Interface of Biology and Mathematics

David B. Damiano

Department of Mathematics and Computer Science
College of the Holy Cross
Worcester, MA
ddamiano@holycross.edu

June 2008

Contents

1 Introduction

2 Design of Experiments

BIOLOGY and MATHEMATICS

Why BIOLOGY and MATHEMATICS?

- MATHEMATICAL BIOLOGY is a rapidly growing area of mathematical inquiry
- BIOLOGY provides interesting and important applications of mathematics
- BIOLOGY reveals the importance of mathematical approaches in understanding the world around us
- MATHEMATICS reveals underlying patterns and relationships in biological data
- MATHEMATICS facilitates the study of large amounts of data generated by 21st century BIOLOGY

Statistics

Why STATISTICS?

- The “first” type of mathematics used in biology
- A way to “make sense” out of data, discern structure in data
- The “most everyday-useful” mathematics

How much math will we use?

- Basic algebra–a few general formulas
- TI-84 Calculators–all instructions provided

Methodology and Goals

The approach?

- Short formal presentations
- Group activities
- Reports on group activities

The takeaway?

- Provide types of (not the exact) exercises to use in your teaching
- Stretch and enhance your ability to use statistics in your teaching
- Enrich your understanding of the use of statistics in the real world

Controlled Experiments–the Gold Standard

Method of Comparison

- Treatment group
- Control group

Guiding Principles

- Random assignment to treatment and control group
- Double blind
  - Subjects do not know which group they belong to
  - Evaluators do not know which group participants belong to
- Conclusion: Difference in responses due to treatment

Observational Studies–Making Do

Why not randomized controlled experiments?

- Difficulty and expense
- Impossibility of placebos, the first blind
- Danger to subjects

The alternative?

- Historical Controls
- Controls chosen to match profile of treatment group, except for treatment

The Issues?

- Confounding factors–Hidden factors that influenced outcome
- Removal of the second blind

The Polio Epidemic

1954–Preventing Polio (poliomyelitis virus)

- The disease
  - 99% cases asymptomatic
  - Flu-like symptoms, attacks central nervous system, paralysis can result within hours
  - Incidence rate 1 in 2000
  - 5-10% of paralyzed victims die from the disease
- The climate
  - Great public outcry–fear of polio
  - High levels of confidence in science and medicine
  - Nationwide research effort led by National Foundation for Infantile Paralysis (NFIP)
  - Questions of basic science: Killed virus vs. live attenuated virus

The Salk Vaccine Field Trial

The Design: Observational Study or Controlled Experiment?

- The Observational Study–the NFIP Plan:
  - Treatment group: All second graders who volunteer
  - Control group: First and third graders and non-volunteer second graders

  Why?
  - Supported by Jonas Salk for ethical reasons
  - Easier to administer
  - Would attract wide public support

  Why not?
  - Experimental design of the observational study
  - Variability of the epidemic
  - Self-selection bias

  The alternative?
  - Double Blind Placebo Controlled Study

NFIP Study Design

A Hybrid: Part Observational Study/Part Controlled Experiment

- 38 States participated
- 27 states: Observational Study
  - Volunteers (69%) placed in the treatment group
  - Those who refused placed in the control group
- 11 states: Controlled experiment
  - Volunteers (60%) randomly assigned to treatment and control groups
  - Treatment: Injected with Salk's vaccine
  - Control group: Injected with a placebo
  - Double blind

Trial Data

Observational Study

	Size	*Rate*
Treatment	225,000	25
Control	725,000	54
No Consent	125,000	44

Controlled Experiment

	Size	*Rate*
Treatment	200,000	28
Control	200,000	71
No Consent	350,000	46

- Data rounded to nearest thousand
- Rate per 100,000

Conclusion:

- The vaccine worked

Design of Experiments References

1. *Statistics*, 3rd Ed., D. Freedman, R. Pisani, & R. Purves.
2. "An evaluation of the 1954 poliomyelitis vaccine trials–summary report," T. J. Francis, Jr., *American Journal of Public Health*, vol. 45, (1955) pp 1-63.
3. "The Salk Polio Vaccine Trial of 1954: risks, randomization and public involvement in research," L. Dawson, *Clinical Trials*, vol. 1, (2004), 122-130.
4. "Jonas Salk," *Wikipedia*.