
We Were There
www.cdc.gov/wewerethere

Ebola in Zaire, 1976: Past as Prologue

September 5, 2019

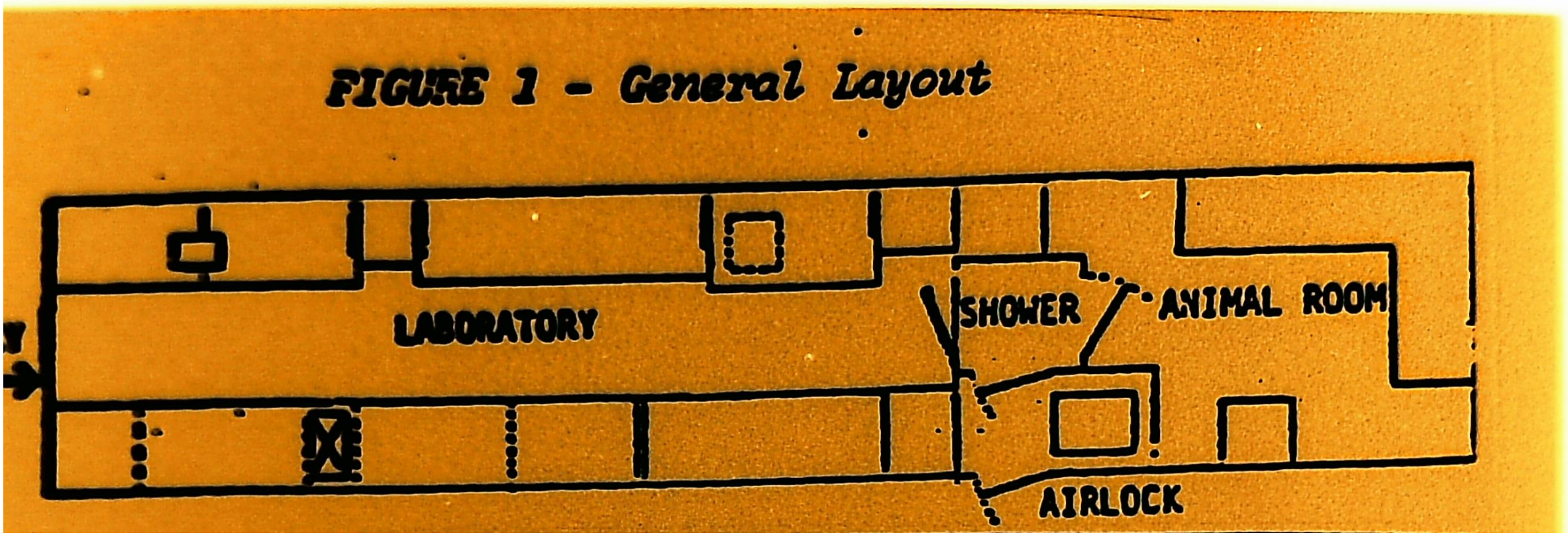
WE WERE THERE (and ready for Ebola)

JAMES V. LANGE, PhD

RESEARCH MICROBIOLOGIST (THEN)

