

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:**

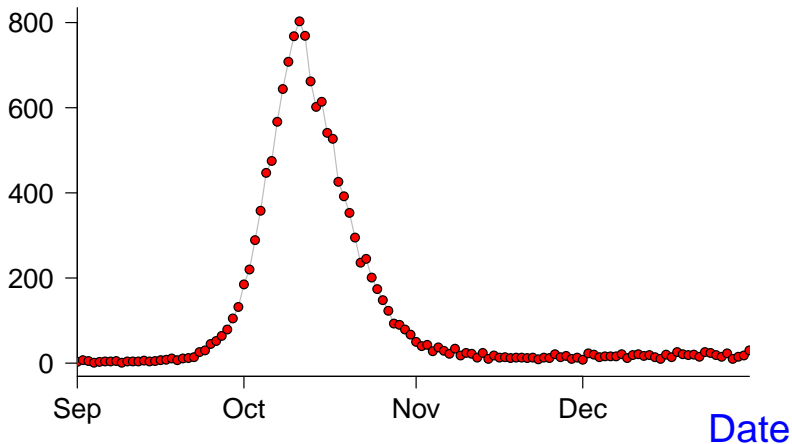
Due Monday 5 February 2018 in class (and by e-mail) at 11:30am.

- **Midterm test:**

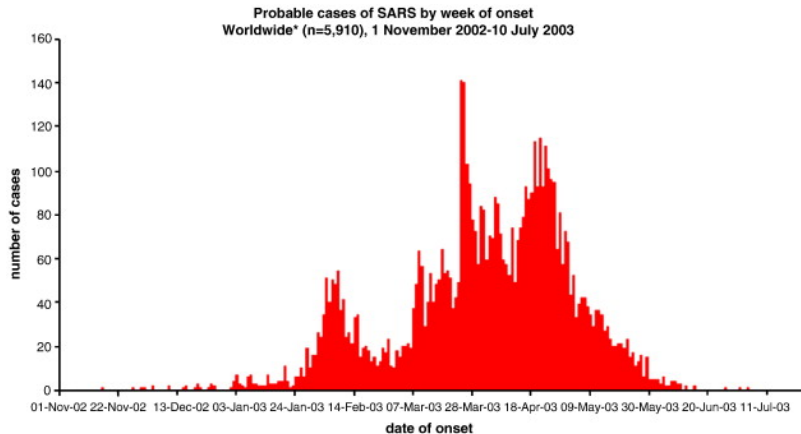
- *Date:* week of 5–9 March? or 12–16 March?
- *Time:* TBA
- *Location:* TBA

P&I Mortality, Philadelphia, 1918

P&I Deaths

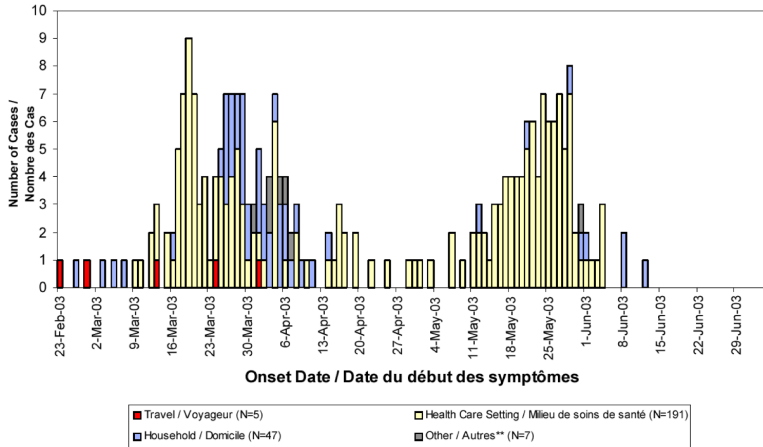


SARS in 2003 (Worldwide)



*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)

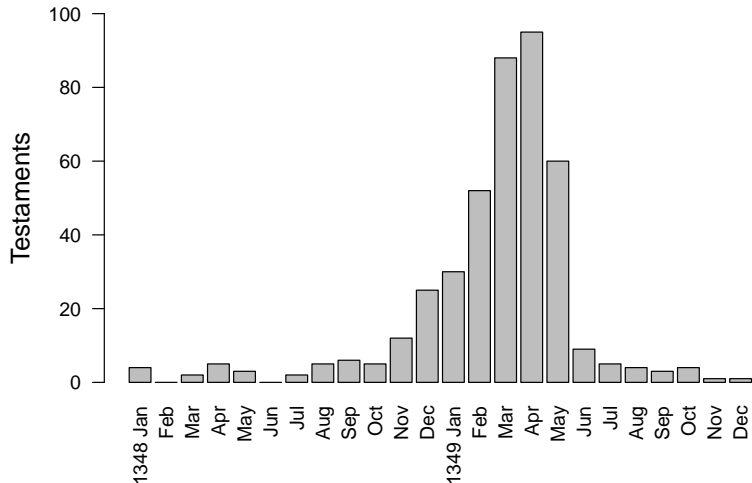


$N = 249$ (of 250 reported)


