Vaccines and Public Health

Johnny Kung

The Blight of Infectious Diseases

- Throughout history, millions succumbed to infectious diseases such as smallpox and polio
- By late 1700s, 400 000 people died per year in Europe from smallpox

Picture Source: Centers for Disease Control and Prevention

Jenner and the Invention of Vaccine

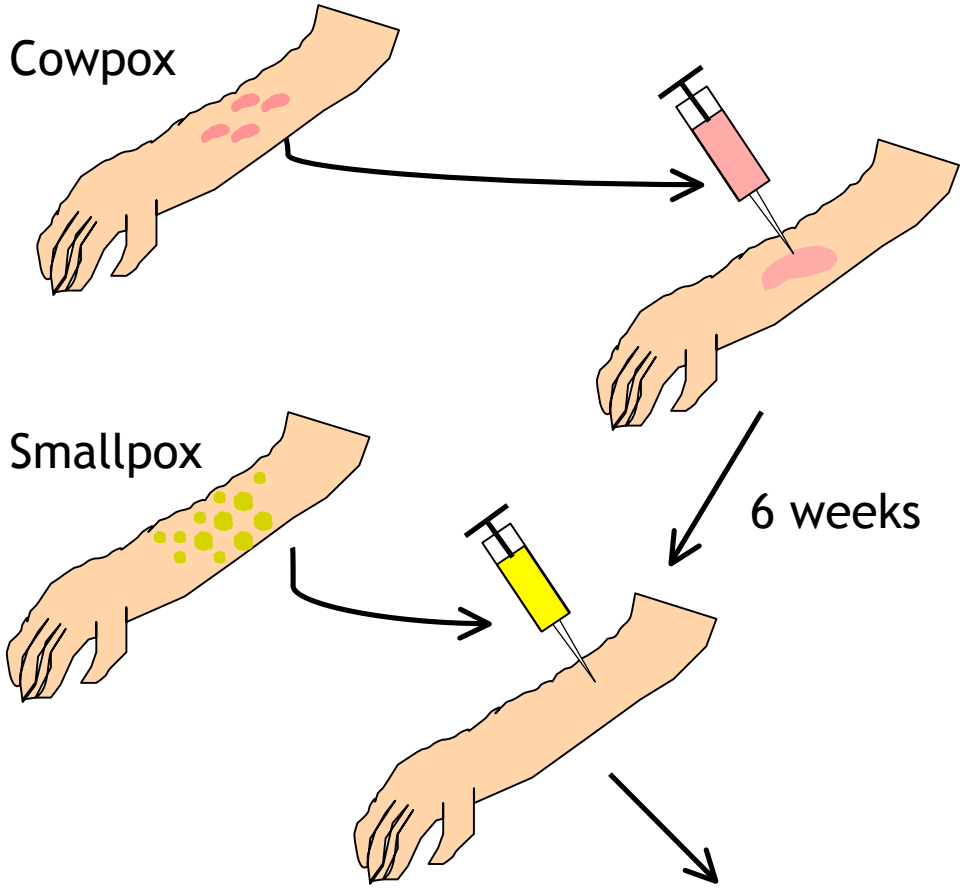
Edward Jenner (1749-1823)

- Common *observation*: dairymaids who have had cowpox (similar to smallpox but much milder) do not contract smallpox
- *Hypothesis*: cowpox conferred *immunity* to smallpox

Picture Source: Public Domain

Jenner and the Invention of Vaccine

— *Experiment* (1796):



— Further confirmed with 22 other cases

— Vaccine, from Latin *vacca* (cow)

