Public health, epidemiology and modeling

Jonathan Dushoff, McMaster University

MMED 2021

Goals

- Define public health
  - Compare and contrast with medicine
- Define epidemiology
- Discuss the role of dynamical modeling

Outline

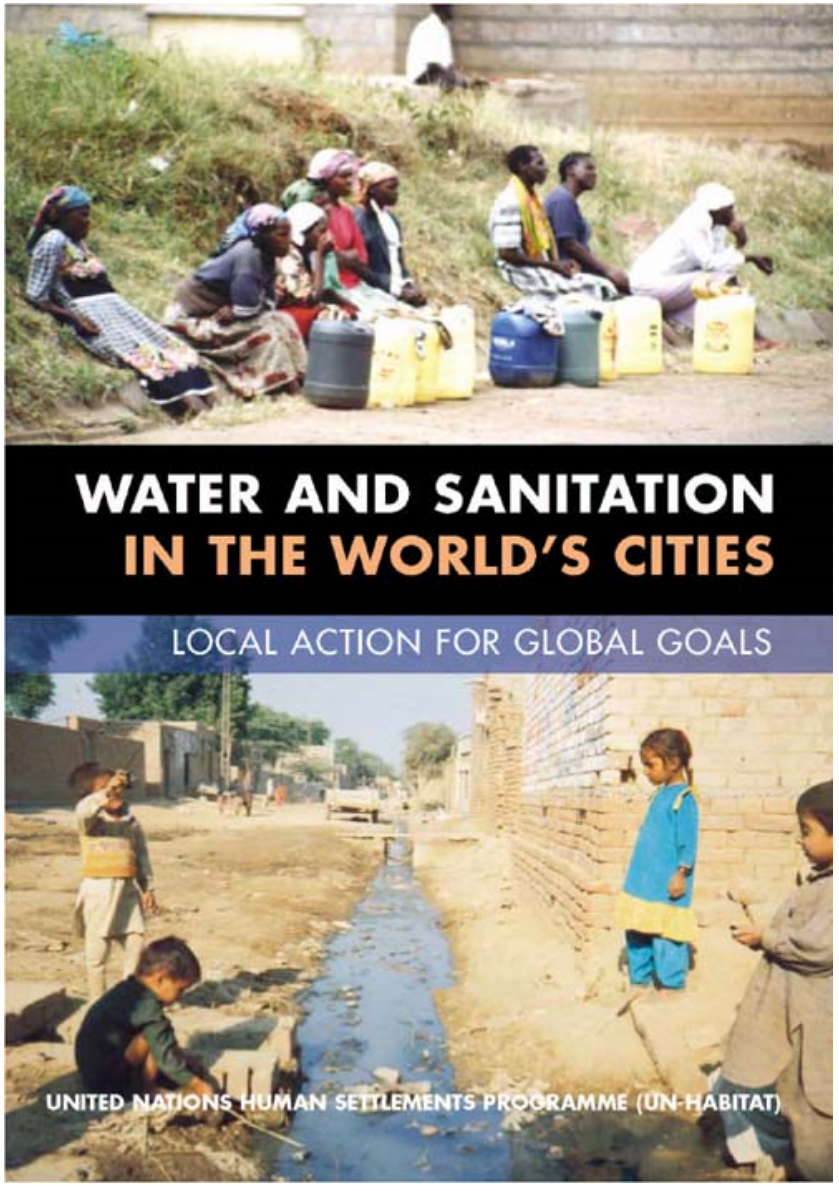
What is public health?

- The science of preventing disease, prolonging life, and promoting physical health and efficiency through organized community efforts...
- *Winslow 1920* *https://zenodo.org/record/1448241*
- *https://www.youtube.com/watch?v=t_eWESXTnic*