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.		From the 26 of September to the 3 of October, 1665.	
		London	From the 26 of September to the 3 of October, 1665
Frighth	11	St Andrew Woodborne	16 49
Goat	1	St George Broadstreet	1 5
Grip	1	St Gregory by St Pauls	26 35
Gripping in the Guts	1	St Helens	6 1
Jaundies	25	St James Duke street	17 13
Impoethame	8	St James Garlickhithe	10 13
Infans	2	St John Baptist	11 10
Kingfevil	2	St John Evangelist	5 1
Misgraome	1	St John Zachary	12 9
Plague	5533	St Katharine Creechurch	14 1
Purples	1	St Lawrence Jewry	2 1
Rickets	2	St Lawrence Poonancey	14 10
Riting of the Lights	13	St Leonard Eastliche	3 1
Rupture	1	St Leonard Fothering	16 13
Scurvy	5	St Magnus Parish	5 4
Spotted Feaver	65	St Margarets Loobury	7 6
Stilbren	10	St Margarets Medow	1 1
Stone	1	St Margarets Newfisherie	13 13
Stopping of the stomach	6	St Margarets Patton	4 3
Suddenly	1	St Mary Abchurch	7 1
Surfeit	36	St Mary Aldermansbury	14 4
Teeth	11	St Mary Aldermany	4 14
Thrush	3	St Mary le Bow	1 1
Tuffick	4	St Mary Bothw	6 4
Vomiting	7	St Mary Colechurch	2 4
Winding	1	St Mary Hill	11 13
Wormes	12	St Mary Mounshaw	4 1
		St Mary Somersec	44 38
		St Mary Spayning	1 4
		St Mary Woolchurch	1 4
		St Mary Woolnoth	7 5
		St Mary Ironmongerie	2 2
		St Martin in the Fields	10 9
		St Andrew Holborn	173 151
		St Bonolph Aldgate	371 338
		St Bonolph Bishopgate	153 121
		St Dunston West	65 59
		St George Southwark	140 153
		St Giles Cripplegate	196 174
		St Olave Southwark	378 281
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Mortality Bills are typically handwritten

LONDON 29 th		From the 4 th of July to the 11 th of August 1665							
Buried.	Plag.	Buried.	Plag.	Buried.	Plag.	Buried.	Plag.		
St Alban Woodstreet	2	1	St Clement Eastcheap	1	St Margaret Newfishst		St Michael Crookedla	4	3
Alhallows Bark			St Dionis Backchurch	2	St Margaret Pattons		St Michael Queenhith	7	
Alhallows Breadstreet	1		St Dunstons East	2	St Mary Abchurch	1	St Michael Quern		
Alhallows Great			St Edmund Lumbardst.	2	St Mary Aldermanbury		St Michael Royal		
Alhallows Honilane	1		St Ethelborough	1	St Mary Alde mary		St Michael Woodstreet		
Alhallows Lef			St Faiths	2	St Mary le Bow		St Mildred Breadstreet		
Alhallows Lumbardst.	1		St Gabriel Fenchurch	1	St Mary Bothaw		St Mildred Poultry		
Alhallows Staining	4	3	St George Botolphlane	2	St Mary Colechurch		St Nicholas Acons		
Alhallows the Wall	1		St Gregories by St.Paul	1	St Mary Hill		St Nicholas Coleabby		
St Alphage			St Hellen	2	St Mary Mag. Milkstr.		St Nicholas Olaves		
St Andrew Hubbard	3		St James Dukes place	1	St Mary Mag. Oldfishst		St Olave Hartstreet		
St Andrew Underthafe	7		St James Garlickhith	1	St Mary Mounthaw		St Olave Jewry		
St Andrew Wardrobe	1		St John Baptist	1	St Mary Summerset	2	St Olave Silverstreet	4	1
St Anne Aldersgate	7	6	St John Evangelist		St Mary Staining		St Pancras Soperlane		
St Anne Blackfyers	7		St John Zichary	1	St Mary Woolchurch		St Peter Cheap		
St Antholiers Parish.	1		St Katharine Coleman	1	St Mary Woolnoth		St Peter Cornhill		
St Austins Parish	1		St Katharine Creechur.		St Martins Iremongerl.		St Peter Paulwharf		
St Barthol.Exchange	1		St Lawrence Jewry		St Martins Ludgate	2	St Peter Poor	1	
St Bennet Fynck			St Lawrence Pountney		St Martins Orgars	1	St Steven Colemanstr.	2	1
St Bennet Gracechurch	7		St Leonard Eastcheap		St Martins Outwich	1	St Steven Walbrook.	2	1
St Bennet Paulwharf.	7		St Leonard Fosterlane.		St Martins Vintrey	1	St Swithin	2	1
St Bennet Sherchog.			St Magnus Parish	1	St Matthew Frydaystr.		St Thomas Apottle	1	1
St Borolph Billingsgate	5	3	St Margaret Lothbury.		St Michael Bassishaw	5	Trinity Parish	1	
Christ Church			St Margaret Moses		St Michael Cornhil		St Vedast alias Fosters		
St Christophers									
Christned in 7 the Parishes within the walls		Buried		86		Plague		28	
St Andrew Holborn	6	40	St Borolph Aldergate	11	4	St Sepulchres Parish	117	81	
St Bartholomew Great	7	4	St Borolph Aldgate	24	9	St Thomas Southwark	7	5	
St Bartholomew Lef			St Borolph Bishopgate	37	20	Trinity Minories			
St Bridget	24	17	St Dunstan West	19	9	At the Pethouse	6	6	
Bridewell Prencit	1								
Christned in the 15 Parishes without the walls		Buried		473		Plague		273	
Christis Church			St Kath. near the Tower	7	1	St Mary Islington	3	2	
St John at Hackney	1		Lambeth Parish	7		St Mary Newington	7	3	
St Giles in the Fields	208	215	St Leonar d Shoreditch	21	13	St Mary Whitechappel	16	3	
St James Clerkenwel	8	43	St Magdalen Bermond.	14					
Christned in the 15 Parishes in Middlesex and Surrey		Buried		455		Plague		280	

