POLIO THEN AND NOW

ancient Egypt and contemporary southern Asia

Egyptian stele, 14th century BC

Wikipedia, 2009

1

POLIOMYELITIS REVISITED

an epidemiological and historical perspective (to 1973)

Neal Nathanson, University of Pennsylvania

- Polio emerges: ancient history and the early outbreaks, through 1916
- Polio triumphant: annual epidemics in the United States, 1916-1955
- Polio in retreat: IPV to first eradication, 1955-1973
- Polio deconstructed: epidemiological enigmas and explanations

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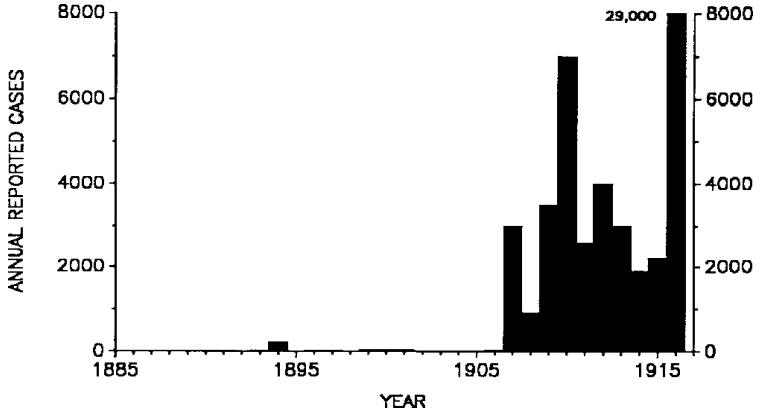
EMERGENCE OF POLIO AS AN EPIDEMIC DISEASE

United States, 1885-1916



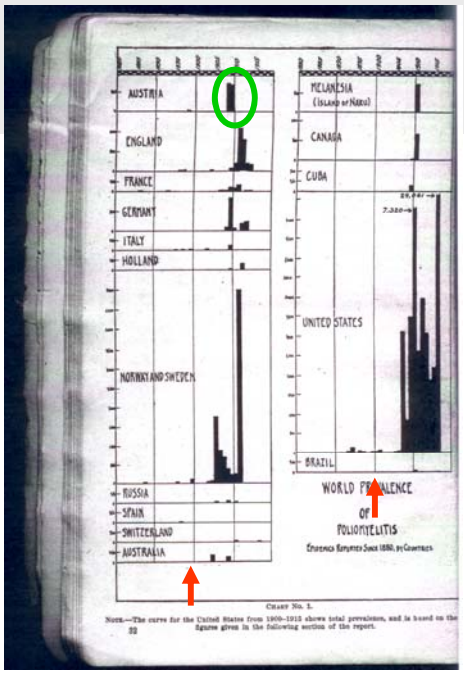
Lavinder et al Public Health Bulletin #1, 1918

3

EMERGENCE OF POLIO AS AN EPIDEMIC DISEASE

the world, 1880-1916

Lavinder et al Public Health Bulletin #1, 1918



EMERGENCE OF POLIO AS AN EPIDEMIC DISEASE
first enigma

OBSERVATION

- Between the years 1890 and 1910 polio appeared as an epidemic disease in the USA and many European countries?

ENIGMA

- What explains the transition from a sporadic to an epidemic disease?

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POLIO DECONSTRUCTED
epidemiological enigmas and hypotheses

HYPOTHESIS

- Poliovirus was ubiquitous prior to appearance of epidemic polio: epidemics do NOT reflect an increase in the number of polio infections
- Appearance of polio epidemics does NOT reflect an increase in virulence of poliovirus
- The appearance of epidemic poliomyelitis was due to a delay in initial infection from infancy to childhood
- Infants infected prior to age 6-12 months were protected against paralysis by maternal antibody while toddlers were not