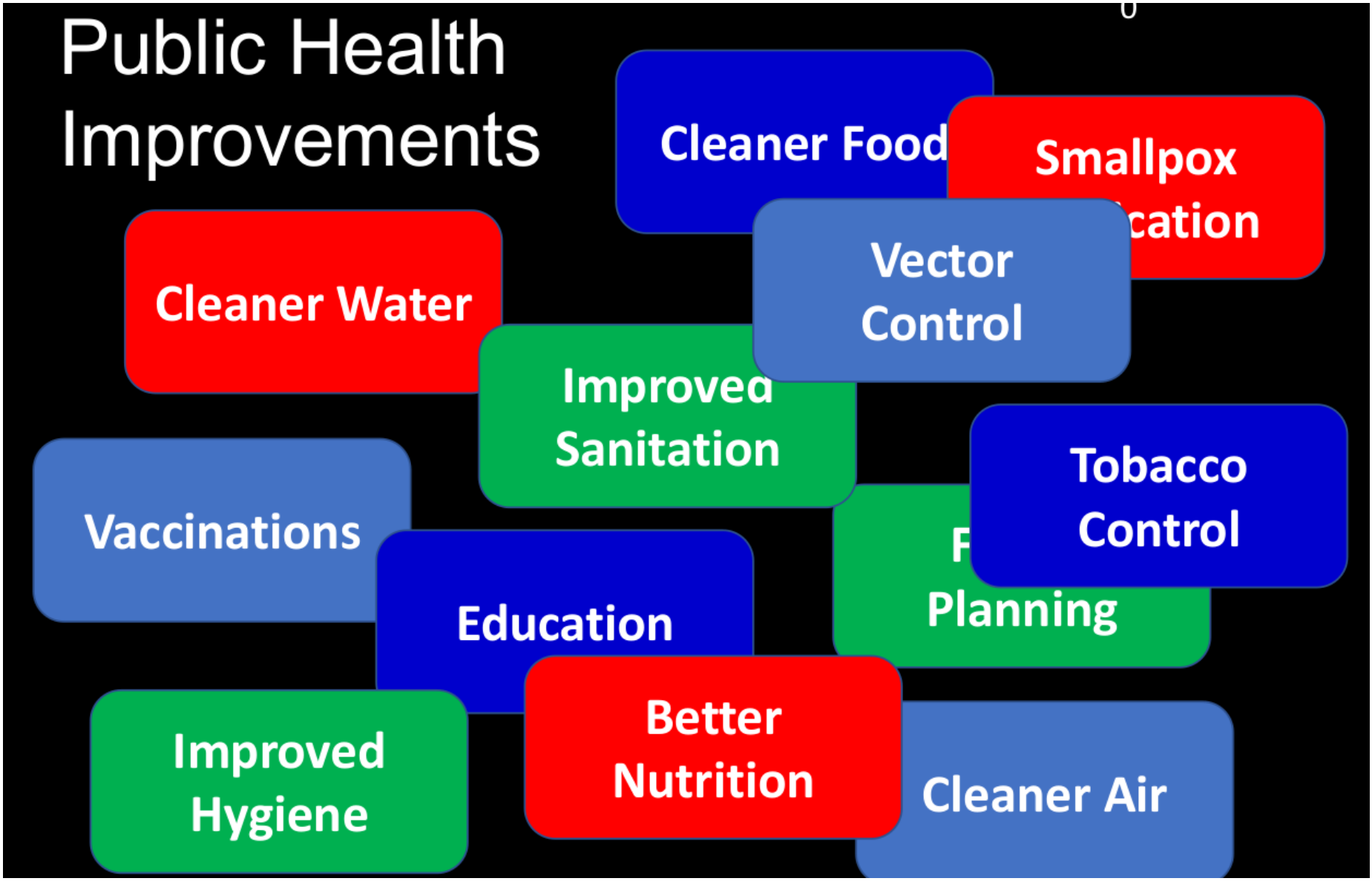
- Works at the population level
- *Prevention* comes first

Examples

- What are some public health interventions?
  - * NOANS


WATER AND SANITATION
IN THE WORLD'S CITIES
LOCAL ACTION FOR GLOBAL GOALS
UNITED NATIONS HUMAN SETTLEMENTS PROGRAMME (UN-HABITAT)

