



Institute for
Healthcare
Improvement

Health Care Symposium

Epidemiology and Transmission of Infections in the Hospital

Don Goldmann

Chief Scientific Officer Emeritus, and Senior Fellow

Institute for Healthcare Improvement

Clinical Professor of Pediatrics

Harvard Medical School

@DAGoldmann

dgoldmann@ihi.org

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No conflicts to declare



Donald A. Goldman, M.D.

served in the

EPIDEMIC INTELLIGENCE SERVICE

of the

CENTER FOR DISEASE CONTROL

July 1971 to July 1973



Donald A. Goldman
Director, Center for Disease Control

Robert G. Anderson
Director, Epidemiology Program

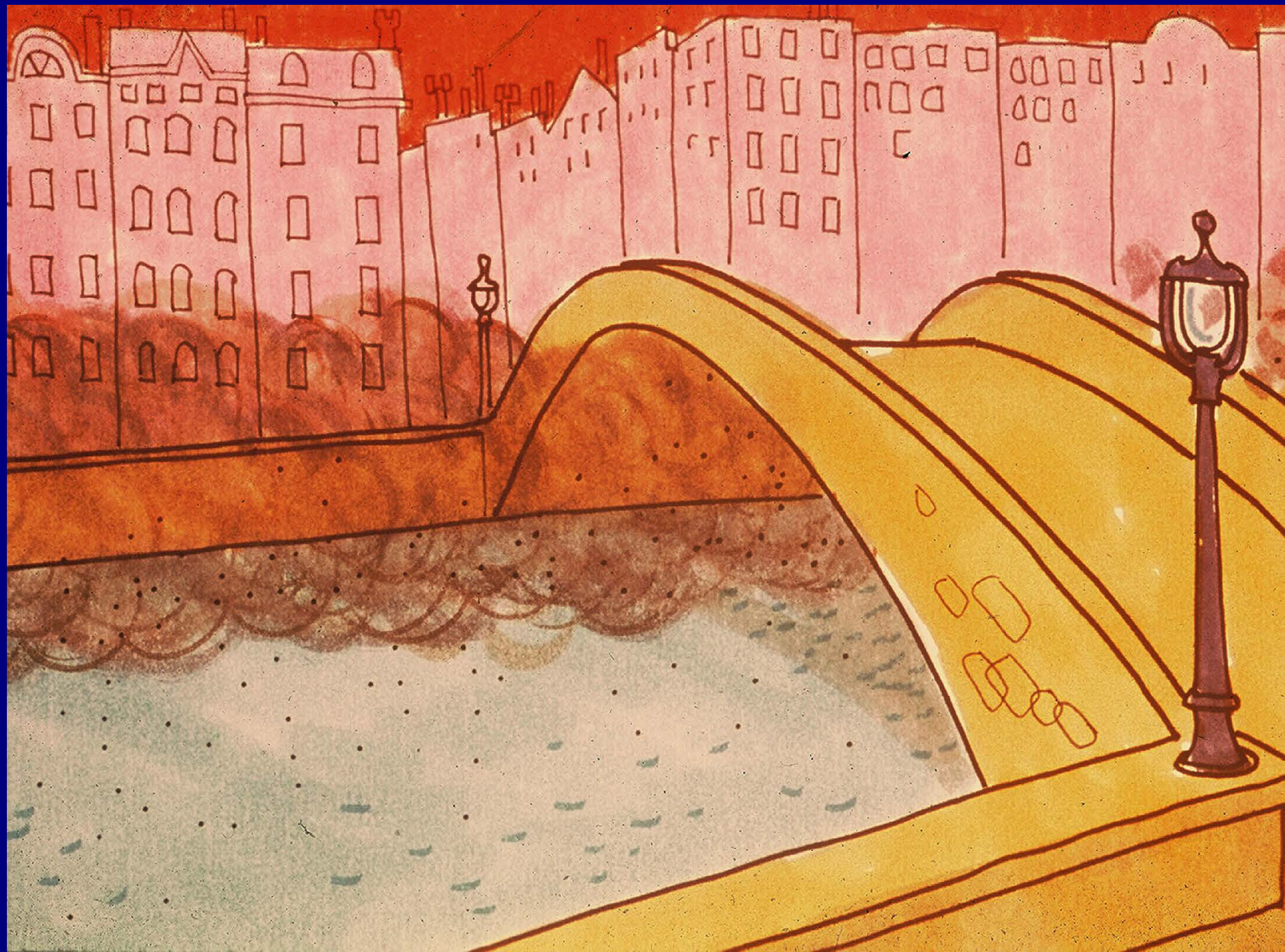




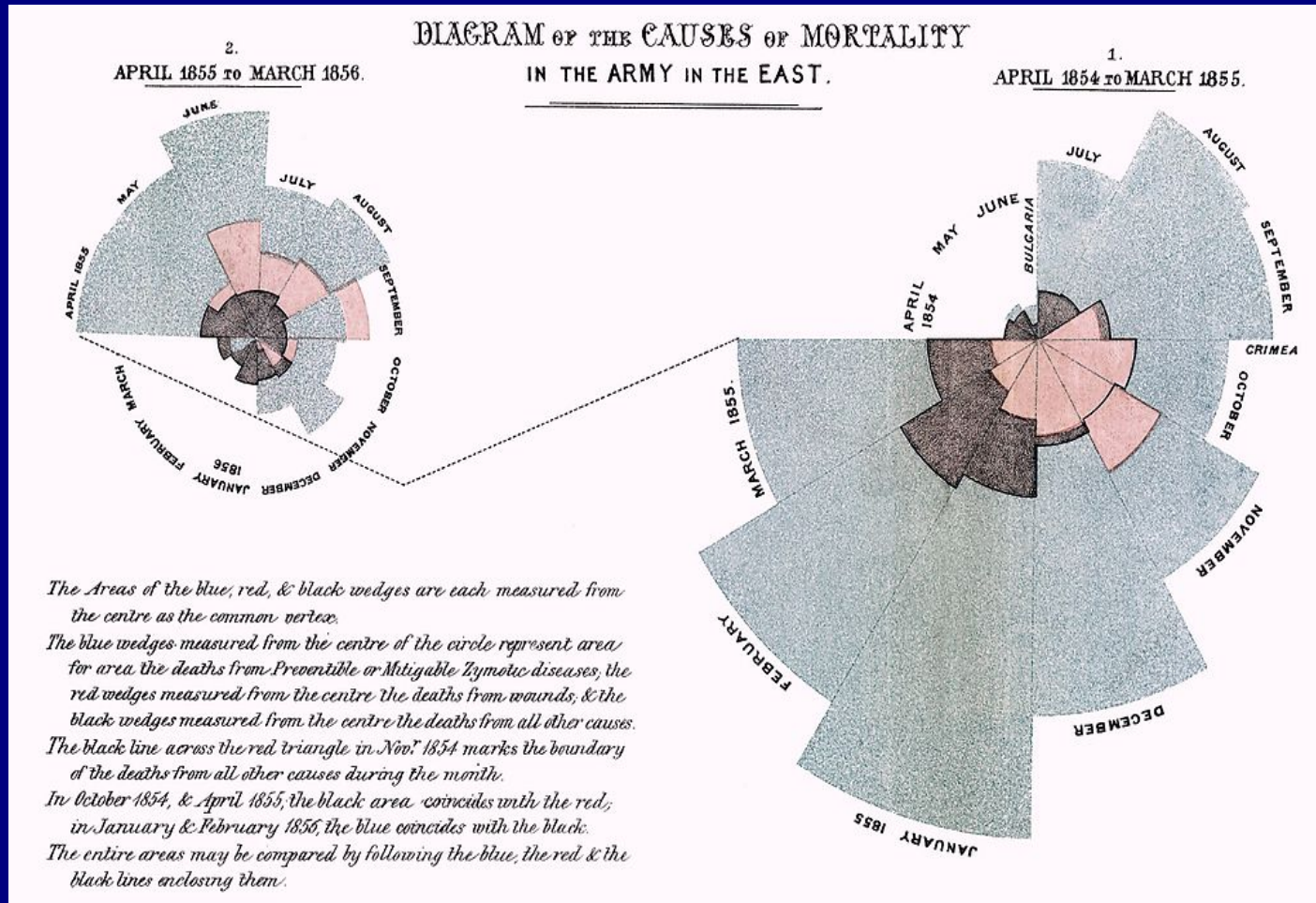
Vorstellung des Doct. Chicogneau Landknecht der Universitaet zu Montpel-
lier, welcher A. 1720. vom Könige in Frankreich nach Marseille geschickt worden,
um denen mit der Pest befallenen Leuten beizuhelfen. Er trug daselbst ein langes Kleid
von Corduan-Leder mit einer Masque, die Augen von Crystall hatte, und deren lange
Nase mit wolriechenden Sachen wieder daruff angefüllet war. Dabey er einen Stab in der hand
führte, womit er auf die Leiber der von der Pest ange-
steckten Personen deutete, wenn er sahe, dass
man zu deren Ansehung kein sollte.



Portrait of a member of the town council with pomander attached to rosary
Heinrich vom Rhein zum Mohren, 1477-1536, Metropolitan Museum of Art



Miasmatic and Zymotic Diseases* – Farr and Nightingale



*Typhus and typhoid fevers, smallpox, scarlet fever, measles, erysipelas, cholera, whooping-cough, diphtheria, etc -