EVIDENCE TO TEST THE HYPOTHESIS

- Seroepidemiological comparison of pre- and post-epidemic regions
- Comparison of two populations in a single city: Casablanca, 1947-1953
- Sero-epidemiology in pre-epidemic population: Casablanca, 1953

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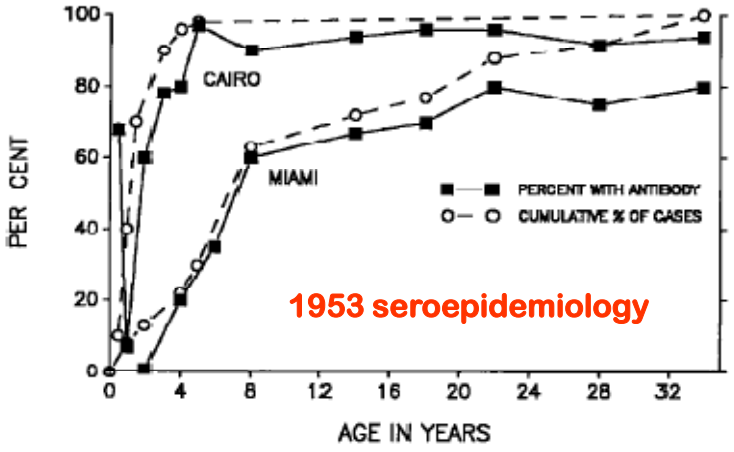
POLIO DECONSTRUCTED

poliovirus is ubiquitous prior to the emergence of epidemic polio infections are delayed in regions where polio is epidemic



Paul WHO Monograph 26, 1955

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POLIO DECONSTRUCTED

polio incidence in two populations in a single city: Casablanca, 1947-1953

	European	Moroccan
Population	125,000	530,000
Paralytic polio cases, 1947-1953	117	25
Average annual attack rate per 100,000	13.4 Epidemic	0.7 Pre-epidemic
1953 cases by age group		
0-1	8	9
2-9	15	2
10-39	5	

Paul and Horstmann Am J Trop Med Hyg 1955, 4: 512

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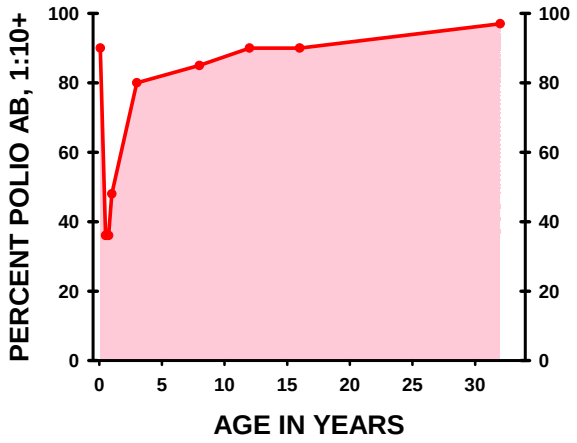
POLIO DECONSTRUCTED

age-specific poliovirus antibody prevalence Moroccan population, Casablanca, 1953



Paul and Horstmann Am J Trop Med Hyg 1955, 4: 512

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POLIO DECONSTRUCTED

Pre-existing serum antibody will confer protection against paralytic poliomyelitis at a titer of ≥1:4

	Unvaccinated placebo children	Vacccinated children	Percent protection against paralytic poliomyelitis
Number of paralytic cases	40	14 (40 expected if no protection)	65%
Percent seroconversions ≥ 1:4	0%	65%	