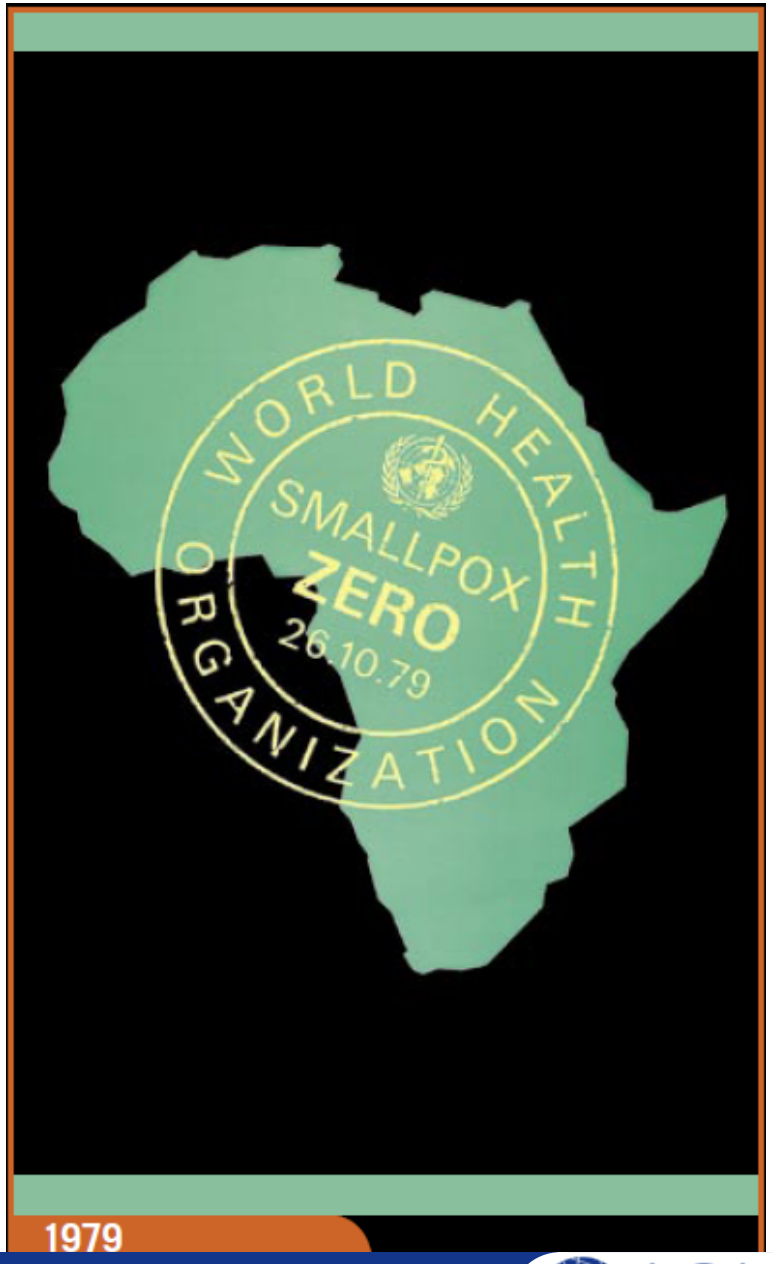

THIS IS PUBLIC
HEALTH.
whatispublichealth.org
ONE
LifeStyles
ULTRA LUBRICATED
Mint
Chocolate
Wet


Public Health Improvements
Cleaner Food
Smallpox
cation
Vector Control
Cleaner Water
Improved Sanitation
Tobacco Control
Vaccinations
Education
Planning
Better Nutrition
Improved Hygiene
Cleaner Air

Jim Scott

Public-health intervention framework

- Define the problem
- Determine risk factors
- Develop interventions
- Implementation
- Maintenance



Barriers

- Economic
- Moral/religious
- Individual freedom
- Political

Outline

Public health vs. medicine

- Medicine
  - individual focus
  - diagnosis
  - treatment
- Public health
  - community focus
  - investigation (epidemiology)
  - intervention (policy)

Medical interventions

- * Drugs
  - * Antibiotics, blood pressure, anti-cancer
- * Surgery

Joint interventions

- Vaccinations
- Treatment as prevention

Conflicts

- Do the individual and population perspectives ever conflict?
  - * NOANS

Antibiotics

- For most patients the safer choice is aggressive, broad-spectrum treatment
- What's the problem?
  - * Drug resistance
  - * Cost

HIV treatment beliefs

- 1980s: treating with AZT is better for the patient but might be worse for the community
- 2000s: Early treatment with highly active combination therapy is better for the community but might be worse for the patient
- Now: Ever-improving treatments are better for everyone