William Farr's Cholera Miasma Theory

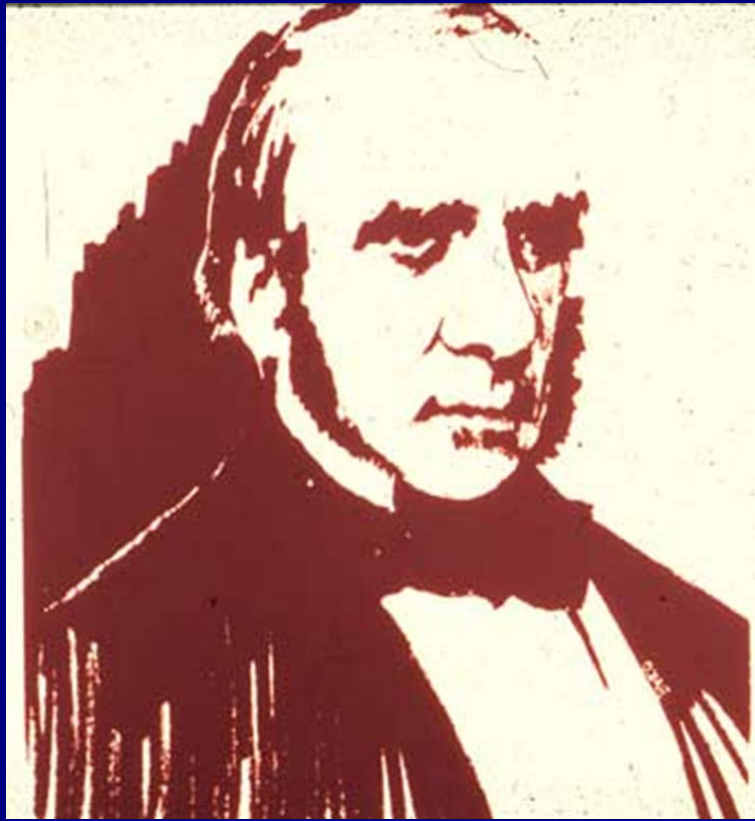
- Eminent statistician
- Ally of Florence Nightingale who used flawed statistics about hospital mortality to advocate for reform
- Analyzed 8 “explanatory variables” (e.g., crowding, house value, elevation)
- Correlation of cholera mortality with elevation above putrid Thames

| Mean Elevation of the Ground above the High- water Mark. | Mean Mortality from Cholera. | Calculated Series. |
|---|---------------------------------------|-----------------------|
| 0 | 177 | 174 |
| 10 | 102 | 99 |
| 30 | 65 | 53 |
| 50 | 34 | 34 |
| 70 | 27 | 27 |
| 90 | 22 | 22 |
| 100 | 17 | 20 |
| <hr/> 350 | <hr/> 7 | <hr/> 6 |

$$c = \frac{90 + 13}{e + 13} \cdot 22 = \frac{103 \times 22}{e + 13} = \frac{2266}{e + 13}$$

“This made it probable that a certain relation existed between elevation and the power of cholera to destroy life. The more exact information which we possess respecting the London districts establishes this connexion beyond doubt. The relation may not be expressed by the same figures in other places, or in London at other times, but it will always be the general rule that the mortality of cholera is inversely as the elevation of the people assailed above the sealevel.”

John Snow and the Broad Street Pump





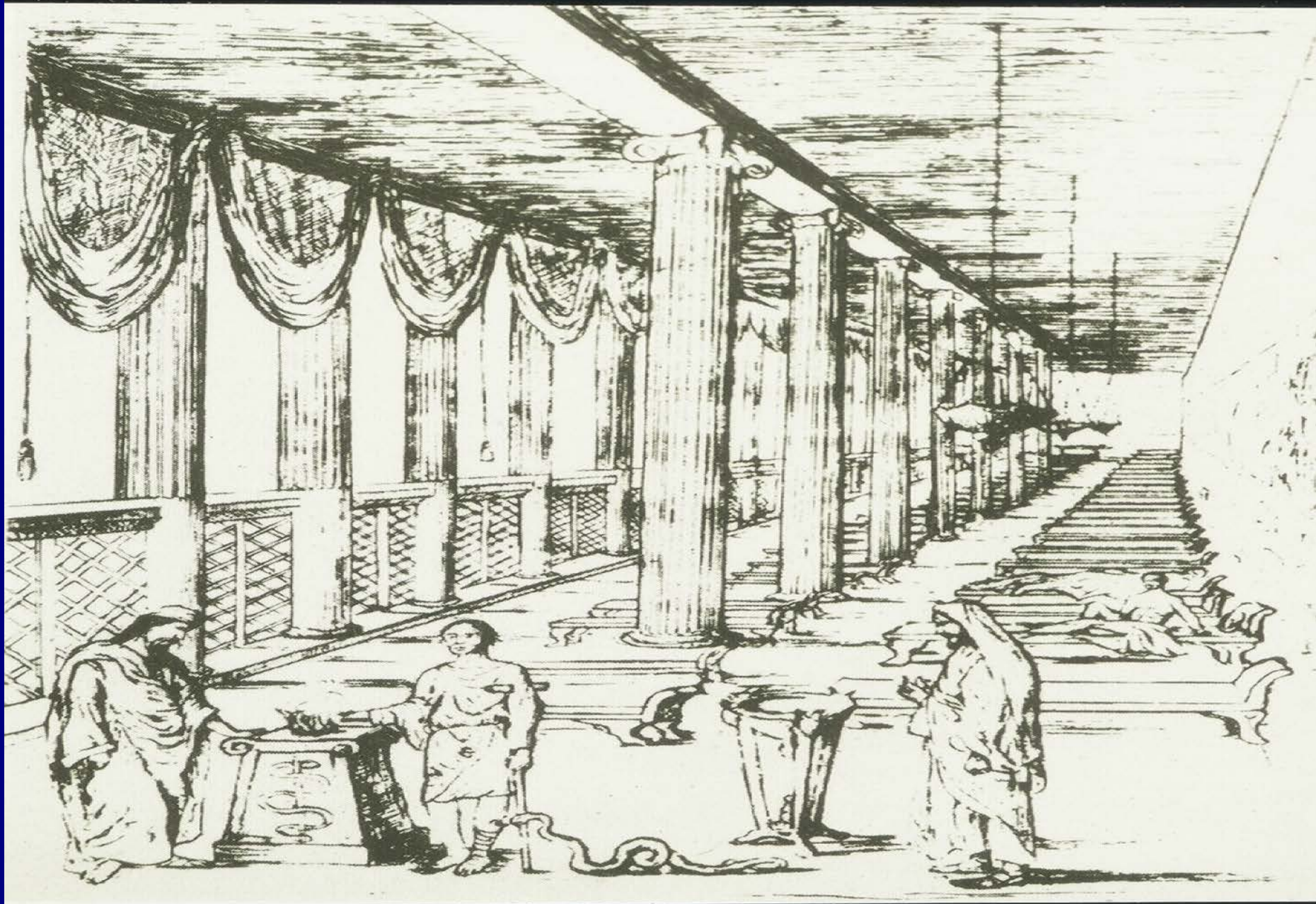
Snow's Voronoi diagram – line shows spots closer to Broad Street Pump than any other pump in terms of *walking distance*

Snow the “Father of Modern Epidemiology?”

- Careful construction of maps showing relationship between location of cases and the putative cause (Broad Street Pump)
- But did not perform a case-control study (i.e., no comparison group)!
- The analysis of cases and controls was left to Reverend Henry Whitehead



Askleipion of Kos, the best preserved instance of a Greek Asklepieion (Healing Center)

















UV light installed at Children's Hospital, Boston

Modes of Transmission

- Direct contact
 - Contact with someone with staphylococcal boil
 - Contact with animal infected with plague; lizard with salmonella
 - Contact with blood & other body fluids (HIV, hepatitis B & C, Ebola)
 - Sexual intercourse with a patient with Zika
- Droplet contact (large droplets, spit)
 - Whooping cough or meningococcal meningitis
- Indirect contract
 - Contaminated hands (antibiotic resistant bacteria on hands of hospital nurses)
 - Contaminated inanimate objects (common cold viruses on doorknob)
 - Fecal-oral (Salmonella) – hands or food
- Endogenous (autoinfection)
 - Urinary tract infection from bowel and vaginal bacteria
- Airborne
 - Droplet nuclei (TB, some viruses)
 - Fungal spores (coccidiomycosis)
- Common vehicle/common source
- Vector (insect)
 - Malaria, dengue and Zika via mosquitoes; Lyme disease via ticks

The Common Cold

Harvard Hospital and Dr. Christopher Andrewes



FIGURE 45.—The American Red Cross-Harvard Field Hospital Unit, assembled in Salisbury, England, from 66,000 pieces of prefabricated building material shipped from the United States. The hospital was used to study wartime epidemics. (Photograph, courtesy American Red Cross.)

Is the “Common Cold” Spread by the Air?

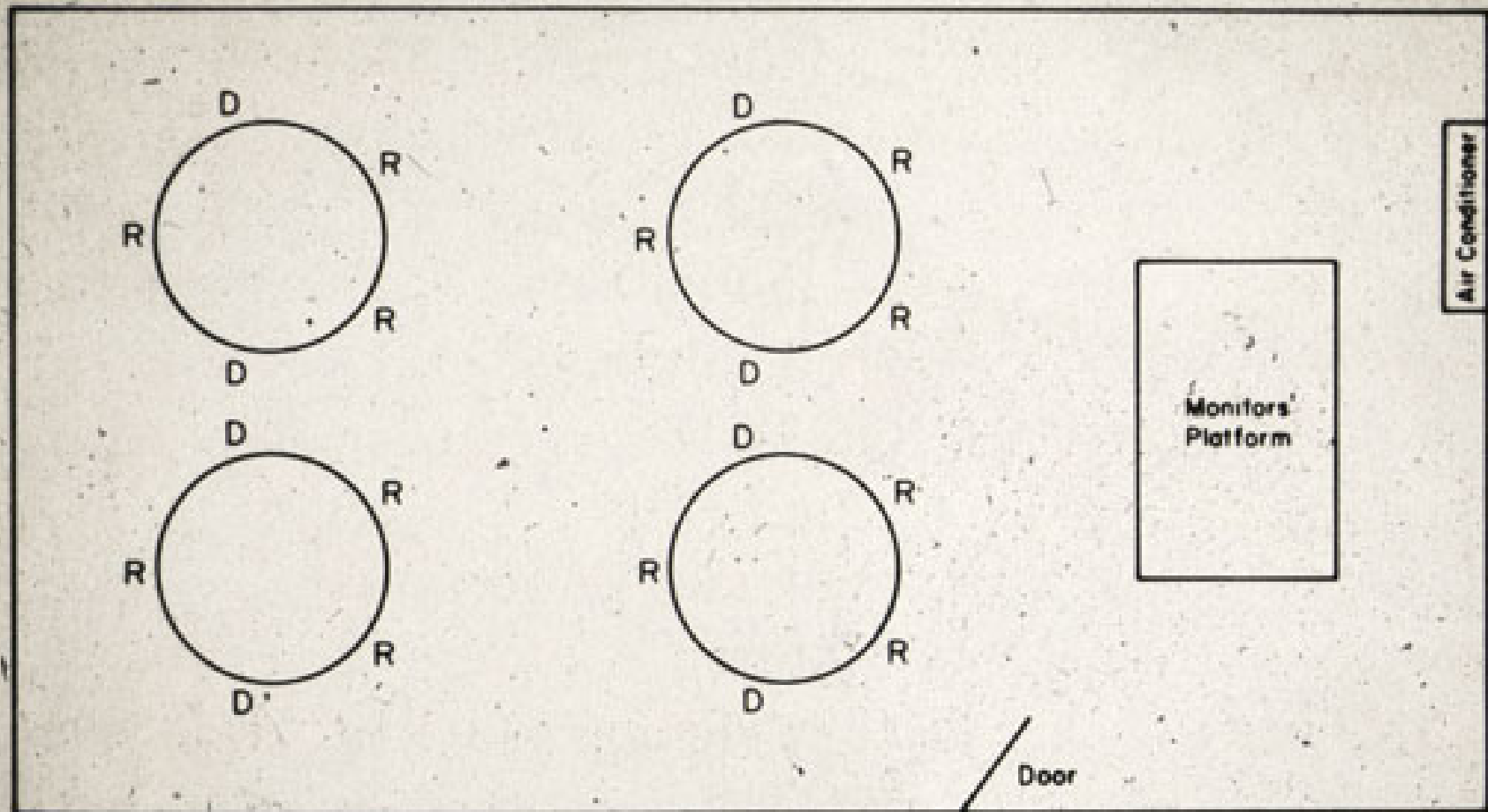


Figure 1. Layout of the room used for the poker game experiment. D = donor and R = recipient.







