Addressing challenges with vaccine manufacturing moving into the future

DCVMN Annual Meeting, Bangkok, October 2015
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Uppsala, Sweden
Infectious Disease

- Infectious diseases are **caused by microscopic organisms** commonly called **germs** or **pathogens**. Pathogens that infect humans include a wide variety of bacteria, viruses, fungi, protozoa, and parasitic worms.
- In addition, it is assumed that some proteins called prions may cause infectious diseases.

**Virus**
e.g., Hepatitis B, Smallpox, HIV

**Bacteria**
e.g., Streptococcus, Anthrax, Cholera

**Protozoa**
e.g., Malaria

**Worms**
e.g., Bilharziasis
Elimination and Eradication of Disease
Jagschies et al. “Handbook of Bioprocessing” in preparation, Elsevier 2016, based on CDC data

<table>
<thead>
<tr>
<th>Disease</th>
<th>Pre-vaccination era</th>
<th>Current morbidity (2008-2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varicella (est.)</td>
<td>4,085,120</td>
<td>449,363</td>
</tr>
<tr>
<td>Tetanus</td>
<td>580</td>
<td>8</td>
</tr>
<tr>
<td>Smallpox</td>
<td>29,005</td>
<td>0</td>
</tr>
<tr>
<td>Congenital Rubella (CRS)</td>
<td>192</td>
<td>0</td>
</tr>
<tr>
<td>Rubella</td>
<td>47,745</td>
<td>6</td>
</tr>
<tr>
<td>Rotavirus, &lt;5 yrs age</td>
<td>62,500</td>
<td>7,500</td>
</tr>
<tr>
<td>Polio, paralytic</td>
<td>16,316</td>
<td>0</td>
</tr>
<tr>
<td>Pneumococcus, &lt;5 yrs age</td>
<td>16,049</td>
<td>4,167</td>
</tr>
<tr>
<td>Pertussis</td>
<td>200,752</td>
<td>21,291</td>
</tr>
<tr>
<td>Mumps</td>
<td>162,344</td>
<td>982</td>
</tr>
<tr>
<td>Measles</td>
<td>530,217</td>
<td>61</td>
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<tr>
<td>Hepatitis B, acute (est.)</td>
<td>66,232</td>
<td>11,269</td>
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<tr>
<td>Hepatitis A (est.)</td>
<td>117,333</td>
<td>11,049</td>
</tr>
<tr>
<td>H. Influenza, &lt;5 yrs age</td>
<td>20,000</td>
<td>243</td>
</tr>
<tr>
<td>Diphtheria</td>
<td>21,053</td>
<td>0</td>
</tr>
</tbody>
</table>

Reduction of morbidity [% USA]

Figure 1–14: Reduction of morbidity with vaccination
## World Immunization Effect & Coverage

### Global mortality (GBD report 2013)

<table>
<thead>
<tr>
<th>Infection</th>
<th>1990</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diphtheria</td>
<td>8,032</td>
<td>3,276</td>
</tr>
<tr>
<td>Tetanus</td>
<td>356,156</td>
<td>58,879</td>
</tr>
<tr>
<td>Pertussis</td>
<td>138,219</td>
<td>60,635</td>
</tr>
<tr>
<td>Polio</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Measles</td>
<td>544,474</td>
<td>95,597</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td>84,991</td>
<td>68,642</td>
</tr>
<tr>
<td>Pneumococcal*</td>
<td>116,770</td>
<td>84,009</td>
</tr>
<tr>
<td>Diarrhea#</td>
<td>2,578,732</td>
<td>1,264,079</td>
</tr>
</tbody>
</table>

* Upper respiratory and pneumococcal meningitis

# all diarrheal diseases, incl. Rotavirus caused (~50% of diarrhea hospitalization w/ children)

### 2014 vaccination coverage

![Bar chart showing vaccination coverage](chart.png)

**2014 vaccination coverage**

- **Diphtheria-Tetanus-Pertussis (DTP3)**
- **Polio**
- **Measles**
- **Hepatitis B**
- **Pneumococcal diseases**
- **Rotaviruses**

DCVMN Annual Meeting 2015

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2015-10-06
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Challenges influencing technical needs and planning for manufacturing
Infectious disease burden

- More than 80% of global mortality from non-communicable diseases (NCDs), but children still being much more at risk from infectious diseases.