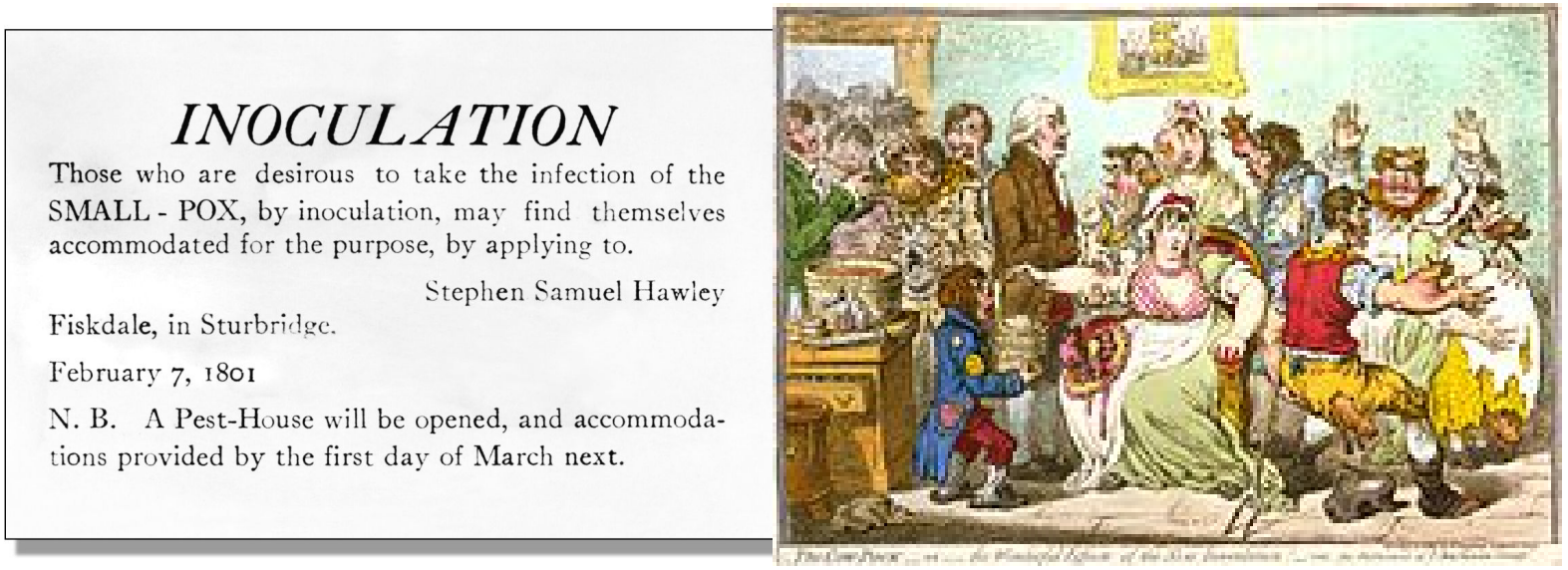
COVID testing

- Public-health people like widely deployed, low-accuracy fast tests
  - They provide useful population-level information for policy and response
- Many medical people dislike them
  - * They provide confusing and unreliable information for diagnosis and treatment

Clinical trials

- Randomized clinical trials are good for society
- * But being randomized to a placebo can be bad for my patient

Inoculation (preview)



INOCULATION

Those who are desirous to take the infection of the SMALL - POX, by inoculation, may find themselves accommodated for the purpose, by applying to.

Stephen Samuel Hawley

Fiskdale, in Sturbridge.

February 7, 1801

N. B. A Pest-House will be opened, and accommodations provided by the first day of March next.

- pest houses are good for the population, but maybe bad for my patient
- *Wikimedia Commons*

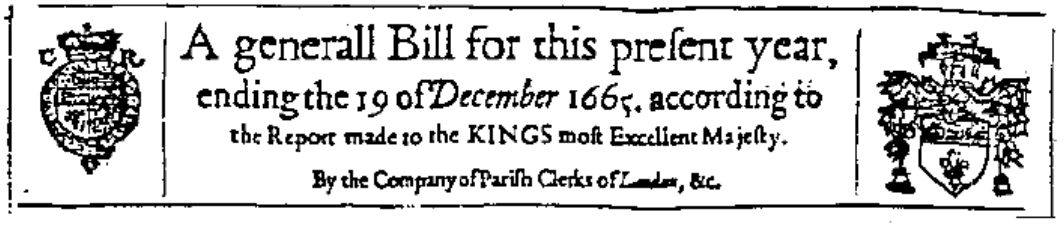
Health care

- Health care $\neq$ medical care
- Health care = medical care + public health
- Public health and economic improvements dominate health progress

Outline

What is epidemiology?

