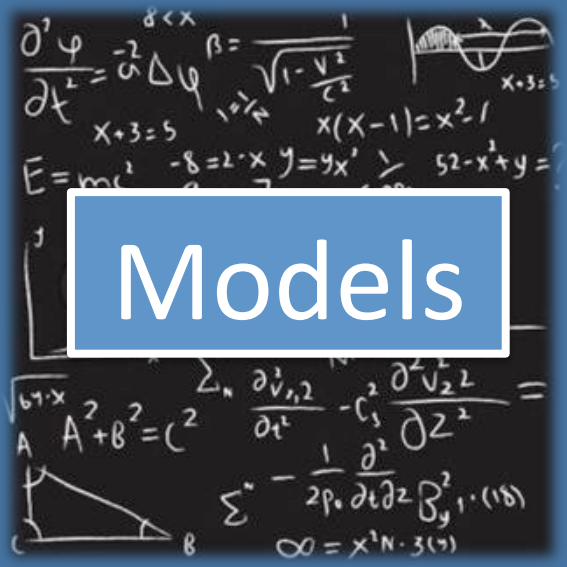
What is Science?



and

Clinic on Dynamical Approaches to Infectious Disease Data

December 15, 2014

Steve Bellan, MPH, PhD

Postdoctoral Fellow, University of Texas at Austin

Telling Science as a Story

- Are stories objective?
- The importance of a narrative
- Communication
- But what is Science?

What is Science?

- The Process

- The Body of Knowledge

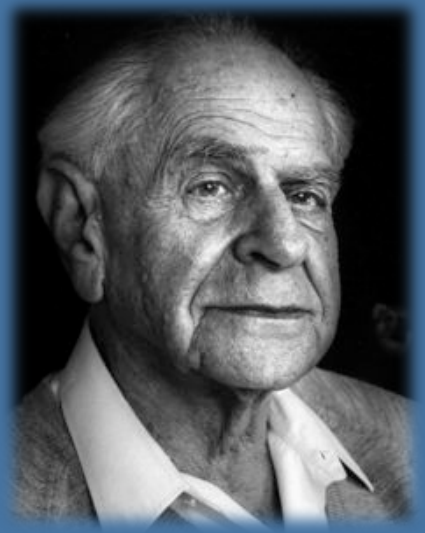
Science as a Process

1. the systematic observation of natural events and conditions in order to discover facts about them and to formulate laws and principles based on these facts. – *Academic Press Dictionary of Science & Technology*

2. Science alone of all the subjects contains within itself the lesson of the danger of belief in the infallibility of the greatest teachers in the preceeding generation… I can also define science another way: Science is the belief in the ignorance of experts. – *Feynman*

Philosophy of Science

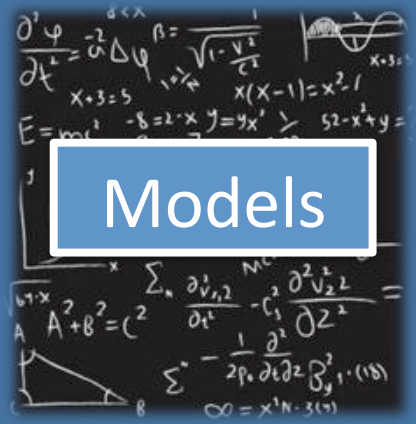
- Karl Popper
  - Empirical Falsification



- Thomas Kuhn
  - Subjectivity
  - Normal Science
  - Scientific Crises
  - Paradigm Shifts

Theory and Observation

- Theory
  - Explanations
  - Guesses
  - Ideas



- Observation
  - Anecdotes
  - Expert opinion
  - Systematic qualitative data
  - Systematic quantitative data

Theory vs Models

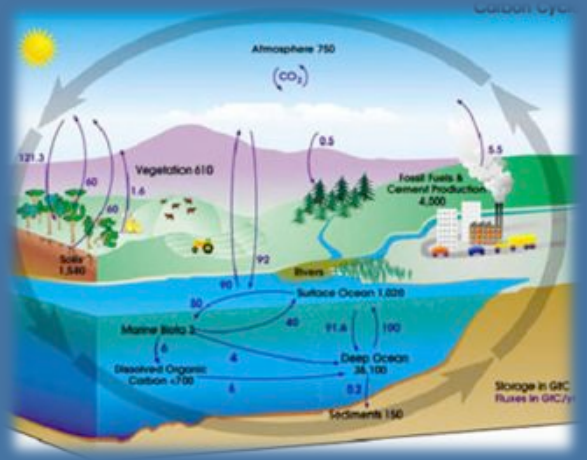
- Theory = set of statements that provides an explanation of phenomena
  - Logically complete & falsifiable
- Model = abstract representation of phenomena
- Hypothesis = testable statement derived from a theory

