
St Anschles Parish			St Katharine Coleman	1		St Mary Woolnoth											
St Aufins Parish			St Katharine Creechur.			St Martins Iremonger											
St Barthol Exchange			St Lawrence Jewry			St Martins Ludgate	2										
St Benner Fynck			St Lawrence Pountney			St Martins Orgars											
St Benner Gracechurch	2		St Leonard Eastcheap			St Martins Outwich	1										
St Benner Paulsharf	7		St Leonard Fosterlane			St Martins Vintrey	1										
St Benner Sherehog			St Magnus Parish	1		St Matthew Frydaystr.											
St Boroloph Billinggate			St Margaret Lothbury			St Michael Balliflaw	5	4									
Christ Church			St Margaret Moles			St Michael Cornhill											
Se Christophs	2	3															
Christened in the 27 Parishes within the walls												86	Plague		28		
St Andrew Holborn	66	40	St Boroloph Aldergate	11	7	St George Southwark	13		St Sepulchres Parish	117	81						
St Bartholomew Great	4	4	St Boroloph Aldgate	27	4	St Giles Cripplegate	103	47	St Thomas Southwark	7	5						
St Bartholomew Less			St Boroloph Bishopgate	37	20	St Olave Southwark	20		Trinity Minories								
St Bridge	24	14	St Dunstan West	19	9	St Saviour Southwark	21	1	At the Pesthouse	6	6						
Bridewell Preinct																	
Christened in the 15 Parishes without the walls												473	Plague		273		
Christ Church			St Kath.near the Tower	7	1	St Mary Islington	3	2	St Paul Shadwell								
St John at Hackney	1		Lambeth Parish	7	1	St Mary Newington	3	2	Rotherhithe Parish	7	3						
St Giles in the Fields	268	213	St Leonard Shoreditch	21	13	St Mary Whitechapel	16	3	Stepney Parish	47	1						
St James Clerkenwel	5		St Magdalens Bermond.	14													
Buried in the 27 Parishes within the walls												455	Plague		286		

But handwriting is usually very clear

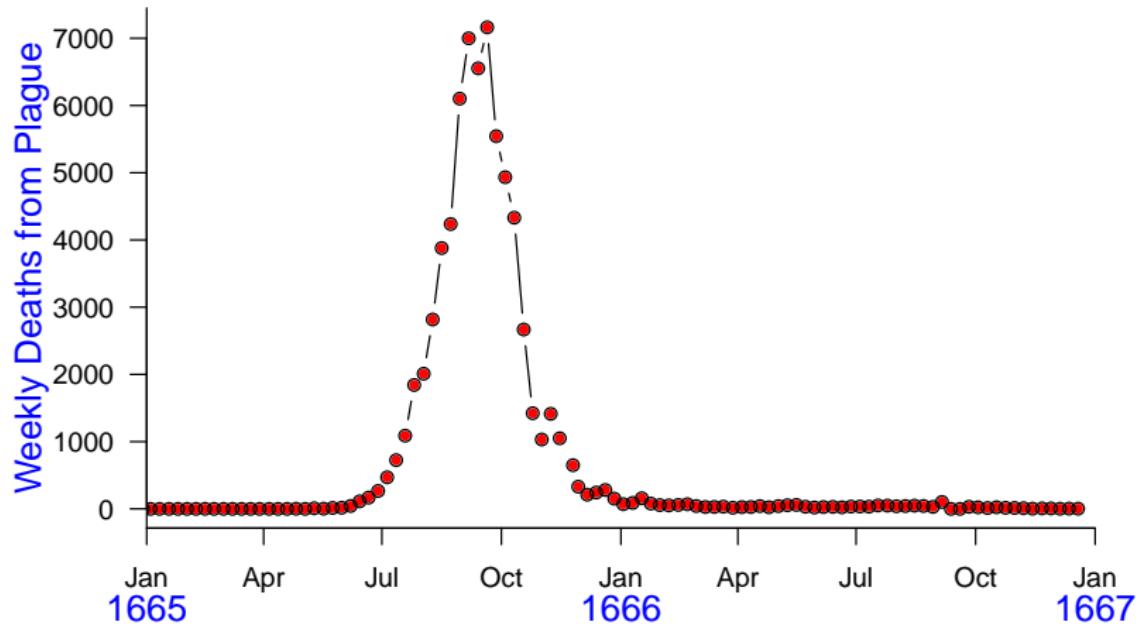
A historical ledger page from London, dated 29th [unclear]. The page is divided into columns for location, burials, and plague cases.

Location	Buried	Plag.
St Alban Woodstreet	2	1
Alhallows Bark-	2	
Alhallows Breadstreet	1	
Alhallows Great	1	

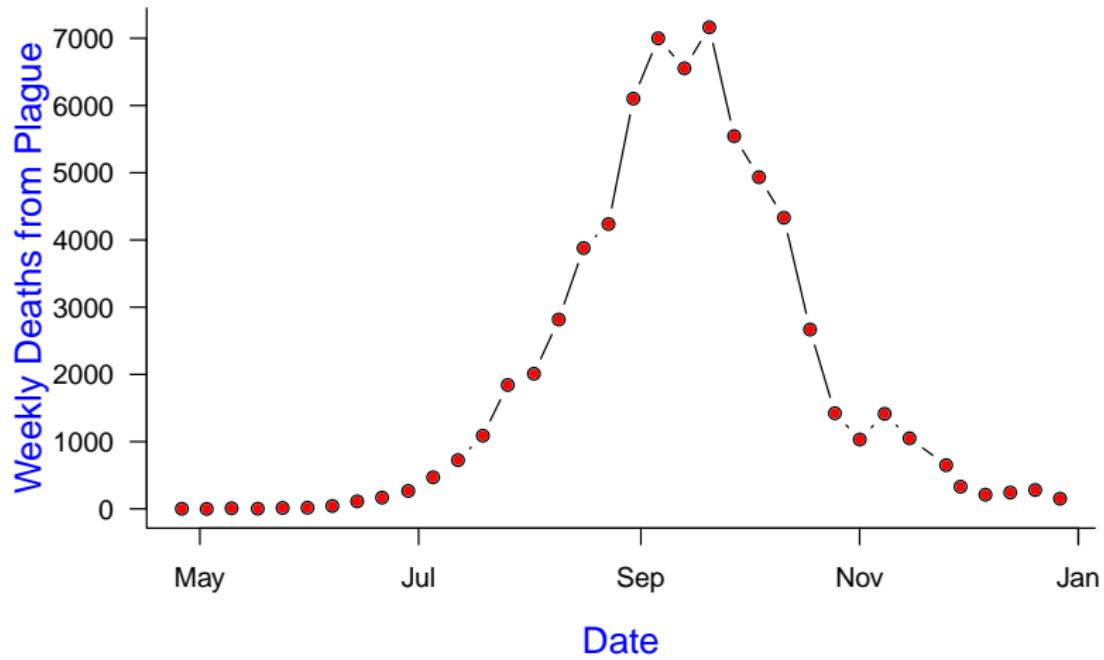
But handwriting is usually very clear

St Christopher's —————— Christened in 971 the Parishes :		
St Andrew Holborn ——————	66	40
St Bartholomew Great	+	+
St Bartholomew Less ——————		
St Bridget ——————	24	14
Bridewell Precept ——————	1	1
Christened in the 16 Parishes :		