Francis et al. 1954 Field Trial of poliovirus vaccine, 1957

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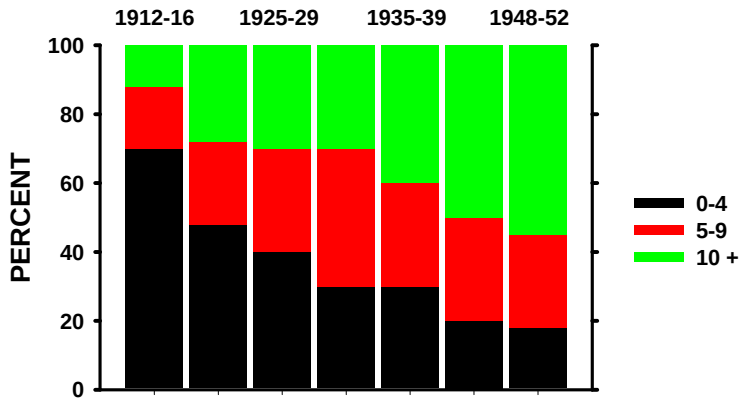
POLIO TRIUMPHANT: ANNUAL EPIDEMICS

Polio age distribution, Massachusetts, 1912-1952



Dauer Pro NY Acad Sci 1955, 61: 943

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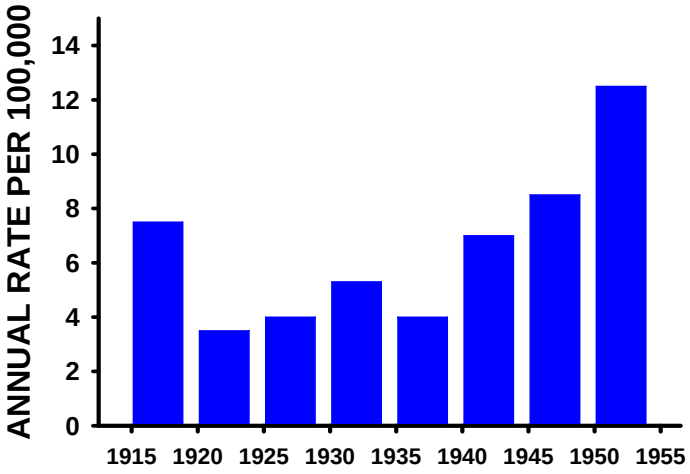
POLIO TRIUMPHANT: ANNUAL EPIDEMICS

Paralytic polio incidence, USA, 1915-1954



Serfling and Sherman Pub Hlth Rep 1953, 68: 453; and CDC, 1955

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POLIO TRIUMPHANT: ANNUAL EPIDEMICS
second enigma

OBSERVATIONS

- After its appearance polio became an annually recurring epidemic disease (USA, 1900-1954)
- During this period the age distribution increased quite dramatically, evolving from "infantile paralysis" into a disease mainly of children and young adults

ENIGMA

- Why did the age distribution evolve?
- Did the advancing age of infection result in an overall increase in incidence?

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POLIO DECONSTRUCTED
epidemiological enigmas and hypotheses

HYPOTHESIS

- Improved sanitation and personal hygiene reduced the probability of transmission and led to a delay in the age of infection (USA, 1900-1950)
- The data are unclear whether this led to an increase in overall incidence of paralytic poliomyelitis

EVIDENCE TO SUPPORT THE HYPOTHESIS

- Studies of the case:infection ratio by age
- Polio incidence in New York City, 1910-1954

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POLIO DECONSTRUCTED

Age-specific paralytic case:infection ratio

Age	Number of seroconverters	Paralytic cases	Cases per 100 seroconverters
<1	450	3	0.66
1-2	1,000	10	1.00
3-4	741	12	1.62
5-9	1,042	25	2.40
10-14	716	13	1.82
TOTAL	3,949	63	1.59

Melnick and Ledinko Am J Hyg 1953, 58: 207

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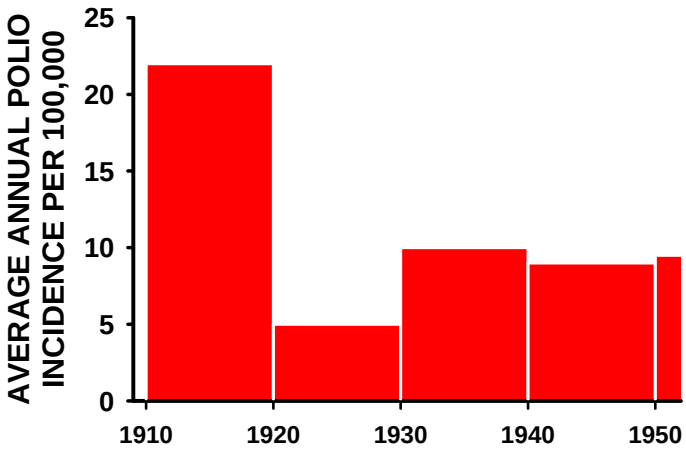
POLIO DECONSTRUCTED

