Disease Emergence
at the Animal-Human Interface

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University of Veterinary Medicine Hannover
Chair One Health Platform

IMED 2018
• Vienna, Austria •
November 9-12, 2018
Plague of Athens: 17th century

Black Death 14th century

Cholera 19th century

Morens et al., Lancet ID 2008

Zoonosis at the basis

Maori monument for the 1918 flu

Human factors at the basis
Trends in infectious disease-related mortality rates in the United States

Deaths per year per 100,000 population

2000

1500

1000

500

1900 1920 1940 1960 1980 2000

——— All diseases

——— Non-infectious diseases

——— Infectious diseases

Data: CDC
Past decades: zoonoses at the origin of major human disease outbreaks


The importance of understanding the human-animal interface: from early hominins to global citizens
(Re-)emerging infectious diseases facilitated by

The Microbial Agent
- Genetic adaptation and change
- Polymicrobial diseases

The Human Host
- Human susceptibility to infection
- Human demographics and behavior
- Intent to harm (bioterrorism)
- Occupational exposures

The Human Environment
- Climate and weather
- Changing ecosystems
- Economic development and land use
- Technology and industry
- Poverty and social inequality
- Lack of public / animal health services
- Animal populations
- War and famine
- Lack of political will

Morens DM et al., PLoS Pathog. 2013 July; 9(7)
The One Health Concept

- **ONE HEALTH RECOGNIZES THAT THE HEALTH OF HUMANS, ANIMALS AND ECOSYSTEMS ARE INTERCONNECTED.**

- **A COORDINATED, MULTIDISCIPLINARY AND CROSS-SECTORAL APPROACH TO ADDRESS RISKS THAT ORIGINATE AT ANIMAL-HUMAN-ECOSYSTEMS INTERFACES.**
The AIDS pandemic: started 30 years ago
>55 million infected, >20 million deaths, 1.8 million infected and about 1 million die annually.

Complex mix of pre-disposing factors

Animal contacts (bush meat consumption)
Behaviour (changing taboos, mores, i.v. drug abuse)
Demography (urbanisation...)
Mobility (air travel, wars ...)
Poverty (vs wealth)
Medical practices (iatrogenic transmission)
Virus adaptation (mutation, recombination)
Experimental HIV vaccine shows promise in early trial

Scientists have created an experimental HIV vaccine that is able to neutralise HIV in animals.

An experimental HIV vaccine is safe and triggers strong immune responses in healthy adults and in monkeys, researchers report.

They say it also protected two-thirds of monkeys against an HIV-like virus.

Though results of animal studies are not always the same in humans, researchers are encouraged by this early-stage study, which included nearly 400 healthy people. For their next step, they are launching a new vaccine trial that will include 2,600 women in southern Africa who are at risk of HIV infection.

According to Statistics South Africa, the
Since smallpox eradication:
animal poxvirus infections in humans!

Wolfs et al. E.I.D. 2002
Zijlstra et al BMJ 2013

ProMED-mail 9 Jan 2003
Stittelaar et al., Nature, 2006
Antiviral treatment is more effective than smallpox vaccination upon lethal monkeypox virus infection

Koert J. Stittelaar¹, Johan Neyts³, Lieve Naesens³, Geert van Amerongen¹,⁴, Rob F. van Lavieren⁵, Antonin Holý⁶, Erik De Clercq³, Hubert G. M. Niesters¹, Edwin Fries¹, Chantal Maas¹, Paul G. H. Mulder², Ben A. M. van der Zeijst⁴ & Albert D. M. E. Osterhaus¹

Figure 3 | Viral load profiles after infection with MPXV. a, Plasma loads of monkeys treated as described in Figs 1, 2. b, Plasma MPXV loads of monkeys (treated as described in Fig. 1) 5 or 7 days after infection. Lines show average ± s.e.m. Statistical analysis of the pairwise comparisons of survival

Vaccine versus antiviral stockpiles for pox outbreak preparedness
Morbilliviruses crossing species barriers
A pandemic risk after measles eradication?