Picture Source: Public Domain

Vaccines and the Triumph over Smallpox

By 1800, vaccines administered across Europe and North America

By 1900: smallpox eliminated from much of industrialized world

1950: Pan Am Health Org – eradication program throughout Americas

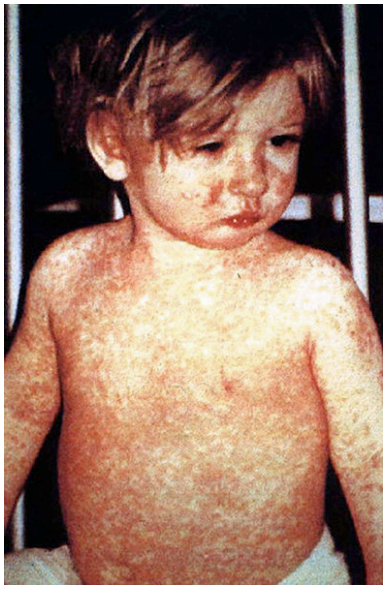
1959: Beginning of global smallpox eradication program

1975: Rahima Banu, one of the last people naturally infected by smallpox

12/9/1979: WHO declared smallpox eradicated

Picture Source: CDC

Other Successes, and Work in Progress



Measles

Polio

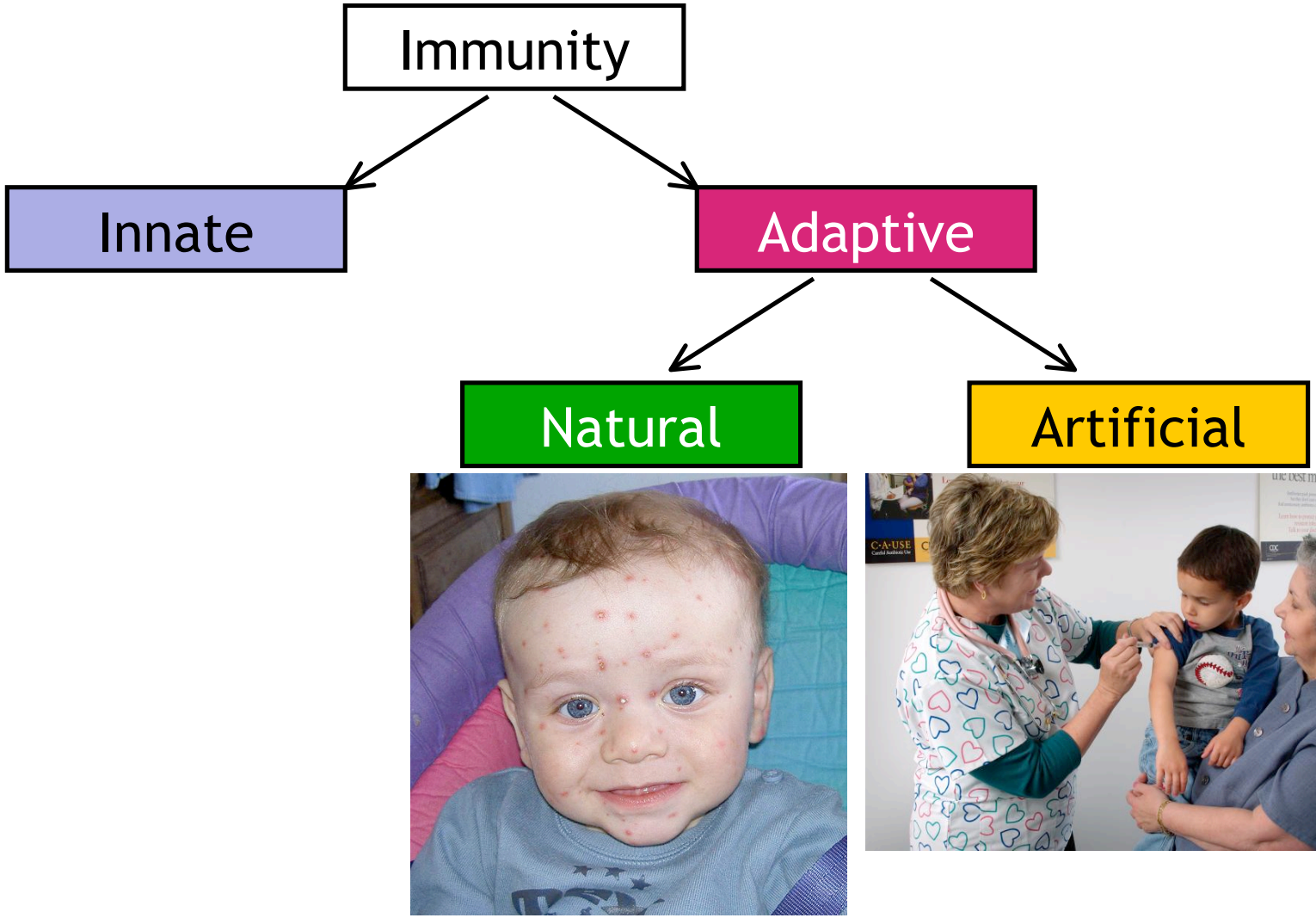
Diphtheria

- Major diseases still to have reliable vaccine: tuberculosis, HIV, malaria
- Smallpox is the first, and only, human disease to be eradicated; polio eradication in progress

Picture Source: CDC

How do vaccines work?

Immunity



Types of Vaccines

Type	Component	Examples
Live, attenuated	Live microbe weakened by growth conditions in lab, or less dangerous relative	measles, rubella, mumps, yellow fever, typhoid, tuberculosis
Inactivated (Killed)	Microbe killed by chemicals, heat or radiation	flu, plague, polio, rabies, hep A, cholera
Subunit	1-20 parts of microbe that best stimulate immune response	hep B, HPV, flu

Other Components of a Vaccine

- Preservatives/stabilizers: antibiotics, formaldehyde, MSG, **thimerosal**
- Adjuvants: substances that enhance immune response by mimicking molecules common to pathogenic microbes