But handwriting is usually very clear

LONDON 29th

	Buried.	Plag.
St Albans Woodstreet	2	1
Alhallows Bark.	2	
Alhallows Breadstreet		
Alhallows Great	1	

But handwriting is usually very clear

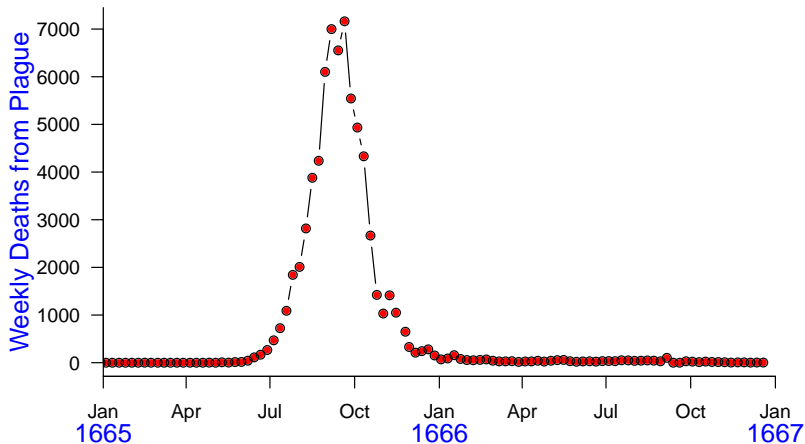
St Christophers

Christned in 97 the Parishes

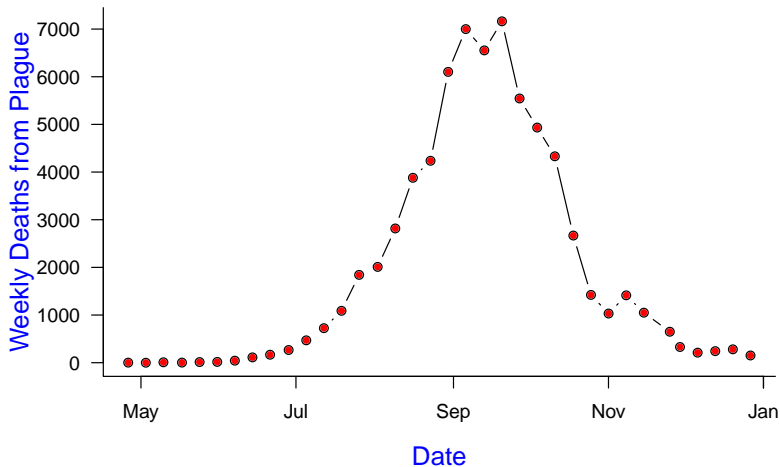
St Andrew Holborn	66	40	St
St Bartholomew Great	7	4	St
St Bartholomew Less			St
St Bridget	24	17	St
Bridewel Precinct	1	1	