- The study of the
  - distribution and
  - determinants
  - of health-related states or events
  - in specified populations
- and the application of this study to control health problems
- *J. Last, Dictionary of Epidemiology* `https://academic.oup.com/aje/article/154/1/93/117432`



A generall Bill for this preſent year,

ending the 19 of *December* 1665. according to the Report made to the KINGS moſt Excellent Majeſty.

By the Company of Pariſh Clerks of *London*, &c.

The Diſeaſes and Caſualties this year.

Abortive and Stillborne	617	Executed	21	Palſie	30
Aged	1545	Flox and Small Pox	655	Plague	68596
Ague and Feaver	5257	Found dead in ſtreets, fields, &c.	20	Planet	6
Appoplex and Suddenly	116	French Pox	86	Pluriſie	15
Bedrid	10	Frighted	23	Poyſoned	1
Blaſted	5	Gout and Sciatica	27	Quinſie	35
Bleeding	16	Grief	46	Rickets	557
Bloody Flux, Scowring & Flux	185	Griping in the Guts	1288	Riſing of the Lights	397
Burnt and Scalded	8	Hangd & made away themſelves	7	Rupture	34
Calenture	3	Headmouldſhot & Mouldfallen	14	Scurvy	105
Cancer, Gangrene and Fiſtula	56	Jaundies	110	Shingles and Swine pox	2
Canker, and Thruſh	111	Impoſtume	227	Sores, Ulcers, broken and bruiſed Limbs	82
Childbed	625	Kild by ſeverall accidents	41	Spleen	14
Chriſomes and Infants	1258	Kings Evill	86	Spotted Feaver and Purples	1929
Cold and Cough	68	Leproſie	2	Stopping of the ſtomick	332
Collick and Winde	134	Lethargy	14	Stone and Strangury	98
Conſumption and Tiſſick	4808	Livergrown	21	Surfet	1251
Convulſion and Mother	2036	Megrom and Headach	12	Teeth and Worms	2614
Diſtracted	5	Meaſles	7	Vomiting	51
Dropſie and Timpany	1478	Murthered and Shot	9	VVenn	1
Drowned	50	Overlaid & Starved	45		

Chriſtned	Males 5114	Buried	Males 48569	Of the Plague 68596
	Females 4853		Females 48737	
	In all 9967		In all 97306	

Getting answers

- Classic epidemiology
  - Who, what, when, where?
- Analytic epidemiology
  - Why and how?
- of disease patterns at the population level

Determinants of disease

Sexual Practices and Risk of Infection by the Human Immunodeficiency Virus

The San Francisco Men's Health Study

Warren Winkelstein, Jr, MD, MPH; David M. Lyman, MD, MPH; Nancy Padian, MS, MPH; Robert Grant, MPH; Michael Samuel; James A. Wiley, PhD; Robert E. Anderson, MD; William Lang, MD; John Riggs, PhD; Jay A. Levy, MD

Table 1.—Association of Number of Male Sexual Partners in Previous Two Years and Human Immunodeficiency Virus (HIV) Serologic Status*

	Study Sample		Population	
No. of Male Partners	No. Examined	% HIV Antibody Positive	% HIV Antibody Positive†	95% Confidence Interval
None	17	17.6	19.2	5.2-41.5
1	66	18.2	17.9	9.5-29.0
2-9	206	31.6	31.9	25.2-39.0
10-49	312	53.8	53.7	47.4-59.6
≥50	195	70.8	70.5	62.7-76.8
Total	**796**	48.5	48.2	44.3-52.0

*Subjects with missing data (n=13) were excluded. The χ^2 for trend of the association of number of partners and HIV antibody seropositivity in the sample is 86.7, $P<.0001$.
†Weighted for sampling fraction and difference in participation rates between census tracts.

More partners → greater likelihood of HIV

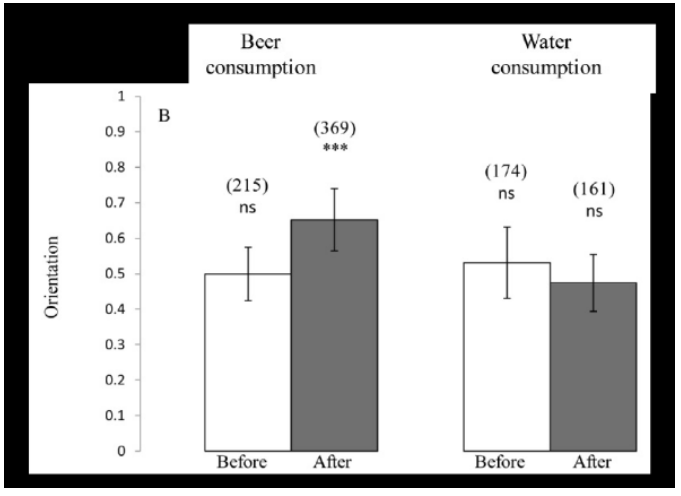
Determinants of disease (preview)