  - Aluminum salts (only type allowed in US)
  - Squalene (derived from shark liver or plant oils)

Vaccines in the US

- Recommended Immunization Schedule:
  - HepA; HepB
  - DTaP (Diphtheria, Tetanus, Pertussis)
  - MMR (Measles, Mumps, Rubella)
  - Varicella (chickenpox); Polio; Rotavirus
  - Hib (against Haemophilus influenzae type b); PCV (against Streptococcus pneumoniae)
  - Meningococcus (at 11-12 years)
  - Human papillomavirus (for females; at 11-12 years)
  - Flu (yearly)

Vaccines in the US

- Immunization coverage in children of 19-35 months

DTaP	85%
Polio	94%
MMR	92%
Varicella	91%
HepB	94%
HepA	40%
Hib	91%
PCV	80%

National Immunization Survey 2008, CDC

How do we *know* a vaccine works and is safe?

- 3 types of evidence:
  - Clinical trials
  - Post-licensing safety monitoring
  - Population-level data

Clinical Trials

	Phase I →	Phase II →	Phase III
Volunteer group size	20-100	100-300	10 000 or more
Duration	up to 2 yrs	2 or more yrs	up to 4 yrs
Looking for	safety, side effects, optimal dose / schedule	safety, immune response	safety, effectiveness

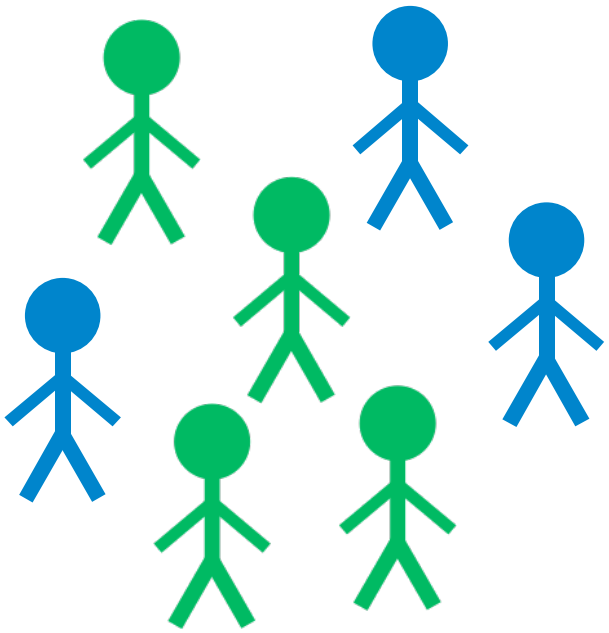
- When enough data is generated, a licensing application will be filed with FDA

Post-Licensing Safety Monitoring

- National programs for reporting adverse events, eg, Vaccine Adverse Event Reporting System (VAERS)
- Need to conduct formal scientific investigation to test link between vaccine and event
  - Coincidence or causal?