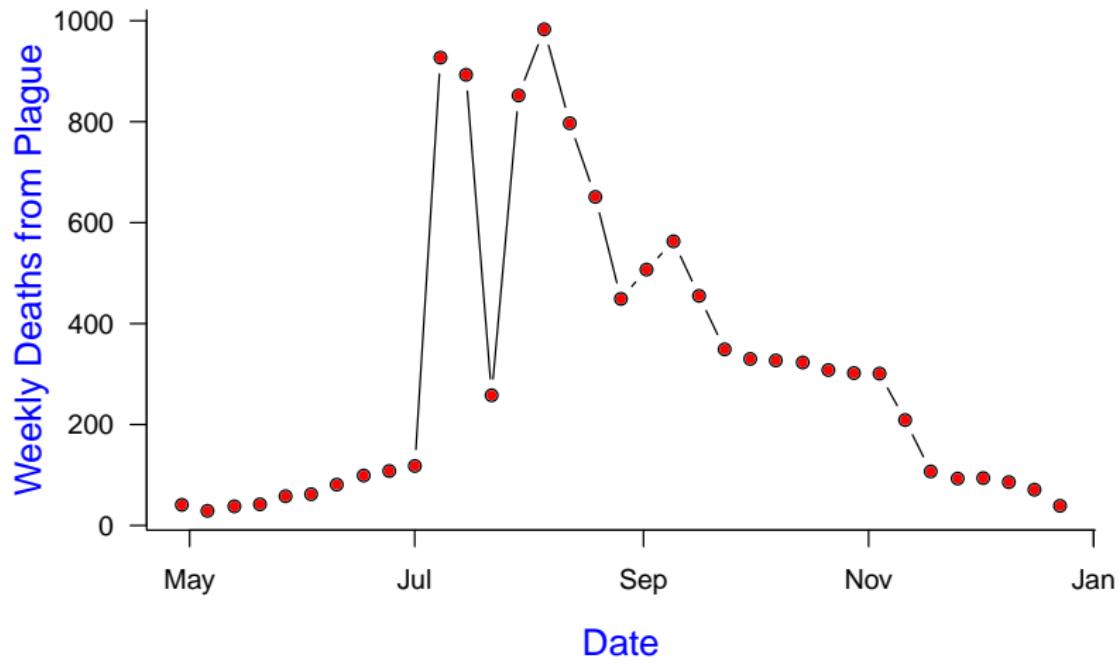
The Great Plague of London, 1665



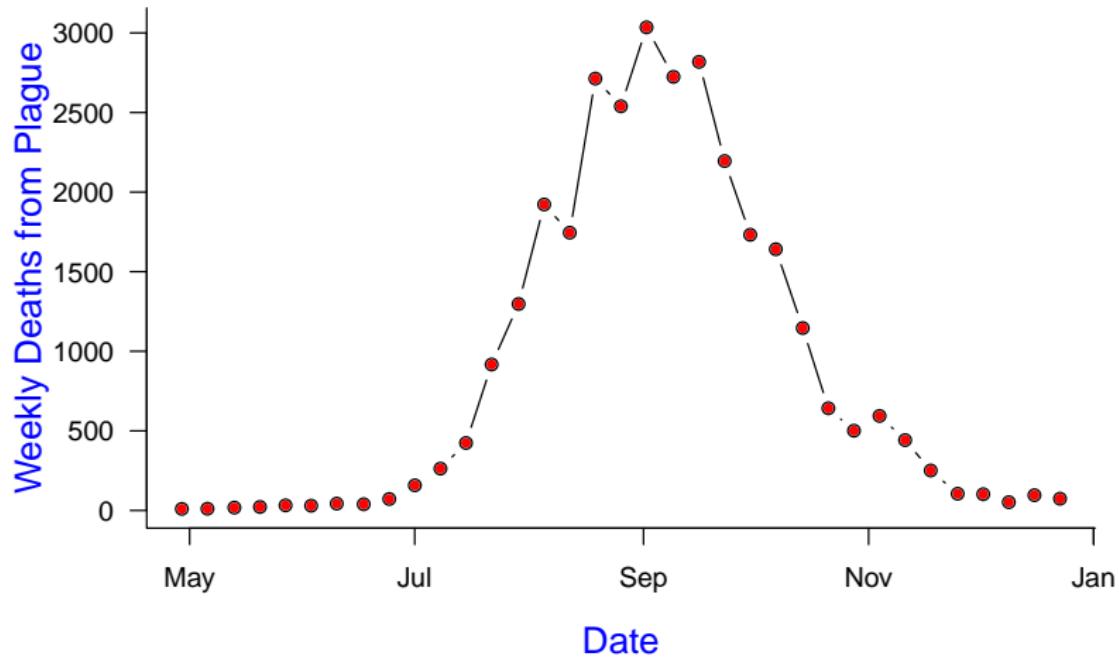
The Great Plague of London, 1665



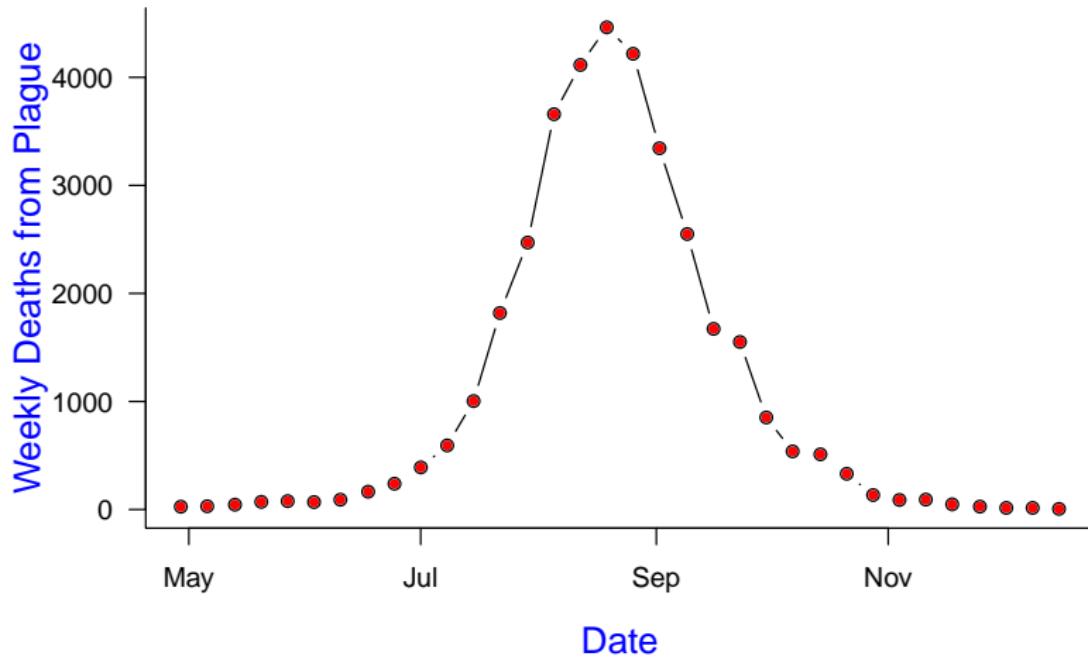
London Plague of 1593



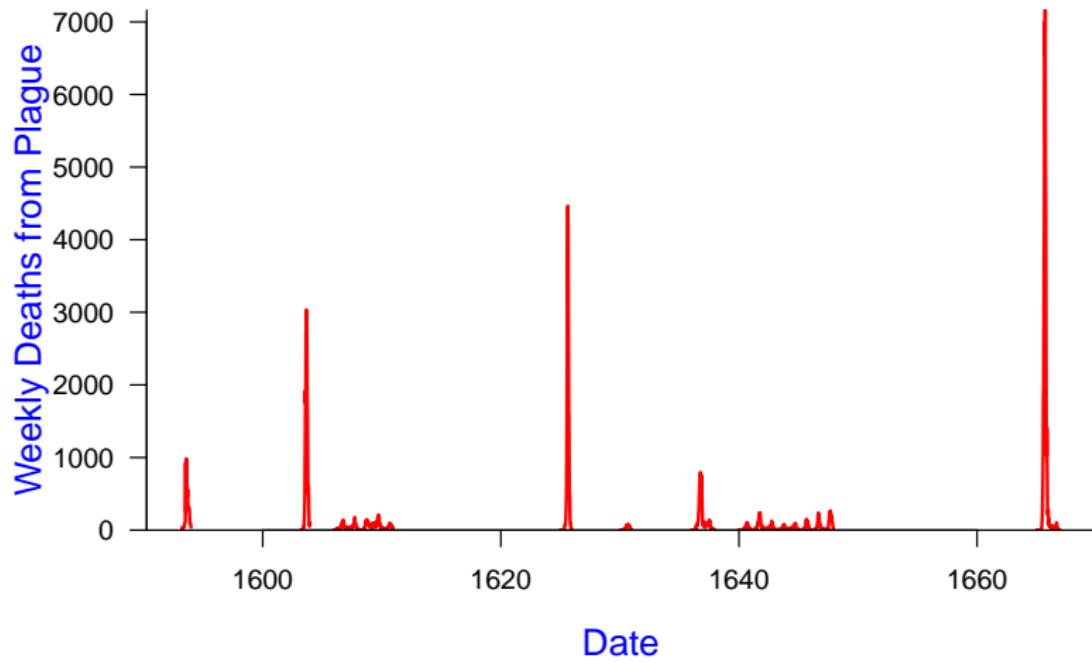
London Plague of 1603



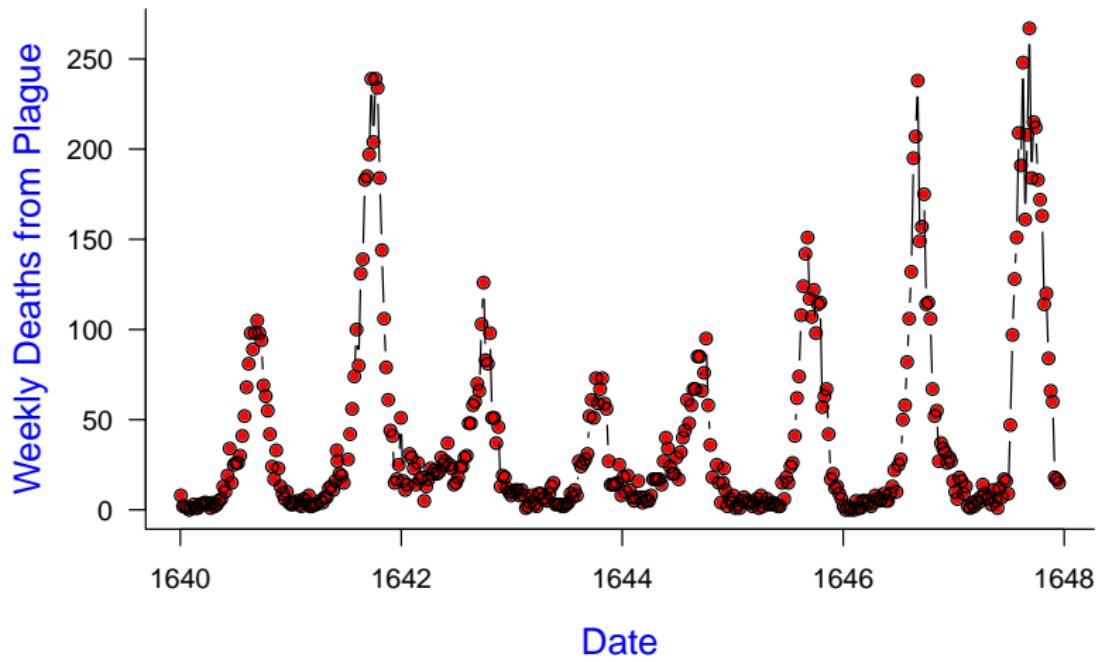
London Plague of 1625



Weekly Deaths from Plague in London, 1592–1666



Weekly Plague in London, 1640–1648



Some Plague Facts

- Plague epidemics recorded from Roman times to early 1900s.
- $\gtrsim 1/3$ Europe's population died in "Black Death" of 1348
 - ~ 300 years for the population to reach the same level.
- Recently (2011) established (at McMaster!) that the pathogen that caused The Black Death was *Yersinia pestis*

[Bos et al. 2011, *Nature* 478, 506–510]

- More recently (2014) established (again at McMaster!) that the pathogen that caused The Plague of Justinian (541–543 AD) was *Yersinia pestis*

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

- *Y. pestis* still a concern?
Yes: Rodent reservoir, antibiotic-resistant strains, bioterrorism
- **Spatial data** for any plagues? Yes, for London in 1665...