Slide Credit: Susan Simm, University of California at Irvine

Types of Models

- Physical

- Conceptual



- Mathematical

$$\frac{\partial}{\partial a}\ln f_{a,\sigma^2}(\xi_1)=\frac{(\xi_1-a)}{\sigma^2}\qquad f_{a,\sigma^2}(\xi_1)=\frac{1}{\sqrt{2\pi}\sigma}$$

$$\int T(x)\cdot\frac{\partial}{\partial\theta}f(x,\theta)dx=\mathrm{M}\left(T(\xi)\cdot\frac{\partial}{\partial\theta}\ln L(\xi,\theta)\right)$$

Models

- When you create a model you are

  proposing what you think could be

  the most important things

  to explain an observed phenomenon

Utility of Models

- All models are wrong but some are useful.
  George Box

- Goal of models is to predict and to explain

Science as a Story

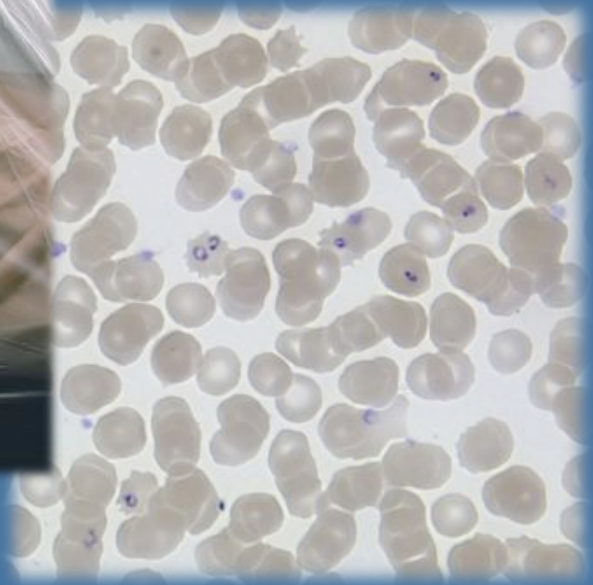
- Are stories objective?
- The importance of a narrative
- Communication
- Story of the process or the body of knowledge?