Vaccines Working at the Population Level

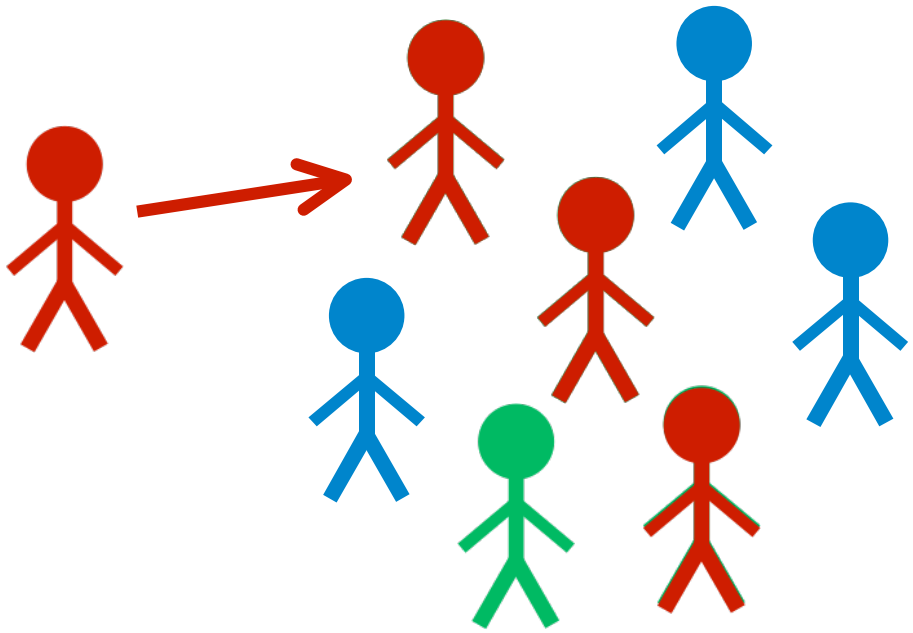
Herd Immunity



Vaccinated, immune

Unvaccinated, susceptible

Herd Immunity

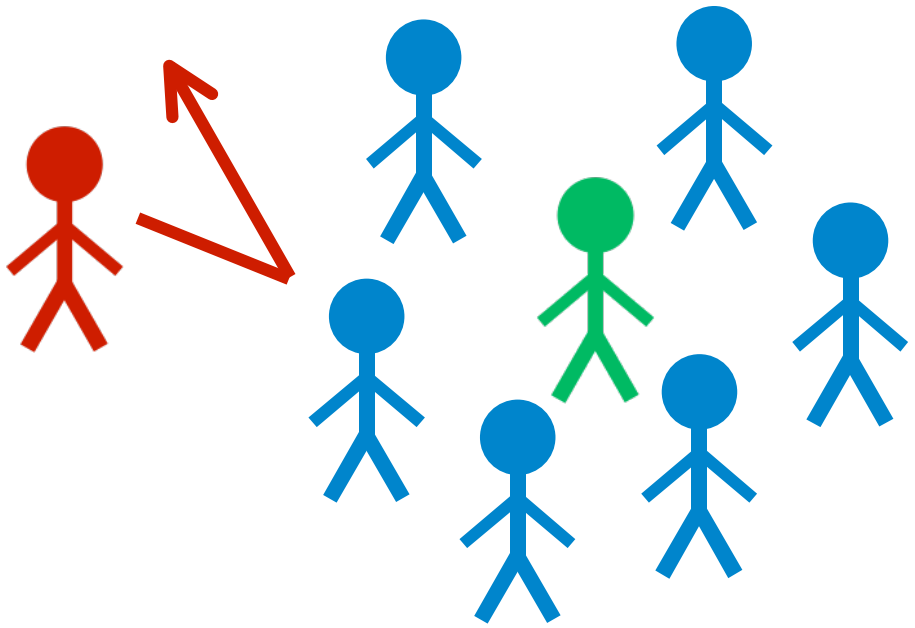


Vaccinated, immune

Unvaccinated, susceptible

Transmitting case

Herd Immunity



Vaccinated, immune

Unvaccinated, susceptible

Transmitting case

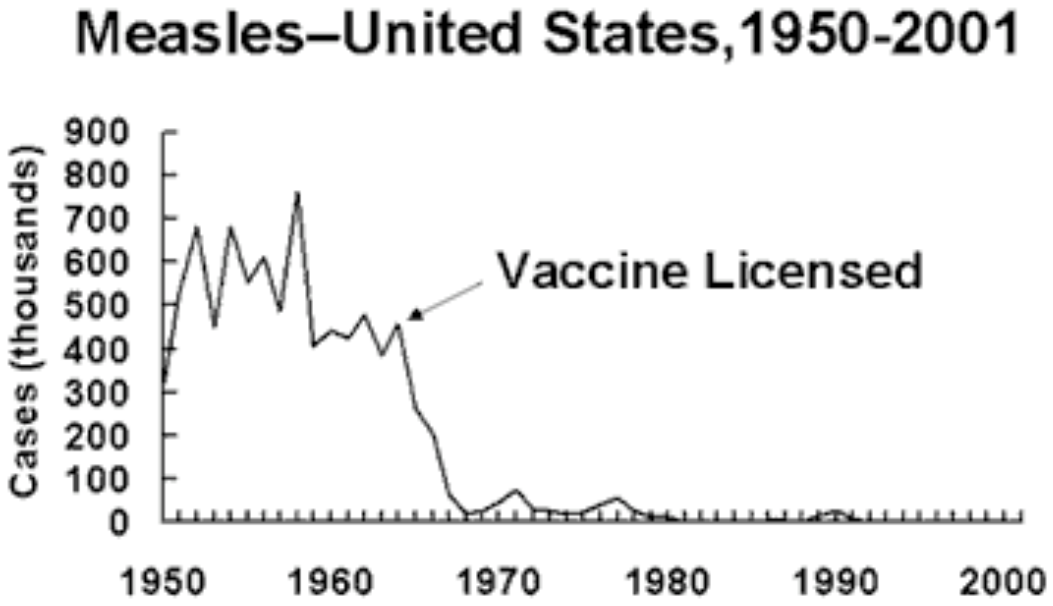
Herd Immunity Threshold

- Estimated % coverage needed to prevent disease from persisting in population

Diphtheria	85%
Pertussis	92-94%
Polio	80-86%
Measles	83-94%
Mumps	75-86%
Rubella	83-85%

CDC and WHO

Why Vaccines are Important



CDC

HARVARD MEDICAL SCHOOL

Why Vaccines are Important

Disease	Annual Cases Pre-Vaccine	2008 Cases
Measles	503 282	55
Mumps	152 209	454
Rubella	47 745	11
Diphtheria	175 885	0
Pertussis	147 271	10 735
Tetanus	1314	19
Polio	16 316	0
Smallpox	48 164	0