Visualization of spatial structure of Great Plague

- GIS encoding of parish boundaries
- Overlay parish boundaries on more modern map for reference
- Colour parishes as they become infected
- Is there evidence for spatial spread or was the spatial pattern random?
- DE low-tech animation...
- CBC high-tech animation...
 - *The Nature of Things*, 21 August 2014.
[http://www.cbc.ca/natureofthings/episodes/
secrets-in-the-bones-the-hunt-for-the-black-death-killer](http://www.cbc.ca/natureofthings/episodes/secrets-in-the-bones-the-hunt-for-the-black-death-killer)



Mathematics
and Statistics

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

Mathematics 4MB3/6MB3 Mathematical Biology

Instructor: David Earn

Lecture 9
Epidemic Data II
Friday 26 Jan 2018

Announcements

■ Assignment 2:

Due Monday 5 February 2018 in class (and by e-mail) at 11:30am.

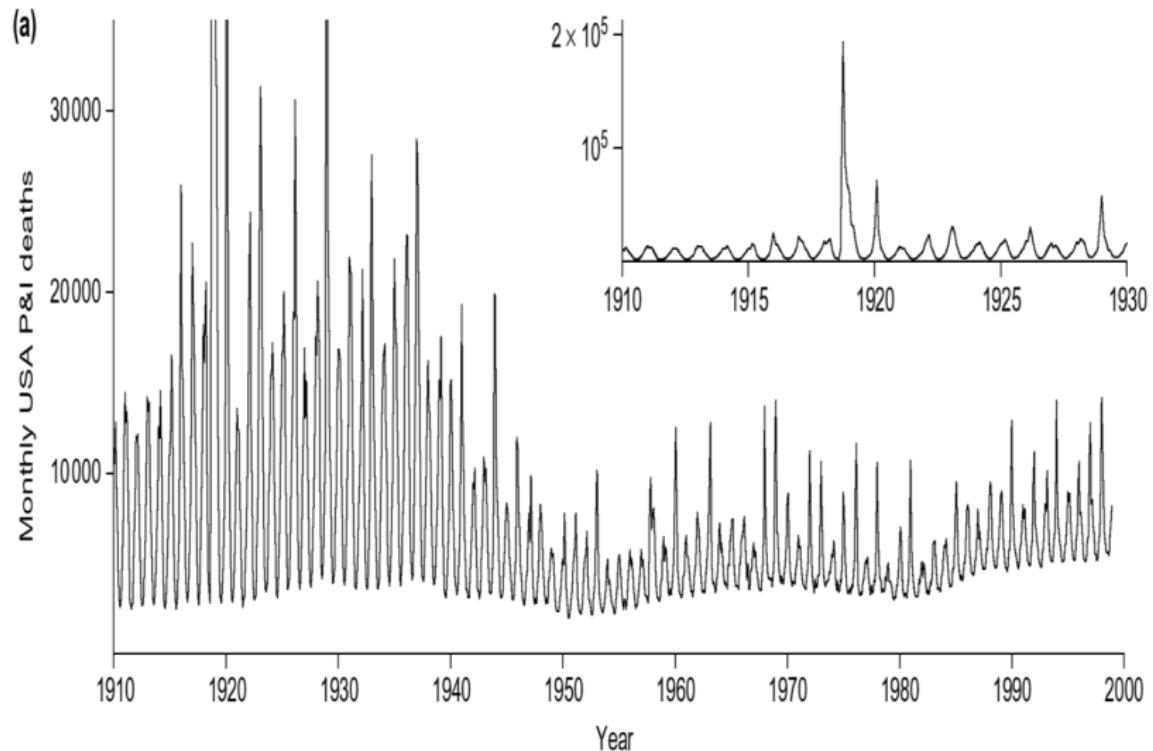
■ Midterm test: We agreed on:

- *Date:* Thursday 8 March 2018
- *Time:* 7:00pm to 9:00pm
- *Location:* TBA

Visualization of entire course of the Great Plague

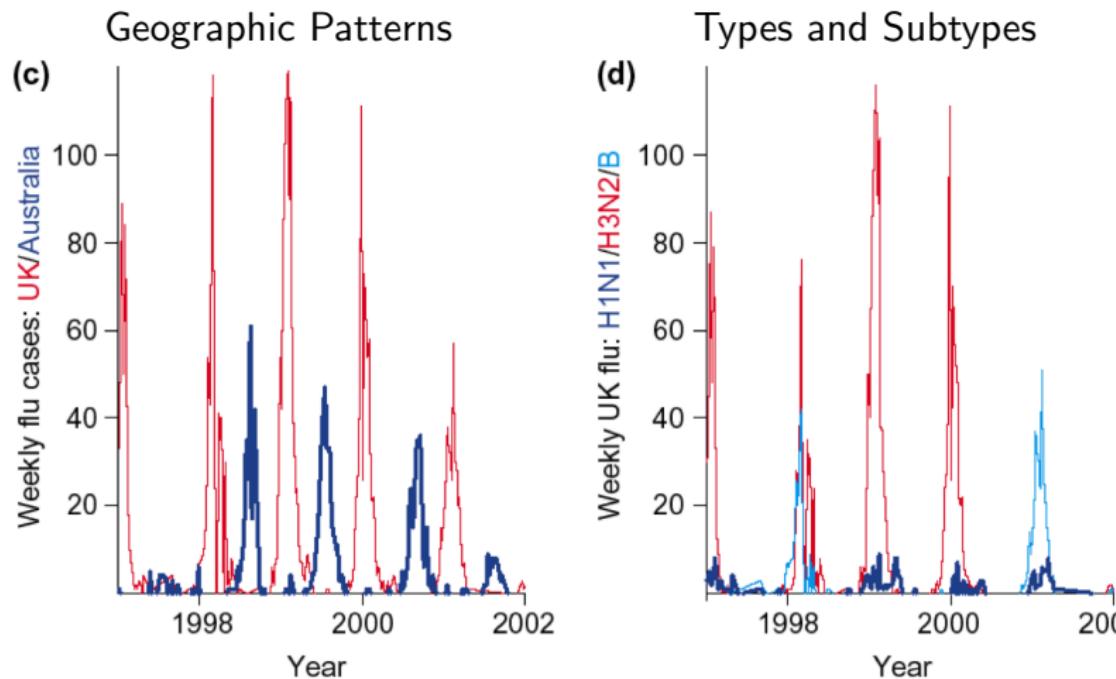
- What happened after initial spatial spread?
- Visualize full spatial epidemic structure
- Show magnitude of epidemic in each parish with cylinder.
- [Epidemic Visualization](#) (EpiVis) software by Junling Ma.