Average annual polio incidence, New York City, 1910-1952



Siegel et al. NE J Medicine 1955, 252: 752

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POLIO TRIUMPHANT: SEROTYPE DIFFERENCES

Frequency of isolates from poliomyelitis cases, by serotype, USA, 1952
data by regions with different overall attack rates

Regions by attack rates per 100,000	Number of isolates	Percent of isolates		
		Type 1	Type 2	Type 3
445-103	270	94%	4%	2%
94-43	156	77%	10%	13%
40-16	235	77%	20%	3%
15-4	133	59%	28%	13%

Shelokov et al Proc NY Acad Sci 1959, 61: 998

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POLIO DECONSTRUCTED

third enigma

OBSERVATION

- The three serotypes of poliovirus appear to vary in epidemic significance: type 1; type 2; type 3
- Wild type 2 poliovirus has been eradicated while types 1 and 3 have not

ENIGMA

- Is this due to differences in environmental survival; infectivity; viremogenicity; neuro-invasiveness; or neurovirulence?

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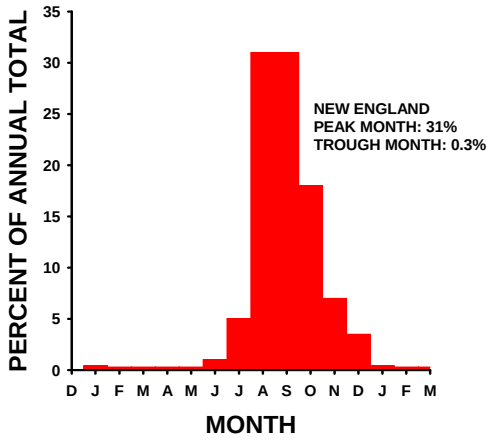
POLIO TRIUMPHANT: SEASONALITY

Poliomyelitis cases by month, New England, 1915-1954



Serfling and Sherman Pub Hlth Rep 1953, 68: 453; and CDC, 1955

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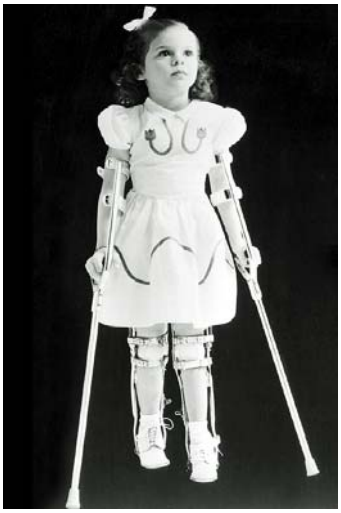
POLIO TRIUMPHANT: A DREAD DISEASE

Past images from the USA



POLIO TRIUMPHANT: A FRIGHTENING SPECTER

Iron lung ward at Rancho los Amigos, Downey, California, USA, 1953

POLIO DECONSTRUCTED

fourth enigma

OBSERVATIONS

- Polio seasonality is marked in cold climates and peaks in late summer
- Seasonality is marked for many viral diseases but peaks occur at different times of year

HYPOTHESIS

- Seasonality does NOT reflect differences in human activity
- Seasonality reflects seasonal differences in humidity but NOT in temperature

EVIDENCE

- Rotaviruses (another enterovirus) has totally different seasonality
- Polio seasonality is associated with seasonal changes in indoor humidity, but not in tropics where humidity is constant and high
- Environment duration of poliovirus infectivity is much greater at elevated relative humidity and constant temperature (20C)