The Economic Benefits of Vaccines

Every  spent on childhood vaccine

Saves  on direct healthcare cost

and  on indirect societal cost

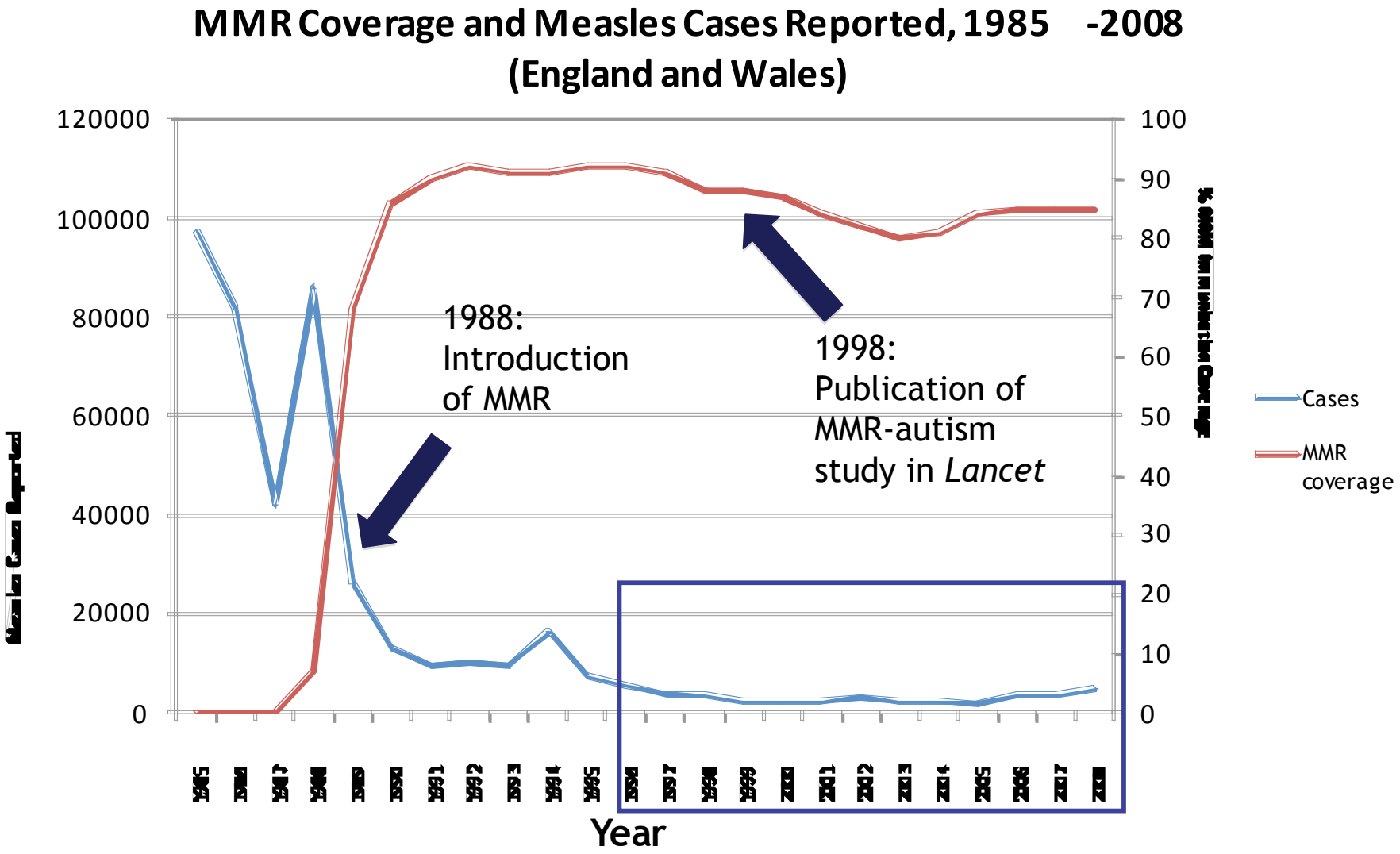
Zhou F., *et al*. *Arch Pediatr Adolesc Med*. 2005; 159(12):1136-1144

HARVARD MEDICAL SCHOOL

Why aren't vaccines perfect?

- Individual variation from person-to-person, due to genetics, environment, other illnesses, etc
- Rare events
  - Serious side effects: 1 in 10000 – 1 in million
- Some people should not be vaccinated
  - Had previous allergic reaction
  - Compromised immune system, eg, HIV / cancer patients

What happens if we stop vaccinating?