- 2013 Global Burden of Disease study found a 24% decline in mortality from infectious diseases since 1990 (2.8 million averted future deaths annually)

- Three big infectious diseases HIV/AIDS, Malaria, and Tuberculosis (TB) still killed 3.5 million people in 2013, the majority of them being children and young adults

- Almost 90% of all deaths from communicable disease occur in low and lower middle income countries

- 2.2 billion cases or 44% of the global prevalence of communicable disease are from 17 diseases that together are referred to as “neglected tropical diseases” (NTDs)

Child mortality driven by infectious disease (~3.3 million below age five)

Global Burden of Disease Study 2010, The Lancet

Effective interventions for neglected tropical disease

Effective interventions for neglected tropical disease

R&D efforts on Malaria, HIV, and TB

Affordable supply to the poorest
Disease Challenges

• Viruses for **new diseases**, such as **Ebola**, have surfaced in Africa.
• In addition to new diseases, known **pathogens may change, or mutate**, creating new, virulent strains.
• Mutations in infectious agents result in **resistance to vaccines** as the serotypes they cover are replaced by others.
• With **global travel**, outbreaks spread very fast and may lead to large epidemics.
• With **climate change** disease might spread together with their vectors.
• **Production methods are too old and inefficient** to meet the challenges.
• The prevalence for **neglected tropical diseases** is 2.2 billion, 40% of all communicable diseases and more than twice as high as all cancers globally.
• **Vaccination rates are too low** to prevent pandemic influenza and too low in developing countries to prevent up to 3 million annual child deaths from other infectious diseases (one child every 20 seconds).
<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Viruses</th>
<th>Parasites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuberculosis</td>
<td>HIV</td>
<td>Malaria</td>
</tr>
<tr>
<td>Group A streptococcus</td>
<td>HCV</td>
<td>Leishmania</td>
</tr>
<tr>
<td>Group B streptococcus</td>
<td>RSV</td>
<td>Schistosoma</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>EBV</td>
<td>Trypanosoma</td>
</tr>
<tr>
<td>Shigella</td>
<td>HSV</td>
<td>Toxoplasma</td>
</tr>
<tr>
<td>Salmonella</td>
<td>CMV</td>
<td>Brucella</td>
</tr>
<tr>
<td>Clamydia</td>
<td>Dengue</td>
<td>Cryptosporidium</td>
</tr>
<tr>
<td>Pathogenic E.coli</td>
<td>Enteroviruses</td>
<td>Entoamoeba</td>
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<tr>
<td>Pseudomonas aeruginosa</td>
<td>Ebola</td>
<td></td>
</tr>
<tr>
<td>Clostridium difficile</td>
<td>Marburg hemorrhagic fever</td>
<td></td>
</tr>
<tr>
<td>Non-typeable Haemophilus</td>
<td>Parvovirus</td>
<td></td>
</tr>
<tr>
<td>Klebsiella pneumoniae</td>
<td>Norovirus</td>
<td></td>
</tr>
</tbody>
</table>

RSV = Respiratory syncytial (sin-SISH-uhl) virus; EBV = Eppstein-Barr Virus; HSV = Herpes Simplex Virus; CMV = Cytomegalovirus
**Diversification of Technology**

40 vaccines still to be developed

Where would this trend lead?