Christned in the 16 Parishes

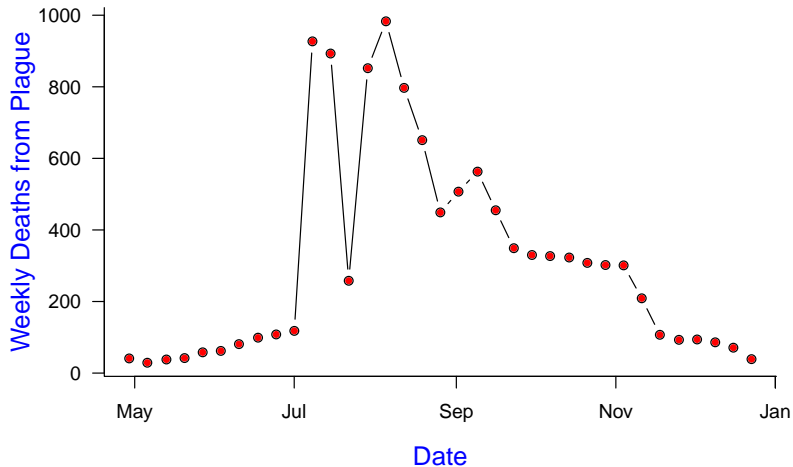
The Great Plague of London, 1665



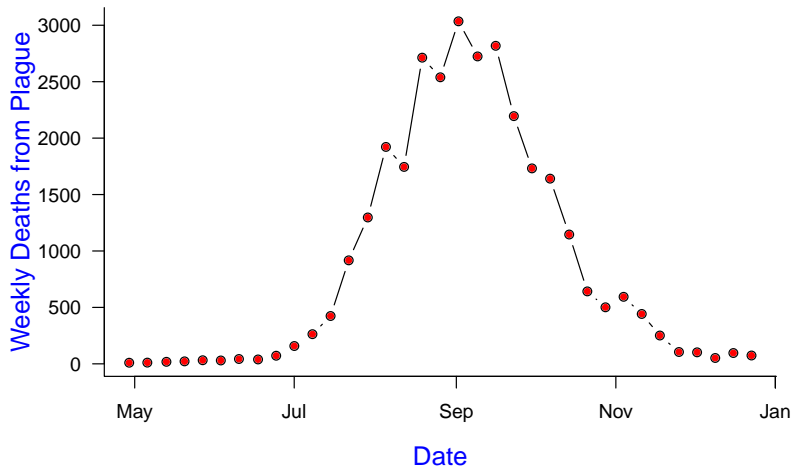
The Great Plague of London, 1665



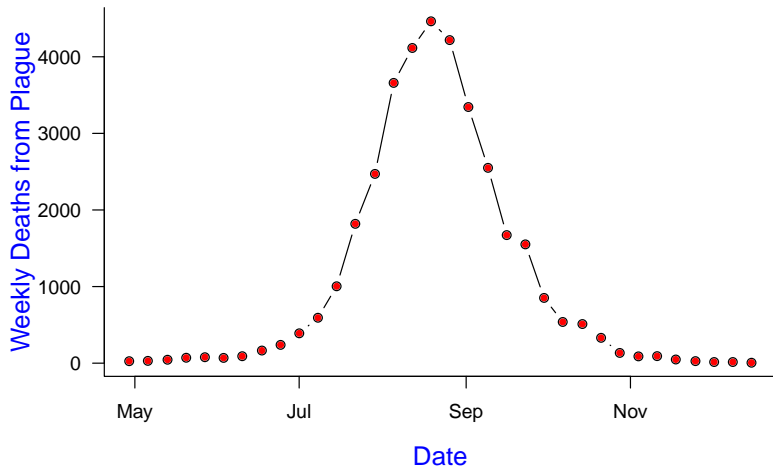
London Plague of 1593



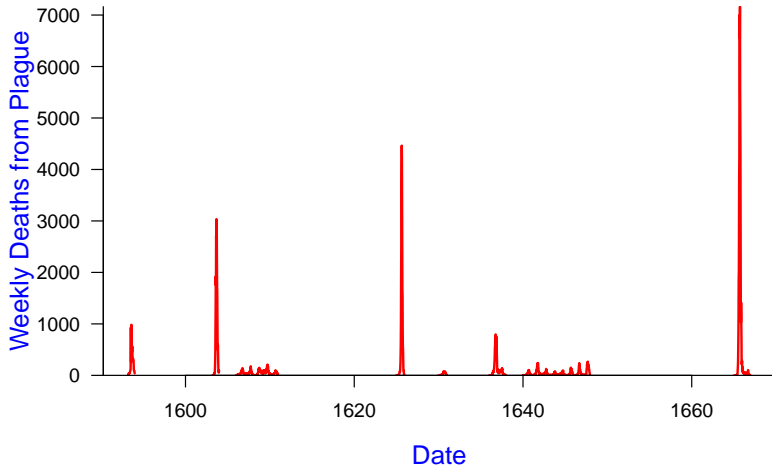
London Plague of 1603



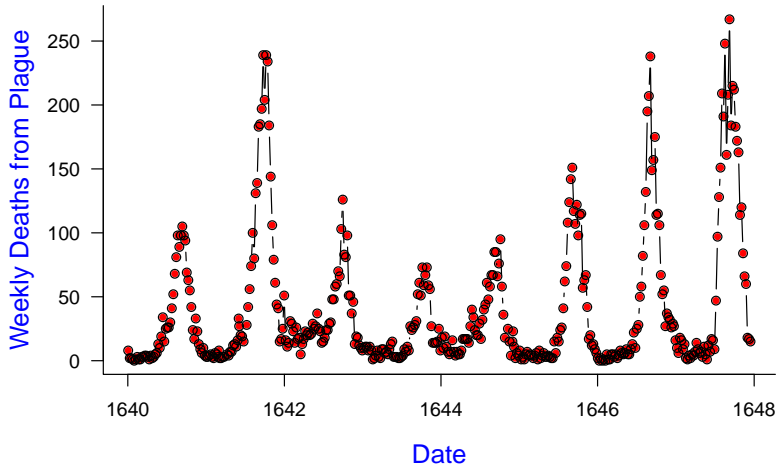
London Plague of 1625



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>



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.