Direct Contact

Direct Contact



Not always so obvious!

Pets and Zoos



Indirect Contact and Fecal-Oral Transmission

- Hands
- Fomites (inanimate objects)
 - Important for certain bacteria: MRSA (methicillin-resistant *Staphylococcus aureus*), spore-forming bacteria (*Clostridium difficile* – antibiotic-associated colitis), probably *Acinetobacter* (nearly untreatable infections)
 - Plays a role in spread of some viruses: RSV (respiratory syncytial virus), coronavirus
- Food and water

Hand Cultures

16 NICU Nurses

| Antibiotic Resistant Organism | No. of carriers |
|---------------------------------|-----------------|
| <i>Citrobacter freundii</i> | 3 |
| <i>E. coli</i> | 4 |
| <i>Klebsiella pneumonia</i> | 5 |
| <i>Enterobacter cloacae</i> | 3 |
| <i>Enterobacter agglomerans</i> | 3 |
| <i>Acinetobacter species</i> | 2 |
| Non-Fermentative gram-negatives | 2 |

11/16 nurses grew Gram-negative bacilli, often 10^5 /ml or higher.
Similar results in 4/4 physicians

RSV Transmission

Table. The proportion of 31 volunteers infected with respiratory syncytial virus according to method of exposure to an infected infant, and the resulting type of illness and incubation period

| <i>Volunteers</i> | <i>Cuddlers*</i> | <i>Touchers†</i> | <i>Sitters‡</i> |
|-------------------|------------------|------------------|-----------------|
| No. exposed | 7 | 10 | 14 |
| No infected | 5 | 4 | 0 |
| Afebrile URI§ | 3 | 3 | — |
| Febrile URI | 2 | 0 | — |
| Asymptomatic | 0 | 1 | — |
| Incubation | 4 days | 5.5 days | |

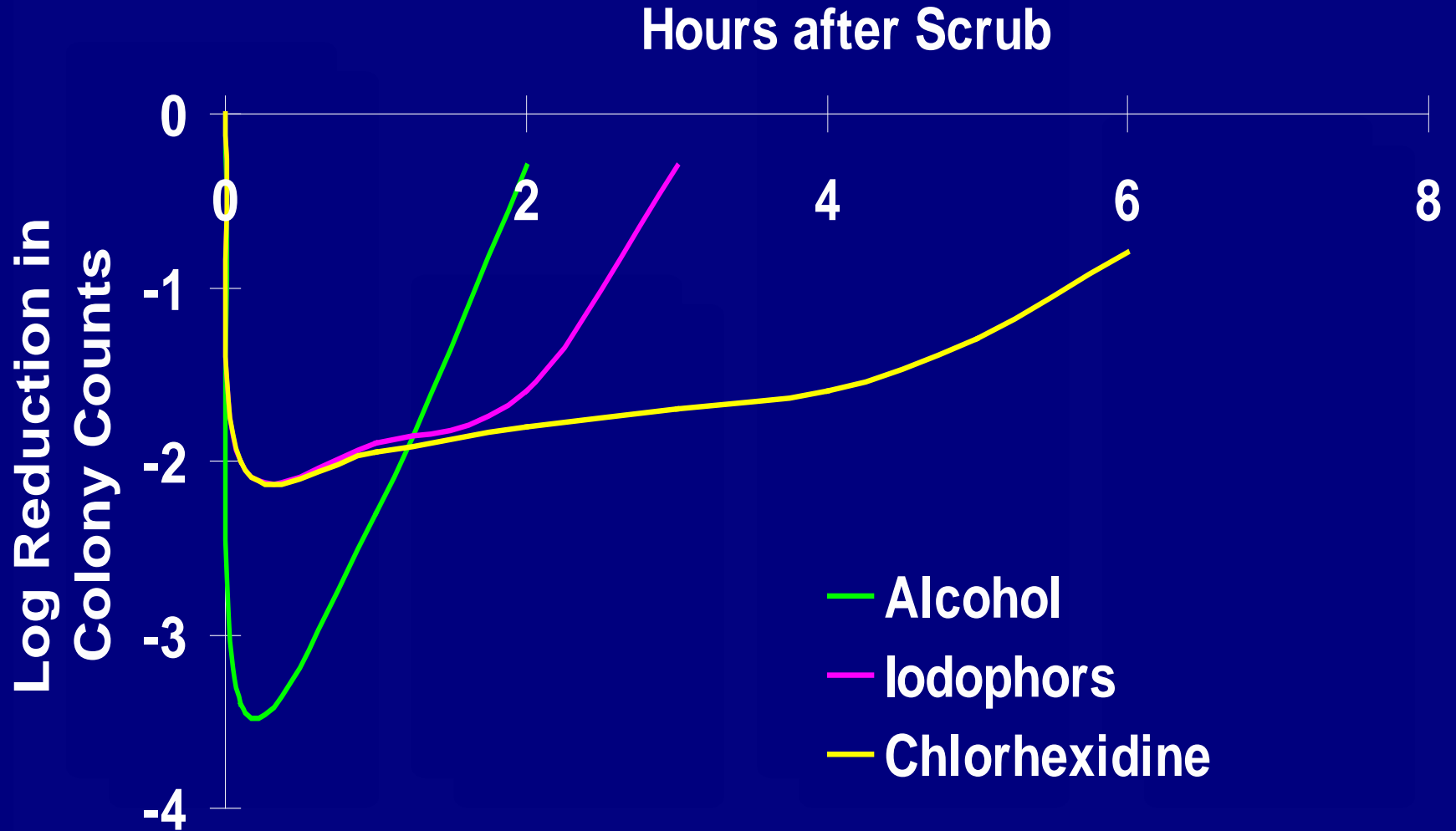
*Volunteers exposed by close contact with infected infants.

†Volunteers exposed by self-inoculation after touching surfaces contaminated by infected infant's secretions.

‡Volunteers exposed only by sitting at a distance of over 6 feet from an infected infant.

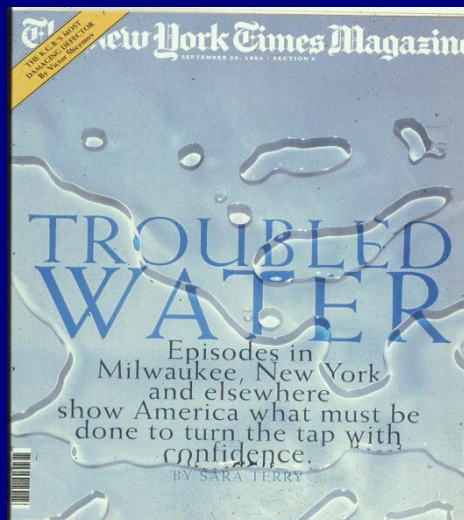
§Upper respiratory tract infection.

Effect of Antiseptics on Colony Counts After Use as a Hand Scrub



Modified from Larson E, et al. Am J Infect Control 1988;16:253.

Food and Water



Drinking
Water
Comes to
A Boil

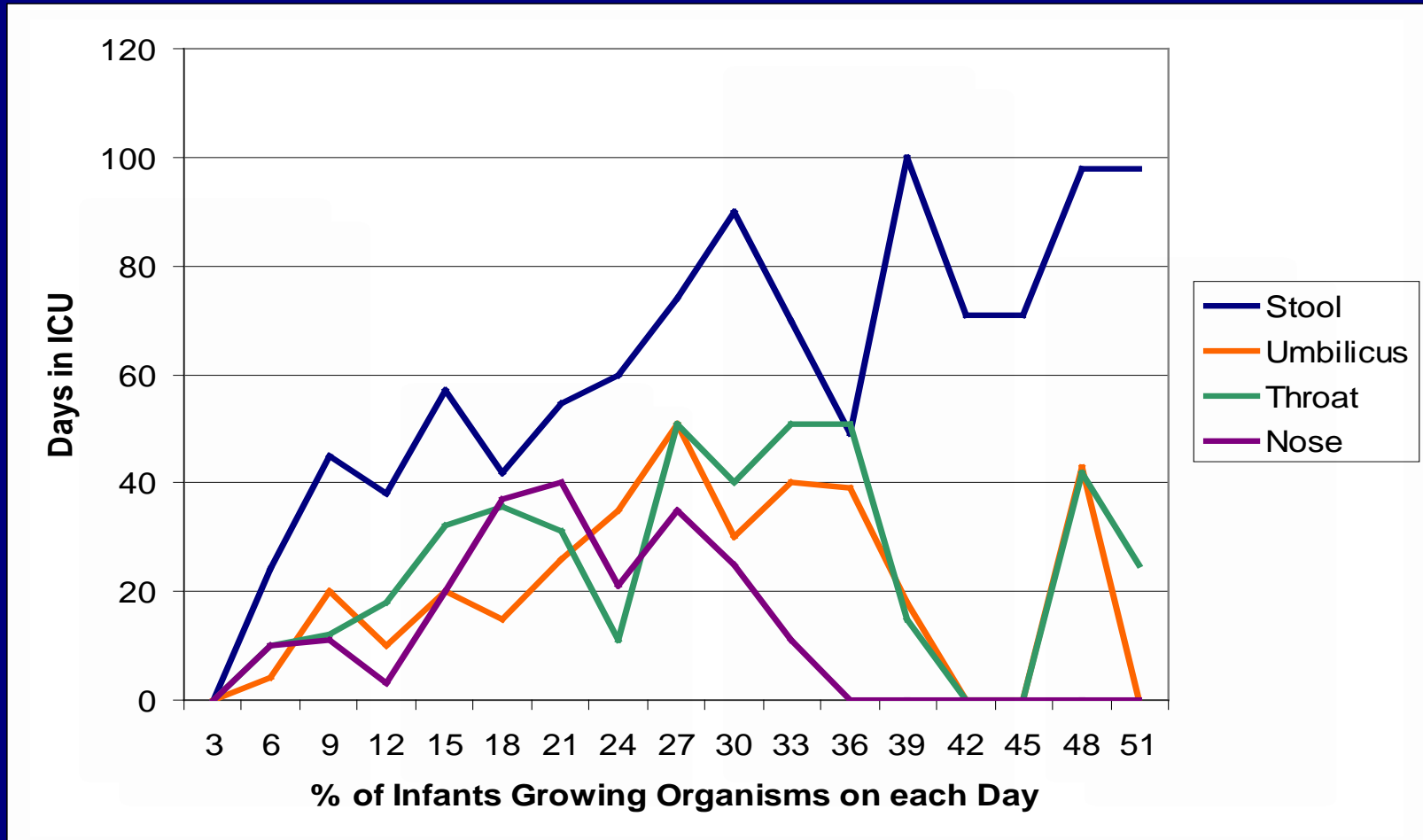


Endogenous Infection

Endogenous Infection – Acquired in the Community

- Urinary tract infection
 - Young women
 - Elderly women
 - Men with prostate disease
- Aspiration pneumonia
 - After a seizure
 - Alcohol-induced unconsciousness
- Wound infection
 - MRSA in football players