### Production system
- CELL CULTURE
  - Sf9
  - Per.C6
  - WI-38
  - MDCK
  - Vero
  - CECC
- EGGs
  - MRC-5

### Vaccine type
- Live
- Live-attenuated
- Inactivated
- VLP
- Inactivated
- Live-attenuated
- CPS/PS
- Toxoid

### Infectious agent category
- Viral
- Bacterial
Who are the players?
What are the issues?
UNICEF Vaccine Procurement

- Total procurement by UNICEF in 2014 was $1,481 M for 2,700 M doses overall.
- Since year 2000 average price per dose has increased 5 fold from 10 $cents to 50 $cents / dose.
- High value vaccines PCV (Pfizer/GSK) and Rotavirus (GSK/Merck) have been added to the portfolio and represent 44% of total procurement value / stand for almost all of dose price increase since 2009.
- High volume vaccine OPV from Western and Indian suppliers has stable to slightly lowered prices from all, represents 14% of value at 60% of doses.
- Price developments have no clear pattern between western and other suppliers:
  - Measles: both Sanofi and SSI increased by 100% since introduction.
  - HepB: both Crucell and LG decreased by 40-50% since introduction.
  - DTP-HepB-Hib: SSI increased by 11% but is $1 cheaper than GSK who decreased price by 16% since introduction.
"The price to fully vaccinate a child is 68 times more expensive than it was just over a decade ago, mainly because a handful of big pharmaceutical companies are overcharging donors and developing countries for vaccines that already earn them billions of dollars in wealthy countries. Donors will be asked to put an additional $7.5 billion dollars on the table to pay for vaccines in poor countries for the next five years, with over one third of that going to pay for one vaccine alone, the high-priced pneumococcal vaccine; just think of how much further taxpayer money could go to vaccinate more children if vaccines were cheaper. We think it’s time for GSK and Pfizer to do their part to make vaccines more affordable for countries in the long term, because the discounts the companies are offering today are just not good enough."

Rohit Malpani
Director of Policy and Analysis for MSF’s Access Campaign.
Vaccine Suppliers to UNICEF

- Two thirds of the UNICEF supply comes from Europe and North America
- The remaining third is delivered by Asian manufacturers
- India is the country with largest share of UNICEF purchase value
- GSK, Serum Institute, and Pfizer are the three largest suppliers to UNICEF at 75% of the total value
Public Agencies Vaccine Procurement
UNICEF Report 2008, vaccines for expanded national vaccination programs

Global volume doses 2008

- Produced for developed markets
  - Global market leading manufacturers:
    - GSK
    - Sanofi Pasteur
    - Merck
    - Novartis
    - Pfizer/Wyeth
  - Produced for public agencies
    - European & US manufacturers:
      - GSK
      - Berna Biotech (Crucell)
      - Sanofi Pasteur
      - Novartis
      - Statens Serum Institut
    - Emerging markets manufacture
      - Panacea Biotech
      - Serum Institute of India
      - Shantha Biotechnics
      - LG Life Sciences
      - Bio-Manguinhos
  - Source: UN/UNICEF

Market value 2014

- ~$ 25,000M
- ~$ 1,400M
- 5-6%

Are healthcare providers paying enough for the value of vaccines?
Vaccine ecosystem in danger
Price is not the shortcut to real solutions, summary of an interview with...

- **Two more of the R&D-conducting vaccine producers have bailed out recently: Baxter and Novartis.**
- Perhaps only four of the six that are remaining are of global production scale: GSK, Merck, Pfizer, and Sanofi Pasteur.
- Of these four global companies investing in cutting-edge vaccine R&D, there are only two able to supply each of the key vaccines globally (i.e., MR/MMR, Rota, HPV, PCV, acellular pertussis-based pentavalent and hexavalent combinations)
- Need to move MR/MRR and Yellow Fever production to new technologies and update facilities to meet future demands.
- **The business case for this investment requires the very low price for the vaccines to be increased.**
  - MR/MRR stopped at Sanofi Pasteur, Yellow Fever continued without margin
  - Yellow Fever stopped at Crucell, significant shortage already observed
  - Of the nine vaccines UNICEF procures for GAVI (for poorer countries), seven are currently in short supply

- **It’s become too cheap to vaccinate populations around the world.** It appears the organizations mentioned above are veering from the goal of providing access to vaccines, to focusing on pushing for the cheapest prices for them.
  - Children don’t get the polio vaccine that costs about 12 cents a dose and they don’t get DTP, which costs about 19 cents a dose. It is hard to find many things in life as inexpensive and as hard to develop and manage distribution for...
  - “Reducing everything to price,” concludes Watson, “is now having negative consequences.”
Profit & Loss (P&L) for Vaccine Businesses

Manufacturing cost > 50%
• Compares to >15% in protein therapeutics

Factors enabling low pricing
(“one dose for the cost of a cup of tea”)
• Companies with supply of basic pediatric vaccines only have low current R&D efforts
• Companies with distribution mainly via UN institutions have low SG&A costs
• Private ownership less sensitive to operating profit pressure

Driving the future
• R&D is key to enable the development of vaccines with better safety and acceptance
• Without R&D neither the remaining nor the new threats will be addressed
• R&D provides competitiveness with improved processes for lower costs and better responsiveness

Typical P&L for vaccine businesses (no or little other business)

Annual Report 2009: Crucell, incl. Berna Biotech

- Manufacturing (Mfg.) 52%
- R&D 20%
- SG&A 17%
- Operating Profit 11%
- CoS

• Legacy technology distorts economics
• Limited process intensification
• Little flexibility
We must ensure that...