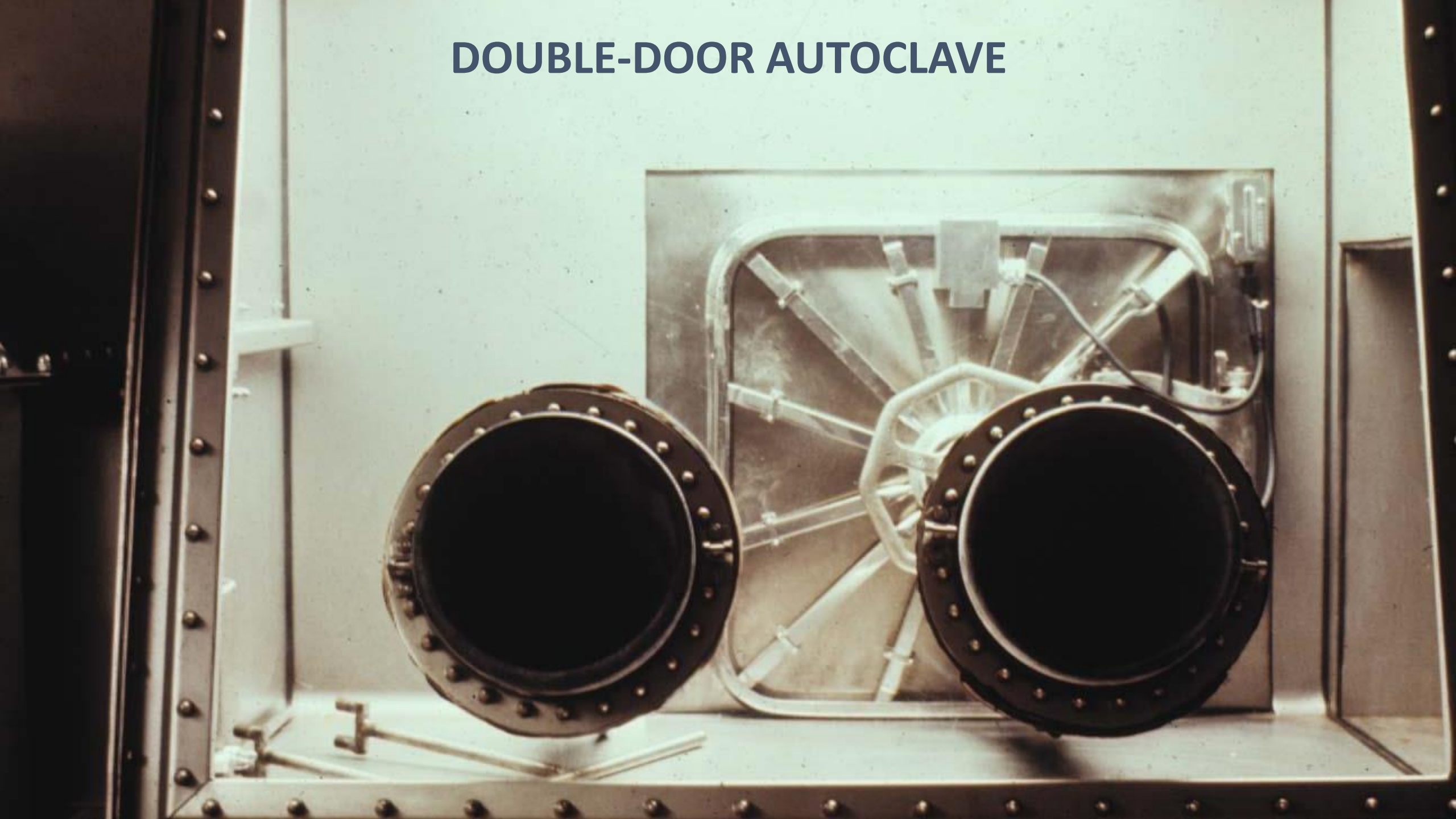
RETIRED (NOW)

