The Immune System and How Vaccines Work

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Keeping it simple...
Outline of talk

• An overview of the immune system
• The journey of a pathogen and the obstacles it meets
• How vaccines work and how soon we are protected
• Types of vaccine – live vs inactivated
• Vaccine components
• Timing of vaccinations, timing of adverse reactions
• Herd immunity
What is the immune system?

- The body’s defense against disease causing organisms, malfunctioning cells, and foreign particles.
Pathogens

- Pathogens: disease causing agents - such as bacteria, virus, and fungi
- Patho - sickness agent
- Gen - to create
The immune system – defence against pathogens

• In other words, how to stop David from killing Goliath...
The immune system

Array of organs, cells and chemicals that:

• Determine self from “non-self”
• Identify potential dangers to the body
• Eliminate them by mounting an immune response
The infant’s immune system...

- Naive – needs exposure to foreign antigen in order to develop normally
- Maternally acquired immunity is temporary and does not protect against all infections.
- The infant immune system has the capacity to cope with a vast array of antigens at any one time.
Immune system components

Source: http://www.webmd.com/a-to-z-guides/components-of-the-immune-system
Organisation of the immune system

Immunity

Adaptive Immunity

Innate Immunity

Natural

Passive (maternal)

Active (Infection)

Artificial

Passive (antibody transfer)

Active (immunization)
Immunity: Active and Passive

Active immunity
- Naturally acquired

Passive immunity
- Naturally acquired
- Artificially acquired

Mumps 12/9/79

Artificially acquired

Serum
The Pathogen’s Journey
Will sickness occur?

Getting sick or remaining well when exposed to a germ is a balance. It depends on the virulence of the germ and the ability of the person to resist the infection.

Both of these things are variable.
The consequences of infection...

- Lifelong immunity (most of the time!)
- May be innocuous

BUT....

- May cause serious disease
- May cause permanent damage to the host
- May cause death
The pathogen soon encounters the first level of defence

- Physical barriers (intact skin, intact mucous membranes, cilia etc....)
- Physiological factors (eg pH, temp)
- Protein secretions (complement, interferons)
- Phagocytes – macrophages and PMNLs

Defining characteristic of innate immunity - \textbf{NO MEMORY PERSISTS.}
Macrophages – part of the first level of defence

- Digest most of the micro-organism
- Regurgitate the antigens
- Display antigens on their surface so that another type of white blood cell (lymphocytes) can take over.
What is an antigen?

Microbe Fragments of Microbe = antigen

“Anything that can be bound by an antibody”
The second level of defence

- Adaptive immunity
- The foreign agent is recognised in a specific manner e.g
  - B Cells
  - T Cells

THE IMMUNE SYSTEM ACQUIRES MEMORY
Cell-Mediated Immune Response

Figure 12.15

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What is an antibody?

- Produced to one specific epitope (ie is antigen specific)
- Neutralises toxins
- Blocks adhesion/ cell entry
- Kills via complement
- Neutralises viral infectivity and prevents replication.
Immune system superheroes!

- Macrophages and Helper T Cells
- T Cells
- Antibodies (from B Cells)

Gone but not forgotten!
Memory cells

• Once infection has been eliminated, some B and T cells become memory cells
• These retain memory of the antigen
• On re-exposure, powerful immune response.
• This ability of the immune system to have a memory for previous antigens is the basis for vaccination.
How soon after exposure to an antigen are we protected?

- Immune response is generated after 4-7/7
- >7/7 get Primary immune response (IgM), lasts 3 weeks, memory cells made.
- Secondary/subsequent immune response, IgG, faster
- It takes 2 weeks to get optimum immune response after vaccination.
K.I.S.S. Summary

**HOW DO VACCINES WORK?**

- Often a weakened form of the disease is injected into the body.
  (Some vaccines are not injected but inhaled, such as some types of the flu vaccine)

- The body thinks the weak virus is a threat. It builds up lots of antibodies (or teams of ninjas).

- If the disease attacks the body, the antibodies are ready to catch and destroy them.
The ideal vaccine

- Produces the same immune protection as an infection without causing disease
- Generates long-lasting immunity
- Interrupts spread of infection
Vaccines can be broadly divided into two types

- Live attenuated
- Inactivated
Basic differences

Live Attenuated – “Weak Pathogen”

• A version of the living microbe that has been weakened in the lab so it can’t cause disease.
• Vaccines are longer lasting and require fewer boosters.
• However, these could mutate back to the pathogenic strain.
• eg BCG/ MMR/ Rotavirus/ Varicella/ Yellow fever

Inactive – “Dead Pathogen”

• Produced by killing the disease-causing microbe with chemicals, heat, or radiation.
• Cannot cause disease.
• Cannot replicate.
• Immune response is antibody-based.
• Antibody titre falls with time.
• 3-5 doses required.
• Classified as inactivated/conjugate/recombinant/subunit.
Live attenuated vaccines

- Produced by weakening a live pathogen and removing its ability to cause disease

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<th>PROS</th>
<th>CONS</th>
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<td>• Large immune response</td>
<td>• Need strict refrigeration</td>
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<td>• Good “teachers” of the immune system</td>
<td>• Could mutate back to disease-causing strain</td>
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<tr>
<td>• Generally only 1-2 doses needed</td>
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- Need strict refrigeration
- Could mutate back to disease-causing strain
Inactivated vaccines