Should we continue measles vaccination for ever?
CD150 is the primary morbillivirus entry receptor

PVRL4 is the morbillivirus receptor on epithelial cells

Long-term measles-induced immunomodulation increases overall childhood infectious disease mortality

Michael J. Mina,1,2* C. Jessica E. Metcalf,1,3 Rik L. de Swart,4 A. D. M. E. Osterhaus,4 Bryan T. Grenfell1,3

Measles immune suppression; lessons from the macaque model.
CD45RA(-) memory T-lymphocytes and follicular B-lymphocytes killed
Trump claims vaccines and autism are linked but his own experts vehemently disagree

The president has tweeted more than 20 times claiming – falsely – there is a link between vaccines and autism
<table>
<thead>
<tr>
<th>Year of Onset</th>
<th>Country</th>
<th>Epicenter or Epicenters</th>
<th>No. of Cases (Case Fatality Rate [%])</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>Zaire (current DRC)</td>
<td>Yambuku</td>
<td>318 (88)</td>
</tr>
<tr>
<td>1977</td>
<td>Zaire (current DRC)</td>
<td>Tandala</td>
<td>1 (100)</td>
</tr>
<tr>
<td>1994</td>
<td>Gabon</td>
<td>Mékouka, Ogooué-Ivindo Province</td>
<td>52 (60)</td>
</tr>
<tr>
<td>1995</td>
<td>Zaire (current DRC)</td>
<td>Kikwit</td>
<td>315 (81)</td>
</tr>
<tr>
<td>1996</td>
<td>Gabon</td>
<td>Mayibout, Ogooué-Ivindo Province</td>
<td>37 (57)</td>
</tr>
<tr>
<td>1996</td>
<td>Gabon</td>
<td>Booué, Ogooué-Ivindo Province</td>
<td>62 (75)</td>
</tr>
<tr>
<td>2001</td>
<td>Gabon and ROC</td>
<td>Mékambo, Ogooué-Ivindo Province (Gabon)</td>
<td>65 (82)</td>
</tr>
<tr>
<td>2001</td>
<td>ROC and Gabon</td>
<td>Mbomo, Kéllé, Cuvette Ouest Region (ROC)</td>
<td>59 (73)</td>
</tr>
<tr>
<td>2002</td>
<td>ROC</td>
<td>Mbomo, Kéllé, Cuvette Ouest Region</td>
<td>143 (89)</td>
</tr>
<tr>
<td>2003</td>
<td>ROC</td>
<td>Mbomo, Cuvette Ouest Region</td>
<td>35 (83)</td>
</tr>
<tr>
<td>2007</td>
<td>DRC</td>
<td>Luebo, Kasai Occidental Province</td>
<td>264 (71)</td>
</tr>
<tr>
<td>2008</td>
<td>DRC</td>
<td>Mweka and Luebo, Kasai Occidental Province</td>
<td>32 (47)</td>
</tr>
<tr>
<td>2014</td>
<td>DRC</td>
<td>Ikanamongo Village, Equateur Province</td>
<td>69 (71)</td>
</tr>
<tr>
<td>2017</td>
<td>DRC</td>
<td>Kagbono, Likati, Bas Uélé Province</td>
<td>8 (50)</td>
</tr>
<tr>
<td>2018</td>
<td>DRC</td>
<td>Ikoko-Impenge, Bikoro, Equateur Province</td>
<td>54 (61)</td>
</tr>
<tr>
<td>2018*</td>
<td>DRC</td>
<td>Mangina and Beni, North Kivu Province</td>
<td>74 (46)</td>
</tr>
</tbody>
</table>

* This outbreak was ongoing as of mid-August. Reported case numbers and case fatality rates are provisional. DRC denotes Democratic Republic of Congo, and ROC Republic of the Congo.

Munster V et al., NEJM 2018
Ebola vaccines: ‘Too many To late’
Reperant et al Science 2015

From rural to urban (…to worldwide)
Role of healthcare workers in early epidemic spread of Ebola: policy implications of prophylactic compared to reactive vaccination policy in outbreak prevention and control

Table 3 Indicative proportion of early outbreak prevented by implementing different vaccination strategies: prospective versus reactive vaccination of healthcare workers