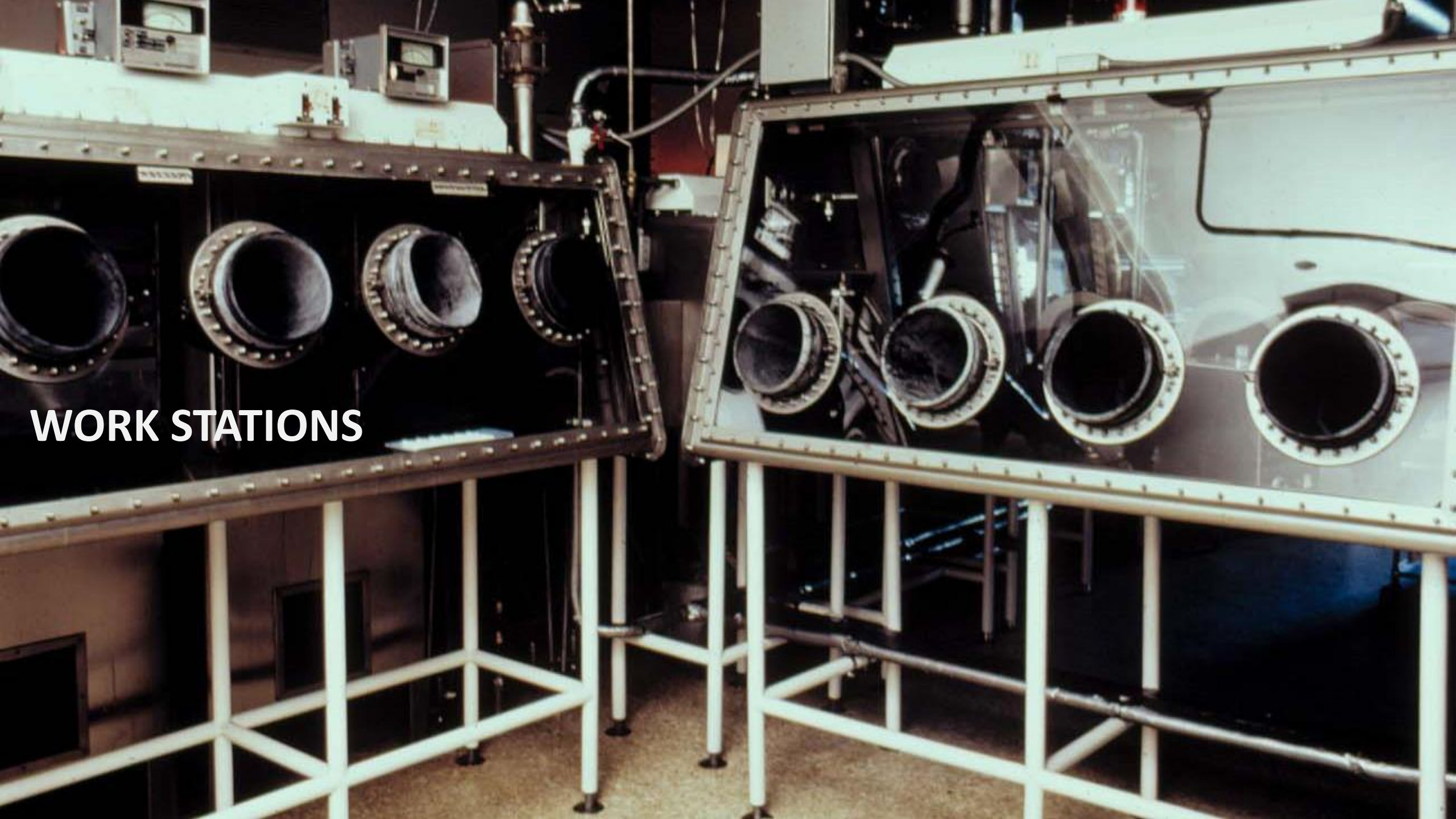
MARBURG TRAILER 1969

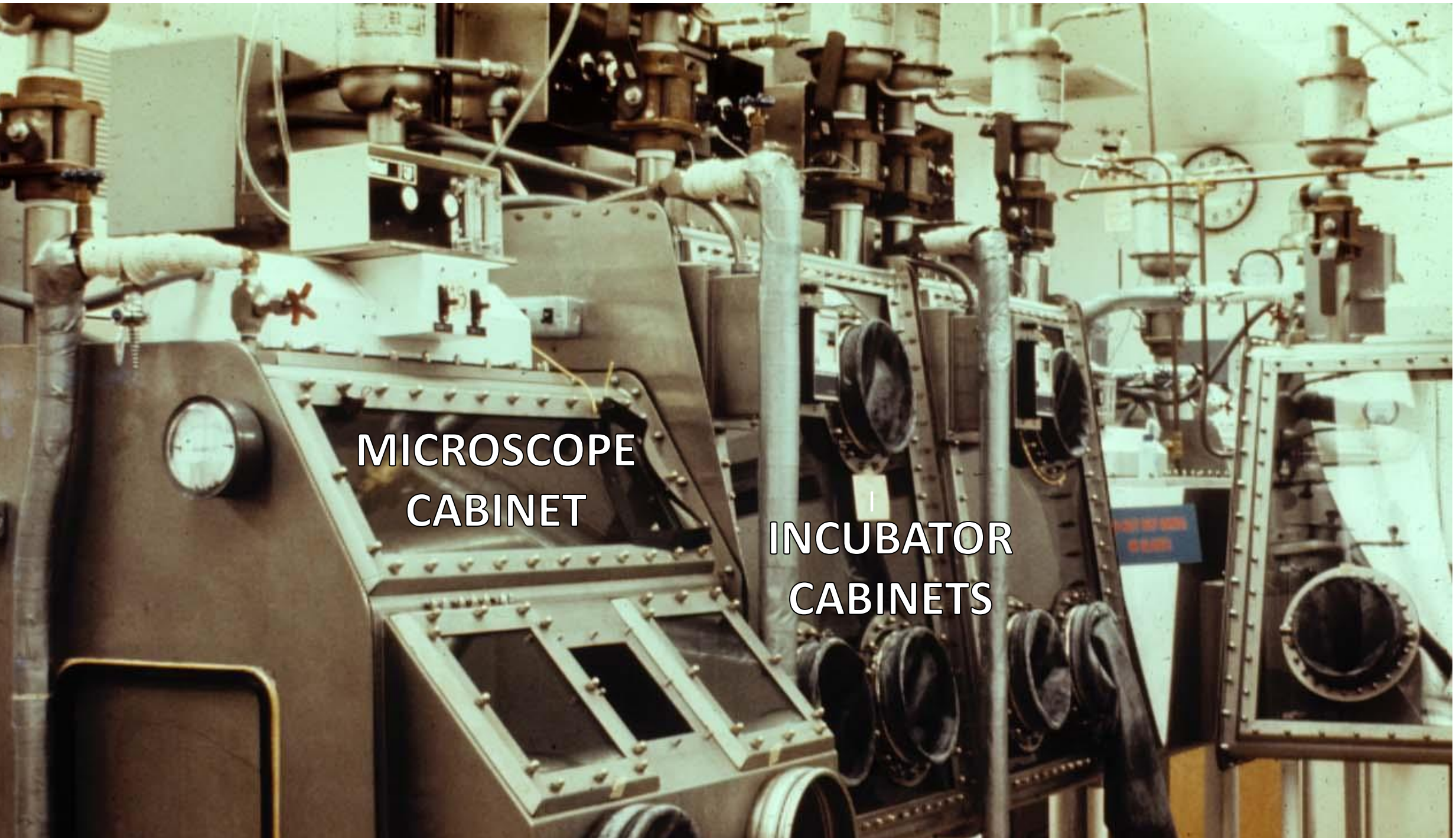