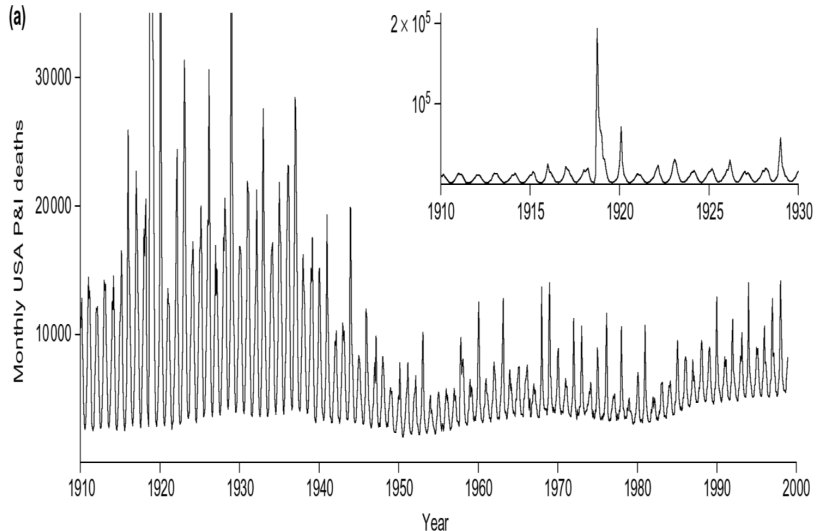
- **Midterm test:** We agreed on:

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

Visualization of entire course of the Great Plague

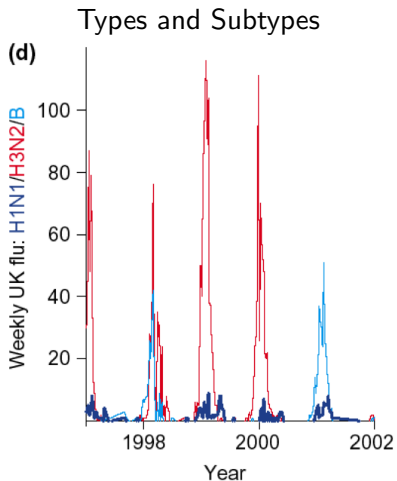
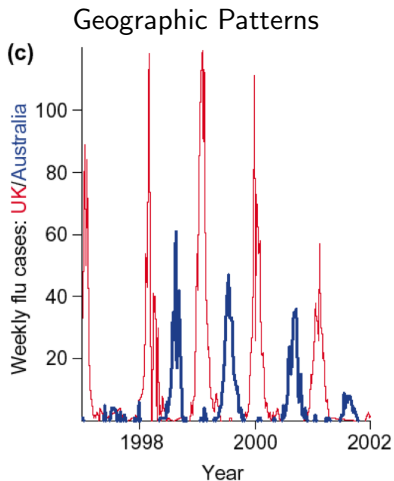
- What happened after initial spatial spread?
- Visualize full spatial epidemic structure
- Show magnitude of epidemic in each parish with cylinder.
- [Epidemic Visualization](#) (EpiVis) software by Junling Ma.