P&I mortality in U.S.A., 1910–1998



Earn, Dushoff & Levin 2002, *Trends in Ecology and Evolution* 17, 334–340

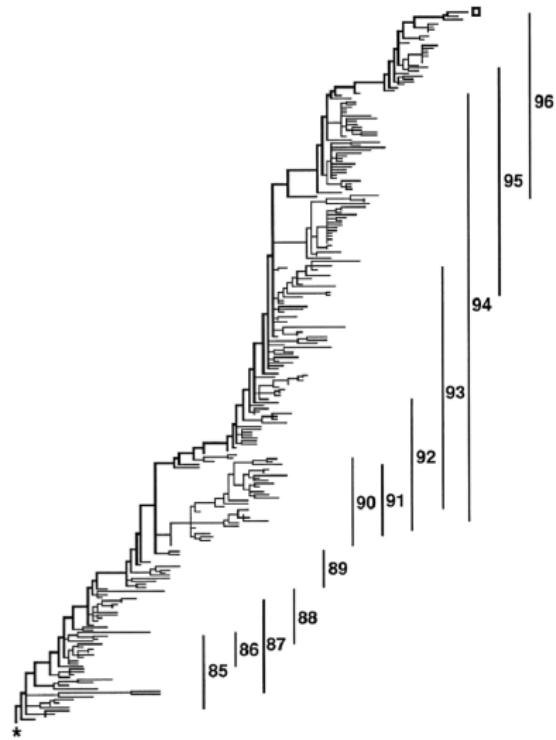
Influenza Incidence Patterns (lab confirmed)



Earn, Dushoff & Levin 2002, *Trends in Ecology and Evolution* 17, 334–340

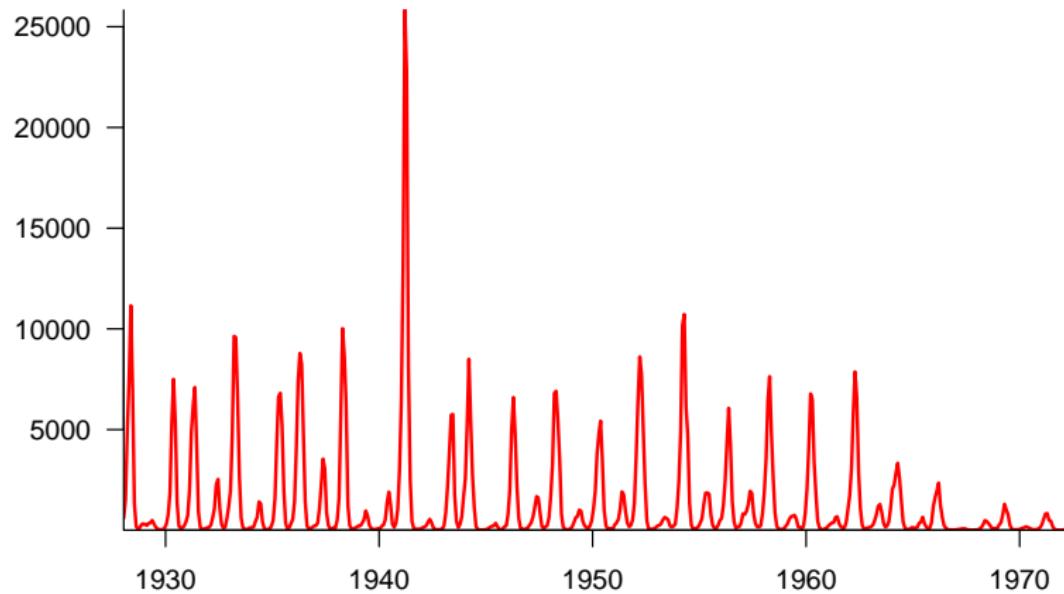
Influenza Evolution

Molecular phylogenetic reconstruction of influenza A/H3N2 evolution, 1985–1996 (Fitch *et al.* 1997)