EVENYONE CAN ACCESS AND AFFORD IMMUNIZATIONS

IMMUNIZATION CONTINUES THROUGH CRISSES
What needs to happen on new developments & with production preparedness
What are the key issues to be addressed?

- Prevent resistance to vaccines
- Develop vaccines for the “big three” (HIV, Malaria, TB)
- Platform vaccine technology and processing
- Upgrade manufacturing networks and process yields
- Secure supply for pandemic influenza
- Solve affordability versus R&D investment issue
- Bring up vaccination rates everywhere

Every dollar spent on vaccination returns between $7 and $20 in avoided costs related to therapy / disease management.
Vaccine technology platform discussion
R&D response to improve how things have always been done?

- Fewer vaccine technologies, e.g., VLPs or similar standard
- One cell substrate for viral vaccines
- Standard harvest & purification steps – impurity removal
- Use standard equipment (modules) in highly flexible facilities
- Standard, multipurpose analytic platforms
- Standardize and simplify delivery to patients, localize supply capability, consider preparedness for ramp-up of demand
- Adjuvant, dose sparing, but is it safe (see pandemic influenza and narcolepsy)?
Advances in biological and microbiological technologies have increased the knowledge of pathogens and led to the development of newer and safer subunit antigens.

These antigens are less effective in inducing protective immune responses and require parallel development of potent adjuvants such as immuno-modulating molecules and particulate delivery systems.

Polysaccharide-based nano systems have demonstrated potential to be successfully used in vaccine formulations.
Perspectives on Recombinant Baculovirus-Sf9 Platform Development and Manufacturing Process

Rapid Manufacture and Release of a GMP Batch of Avian Influenza A(H7N9) Virus-Like Particle Vaccine Made Using Recombinant Baculovirus-Sf9 Insect Cell Culture Technology

Rapid Manufacture and Release of a GMP Batch of Zaire Ebolavirus Glycoprotein Vaccine Made Using Recombinant Baculovirus-Sf9 Insect Cell Culture Technology
Novavax Nanoparticle Vaccines

Virus-Like Particles (VLP) Seasonal & Pandemic Influenza

- HA, NA Protein
- Empty - No genetic material
- M1 Matrix Protein
- Configuration and size of the virus without RNA genome

Recombinant Protein Micelles
RSV, Rabies, Ebola

- Hydrophilic head of protein particle
- Hydrophobic tail of protein particle
- Protein particles form micelles for efficient antigen presentation:
  - Single antigen
  - Repeating unit

Novavax RSV F Nanoparticles
Vaccine manufacturing

- Bacteria
- Eggs
- Cell lines

- Bioreactors
- Culture conditions
- Filtration

- Chromatography
- Filtration
- Sucrose Centrifugation

- Substrate Dev
- Fermentation
- Cell Culture

- Clarification
- Concentration
- Purification
- Formulation
- Filling
- Release

Major challenges

- Product titer
- Yield
- Scale-up
- Consistency
- Yield
- Aggregation

- Yield
- Aggregation
- DNA removal

- Potency
- Analytical precision
- Number of methods

Recent and emerging technologies

- Vaccine technologies
- Cell lines
- Expression systems
- Disposable bioreactors
- Microcarrier
- Animal-free culture media

- Filters
- Novel Chromatography resins
- Single-use equipment

- Adjuvant
- Analytical methods
- Bioassays

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Elements of the improvement effort

Complex designs & processing scenarios need multipoint optimization

Isolated improvements will hardly result in significant savings, nor can they be justified due to the resulting “cost of change”

To get away from costly and inflexible legacy manufacturing concepts. Process designs need to enable smaller scale operations with:

- Higher productivity of each step
- Flexibility from modular unit operations and from scheduling freedom
- Single-use equipment as a means to delete non-productive activities from the operation

Once deployed smartly, the combination of such...