‘Endogenous’ Infection Acquired in the Hospital



Percent of neonates colonized with antibiotic-resistant Gram-negative bacilli

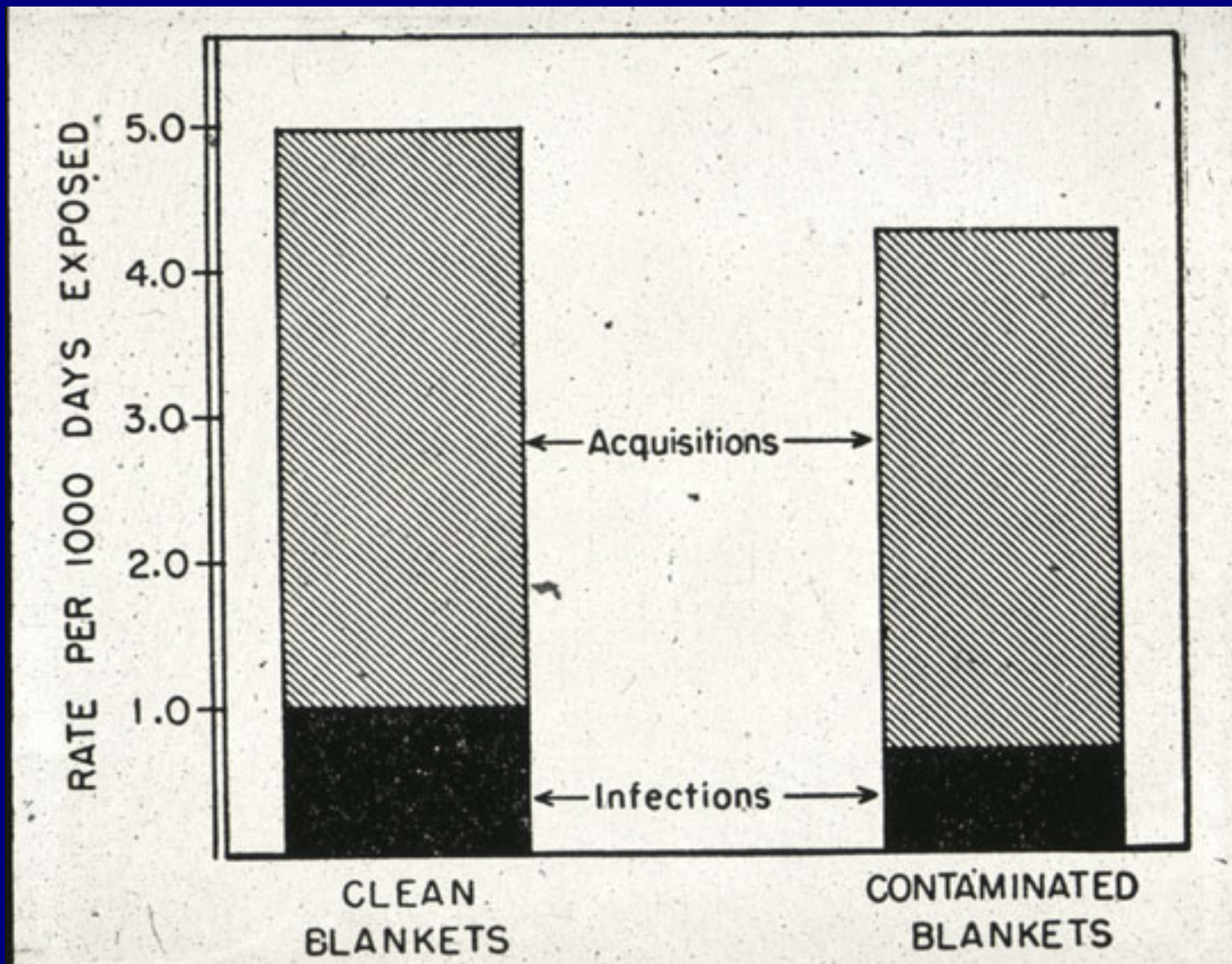
Droplet Contact

Droplet Contact



Group A strep, pneumococci, meningococci, pertussis (whooping cough) and some viruses (within about 3 feet)

Randomized Trial of Exposure to Strep-Contaminated Blankets



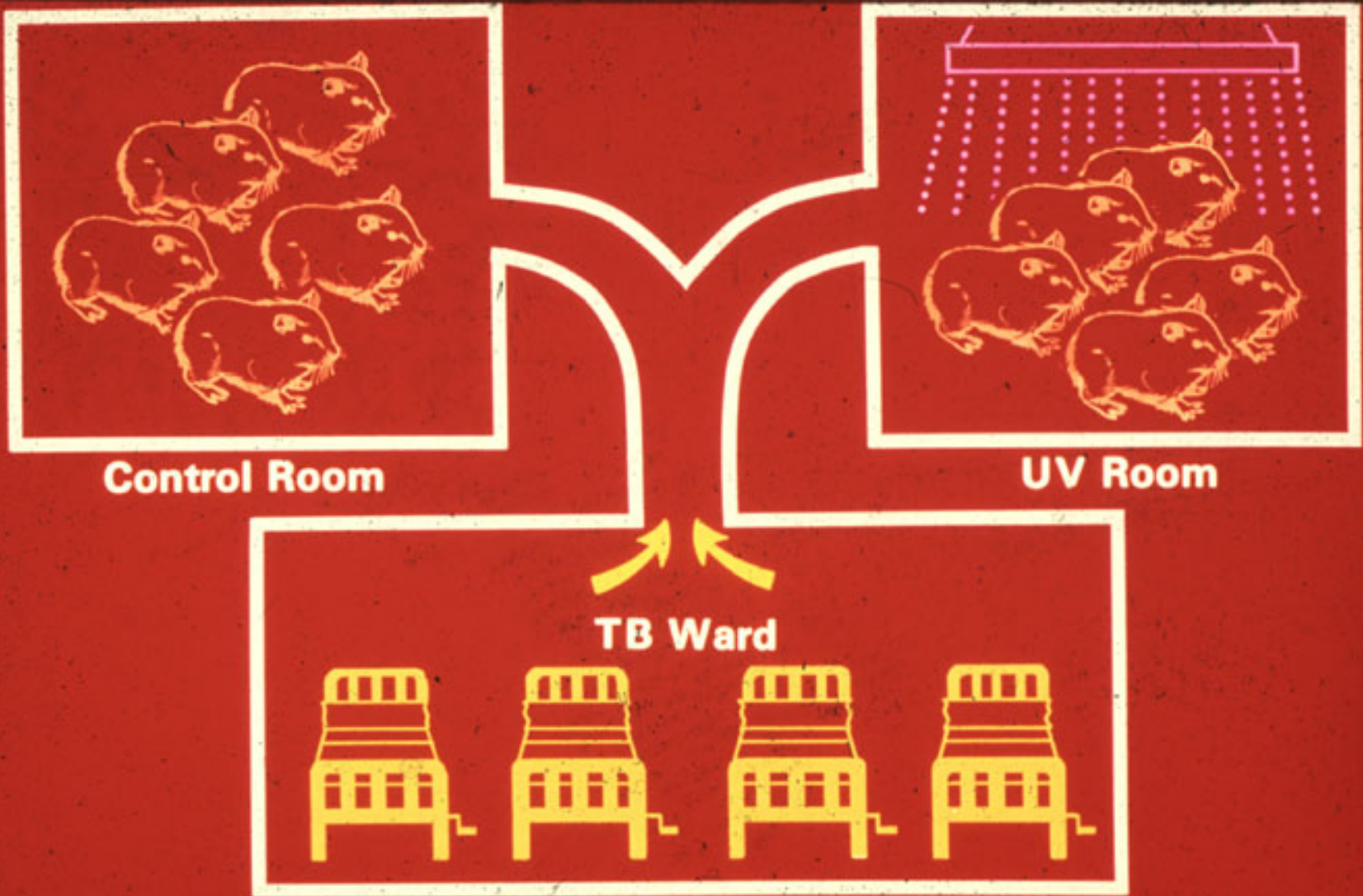
Airborne

- Droplet nuclei
- Fungal spores
- Shedding of skin scales

Droplet Nuclei

- 1-5 microns
- Remain suspended in air
- Evade respiratory tract defenses to reach periphery of lung
- Iconic work of Richard Riley and his mentor William Wells at Johns Hopkins





