

# Mental Models of Viruses, Vaccines, and the Causes of Infectious Disease

Benjamin D. Jee<sup>1</sup> (bjee@holycross.edu), David H. Uttal<sup>2</sup>, Judy Diamond<sup>3</sup>, and Amy Spiegel<sup>4</sup>

<sup>1</sup>College of the Holy Cross, <sup>2</sup>Northwestern University, <sup>3</sup>University of Nebraska State Museum, <sup>4</sup>University of Nebraska-Lincoln

## Introduction

- Beliefs about the cause of illness vary across cultures<sup>1</sup> and age groups<sup>2</sup>, and can have a substantial impact on people's health practices<sup>3</sup>
- Viral infection, illness, transmission, and vaccination are all related to the basic microbiological properties of viruses and the organisms that they infect
- What do people believe about the *microbiological level*?

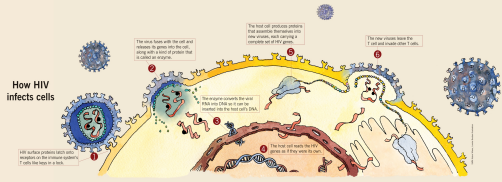


Fig. 1. How HIV infects cells. Image courtesy of the University of Nebraska State Museum for Explore Evolution funded by the National Science Foundation.

## Objectives

- Compare beliefs about the microbiology of viruses across three levels of science experience: public school students, public school teachers, and professional virologists
- Capture the structure of people's intuitive mental models

## Method

### Participants

- 13 ninth grade public school students\*, 14-15 yrs old
  - 18 public school teachers\*
  - 7 professional virologists
- \* From a large, urban school district in the Midwest

### Materials & Procedure

All participants completed a semi-structured (approx 60 min.) interview about viruses, including probes such as:

- What is a virus?...Does a virus contain anything?
- How do viruses infect living things?
- How does the body respond to infection?
- What is a vaccine?...How does a vaccine work?

### Predictions

- Participants with greater science experience will have more extensive knowledge of the structure, behavior, and function of microbiological entities<sup>4</sup>
- Participants will express qualitatively different mental models of microbiological processes
- Non-experts will endorse scientifically inaccurate models

### Interview coding

- Transcribed interviews were coded using a scheme created by two primary researchers and a virologist (Cohen's Kappa = .88)
- 8 key topics were identified, each mentioned by > 20% of respondents
- Coded presence of **structural**, **behavioral** and **functional** descriptions<sup>4</sup>

## Results: Quantitative Analyses

Table 1. Mean number of structures, behaviors, and functions by experience level

	Structures	Behaviors	Functions	Total
Students	2.69	2.92	1.92	2.51
Teachers	3.56	3.22	3.33	3.37
Experts	5.86	5.57	4.43	5.29
Total	3.68	3.55	3.05	

- Experts discussed more key topics in total than students and teachers
- Participants described structures most often, followed by behaviors and functions

Table 2. Proportion of participants discussing topics at each level of description

Topic	Students			Teachers			Experts		
	S	B	F	S	B	F	S	B	F
Virus appearance	.23	.15	.08	.39	.28	.28	1.0	.57	.57
Host appearance	.15	.08	.08	.17	.00	.00	.43	.29	.00
Virus contents	.85	.38	.31	.83	.72	.67	1.0	1.0	1.0
Host contents	.46	.08	.00	.61	.22	.17	1.0	.29	.14
Replicated virus	.00	.31	.00	.06	.56	.44	.57	.86	.43
Immune resp.	.00	.62	.31	.00	.22	.39	.00	.86	.43
Immune cell	.54	.46	.23	.50	.29	.44	.86	.71	.86
Vaccine	.46	.85	.92	1.0	.83	.94	1.0	1.0	1.0

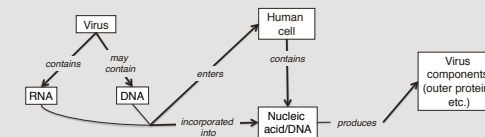
■ > 33% of the group discussed this topic

- All groups discussed virus contents, immune cell and vaccines at multiple levels of description
- Experts discussed experts described almost every topic at multiple levels of description

## Results: Qualitative Analyses

### Mental models of the contents of the virus: virus replication

#### Expert model (plus several teachers and students)



**Virologist on replication:** "A virus has RNA on the inside and some have DNA...When [the virus nucleic acid] gets into the cell it incorporates itself into the nucleic acid of the human cell. So it's using the human cell and it's using its code to tell that cell to make [the virus] coat, outer protein and everything else."