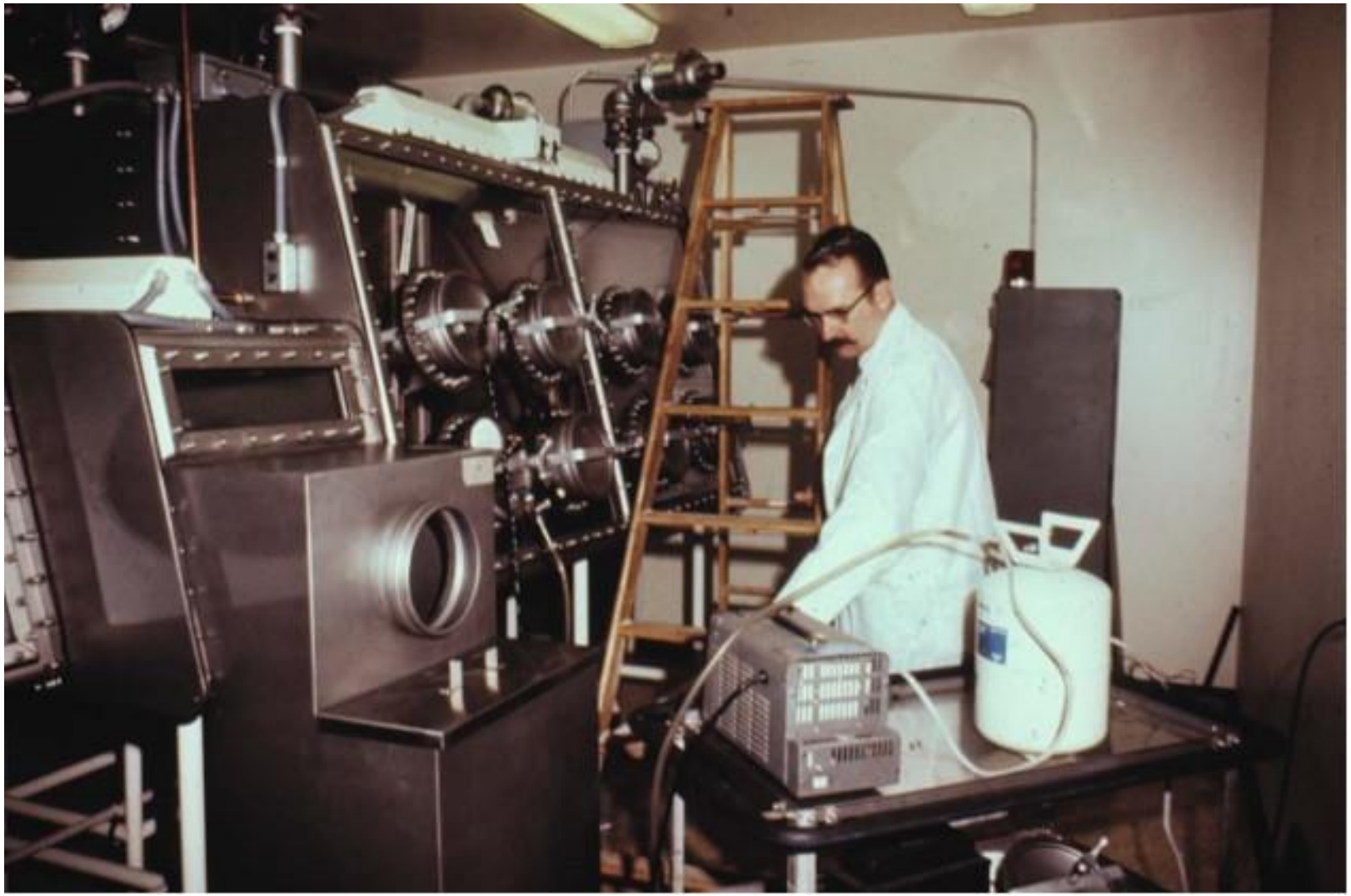

BLDG 8 OPENED IN 1972 (aka 5A, 7A)