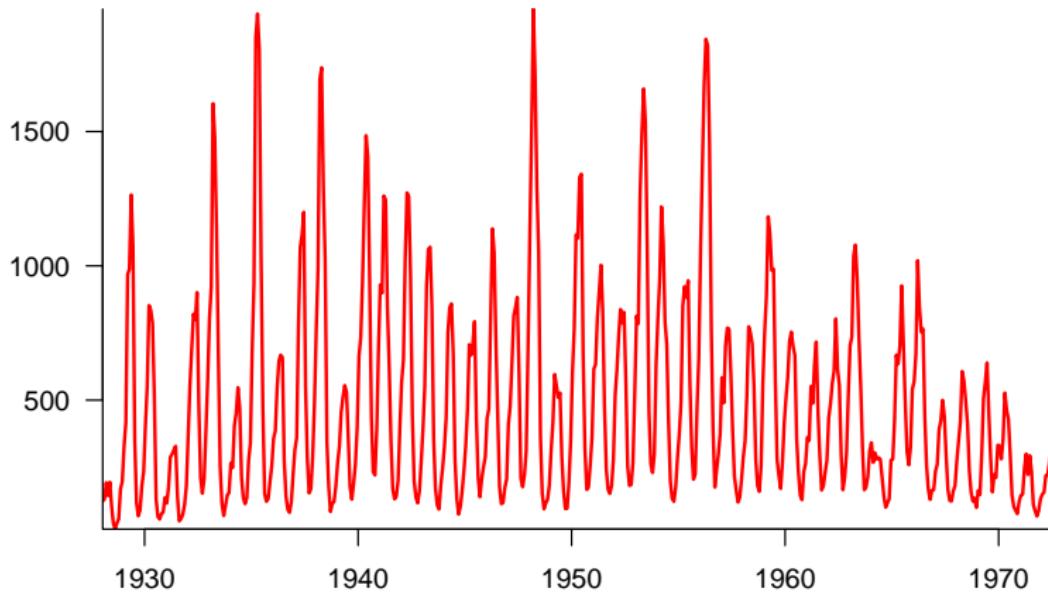
Measles in New York City, 1928–1972

Monthly Cases



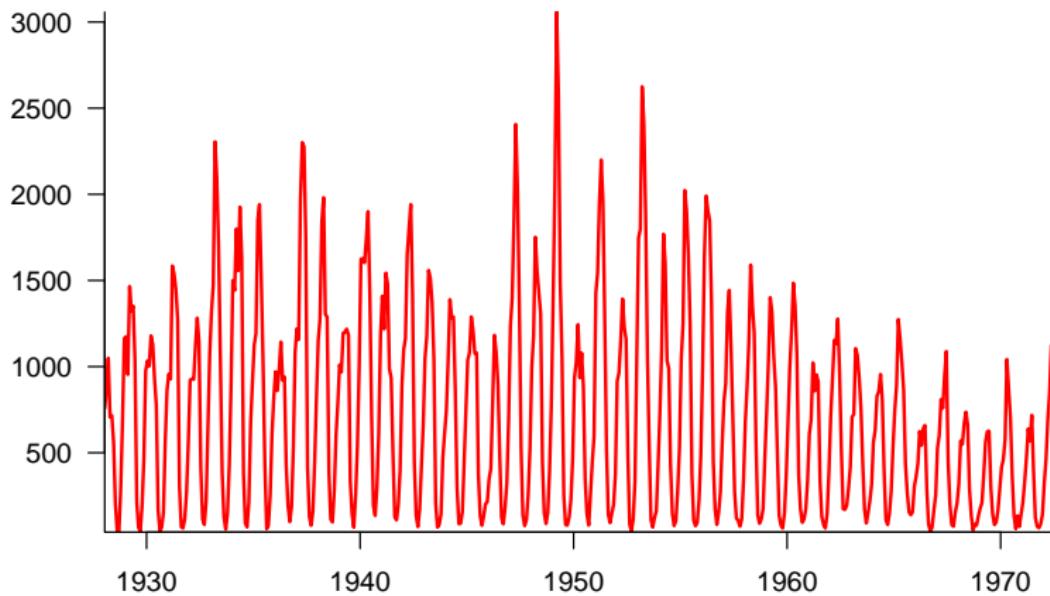
Mumps in New York City, 1928–1972

Monthly Cases

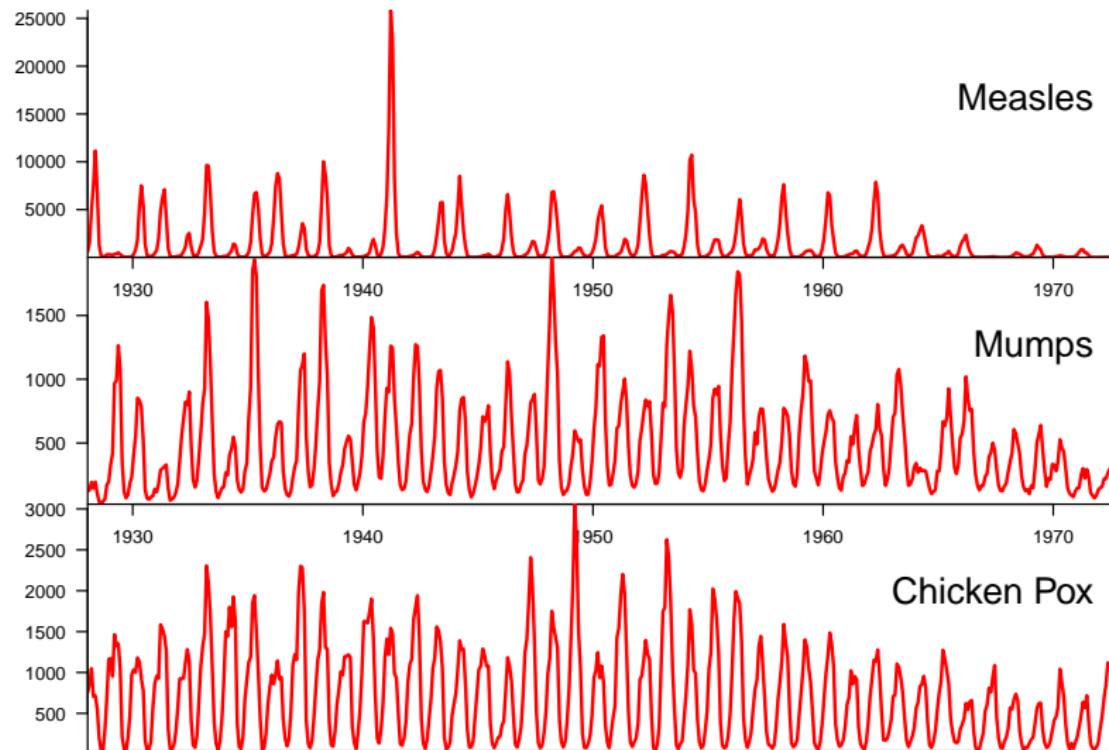


Chicken Pox in New York City, 1928–1972

Monthly Cases

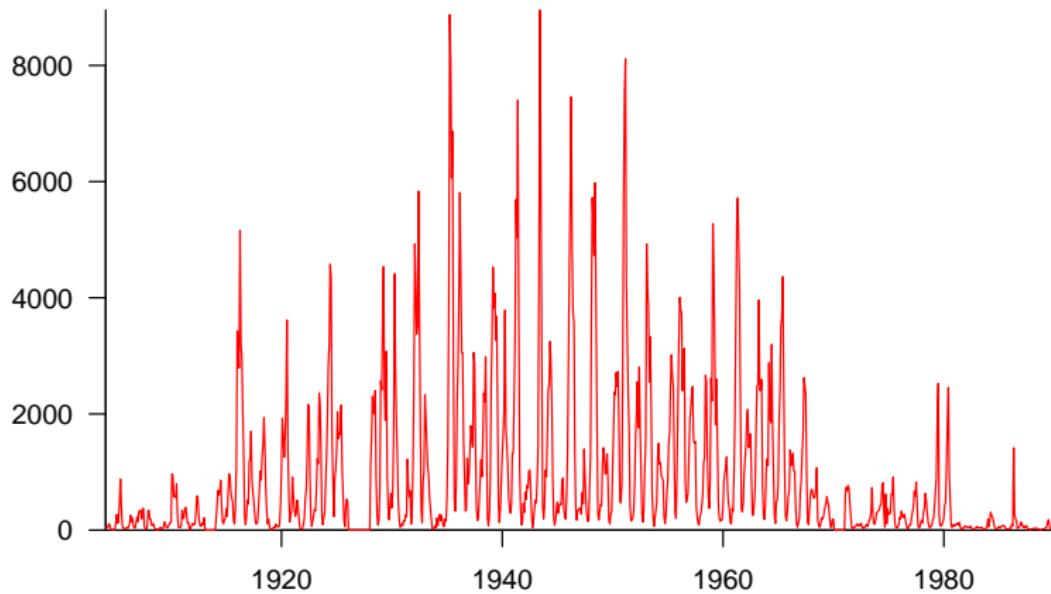


Childhood diseases in New York City, 1928–1972



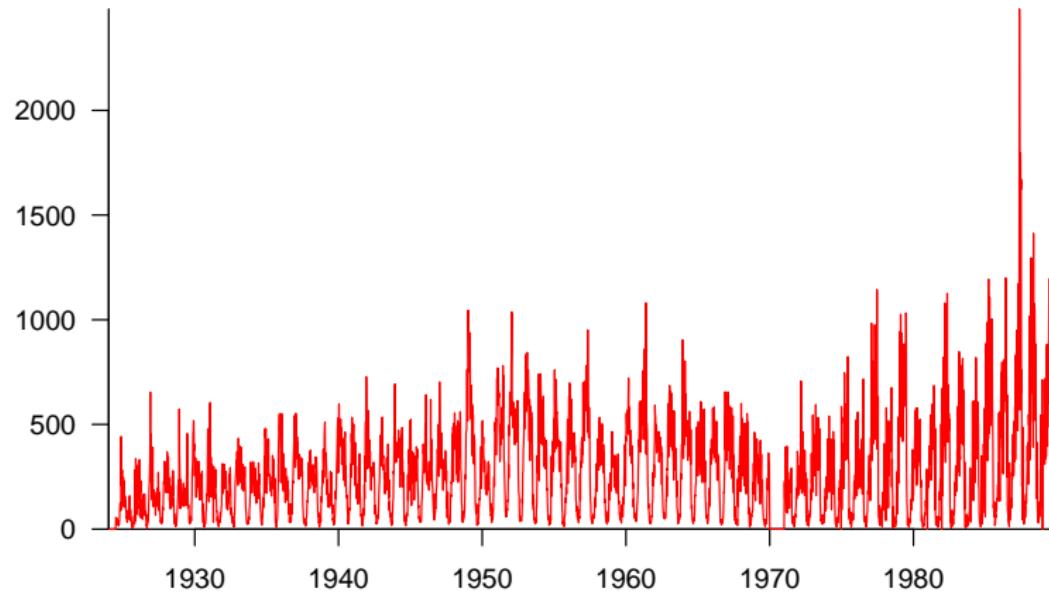
Measles in Ontario, 1904–1989

Monthly Cases



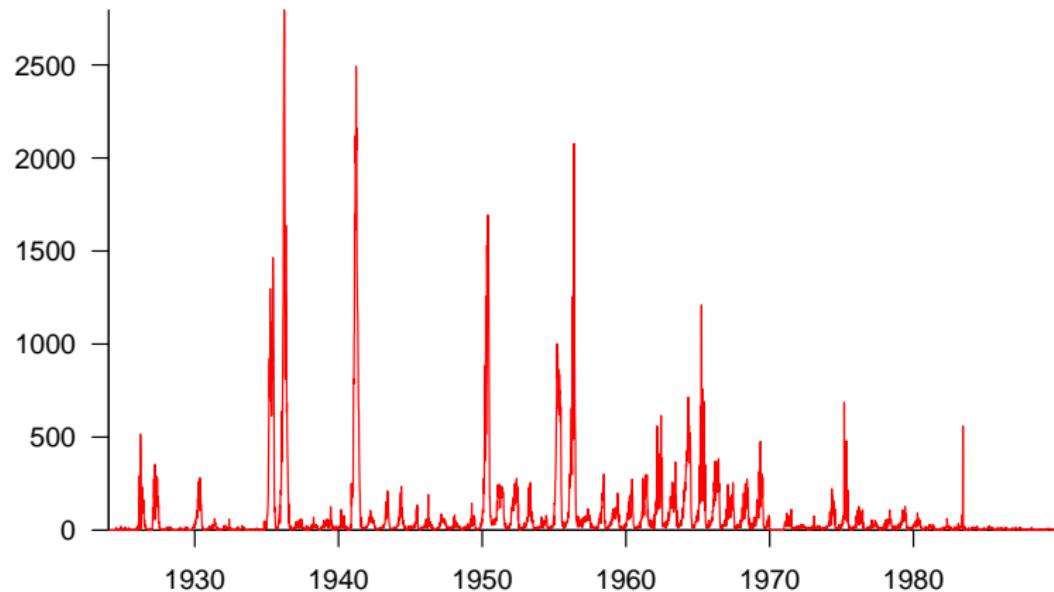
Chicken Pox in Ontario, 1924–1989

Monthly Cases



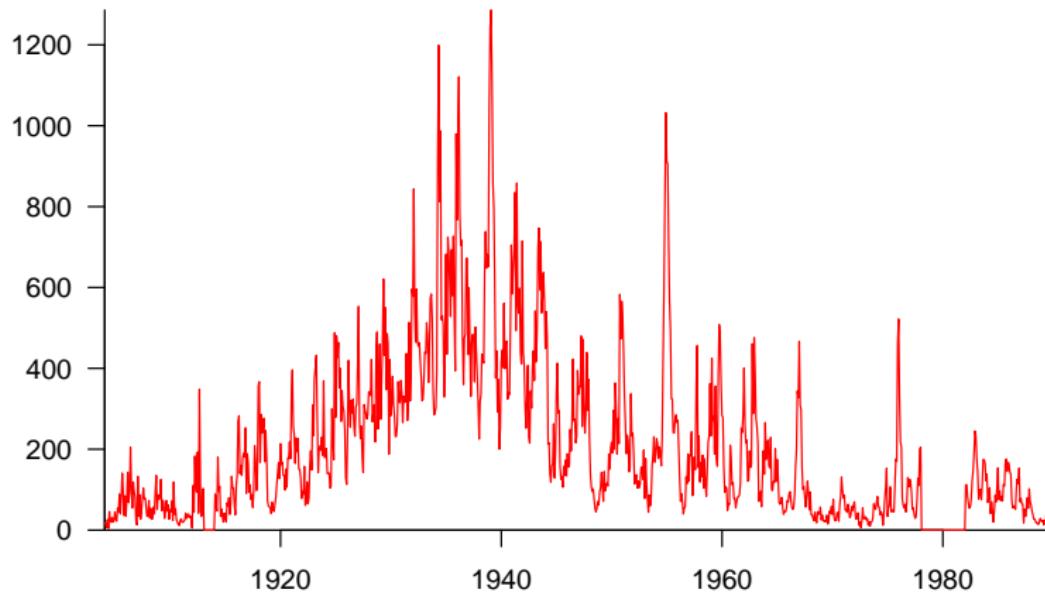
Rubella in Ontario, 1924–1989

Weekly Cases

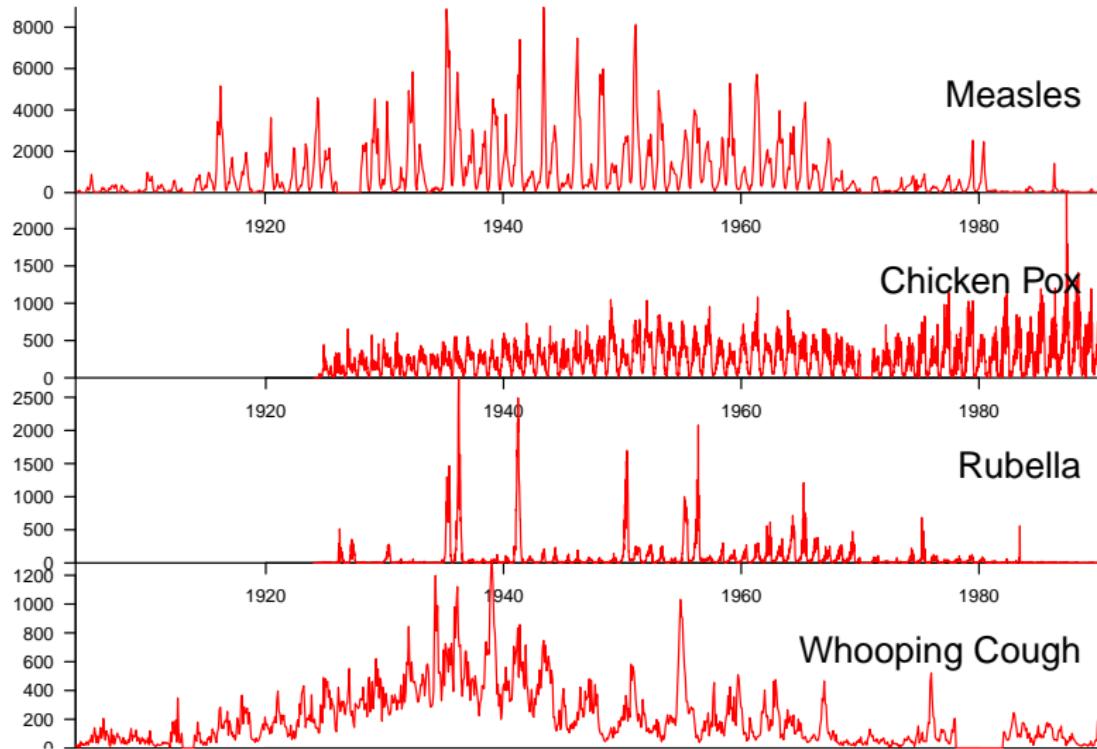


Whooping Cough in Ontario, 1904–1989

Monthly Cases



Childhood diseases in Ontario, 1904–1989



Ontario Disease Notification Data

Province of Ontario

YEAR: 1939 COUNTY..... MUNICIPALITY.....

Month	Week End.	CSM		C.P.		DIP.		DYS. A/B		EN. LETH.		ERYS.		G.C.		FLU.		INF. JAUN.		G.M.		MEAS.		MUMPS		PARA-TYPH.	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