<table>
<thead>
<tr>
<th>Epidemic</th>
<th>Country</th>
<th>Total number of cases</th>
<th>Total number of deaths</th>
<th>Cases included in epidemic tree</th>
<th>Strategy 1: Vaccinate prophylactically (100% coverage)</th>
<th>Strategy 2: Vaccinate prophylactically approx. 75% of HCWs</th>
<th>Strategy 3: Vaccinate reactively (lag-time 42 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 West Africa</td>
<td>Guinea [22]</td>
<td>3,792</td>
<td>2,530</td>
<td>71</td>
<td>61 % (43/71)</td>
<td>366 % (26/71)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Liberia [24–28]</td>
<td>10,672</td>
<td>4,808</td>
<td>9</td>
<td>67 % (6/9)</td>
<td>11 % (1/9)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Sierra Leone</td>
<td>13,683</td>
<td>3,953</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Nigeria [23]</td>
<td>20</td>
<td>8</td>
<td>20</td>
<td>80 % (16/20)</td>
<td>50 % (10/20)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mali [32–34]</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>38 % (3/8)</td>
<td>13 % (1/8)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>USA [35]</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>75 % (3/4)</td>
<td>50 % (2/4)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>UK [36] and</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>100 % (2/2)</td>
<td>50 % (1/2)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Spain [37]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Senegal [38]</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>28,183</td>
<td>11,306</td>
<td>115</td>
<td>63.5 % (73/115) (95% confidence interval 0.54–0.72)</td>
<td>35.7 % (41/115) (95% confidence interval 0.27–0.45)</td>
<td>0</td>
</tr>
<tr>
<td>Historic outbreaks</td>
<td>Kikwit [6, 39–43]</td>
<td>315</td>
<td>250</td>
<td>9</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mosango [44]</td>
<td>23</td>
<td>18</td>
<td>23</td>
<td>100 % (9/9)</td>
<td></td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td>Yambuku [2]</td>
<td>318</td>
<td>280</td>
<td>45</td>
<td>65.1 % (125/192) (95% confidence interval 0.58–0.72)</td>
<td>42.0 % (58/138) (95% confidence interval 0.34–0.51)</td>
<td>0 % (0/609)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>192</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Cases numbers accurate as of 06/09/2015
NR, Not reported
Chikungunya virus
Past years
ZIKA: Out of Africa
### Arbovirus vaccines: most are still lacking

<table>
<thead>
<tr>
<th>Arbovirus</th>
<th>Preclinical</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Approved ex US</th>
<th>Approved US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dengue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japanese encephalitis</td>
<td></td>
<td></td>
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<tr>
<td>West Nile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chikungunya</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow fever</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ross River</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VEE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rift Valley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zika</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sindbis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ARBOVIRUSES: PREVENT ARTHROPOD BITES**
### Identification of viral pathogens

**ErasmusMC / RIZ TiHo**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>CDV as the cause of mass mortality in Serengeti lions</td>
</tr>
<tr>
<td>1996</td>
<td>γ-herpesvirus in seals (phocid herpesvirus-2)</td>
</tr>
<tr>
<td>1997</td>
<td>Monk seal morbilliviruses (MSMV-WA/G)</td>
</tr>
<tr>
<td>1997</td>
<td>Influenza A (H5N1) virus in humans</td>
</tr>
<tr>
<td>1998</td>
<td>Lentivirus from Talapoin monkeys (SIVtal)</td>
</tr>
<tr>
<td>1999</td>
<td>Influenza B virus in seals</td>
</tr>
<tr>
<td>2000</td>
<td>Human metapneumovirus (hMPV)</td>
</tr>
<tr>
<td>2002</td>
<td>Re-emerging PDV in Europe</td>
</tr>
<tr>
<td>2003</td>
<td>SARS CoV cause of SARS in humans (Koch`s postulates)</td>
</tr>
<tr>
<td>2003</td>
<td>Influenza A (H7N7) virus in humans</td>
</tr>
<tr>
<td>2004</td>
<td>Fourth human coronavirus (CoV NL)</td>
</tr>
<tr>
<td>2005</td>
<td>H16 influenza A viruses (new HA) in black headed gulls</td>
</tr>
<tr>
<td>2008</td>
<td>Dolphin herpesvirus</td>
</tr>
<tr>
<td>2009</td>
<td>Deer astrovirus</td>
</tr>
<tr>
<td>2010</td>
<td>Human astrovirus, human picobirnavirus</td>
</tr>
<tr>
<td>2011</td>
<td>Ferret coronavirus, ferret HEV, porcine picobirnavirus, stone marten anellovirus. Influenza A (H1N1) virus in dogs</td>
</tr>
<tr>
<td>2012</td>
<td>Human calicivirus, MERS CoV, boa arenaviruses</td>
</tr>
<tr>
<td>2013</td>
<td>Seal parvovirus, seal anelloviruses, deer papillomavirus, fox hepevirus, fox parvovirus, turtle herpesvirus</td>
</tr>
<tr>
<td>2014</td>
<td>Canine bocavirus, porcine bocavirus, python nidovirus, camel circovirus, phocid herpes virus-7</td>
</tr>
<tr>
<td>2015</td>
<td>Influenza A (H10N7) virus seals</td>
</tr>
<tr>
<td>2017...</td>
<td>Morbillivirus fin whale, hepadnavirus Tinamou, rec.canine circovirus, rec.canine bocavirus, herpesvirus sperm whale, Batai virus seal, avian metapneumovirus, novel pestivirus...</td>
</tr>
</tbody>
</table>