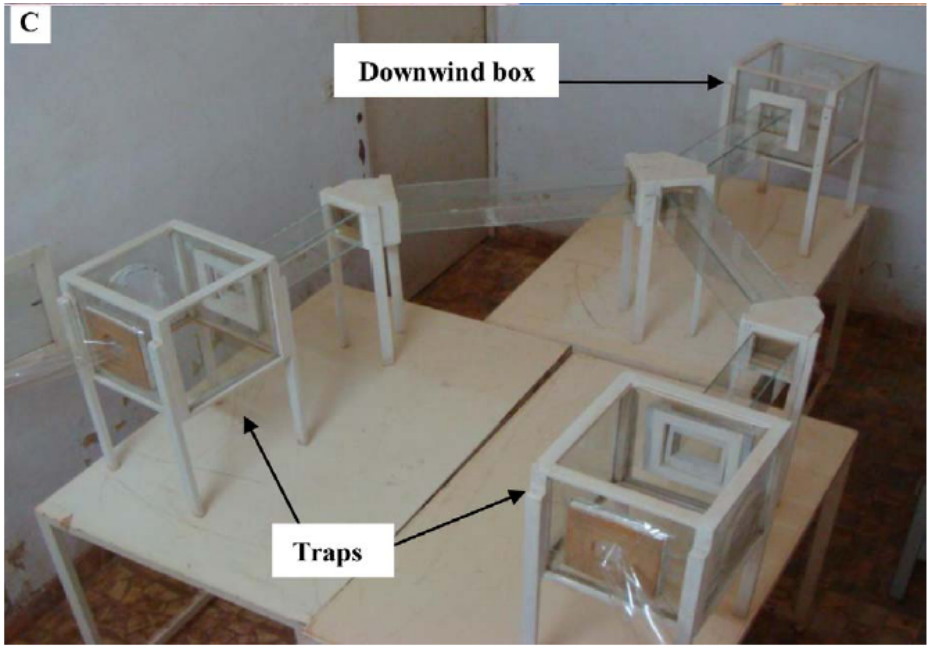
OPEN ACCESS Freely available online

PLoS one

Beer Consumption Increases Human Attractiveness to Malaria Mosquitoes

Thierry Lefèvre[1]*, Louis-Clément Gouagna[2,3], Kounbobr Roch Dabiré[3,4], Eric Elguero[1], Didier Fontenille[2], François Renaud[1], Carlo Costantini[2,5], Frédéric Thomas[1,6]





Observational studies

Is it OK to use observational studies to shape policy?

Parachutes reduce the risk of injury after gravitational challenge, but their effectiveness has not been proved with randomised controlled trials

Classical epidemiology

When do we need to know why?

Comparison of the date of discovery of a measure to prevent a disease with the date of identification of its true causative or preventive agent

Disease	Discoverer of preventive measure	Year of discovery preventive measure	Year of discovery of agent	Discoverer of agent
Scurvy	J. Lind	1753	1928	A. Szent-Gyorgi
Pellagra	J. Goldberger	1755	1924	G. Casal et al.
Scrotal cancer	P. Pott	1775	1933	J.W. Cook et al.
Smallpox	E. Jenner	1798	1958	F. Fenner
Puerperal fever	I. Semmelweis	1847	1879	L. Pasteur
Cholera	J. Snow	1849	1893	R. Koch
Bladder cancer[a]	L. Rehn	1895	1938	W.C. Hueper et al.
Yellow fever	W. Reed et al.	1901	1928	A. Stokes et al.
Oral cancer[b]	R. Abbe	1915	1974	D. Hoffmann et al.