Riley's proof that TB is airborne

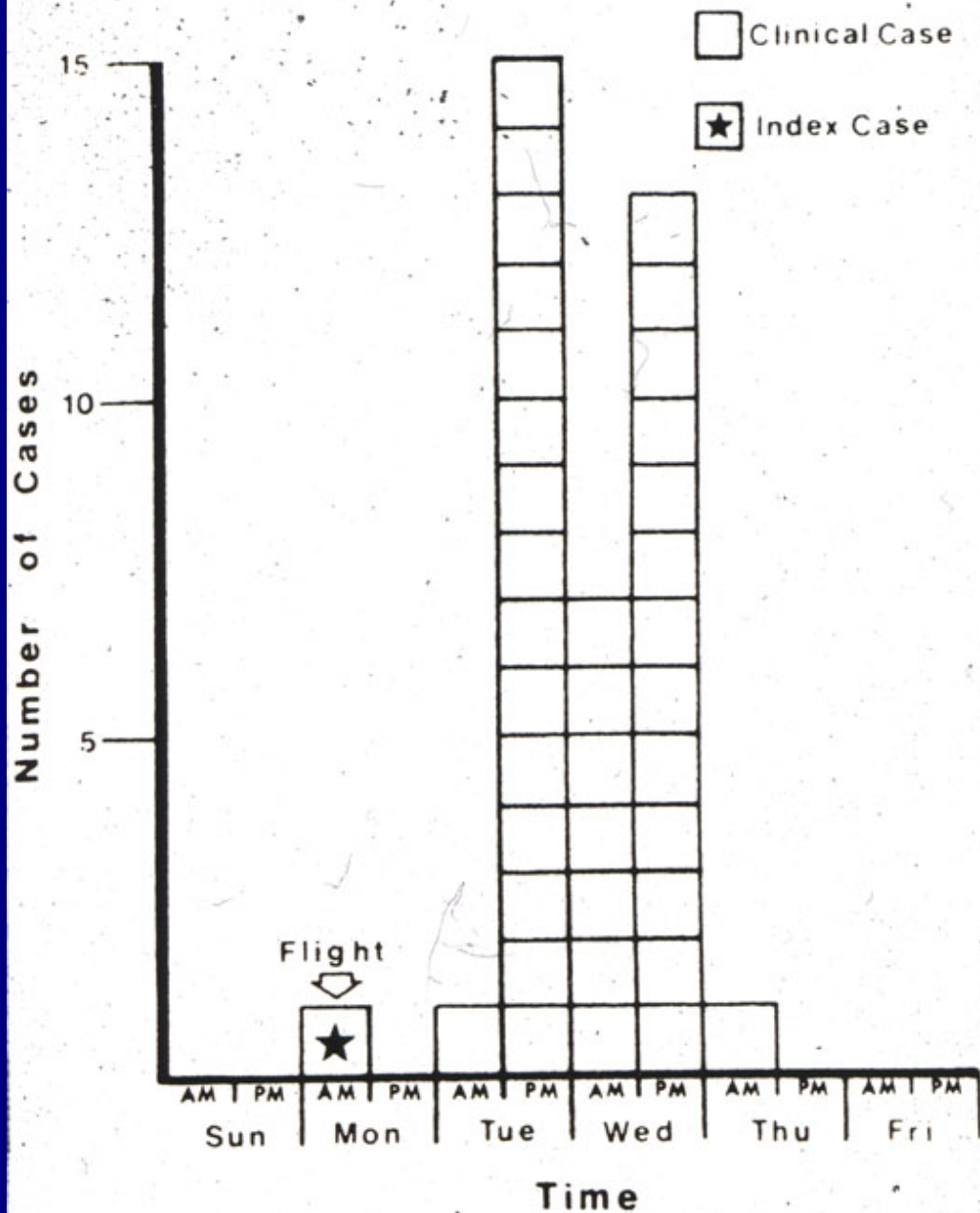
Influenza Virus

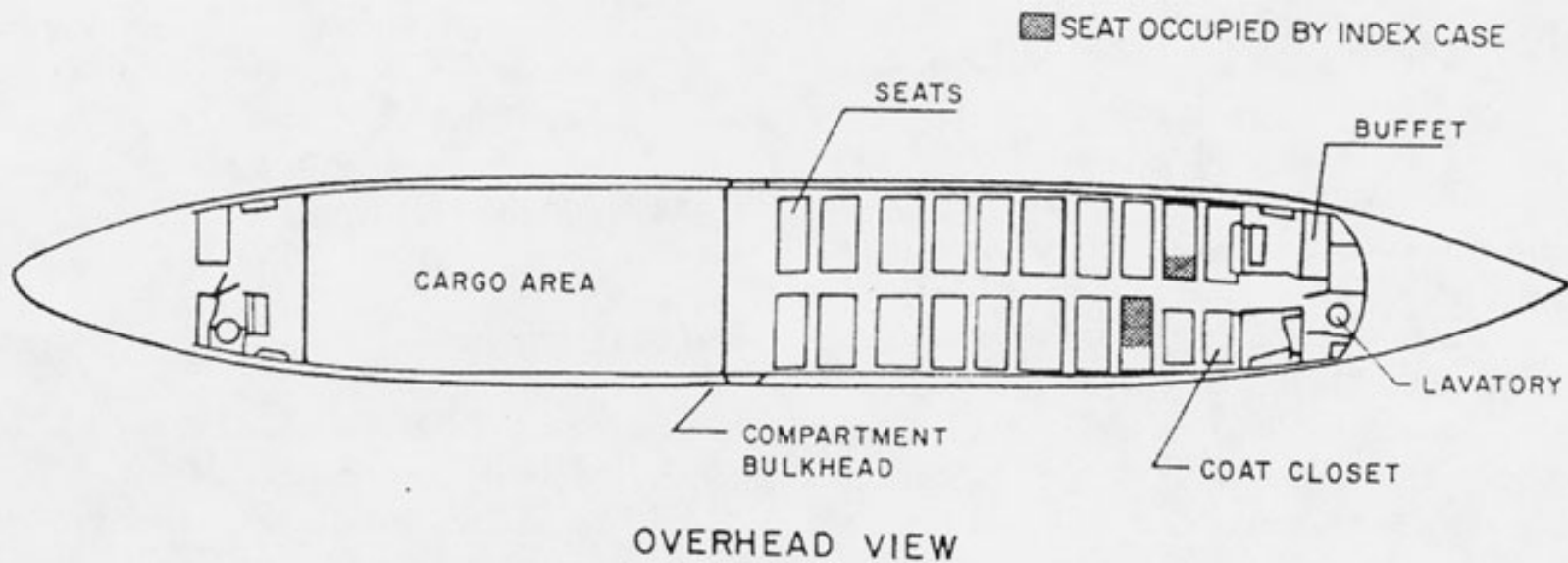
Influenza Disease



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Measles Outbreak, Minnesota Special Olympics

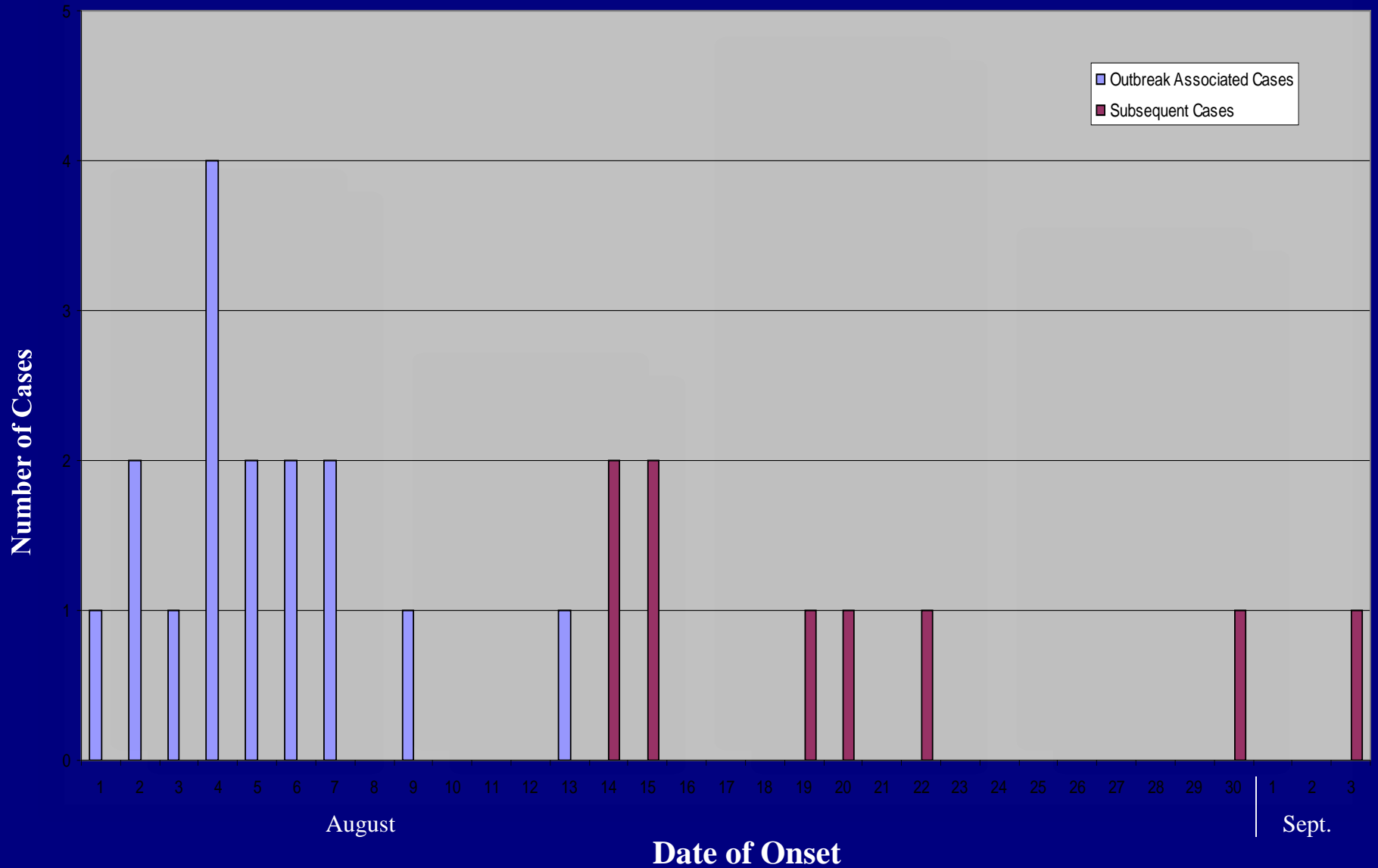
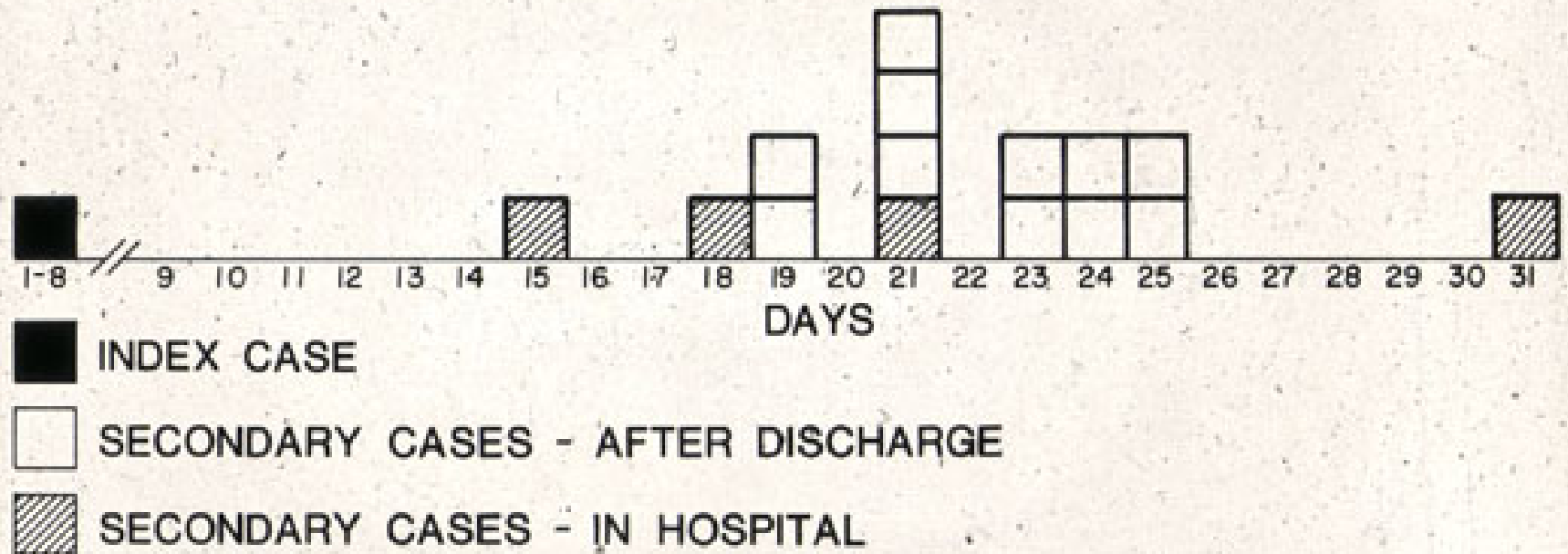


Figure 1. Measles cases by date of onset beginning with International Special Olympics, Minnesota, 1991.