...improvement elements will yield the cost targets
Cell based Influenza pilot case study

Focus on removal of DNA - Capto™ Q

10 fold lower resin cost than comparable legacy Q adsorbers

Reduces DNA below detection, < 11ng/ml
Levels at limit 0.2 ng DNA/µg HA

Focus on removal of HCP - Capto™ Core 700

20 fold more product per liter resin in half the time

Reduces protein/HA: 4-6x
Level well below 6 µg prot/HA

Capto Q and Capto Core 700 operated in flow-through mode can be connected in series, as one integrated step!
Egg based Influenza case study

- High density culture
  - Smaller scale
  - Decoupling of steps
  - Flexible operation

- High capacity resins
  - Smaller scale
  - Higher yields
  - Modular use

- Single-use systems
  - Fast set-up
  - Efficient use of time
  - Improved cash-flow

Conclusions
- HA recovery over Capto Core 700 step > 90%
- Excellent ovalbumin reduction
Core beads – the application principle

- DNA
- Host Cell Proteins
- Virus vaccine or VLPs
## Single-Use Vaccine Mfg. Case Studies

<table>
<thead>
<tr>
<th>Product</th>
<th>Purpose</th>
<th>Cell Line</th>
<th>Bioreactor Scale/type</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Nile subunit vaccine</td>
<td>GMP Mfg. for Client Partner</td>
<td>S2 Insect cells</td>
<td>XDR-200 mammalian</td>
</tr>
<tr>
<td>YF Inactivated Virus vaccine</td>
<td>GMP Mfg. for Xcellerex Product</td>
<td>Vero cells microcarriers</td>
<td>XDR-50 mammalian</td>
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<tr>
<td>recombinant Protective Antigen (rPA)</td>
<td>DoD Accelerated Mfg. Contract</td>
<td>Pfenex pseudomonas bacteria</td>
<td>XDR-50 microbial</td>
</tr>
<tr>
<td>Swine flu H1</td>
<td>DoD Accelerated Mfg. Contract Live Fire</td>
<td>Pfenex pseudomonas bacteria</td>
<td>XDR-50 microbial</td>
</tr>
<tr>
<td>Swine flu H1N1 VLP</td>
<td>GMP CMO Contract</td>
<td>SF-9 Insect cells</td>
<td>XDR-1000</td>
</tr>
<tr>
<td>Dengue soluble antigen 4 serotypes</td>
<td>GMP mfg. for clinical trials</td>
<td>Insect cells</td>
<td>XDR-200</td>
</tr>
</tbody>
</table>
Yellow Fever Vaccine Mfg. Experience
Vero cell based, killed virus vaccine

1st Gen process:
- Cytodex 1, 50L scale USP, titer = $1 \times 10^8$ pfu/mL
- SF and protein free medium
- 25L DSP process, validated BPL virus kill step
- alum adjuvanted
- Yield: 60 purified doses/L (8.6 log 10/0.5mL)
- 4 GMP batches, IND filed, Phase 1 trial complete

2nd Gen process – COGS reduction, efficiency improvements:
- USP: cell density improved by 2x, bead to bead process
- DSP: Improved yield from 25% to 75% at RT
- Overall improved combined yield TBD – expect 200 doses/L
- Removed UF/DF, introduced chromatographic separations
- Eliminated ultracentrifuge step
- Lowered HCP to <200 ng/mL, DNA to < 10 pg/mL
Problem statement:
- One-time and repetitive step preparation can take more time than the step itself
- Waiting for hand-over between steps is standard in non-integrated processes
- Classic equipment requires significant capital long before revenue generation starts

Single-use: focus on core function of step, pay when run, release plant time

Value added work
- Non-value added work
- Necessary non-value added work

Single-use can shrink the process related plant occupancy by 50%
Six-fold reduction in setup time

Prep time savings enable use of one system for three steps

Single-use systems

- Fast set-up
- Efficient use of time
- Improved cash-flow

High density culture
- Smaller scale
- Decoupling of steps
- Flexible operation

Failure free packing
- Easy transfer
- Improved TCO

Smart columns

Delete non-value added activities
ÄKTA™ ready chromatography system & columns

- System preparation incl. column packing down from 11 hrs to < 2 hrs
- Disposable flow path, 30 min to next run
- One system for all chromatography in a vaccine process

Günter Jagschies
GE Healthcare Life Sciences
Uppsala, Sweden
Additional opportunities