- Many interventions were implemented long before they were understood
- *R. Bertollini, Policy Implications of Our Understanding of the East-West Life Expectancy Gap (DOI broken!)*

Testing interventions

Randomized, Controlled Intervention Trial of Male Circumcision for Reduction of HIV Infection Risk: The ANRS 1265 Trial

Bertran Auvert[1,2,3,4*], Dirk Taljaard[5], Emmanuel Lagarde[2,4], Joëlle Sobngwi-Tambekou[2], Rémi Sitta[2,4], Adrian Puren[6]

PLoS Medicine | www.plosmedicine.org November 2005 | Volume 2 | Issue 11 | e298

Table 4. Multivariate RRs of HIV Incidence

Categories of Factors	Factors	Values of Factors	HIV Cases	Follow-Up (py)	HIV Incidence Rates (95% CI; per 100 py)[a]	Incidence RRs (95% CI) of Intervention versus Control (95% CI)[a,b]
	Randomization group	Intervention	20	2,354	0.85 (0.55–1.32)	0.39 (0.23–0.66) $p = 0.00049$
		Control	49	2,339	2.11 (1.60–2.80)	1

Circumcision reduces male HIV incidence by 60%

Outline

Risk factors for heart disease

- Fatty diet
- Poor exercise
- Genetics
- Stress

Risk factors for tuberculosis

- Poor nutrition
- Crowded living conditions
- Stress
- * Bacteria!

Risk factors for measles

- Poor nutrition
- Crowded living conditions
- Stress
- * Vaccines
- * Viruses!!!!!

Dynamics

- You are at risk if your neighbors have the disease
- Your neighbors are at risk if *their* neighbors have the disease
- Their neighbors are at risk . . .
- Dynamical models are the tool for understanding this

Thresholds for control

- Ronald Ross: if we reduce the number of mosquitoes beyond a critical level, yellow fever should not be able to persist

Predicting dynamical impacts

	Deaths (thousands)	Deaths averted (thousands)
Neither strategy		
2015	269	..
2030	263	..
2050	263	..
2008–50	11078	..
ART started when CD4+ count <350 cells per µL		
2015	193	76
2030	202	61
2050	210	53
2008–50	8658	2419
ART started when CD4+ count <350 cells per µL and universal voluntary HIV testing/immediate ART		
2015	165	104
2030	76	187
2050	17	246
2008–50	3879	7199
ART started when CD4+ count <350 cells per µL, universal voluntary HIV testing/immediate ART, and other adult prevention strategies		
2015	164	105
2030	72	191
2050	12	251
2008–50	3727	7350

ART=antiretroviral therapy.

Table: Estimated number of AIDS-related deaths for the years 2015, 2030, 2050, and 2008–50 with different strategies

- Studied universal testing and treatment for HIV
- Direct benefits
- Indirect benefits
- *Granich et al., 2009* `https://pubmed.ncbi.nlm.nih.gov/19038438/`

Age x	Alive $P(x)$	Susceptible $S(x)$	Immune $R(x)$	Smallpox deaths	No smallpox $P^*(x)$
0	1300	1300	0	17.2	1300
1	1000	896	104	12.3	1015
2	855	685	170	9.8	879
3	798	571	227	8.2	830
4	760	485	275	7.0	799
5	732	416	316	6.1	777
6	710	359	351	5.2	760
7	692	311	381	4.6	746
8	680	272	408	4.0	738
9	670	238	432	3.5	732
10	661	208	453	3.0	726
11	653	182	471	2.7	720
12	646	160	486	2.3	715
13	640	140	500	2.1	711
14	634	123	511	1.8	707
15	628	108	520	1.6	702
16	622	94	528	1.4	697
17	616	83	533	1.2	692
18	610	72	538	1.1	687
19	604	63	541	0.9	681
20	598	55	543	0.8	676
21	592	49	543	0.7	670
22	586	42	544	0.6	664
23	579	37	542	0.5	656
24	572	32	540		649
⋮	⋮	⋮	⋮	⋮	⋮

'I simply wish that, in a matter which so closely concerns the wellbeing of the human race, no decision shall be made without all the knowledge which a little analysis and calculation can provide'

Daniel Bernoulli 1760.

Summary

- Public health
  - Population level view; the complement of medicine
  - Prevention first!
- Epidemiology
  - the cornerstone of public health
  - distribution and determinants of disease
- Models
  - Understand dynamical disease processes
  - Investigate dynamical effects of changes

Title: Public health, epidemiology and modeling
Attribution: Jonathan Dushoff, McMaster University, MMED 2021

Source URL: http://www.ici3d.org/MMED/schedule/
For further information please contact admin@ici3d.org.