- The teacher and student responses were often less specific, but involved the same mechanism of replication: taking over the host cell's DNA

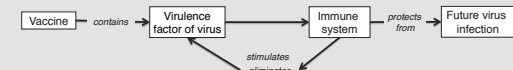
#### Common naïve model (several teachers and a student)



**Teacher on replication:** "Viruses reproduce by splitting...the [virus] DNA lines up, splits and so there's two what they call daughter cells and they're identical cells. So that's how they reproduce. They just kind of make clones of themselves and copies."

## Mental models of vaccines and vaccination

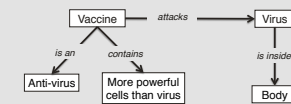
### Expert model (plus several teachers and students)



**Virologist on vaccines:** "A vaccine is really an artificial means of stimulating the immune system to protect you against some infectious agent... You find out what part of the viral particle could be part of the virulence factor of the virus and you try to find a way to stimulate the immune system to knock that out."

**Teacher on vaccines:** "A vaccine...is a small amount of the virus that they are putting into your body to hope that your body will take that and make antibodies, if I'm thinking correctly, against that disease. So that if you come in contact with [the virus] you will not get it." (Teacher)

### Common naïve model (majority of students)



**Student on vaccines:** "A vaccine...is like an anti-version of the virus...a vaccine works the same way viruses attack our cells...I think the chemicals or whatever they inject has cells to it... and those are more powerful than the virus itself and it attacks the virus in the body."

## Discussion

- The depth and breadth of knowledge increased with experience level
- Several teacher and student explanations of replication and vaccination deviated greatly from the virologists'
- Misunderstanding of microbiology could lead to suboptimal health decisions
  - If a person thinks of vaccines as an antiviral, they may not consider vaccination until they are already experiencing the symptoms of illness
- Given such misconceptions, presenting people with statistics and arguments about the effectiveness of vaccination programs may have limited effectiveness
  - Educational interventions must attempt to replace or refine preexisting beliefs to support a deeper understanding of why certain health practices are worth adopting<sup>5</sup>

## References

- Legare, C. & Gelman, S. (2008). Bewitchment, biology, or both: The co-existence of natural and supernatural explanatory frameworks across development. *Cognitive Science*, 32, 607-642.
- Sigelman, C. K. (2012). Age and Ethnic Differences in Cold Weather and Contagion Theories of Colds and Flu. *Health Education & Behavior*, 39(1), 67-76.
- Au, T. K., Chan, C. K., Chan, T. K., Cheung, M. K., Ho, J. Y., & Ip, G. W. (2008). Folkbiology meets microbiology: A study of conceptual and behavioral change. *Cognitive Psychology*, 57, 1-19.
- Hmelo-Silver, C. E., & Pfeffer, M. G. (2004). Comparing expert and novice understanding of a complex system from the perspective of structures, behaviors, and functions. *Cognitive Science*, 28, 127-138.
- Au, T. K., & Romo, L. F. (1996). Building a coherent conception of HIV transmission: a new approach to AIDS education. In D. Medin (Ed.), *The Psychology of Learning and Motivation*, 35, 193-241. San Diego: Academic.

## Acknowledgments

This research was supported by the Omaha Schools Foundation and World of Viruses project. World of Viruses is funded by the National Center for Research Resources at the National Institutes of Health through the Science Education Partnership Award (SEPA) Grant No. R25 RR024267-01 (2007-2012). Its content is solely the responsibility of the authors and does not necessarily represent the official views of NCRHR or NIH. We thank Carolyn Crouch, Kristin Watkins and LaShawnda Lindsey-Dennis for assistance with data collection and coding.

**SEPA** SCIENCE EDUCATION PARTNERSHIP AWARD  
Supported by the National Institutes of Health