Theory of Mosquito-Borne Transmission

Aedes aegypti

Anopheles gambiae

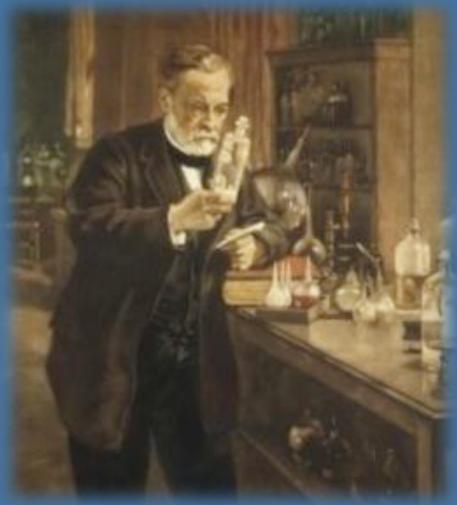
Homo sapiens



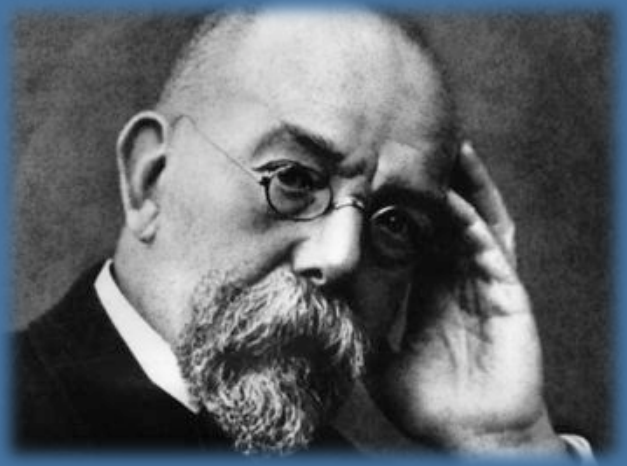
Plasmodium falciparum

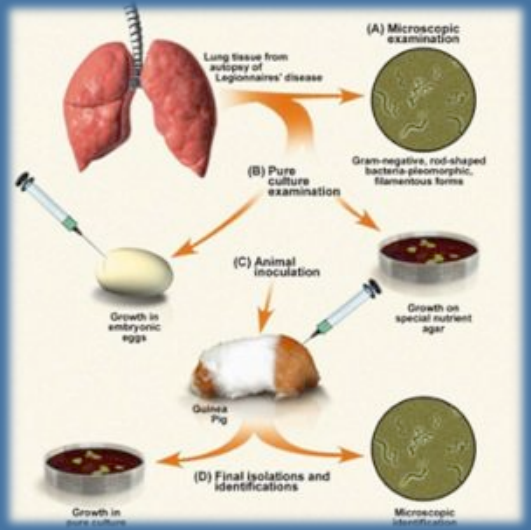
Germ Theory

- Louis Pasteur



- Robert Koch





Koch's postulates in
The Genesis of Germs
Gilken (2007)