Airborne Chickenpox Outbreak

FIGURE 1: EPIDEMIC CURVE



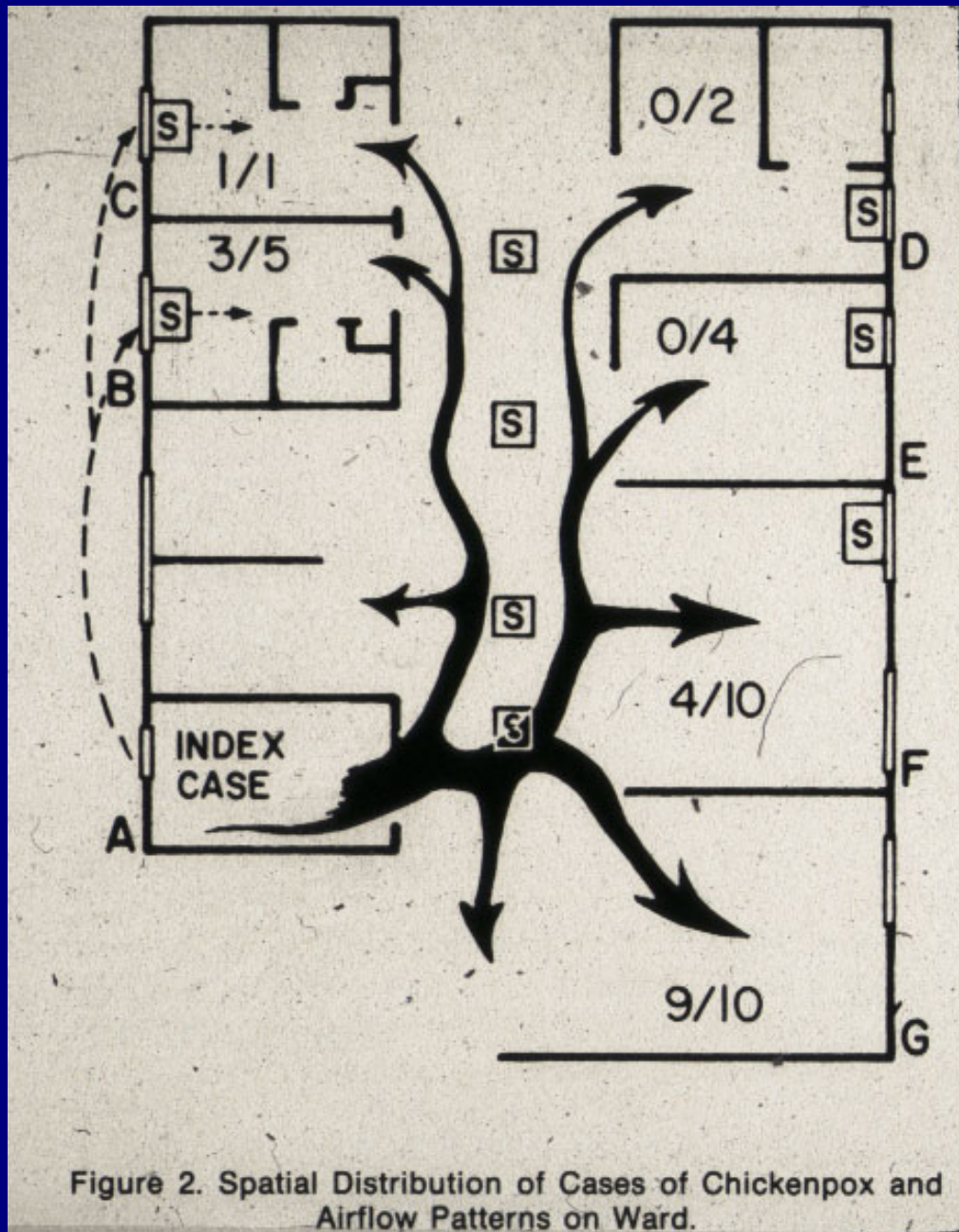
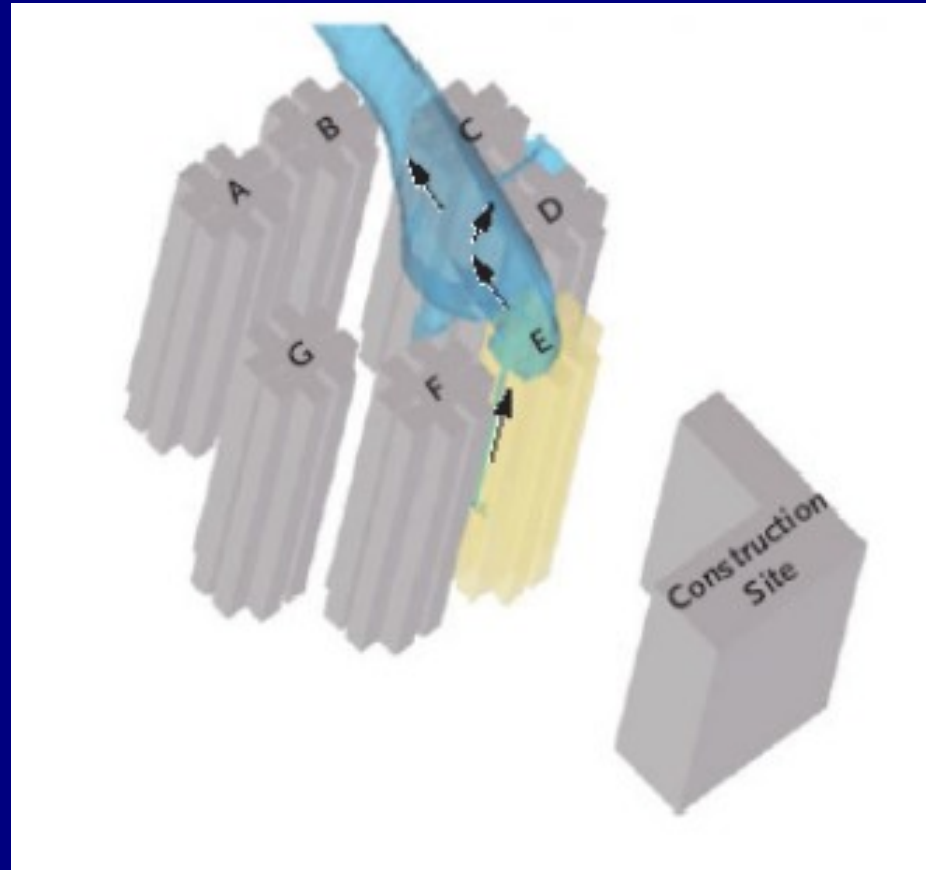


Figure 2. Spatial Distribution of Cases of Chickenpox and Airflow Patterns on Ward.



SARS airborne transmission, Hong Kong apartment complex

Fungal Spores



Shedding

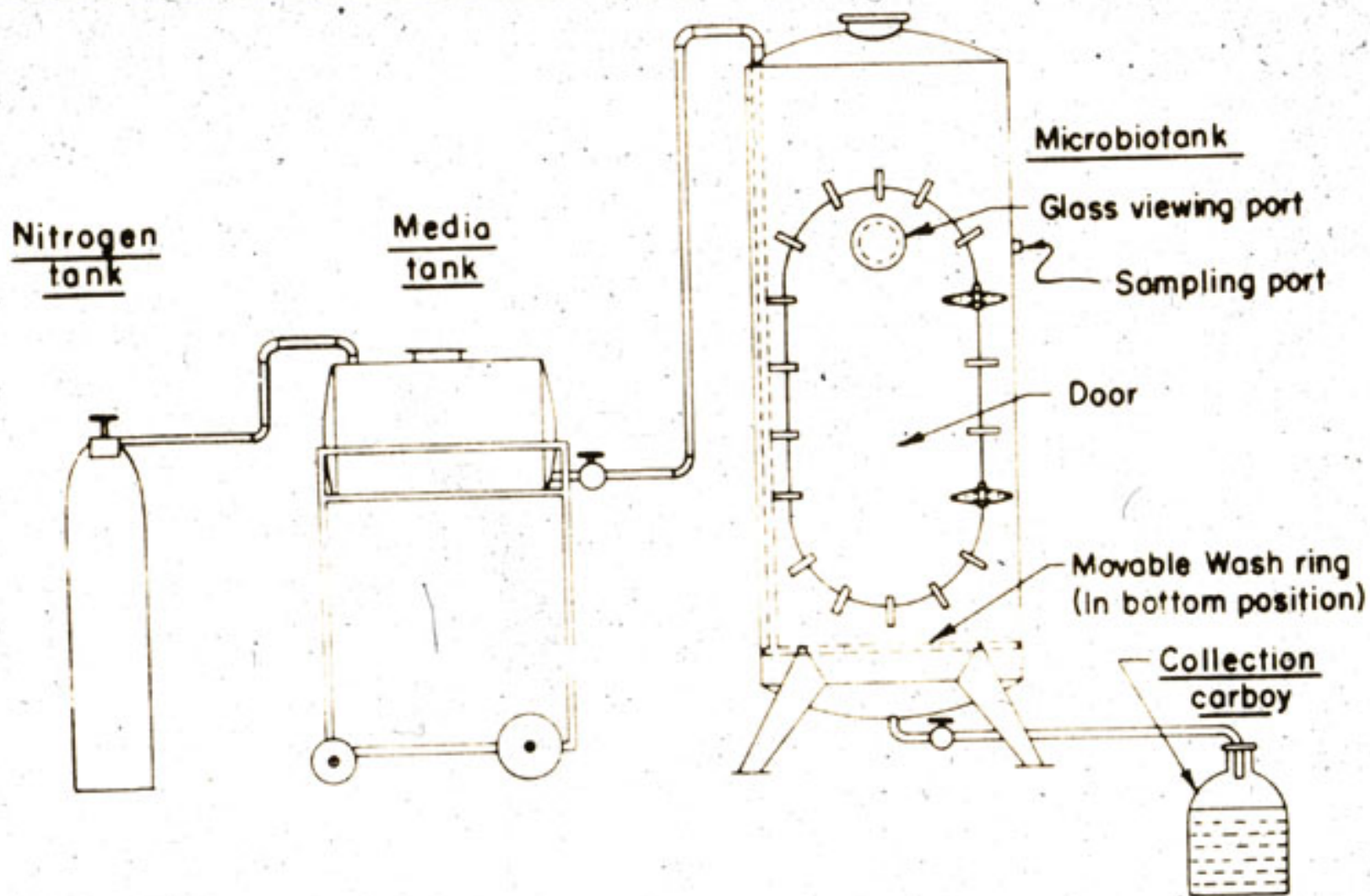


FIGURE 1 — The microbiotank.