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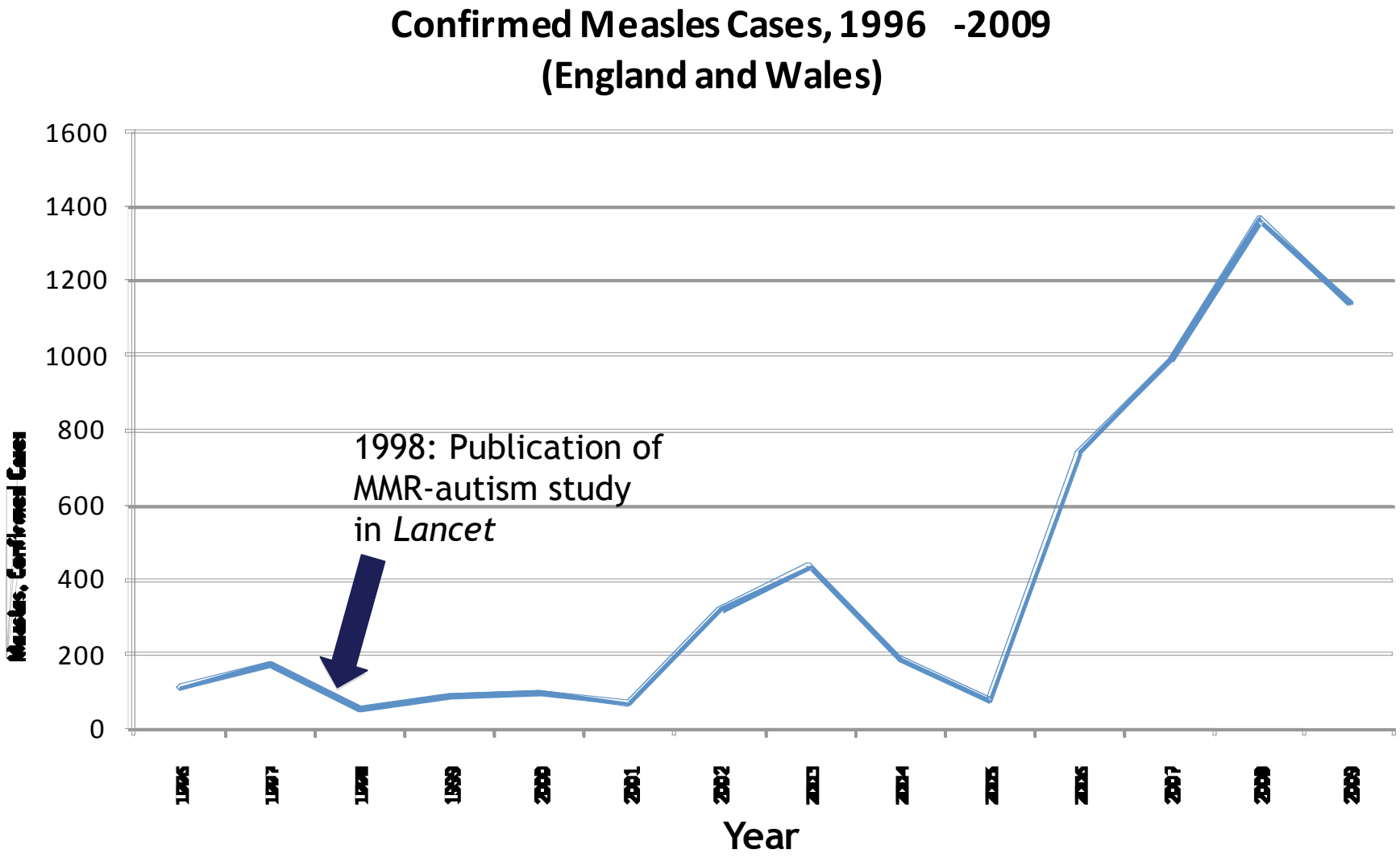

Summary

- Invention of vaccines had led to dramatic decrease in many infectious diseases
- Vaccines work by “teaching” immune system to respond quickly to real disease in future
- A vaccine is licensed only with enough evidence of its safety and efficacy
- Immunization coverage strongly correlated with changes in disease incidence