Miasmatic Theory of Disease

Disease = poisoning by foul emanations from soil, air, water

model

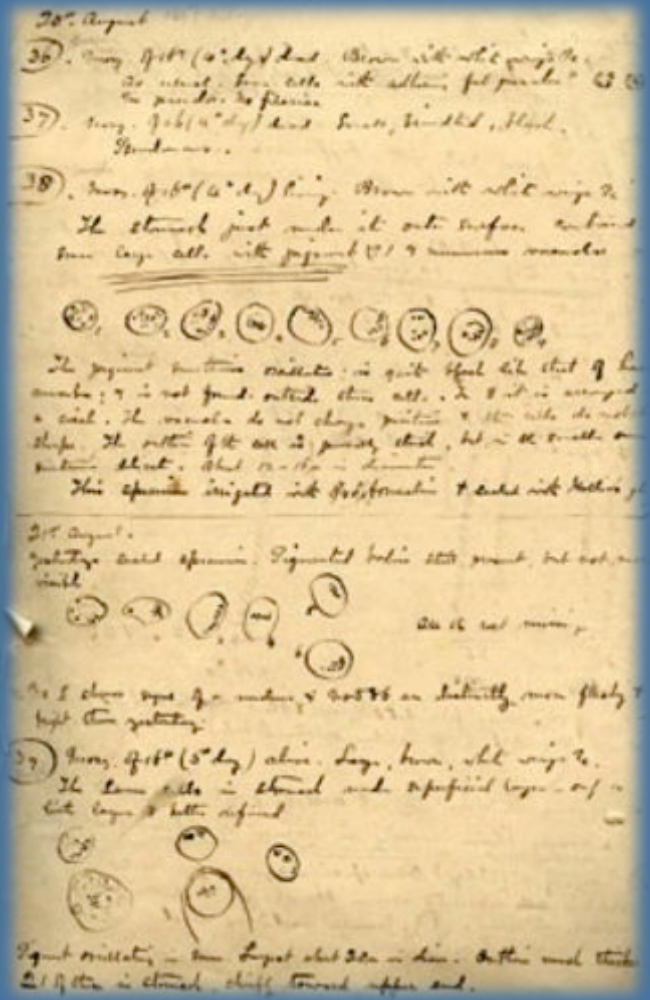
The Black Death as Miasma

Advocates

William Farr
1851 London
cholera outbreak

Florence Nightingale

Ronald Ross & Malaria



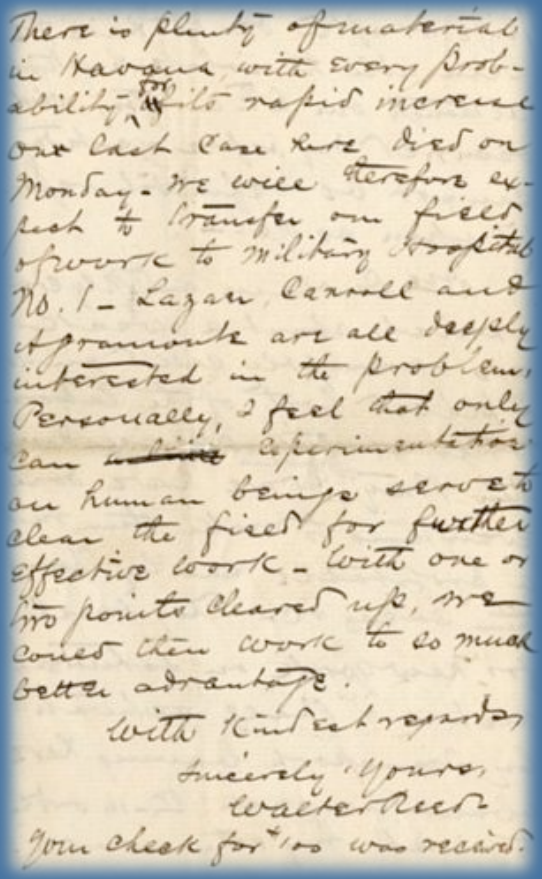
Ross' 1897 drawings of *Plasmodium* oocysts

After 2 years of feeding various insects on malarious patients Ross tried an *Anopheles* sp. and found the infectious life state microscopically.

models and data

Walter Reed & Yellow Fever

Letter from Walter Reed to George Miller Sternberg
July 24, 1900



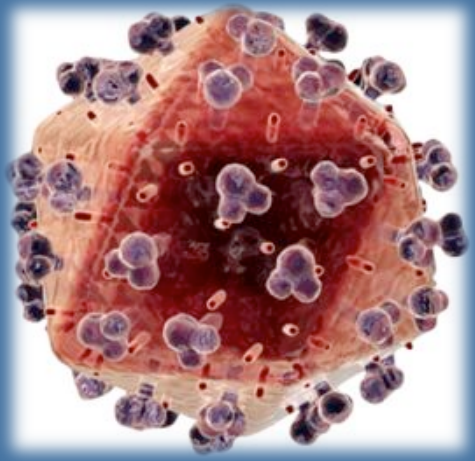
There is plenty of material in Havana with every probability of rapid increase. One case has died on Monday. We will therefore ask to transfer our field of work to Military Hospital No. 1 – Lazear, Carroll and myself are all deeply interested in the problem. Personally, I feel that only experimentation on human beings serves to clear the field for further effective work – with one or two points cleared up, we could then work to so much better advantage.

With kindest regards,
Sincerely Yours,
Walter Reed

Your check for $100 was received.

Credit Am Trop Med Hyg

"Personally, I feel that only can experimentation on human beings serve to clear the field for further effective work -- with one or two points cleared up, we could then work to so much better advantage."



yellow fever virus

models and data

experimental infections

Theory of Mosquito-Borne Transmission

- So mosquitoes transmit disease…
- But what aspects of mosquito biology are most important in determining disease burden?

  Population density?

  Mosquito lifespan?

  Bite rate?

  Mosquito movement?

  Reproduction?

Can these inform effective interventions?

Ross' *A Priori* Pathometry

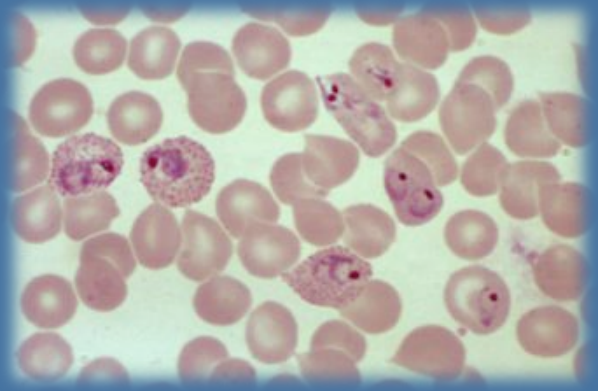
"what percentage of diminution in mosquito-borne disease may be expected to follow a given percentage reduction in the number of mosquitoes?"