- Produced by killing the pathogen

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| • They may not have to be stored as carefully.  
• They will never come back to life and cause the disease. | • They usually require booster shots because they only weakly stimulate the immune system to make antibodies. |
Types of inactivated vaccine

**Whole**
- viruses
- bacteria

**Fractional**
- protein-based
  - toxoid
  - subunit
- polysaccharide-based
  - pure
  - conjugate
Toxoid vaccines

- Produced by inactivating the toxin produced by some pathogens eg tetanus and diphtheria

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| • Generally only need one or two shots  
• They will never come back to life and cause the disease. | • Require refrigeration |
Subunit vaccines

- Produced by extracting the antigenic part of a micro-organism. Eg hep B and strep pneumo

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<td>• They will never come back to life and cause the disease.</td>
<td>• They are more difficult to make and require new, expensive technology.</td>
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How vaccines are made

Microbes grown on suitable medium

Purified to remove compounds that could cause allergic reactions

(not always possible)
Vaccine components

- Suspension fluid (water, saline etc)
- Preservatives, stabilisers, antimicrobial agents (eg formaldehyde, antibiotics)
  a) Trace amounts
  b) May cause allergic reaction
- Adjuvants
  a) Aluminium salts – to increase immunogenicity
  b) Eg hep B, tet, diphth
Worried about formaldehyde?

Concerned about formaldehyde in vaccines? Consider the pear...

A 200 g pear contains up to 12,000 µg of formaldehyde, naturally.

Vaccines contain up to 100 µg, or 0.83% of the formaldehyde in a pear.

The amount of formaldehyde in a vaccine is so tiny that it doesn't even affect the naturally occurring levels of formaldehyde in a child's blood.

Source: http://tinyurl.com/foodCH20

Refutations to Anti-Vaccine Memes.
Worried about aluminium?

Aluminum in perspective

A cup of tea contains as much aluminum as one vaccine shot.

Sources: Aluminium in tea—concentrations, speciation and bioavailability. Trond 2002, Coordination Chemistry Reviews, and The Agency for Toxic Substances and Disease Registry of the CDC

A vaccine shot’s worth of aluminum enters our bloodstream every twenty days through our diet. Typically, we ingest 8 mg of aluminum daily, but common antacids increase that by a factor thousand. They, too, are harmless for most of us, though not recommended for people with renal failure.

Want to know more? Visit thoughtscapism.com
True or False?

Several childhood vaccines contain mercury, which is toxic to the nervous system.
Thiomersal

• Mercury containing compound used as a preservative and an inactivating agent
• In 1999 EU and US manufacturers decided to decrease thiomersal levels in vaccines as a precaution and to retain trust in vaccine supply
• WHO state that there is no evidence of toxicity
• All vaccines in the infant immunisation programme are thiomersal free
Timing of vaccinations
Why are gaps needed between doses?

• To allow each immune response to develop eg primary immunisation
• To avoid immune interference – if another live vaccine is given while the immune system is making a primary immune response, the activation of the innate immune system may neutralise the second vaccine. Hence we wait 4 weeks.
Timing of Primary Immunisation Course

- Maternal IgG is transferred across the placenta
- Passively acquired IgG can suppress response to DTP, Polio, Men C and Hib for 2 months
- Maternal antibody to measles may interfere for 1 year.
True or False?

Vaccinations can “overload” the immune system.
Can vaccines “overload” the immune system?

• We are exposed to countless antigens every day, in the food we eat, in the air we breathe, in the water we drink.
• The human body contains 100 trillion bacteria.
• The immune system is capable of responding to 100,000,000,000 antigens at a given time.
• The MMR contains only 24 antigens.

NO EVIDENCE THAT VACCINES OVERLOAD THE IMMUNE SYSTEM
Arguing that vaccines will overwhelm a child’s immune system is like arguing that a tablespoon will make an Olympic swimming pool overflow.
Vaccine Failures and Reactions

When it's a joke for everyone, except the guy next in line.
Vaccine failures

• Primary failure – when an individual fails to respond to the initial vaccine (eg 10% MMR)
• Secondary failure – responds initially but response wanes over time (most inactivated vaccines)
Timing of vaccine reactions

- Inactivated – generally within 48h
- Live vaccine – according to time taken for virus to replicate

Eg  MMR vaccine
a) Reactions to measles (malaise, fever, rash) occur in 1st week
b) Rubella (pain, joint swelling) in 2nd week
c) Mumps (parotid swelling) in 3rd week
Adverse events

• Live vaccine – frequency of adverse events falls with number of doses
• Inactivated vaccines – frequency of adverse events increases with number of doses...

if antibody levels are good, this binds to antigen in subseq dose, producing an Immune response which, if big enough, is inflammatory
Herd immunity

• When most people in community are immune to a particular infection that is spread from *person to person*, the natural transmission of the infection is effectively inhibited

• Vaccine uptake rates >90% (measles 95%)

• Not tetanus!
Herd Immunity

HERD IMMUNITY

• If enough of the population is immunized, even those that aren’t are protected
• Who relies on herd immunity?
  • Infants
  • Elderly
  • Those with weakened immune systems
  • Those who are allergic to the vaccine

http://www.vaccines.gov/basics/protection/
Thanks!

SMILES ARE CONTAGIOUS!

DON'T WORRY, I'M VACCINATED