**Funding:**

**EU:** EMPERIE; ANTIGONE; PREPARE; COMPARE...

**NL:** VIRGO-FES...

**DFG:** N-RENNT
Press conference of SARS etiology network

Official declaration of SARS-CoV as the etiologic agent

April 16, 2003
WHO Geneva

Short- and mid-term objectives:
- clarification of transmission routes and natural history
- establishment and evaluation of diagnostic tools

Fouchier et al., Nature 2003
Kuiken et al., Lancet 2004
To date: estimated >2260 cases in 27 countries with >800 deaths

Saudi Arabia, Malaysia, Jordan, Qatar, Egypt, the United Arab Emirates, Kuwait, Oman, Algeria, Bangladesh, the Philippines, Indonesia (none confirmed), UK, and USA

Zaki et al NEJM 2012
Antibodies in dromedary camels
(Reusken et al. Lancet ID 2013)

Dromedary camels: carriers of MERS-CoV
(Haagmans et al., Lancet ID 2013)

Identification of the CD 26 MERS-CoV receptor
(Raj et al., Nature 2013)
MVA expressing the MERS-CoV spike protein: PREVENTION AT THE SOURCE?

Fei Song et al. JV 2013

A ONE HEALTH APPROACH

Haagmans et al., Science 2016
MVA expressing the MERS-CoV spike protein: PREVENTION AT THE SOURCE?

A ONE HEALTH APPROACH

MVA MERS-S vaccine now in human trials (HCW’s, camel handlers, immune-compromised)

Fei Song et al. JV 2013

Haagmans et al., Science 2016
MERS-CoV vaccine candidates
preclinical development and phase 1 trials

- Plasmid DNA vaccine (Innovio/GeneOne)
- Plasmid DNA vaccine (NIAID, VRC)
- Virus like particles (Novavax)
- MVA vaccine (Sutter / Jenner Institute)
- Adenovirus based vectors (Jenner institute)
- RBD vaccine (Jiang)

MVA expressing the MERS-CoV spike protein:

PREVENTION AT THE SOURCE

A ONE HEALTH APPROACH
Induction of antibodies that neutralize MVA but also camel pox virus

**PRNT90 MERS-CoV virus neutralization titers**

**MVA neutralization**

**Camel pox virus neutralization**

Haagmans et al., Science 2016
Chimeric camel/human heavy-chain antibodies protect against MERS-CoV infection

V. Stalin Raj,1,** Nisreen M. A. Okba,1,* Javier Gutierrez-Alvarez,2 Dubravka Drabek,3 Brenda van Dieren,4
W. Widagdo,1 Mart M. Lamers,1 Ivy Widjaja,2 Raul Fernandez-Delgado,2 Isabel Sola,2 Albert Bensaid,5
Marion P. Koopmans,1 Joaquim Segalés,6,7 Albert D. M. E. Osterhaus,8,9 Berend Jan Bosch,4 Luis Enjuanes,2 and
Bart L. Haagmans1,†

Schematic overview of VHH identification by direct cloning using bone marrow from immunized dromedary camels.
and log relationship was found between cumulative area vaccinated in Switzerland was relatively inexpensive (table 1). Amongst those that spent most on ORV, whereas rabies varied considerably. Poland and Germany were approximate expenditure by different countries to eliminate effort was required in the final phase of elimination (figure 4). The approximate expenditure required to reduce initial incidence by 50 per cent followed (see the electronic supplementary material, figure S2). Cumulative was achieved, albeit with high variation between countries smaller reductions in rabies incidence until elimination increasing cumulative expenditure resulted in progressively (see the electronic supplementary material, figure S1). Previous evaluation of ORV in Europe have focused on individual countries with a single vaccine bait (y axis) and an assumed average bait density of 20 baits/km². Numbers of vaccine doses of different oral vaccine strains against rabies over the past four decades (x axis) based on the cumulative area ever vaccinated was estimated as: c 1/ \(a\) a c \(b\) \(c\) b 1/ 2010 1983. Figure 2. ORV effort and rabies cases. (a) Spatial extent of ORV area and the total number of ORV campaigns conducted in each country between 1978 and 2010. Reported rabies cases in (b) 1983 and (c) 2010.
Last four pandemics

1918
“Spanish Flu”
>40 million deaths

A(H1N1)

1957
“Asian Flu”
1-4 million deaths

A(H2N2)

1968
“Hong Kong Flu”
1-4 million deaths

A(H3N2)