Anopheles quadrimaculatus larvae

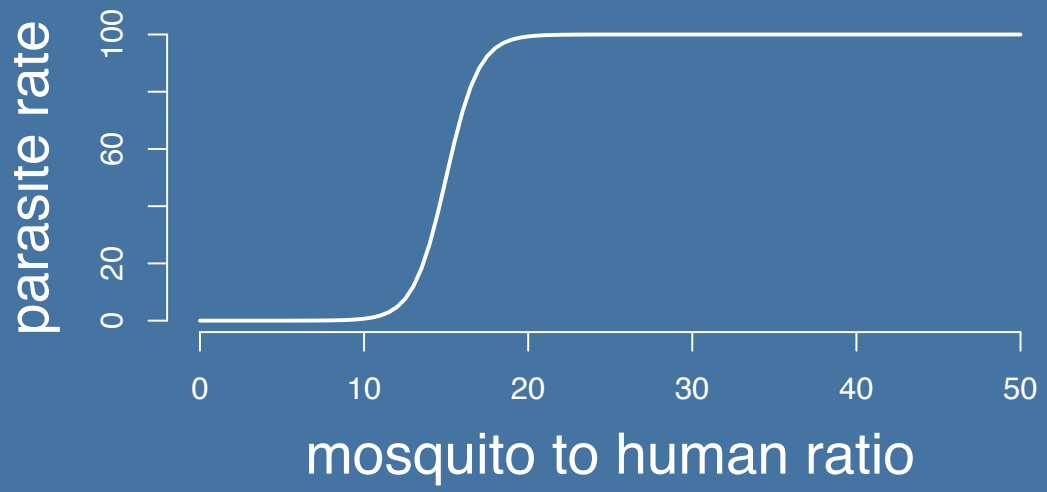
Ross R (1902) Mosquito brigades and how to organize them. London: Longmans, Green.

Stimulation of Empirical Research: Quantifying transmission

- Parasite Rate



- "Happenings" and the force of infection



Ross Model of Malaria Transmission

- causal relationship between the ratio of mosquitoes to humans & # infected humans

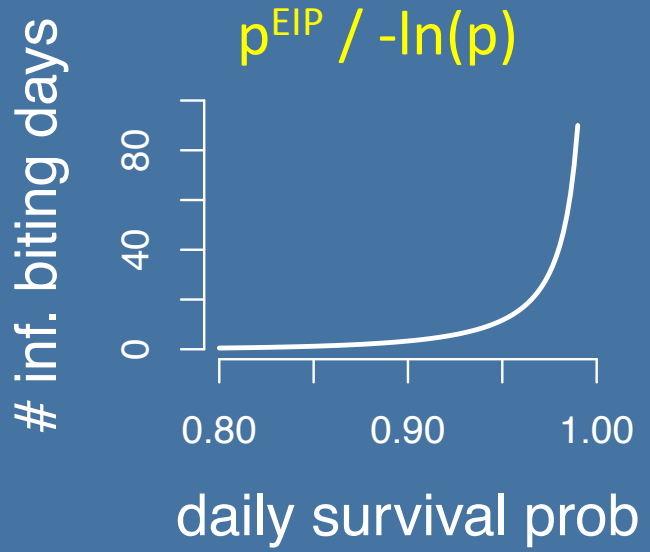
- unnecessary to kill every mosquito to end transmission

Mosquito Longevity

- George MacDonald, DDT & Global Malaria Eradication Program (1955-1969)

- Mosquito Survival

  Transmission depends on their ability to survive extrinsic incubation period & life expectancy thereafter



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  on their ability to survive
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  & life expectancy thereafter

What was the point of this story?

- Successive discoveries by testing ideas (models) against observations (data)
- Models drive empirical developments and vice versa
- Complicated relationships required mathematization of models

Statistical Models

- Account for bias and random error to find correlations that may imply causality.
- Often the first step to assessing relationships.
- Assume independence of individuals (at some scale).

Dynamical Models

- Systems Approach: Explicitly model multiple mechanisms to understand their interactions.
- Links observed relationships at different scales.
- Explicitly focuses on dependence of individuals

Questions in Epidemiology

Statistical Models

- Is HIV status positively associated with the risk of TB infection?

Dynamic Models

- Based on increased TB risk due to HIV, how much should we expect TB notification rate to increase for a given HIV prevalence?

Questions in Epidemiology

Statistical Models

- Are Insecticide Treated Bednets (ITNs) or Indoor Residual Spraying (IRS) more effective for controlling malaria?

Dynamic Models

- How do we expect the age-distribution of malaria incidence to change after implementing ITNs or IRS?

What is Science? Data and Models

- Science is a systematic process by which we construct narratives (theories) about the world
- Models are abstract representations of the world, created within this narrative framework
- Data and observations allow us to falsify or assign probabilities to particular models and narrow down our understanding.

The End