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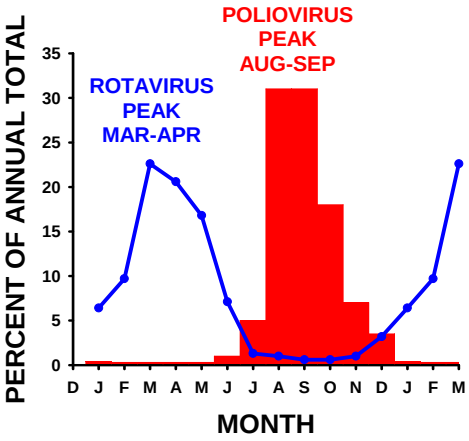
POLIO DECONSTRUCTED

Seasonality of polio and rotaviruses, USA



Serfling and Sherman Pub Hlth Rep 1953, 68: 453; Torok et al. Ped Inf D J 1997, 16: 941

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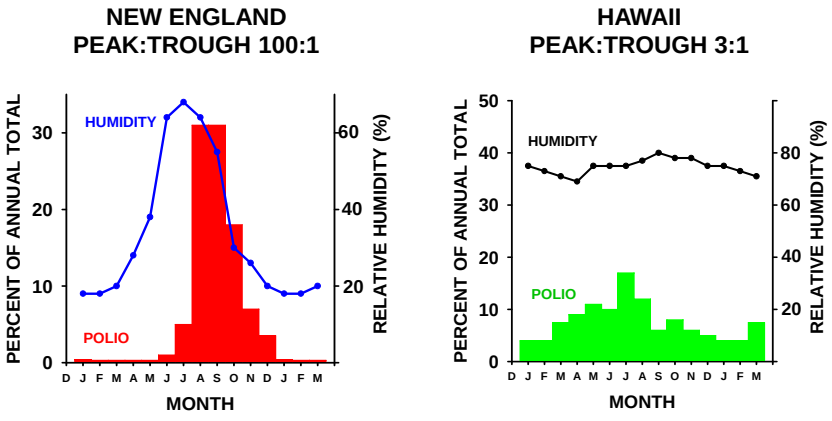
POLIO DECONSTRUCTED

Seasonality, New England and Hawaii compared



Nathanson and Martin Am J Epidemiology 1979, 110: 672

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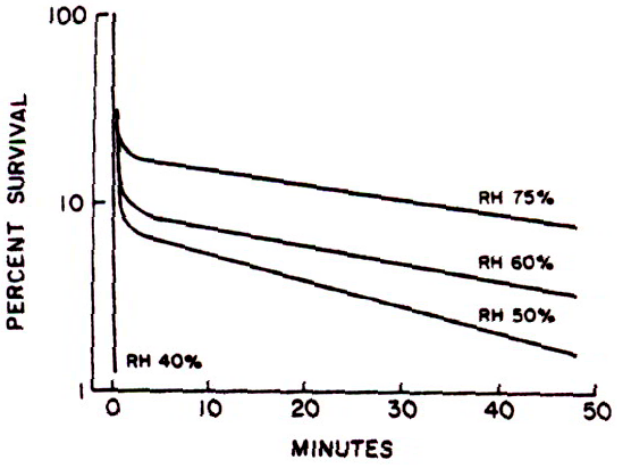
POLIO DECONSTRUCTED