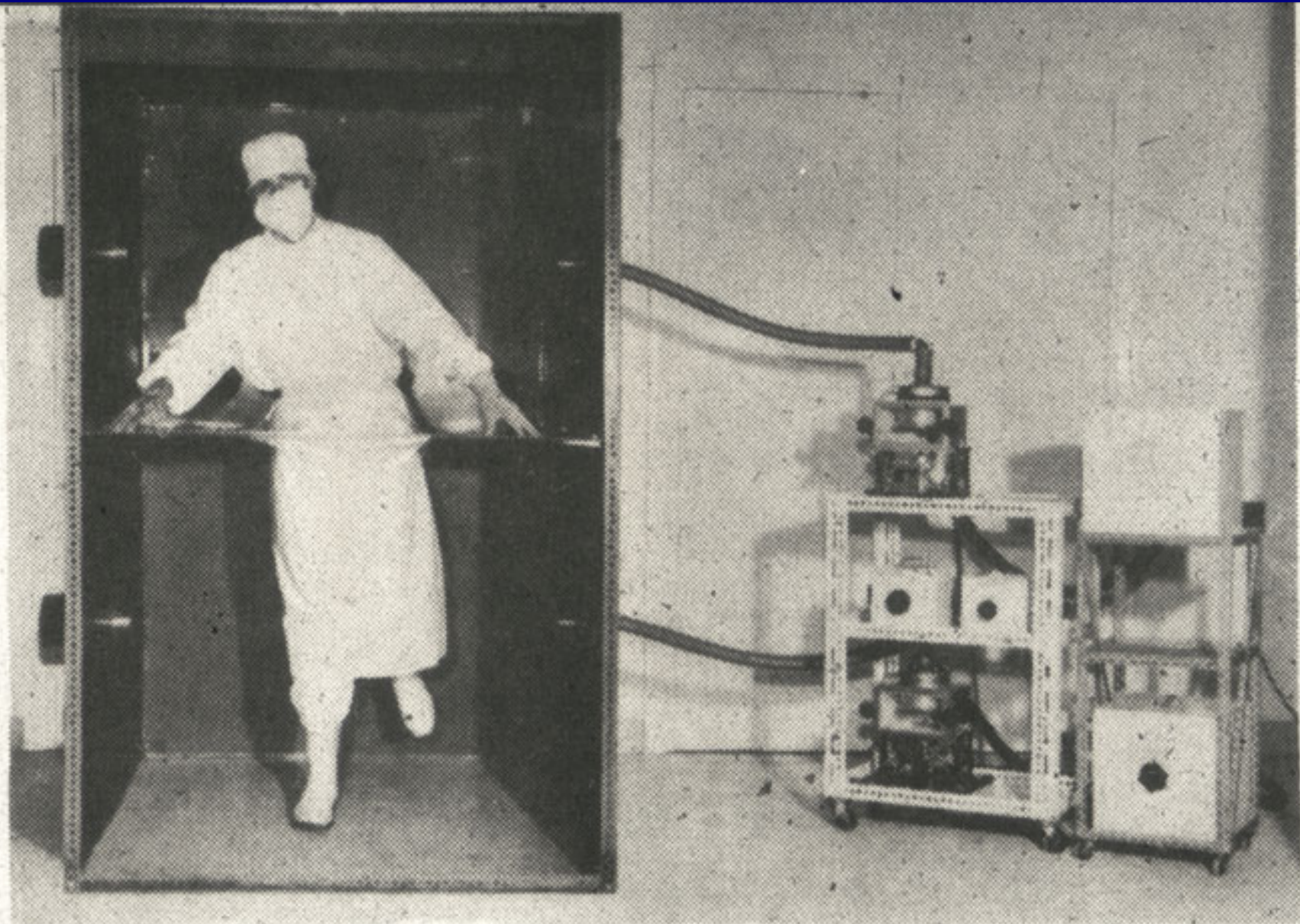


Fig. 1—Test chamber with door removed showing waistline division, air-inlet filters, and air-sampling equipment.

Common Source/Common Vehicle Outbreaks

BOSTON



HERALD

BOSTON HERALD, MONDAY, SEPTEMBER 16, 1997 5

Bacteria blamed in four infant deaths at Children's Hospital

By JOE HEANEY and TOM FARMER

The neonatal intensive care unit at Children's Hospital will remain closed until at least midweek following a recent bacteria outbreak there that killed four newborns within a month, a hospital official said.

The common, but fast-killing strain called *Pseudomonas aeruginosa*, or another previously unknown strain, may have killed a

fifth infant last year. The four who died this summer were critically ill before contracting the bacteria, officials said.

The hospital and state Department of Public Health are investigating whether the same bacteria strain was detected in several other infants in the ward who did not die.

"Children's Hospital has moved aggressively, responsibly and effectively to iso-

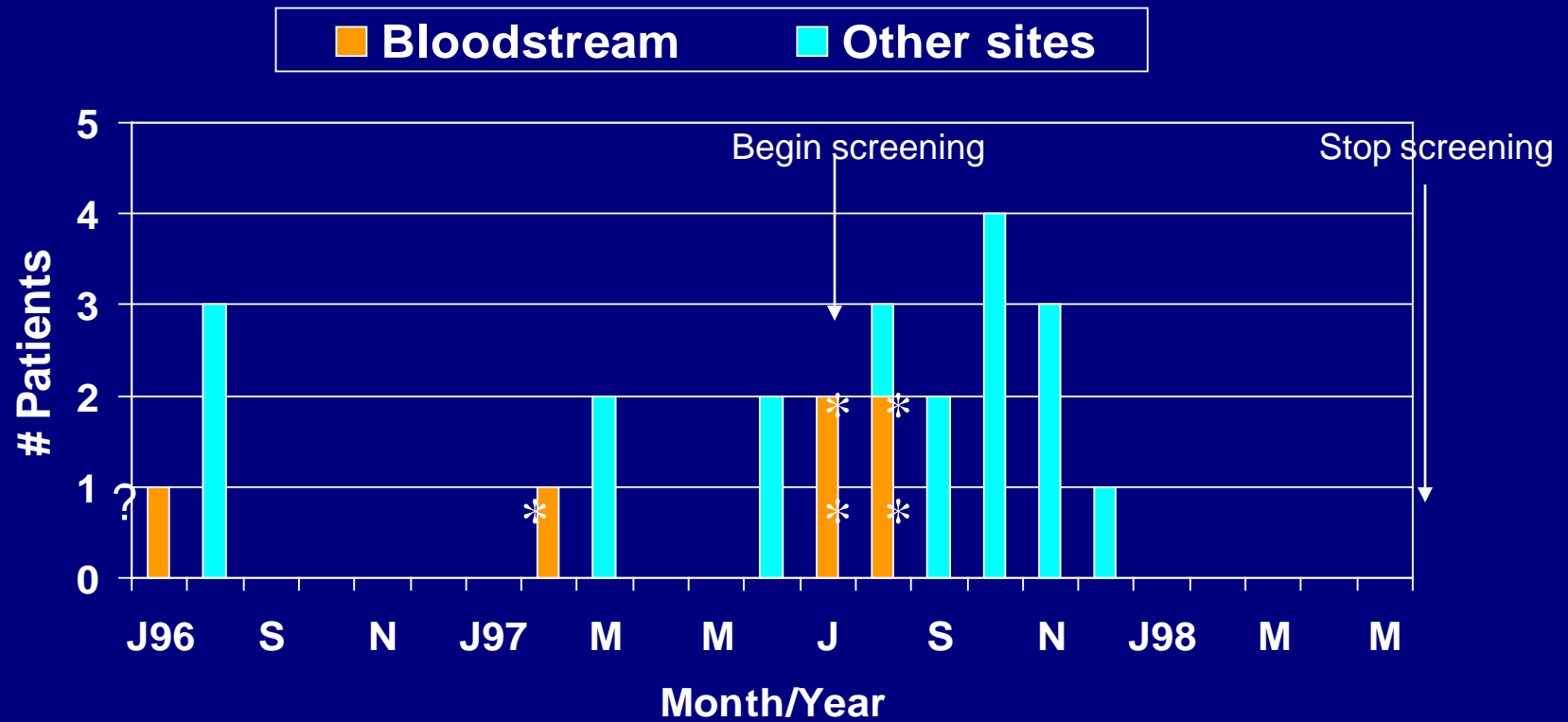
late and identify a strain of bacteria that has infected and contributed to the deaths of four infants this summer," the hospital said in a statement yesterday.

"The infections were isolated in the neonatal intensive care unit which we closed to new admissions Aug. 29. We have experienced no new cases since then and plan to reopen the unit sometime this week. The hospital has reported all rele-

vant information to the appropriate authorities."

The neonatal care unit cares for seriously ill babies. Infants who would have been admitted to the unit were sent to other hospitals or other wards at Children's. Two infants remain in the ward because they have tested positive for another, less harmful strain of the bacteria and are expected to recover.