P&I mortality in U.S.A., 1910–1998



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

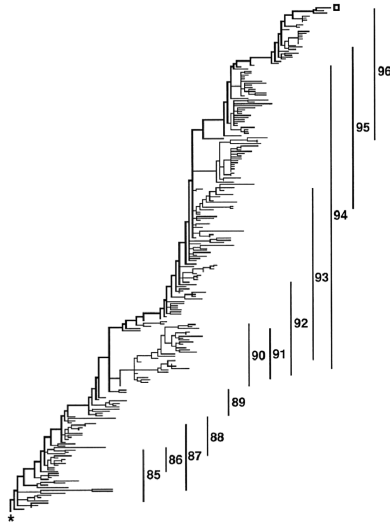
Influenza Incidence Patterns (lab confirmed)



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

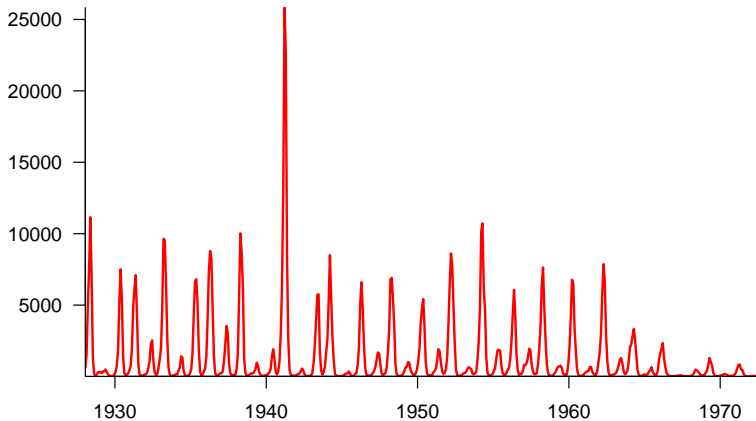
Influenza Evolution

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



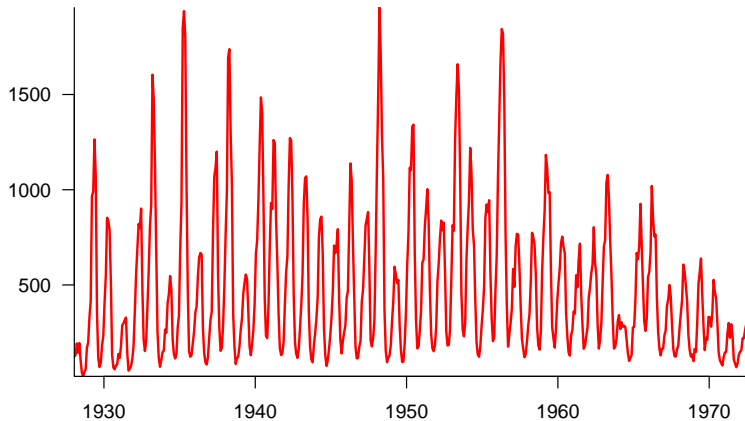
Measles in New York City, 1928–1972

Monthly Cases



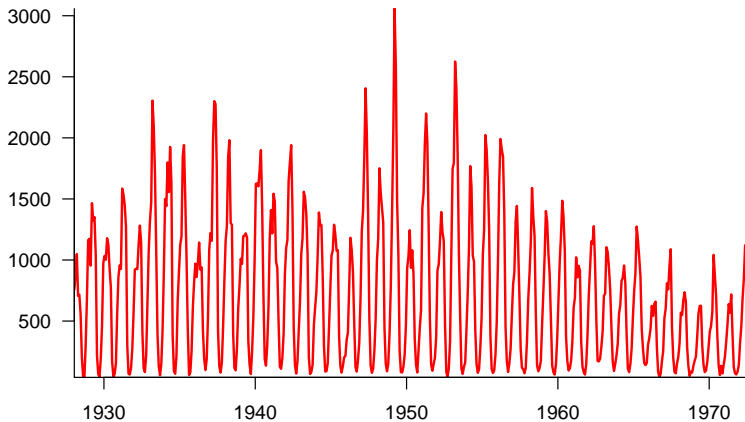
Mumps in New York City, 1928–1972

Monthly Cases

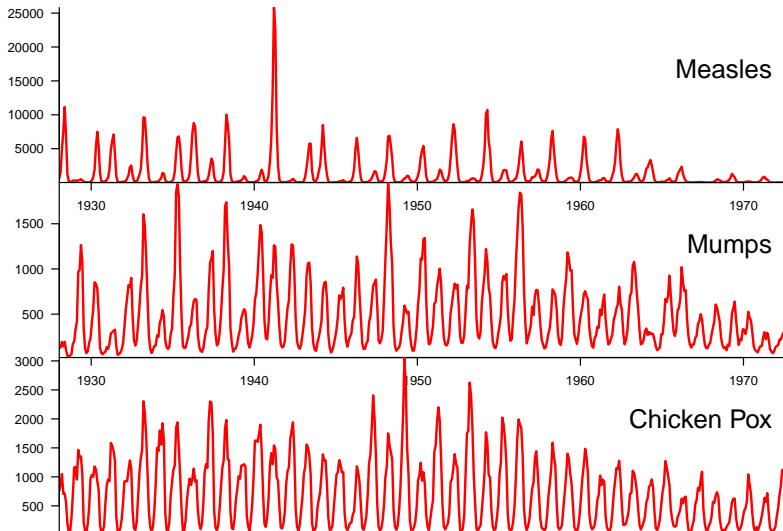


Chicken Pox in New York City, 1928–1972

Monthly Cases

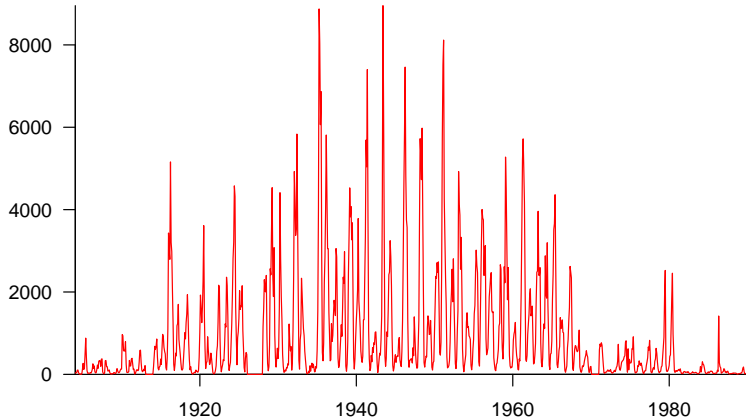


Childhood diseases in New York City, 1928–1972



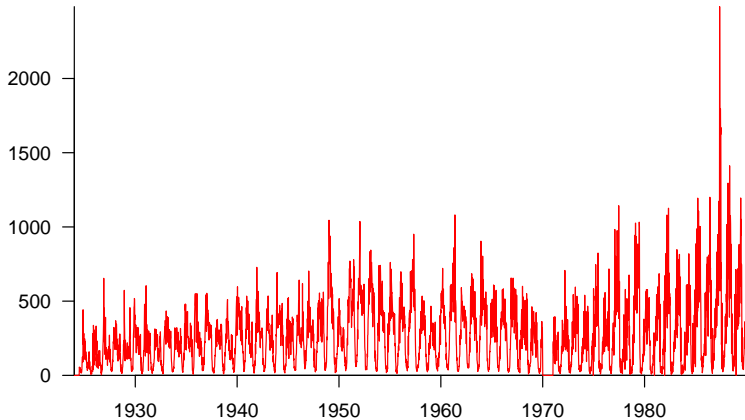
Measles in Ontario, 1904–1989

Monthly Cases



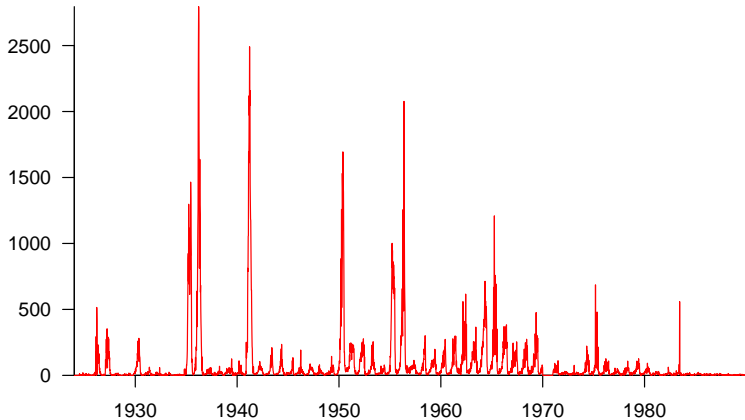
Chicken Pox in Ontario, 1924–1989

Monthly Cases



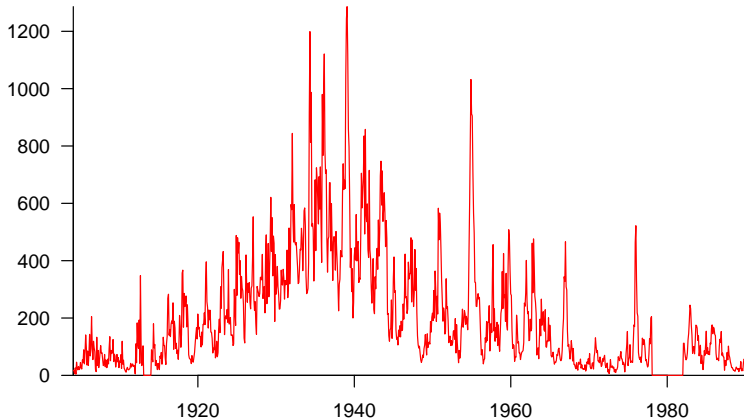
Rubella in Ontario, 1924–1989

Weekly Cases

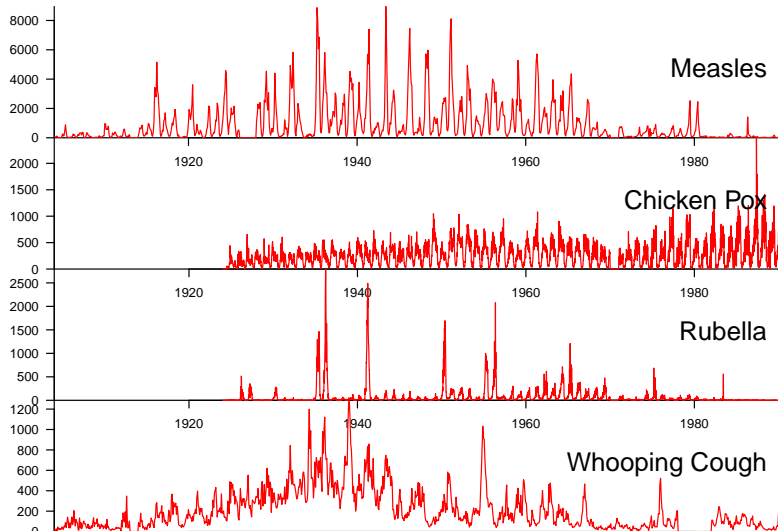


Whooping Cough in Ontario, 1904–1989

Monthly Cases



Childhood diseases in Ontario, 1904–1989