Poliovirus survival at 20C is sensitive to reduced humidity



Hemmes et al Ant V Leeuwanhoek 1962, 28: 221

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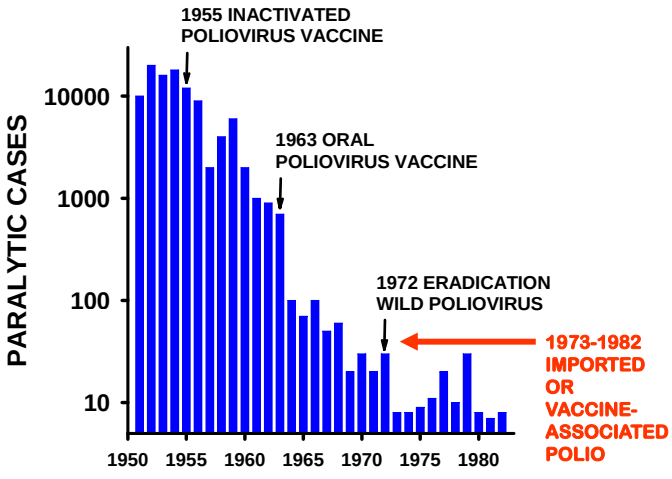
POLIO IN RETREAT: IPV TO FIRST ERADICATION

Polio incidence, USA, 1952-1979



Nathanson and Martin Am J Epidemiology 1979, 110: 672

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POLIO DECONSTRUCTED
fifth enigma

OBSERVATIONS

- Prior to the introduction of polio vaccine in 1955, ~16% of the population (24 million) were susceptible to polio
- In the USA, by 1970, vaccination programs (IPV and OPV) had reduced susceptibles to ~2.6% of the population (>5 million)
- It was assumed that the residual susceptible group would continue to circulate wild polioviruses: control not eradication

HYPOTHESIS

- IPV and OPV-induced "herd immunity" that reduced circulation of wild polioviruses
- Seasonality played a key role in the disappearance of wild polioviruses in the USA

EVIDENCE

- Both OPV and IPV reduced circulation of wild polioviruses?
- Wild polioviruses faded out during winter trough?
- Stepwise fadeouts in individual States

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POLIO DECONSTRUCTED
Observed polio incidence, USA, 1958-1961 vs expected based on pre-vaccine incidence, 1951-1954

Polio incidence by year	Expected if no vaccine	Expected if 65% IPV protected	Observed
1958	27,316	11,794	3,795
1959	28,224	10,191	6,358
1960	28,964	8,964	2,556
1961	29,521	8,471	1,002
1958-1961	114,025	39,420	13,711
Percent of baseline	100%	35%	12%
Vaccine protection: (% immunized with IPV) X (% IPV efficacy)			

Stickle Am J Pub Hlth 1964, 54:1222

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POLIO DECONSTRUCTED

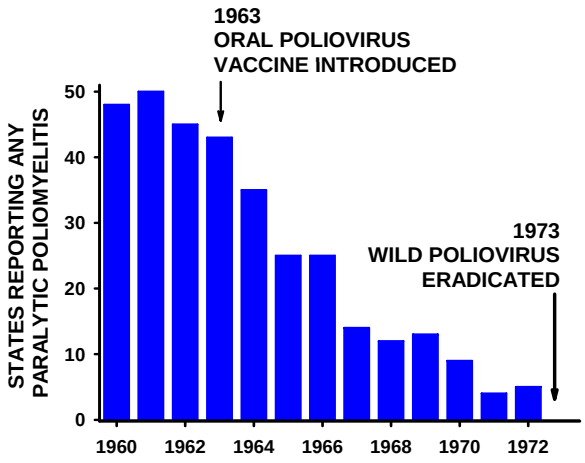
Calculated perpetuation of wild polioviruses during seasonal trough in New England, 1950 and 1970

	Pre-vaccine 1950	Post-vaccine 1970
Total population	1,000,000	1,000,000
Polio susceptible population	160,000	26,000
Annual polio infections	20,000	1,000
Polio infections per generation period at seasonal trough (0.1% of annual total)	20	~1

Nathanson J Infectious Diseases 1984 6 (S2): S308; Stickle Am J Pub Hlth 1964, 54:1222 29

POLIO DECONSTRUCTED

States reporting any polio, USA, 1960-1973



Nathanson and Martin Am J Epidemiology 1979, 110: 672 30

FINIS

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