Specifically selective resins for vaccine purification for Influenza and Adeno Associated Virus (AAV)

Columns with automated packing and low operator dependency. Smooth site transfer with minimal risk for time losses and failures

Continuous chromatography reduces resin volume by up to 50% and improves yield to near 100%. Simple, smart controls.
Pandemic Influenza – a global challenge

• This is not just about a pandemic, but about the whole direction of a country’s or region’s health care policy
• Preparedness includes a solid every day basis of vaccine manufacturing AND an ability to ramp up one particular vaccine production if or when needed.
• The combination of capability for the normal situation with the ability to respond to an emergency requires efficient coordination, infrastructure support, and collaboration.
• Today it is unlikely that one organization or one country can do this alone.
Small facility investment cost
Published CAPEX values: large stainless steel plants

Construction costs are adjusted to 2009 level using 3% constant inflation rate.

Legacy facilities bear a huge fixed cost burden

\[ y = 2,9251x + 37,813 \]
\[ R^2 = 0,9631 \]

<table>
<thead>
<tr>
<th>Bioreactors [L]</th>
<th>Configuration</th>
<th>Cost [$ M]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.000</td>
<td>2x 1.000</td>
<td>43.7</td>
</tr>
<tr>
<td>6.000</td>
<td>6x 1.000</td>
<td>55.4</td>
</tr>
<tr>
<td>12.000</td>
<td>6x 2.000</td>
<td>72.9</td>
</tr>
</tbody>
</table>

CAPEX can be 30% lower for single-use facility

Confirmed in bottom-up analysis by M+W authors ($42.6M)
Elements of an Emergency Ramp-up

• Have a vaccine technology ready-to-go, you can’t hope for such technology to become available when the emergency happens.
• Have ongoing production and solid production experience with the staff managing and operating the facilities.
• Have facilities with re-configurable production areas enabling a switch to the emergency program.
• Have facilities with additional space to grow production under the emergency program: surge capacity.
• Have similar facilities throughout the country or region that can do the same things when needed, in the same way.
• Have a scale up concept verified that grows production through adding lines rather than through increasing the size of the line (the latter requires to re-design the entire plant).
• Assume the worst: 50% of the workforce will get sick, borders will close, delivery agreements will not be met, national interests and protection will be prioritized.
Final word on the money...
Sources of cash to pay (more) for vaccines

A different perspective on the debate about vaccine affordability, rather targeting the illegal or unwanted...

Illegal drugs: $300-400 billion

Global corruption: $2,600,000,000,000/yr (OECD)²

The African Union (2002) estimates that 25% of the GDP of African states or $148 billion, is lost to corruption every year.

Illegal small arms: $5-10 billion

State leader embezzlement: $30,000,000,000 (Transparency International)³

³ 10 known leaders of countries with average GDP per capita < $1,000 (total during their time in power)

Average armed conflict: $250,000,000,000/yr (CCC)⁴

Without peace there cannot be development and the Millennium goals become unattainable.

Revenue top vaccine players (2014): $25,000,000,000/yr (Sanofi, Merck, GSK, Pfizer, Novartis)

There is a heated debate about vaccine pricing by the leading manufacturers. While correct in a number of observations, this debate may not focus on the right target...

Vaccines only

Profit¹ top vaccine players (2014): $4,000,000,000/yr (Sanofi, Merck, GSK, Pfizer, Novartis)

¹ author’s profit estimate: 15%

For the period 1990-2008 (18 years) there were 132 actual conflicts. CCC assumes 4 per year each lasting 4 years

2 Income per capita of $2000 could expect to see its income rise to $8000 in the long run.

Child mortality could fall as much as 75 percent

² Corruption is not just a problem of the developing world

³ 10 known leaders of countries with average GDP per capita < $1,000 (total during their time in power)

⁴ Copenhagen Consensus Center 2012
World Immunization Week 2015 (WHO)

A WORLD FREE OF VACCINE-PREVENTABLE DEATH IS IN REACH
Summary

Preparedness

• Management / government decisions paving the way
• Standardized process modules enable ramp-up
• Local modular facilities give faster response
• R&D needs to ramp up for vaccine future
• Building the capability and capacity of DCVMN members

Agility and flexibility…
…ready to process!
Acknowledgement

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Q&A