Ontario Disease Notification Data

Province of O

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

Handwritten notes on the left margin:
 *
 CSM
 C.P.
 DIP.
 DYS. A/B
 EN. LETH.
 ERYS.
 G.C.
 FLU.
 INF. JAUN.
 G.M.
 MEAS.
 MUMPS
 PARA. TYPH.

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	1490	0	8	0					5	0	82	0	21	1	18	0	18	0	850	0	92	0	1	0	
	21	3	2	1511	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	1931	1	22	3	1	0	0	1	17	1	343	0	208	4	71	0	85	0	3385	2	210	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	1363	0	1	0	1	0			7	0	82	0	27	1	47	1	29	0	1033	0	91	0	1	0	
	18	7	2	1354	1	2	0					4	1	68	0	103	1	35	0	44	0	1161	0	59	0			
	25	8	1	1308	0	2	0					9	0	56	0	177	0	19	0	28	0	999	0	73	0			
	Total	5	3	1388	1	12	1	2	0			23	1	289	0	367	3	19	1	126	0	4788	1	338	0	2	0	
Mar.	4	9	1	271	0	7	1	3	1			7	0	93	0	114	19	21	0	40	0	1131	2	109	0	1	0	
	11	10		239	0	7	0	2	0			8	1	61	0	137	8	31	0	32	0	845	0	91	0	2	0	
	18	11		166	0							6	0	66	0	122	6	5	0	59	0	969	2	69	0	1	0	
	25	12	1	236	0	1	0	1	0			7	0	63	0	306	16	9	0	20	0	879	0	170	0	1	0	
	Total	2	3	912	0	15	1	6	1			28	1	283	0	623	49	66	0	151	0	3824	4	383	0	34	0	