NICU Patients with *Pseudomonas aeruginosa* July 1996 - May 1998



* = Genotype A

? = isolate not available for testing

Nationwide Outbreak of Erwinia Bloodstream Infection Traced to Contaminated IV Fluid

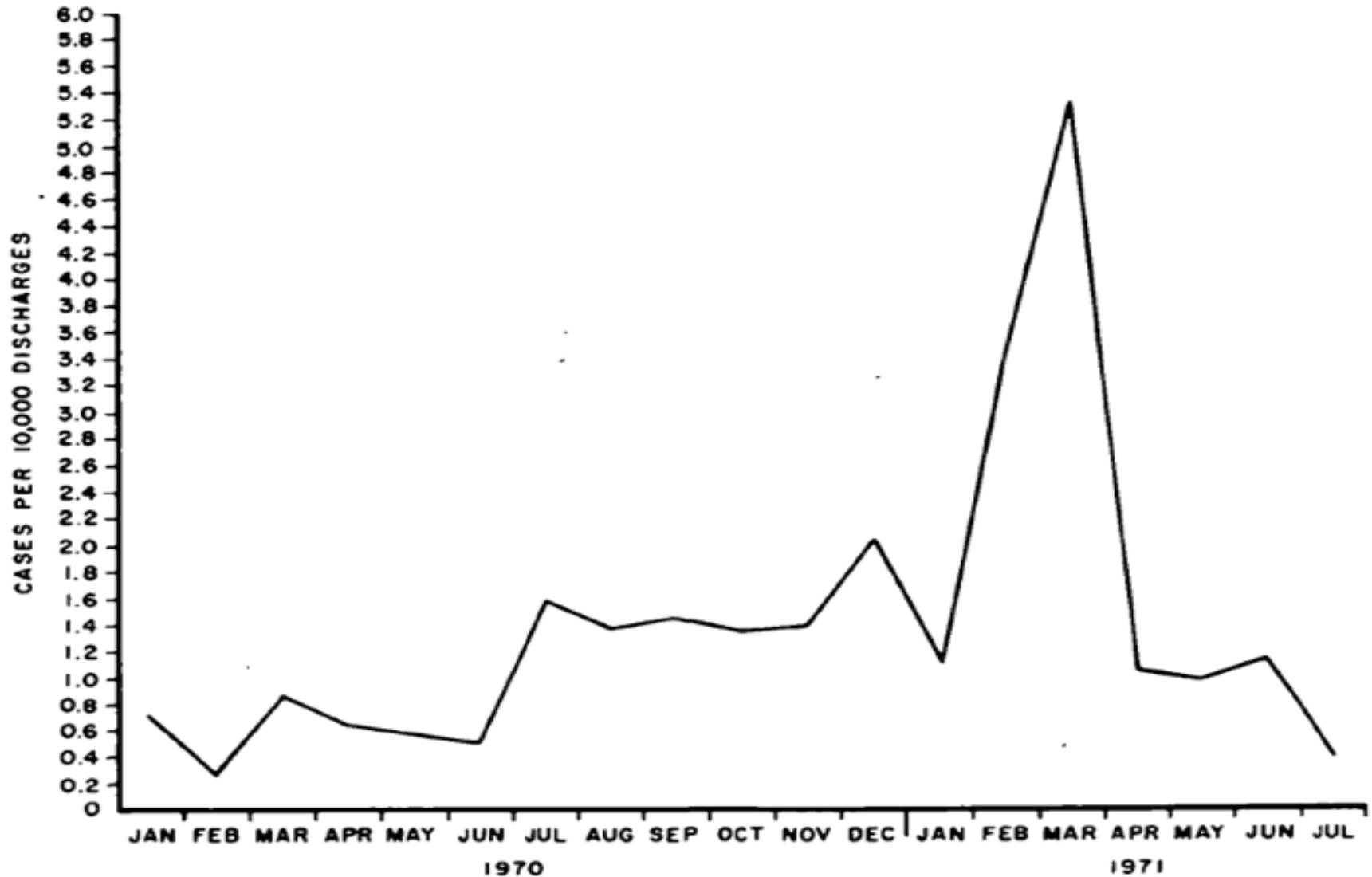
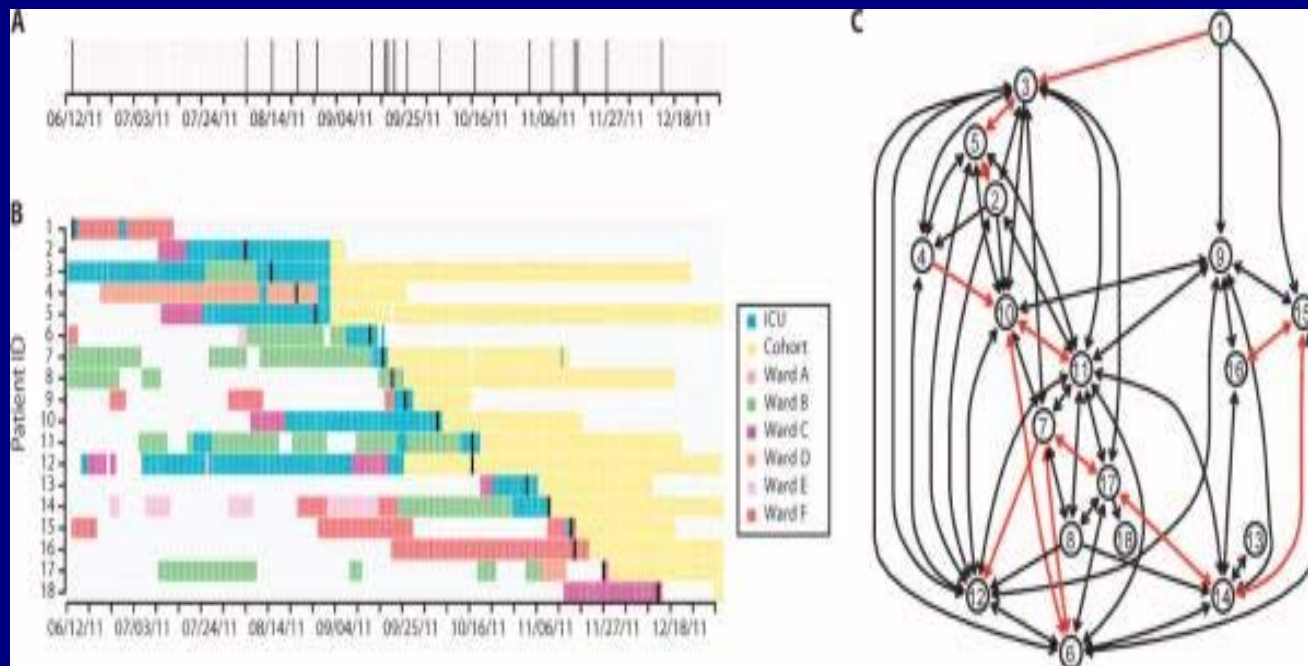


FIGURE 1. Incidence of primary Enterobacter and Erwinia bacteremia in all 84 reporting hospitals, United States, December, 1970–March, 1971.

Untreatable Klebsiella Infection NIH Clinical Center

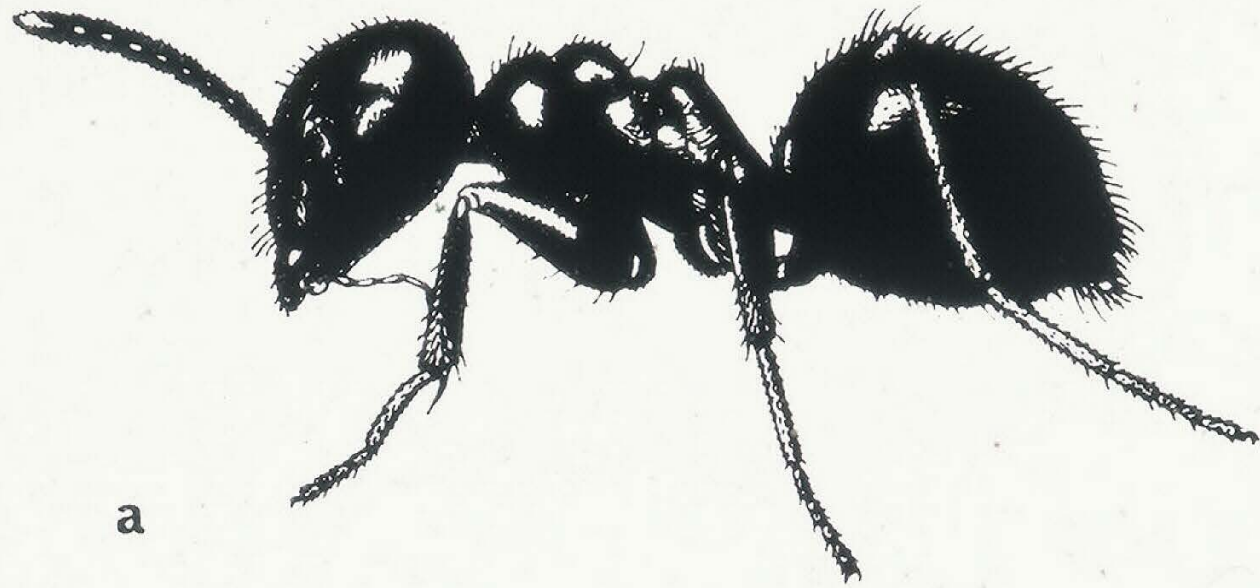


Common source patient, then indirect contact spread

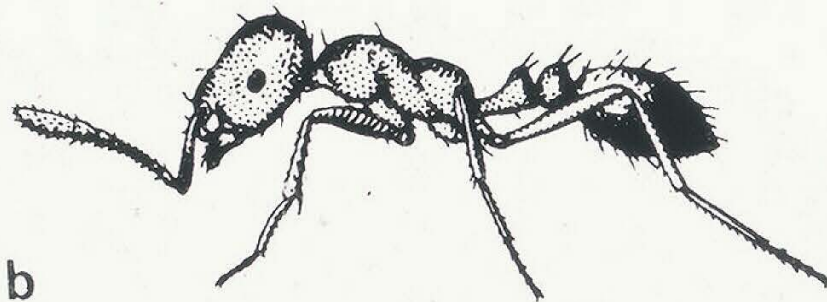
Vector

- Mosquito – Malaria, Dengue, Yellow Fever, Zika, West Nile Virus, Eastern Equine Encephalitis, Chikungunya Fever
- “Kissing” (reduviid, triatomine) bug – Chagas Disease
- Flea – plague
- Louse – typhus
- Tick – Lyme, anaplasmosis, erlichiosis, tularemia, Rocky Mountain Spotted Fever, babesiosis, Powassan virus
- Direct invaders (Aliens) – Bot fly





a



b

Common black ant (*Lasius niger*) (a) and Pharaoh's ant (*M. pharaonis*) (b) ($\times 10$).