Jan.	7 1			452	1	3	0	1	0			5	1	101	0	8	1	17	0	17	0	670	1	56	0	2	0
	14 2	2	1	490	0	8	0					5	0	82	0	21	1	18	0	18	0	850	0	92	0	1	0
	21 3	2	1	511	0	9	3			0	1	5	0	89	0	16	2	26	0	22	0	932	0	98	0		
	28 4	1	0	384	0	2	0					2	0	73	0	164	0	10	0	28	0	933	1	24	0		
	Total	5	2	193	1	27	3	1	0	0	1	17	0	218	4	71	0	65	2	338	5	240	0	3	0		
Feb.	4 5			355	0	7	1	1	0			3	0	83	0	57	1	24	0	25	0	1335	1	110	0	2	0
	11 6	2	1	363	0	1	0	1	0			7	0	82	0	27	1	49	1	29	0	1033	0	91	0	1	0
	18 7	2	1	354	1	2	0					4	1	68	0	103	1	35	0	44	0	1161	0	59	0		
	25 8	1	1	308	0	2	0					9	0	560	1	77	0	19	0	28	0	999	0	73	0		
	Total	5	3	1980	1	19	1	2	0			34	1	319	1	19	1	126	0	158	1	338	0	240	0	3	0
Mar.	4 9	1	1	271	0	7	1	3	1			7	0	93	0	114	19	21	0	40	0	131	2	109	0	1	0
	11 10			239	0	7	0	2	0			8	1	61	0	137	18	31	0	32	0	845	0	91	0	2	0
	18 11			166	0							6	0	66	0	1322	6	5	0	59	0	969	2	69	0	1	0
	25 12	1	2	236	0	1	0	1	0			7	0	63	0	806	16	9	0	20	0	879	0	120	0	case	PAH
	Total	8	3	118	0	15	1	6	1			28	1	283	0	613	4	66	0	151	0	353	1	389	0	34	0
Apr.	1 13	2	0	139	0	3	0	1	0			8	0	95	0	667	6	1	0	24	0	950	0	89	0	3	0