Apr.	1	13	2	0	139	0	3	0	1	0			8	0	95	0	66	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	73	22			14	0	790	0	65	0	1	0
	15	15	2	0	108	0	1	0			0	1	11	0	41	0	52	16	2	0	16	0	745	0	56	0		
	22	16	5	1	134	0	2	0	1	0	1	1	6	0	64	0	24	5	2	0	26	0	845	0	54	0		
	29	17	1	1	167	0	4	0	2	0	2	1	3	0	55	0	124	9	2	1	13	0	746	1	120	0		
		Total	13	2	710	0	11	0	5	0	3	3	33	0	372	0	634	61	7	1	99	0	4016	1	384	0	4	0
	6	18	2	0	104	0	1	0	2	0			4	0	71	0	76	3	1	0	14	0	877	0	63	0	3	0

Dominion Bureau of Statistics Disease Notification Data

VITAL STATISTICS BRANCH - COMMUNICABLE DISEASE SECTION

Cases of *H. Hooping Cough* Reported by Provincial Health Departments, Year *1924*

WEEK ENDING	P.E.I.		N.S.		N.B.		QUE.		ONT.		MAN.		SASK.		ALTA.		B.C.		CANADA		
	WKS	NOT	WKS	NOT	WKS	NOT	WKS	NOT	WKS	NOT	WKS	NOT	WKS	NOT	WKS	NOT	WKS	NOT	WKS	NOT	
1 JAN 5			11										1							12	
2 12			29										18							47	
3 19			37										32							69	
4 26			75	52			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 8													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	37	16	47			67		5			33	394	
18 MAY 3			26										2							28	