2009
“Mexican flu”
0.2-0.3 million deaths

A(H1N1)

Credit: US National Museum of Health and Medicine
## Recent zoonotic transmissions from birds -confirmed human cases-

<table>
<thead>
<tr>
<th>Subtype</th>
<th>Country</th>
<th>Year</th>
<th># Cases</th>
<th># Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>H7N7</td>
<td>UK</td>
<td>1996</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>H5N1</td>
<td>Hong Kong</td>
<td>1997</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>H9N2</td>
<td>SE-Asia</td>
<td>1999</td>
<td>&gt;2</td>
<td>0</td>
</tr>
<tr>
<td>H5N1</td>
<td>Hong Kong</td>
<td>2003</td>
<td>2?</td>
<td>1</td>
</tr>
<tr>
<td>H7N7</td>
<td>Netherlands</td>
<td>2003</td>
<td>89</td>
<td>1</td>
</tr>
<tr>
<td>H7N2</td>
<td>USA</td>
<td>2003</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>H7N3</td>
<td>Canada</td>
<td>2004</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>H5N1</td>
<td>SE-Asia/M-East/</td>
<td>2003-18*</td>
<td>&gt;840</td>
<td>&gt;450</td>
</tr>
<tr>
<td></td>
<td>Europe/W-Africa</td>
<td></td>
<td></td>
<td>(increasing)</td>
</tr>
<tr>
<td>H7N9</td>
<td>PR China</td>
<td>2013-18</td>
<td>&gt;1500</td>
<td>&gt;600</td>
</tr>
<tr>
<td>H9, H10, H6..</td>
<td>Asia...</td>
<td>ongoing</td>
<td>&lt;5</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>
Most H5N1 outbreaks in European wild birds occurred where surface temperatures were just above freezing.

Avian Influenza: Asia
HPAI H5N1 virus passaging in ferrets - toward transmissibility -

Five substitutions are sufficient for airborne transmission between ferrets

Munster et al., Science 2009
Herfst et al., Science 2012
Russel et al., Science 2012
Linster et al., Cell 2014
Low and highly pathogenic avian influenza A viruses H7N9

Laboratory confirmed: 1584
Deaths: 612
Recoveries: 972

Source: FAO, as of 23 Aug. 2017

Gao et al., 2013
Highly pathogenic avian influenza A virus in poultry/wild birds

Source: FAO, as of 24 Aug. 2017
Crucial ‘peace time’ preparedness elements

 Syndrome surveillance in humans & animals
 Pathogen discovery / identification platforms for humans & animals
 Diagnostics development and distribution platforms
 Mathematical modeling capacity
 Animal models capacity (BSL3/4)
 Pathogenesis study platforms for new infections (transmission…!)
 Preventive intervention platforms (societal, vaccination, antiviral)
 Therapeutics discovery platforms (antivirals, antibiotics, BRM’s…)
 Communication strategies

International collaboration and coordination

- using all available technology (classical and novel!!!)
- are of key importance for their future control !!!
Combating emerging infections at the source in a One Health Approach

Syndrome surveillance in humans & animals
Pathogen discovery / identification platforms for humans & animals
Diagnostics development and distribution platforms
Mathematical modeling capacity
Animal models capacity (BSL3/4)
Pathogenesis study platforms for new infections (transmission...!)
Preventive intervention platforms (societal, vaccination, antiviral)
Therapeutic discovery platforms (antivirals, antibiotics, BRM’s...)
Communication strategies

International collaboration and coordination
- using all available technology (classical and novel!!!!)
- are of key importance for their future control !!!

Crucial ‘peace time’ preparedness elements
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Respiratory Viruses Erasmus MC and TiHo

R. Fouchier / M.Ludlow  Mol.Virology
W.Baumgärtner  Pathology
M. Koopmans  Epidemiology
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B. Haagmans  Virology
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SARS collaborations

Drosten C.  Bonn University Germany
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Guan Y  University of Hongkong
Tam JS  Hongkong Polytech. University
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Rota PA  CDC Atlanta
Stöhr K  WHO Geneva
Tashiro M  NIC Tokyo
v.d. Werf S  Pasteur Paris
Zambon MC  PHE London

MERS and Flu collaborations

Drosten C.  Bonn University Germany
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Bosch BJ  Utrecht University Netherlands
Sutter G  Max. Univ. München Germany
Segalis Q  CRESA Barcelona Spain
Zambon MC  PHE London
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NEWFLUBIRD

NIH-NIAID

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SAVE THE DATE 14-18 June 2020