	8 14	2	0	162	0	1	0	1	0			5	0	67	0	731	22			14	0	790	0	65	0	1	0
	15 15	2	0	108	0	1	0			0	1	11	0	41	0	529	16	2	0	16	0	745	0	56	0		
	22 16	1	1	134	0	2	0	1	0	1	1	6	0	64	0	245	8	2	0	26	0	845	0	54	0		
	29 17	5	1	167	0	4	0	2	0	2	1	3	0	55	0	124	9	2	1	13	0	746	1	120	0		
	Total	12	2	110	0	10	0	3	0			33	0	312	0	613	1	1	0	24	0	450	0	384	0	47	0

Dominion Bureau of Statistics Disease Notification Data

VITAL STATISTICS BRANCH - COMMUNICABLE DISEASE SECTION

Cases of ~~Influenza~~ Reported by Provincial Health Departments, Year 1924

WEEK ENDING	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	CANADA
	W15-22	W15-22								
Jan 5		11					1			12
2	12	29					18			47
3	19	37					32			69
4	26	75 152		68	181	36	13 64	97	4 88 602	
5 FEB 2	12	1					53			66
6	9	5					40			45
7	16	31					14			45
8	23	- 2 50	1 2	267	202	48	4 111	116	1 7 797	
9 MAR 1		2					21			23
10	1						9			9
11	15	3					11			14
12	22	60					34			94
13	29	2 61		144	140	52	15 90	15	7 17 515	
14 APR 5		9					11			20
15	12	1					12			13
16	19	26	1				8			35
17	26	14 50	3 4	42	140	39	16 47	67	5 33 394	
18 MAY 3		26					2			28