DOUBLE-DOOR AUTOCLAVE




WORK STATIONS

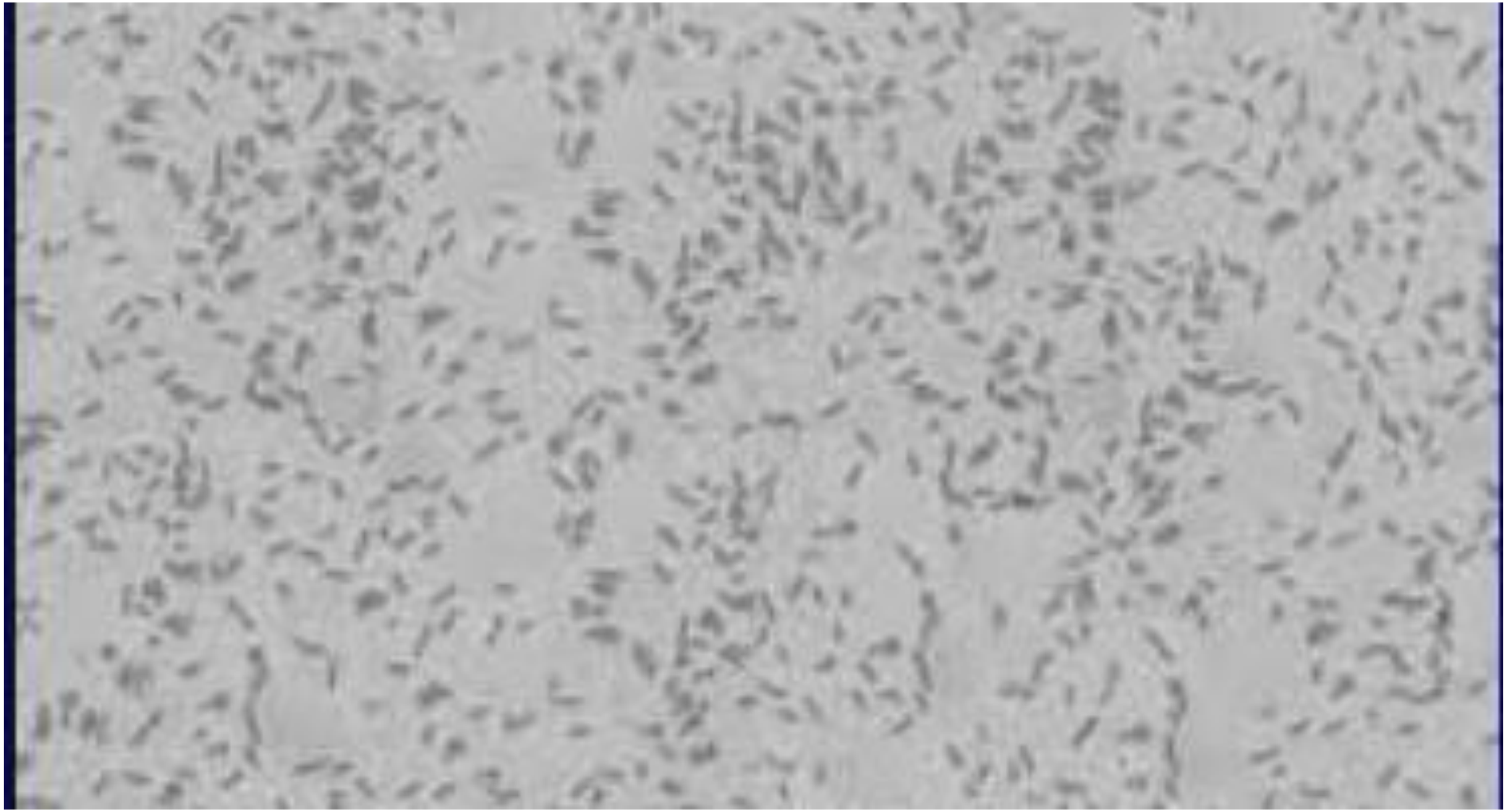

MICROSCOPE
CABINET
INCUBATOR
CABINETS



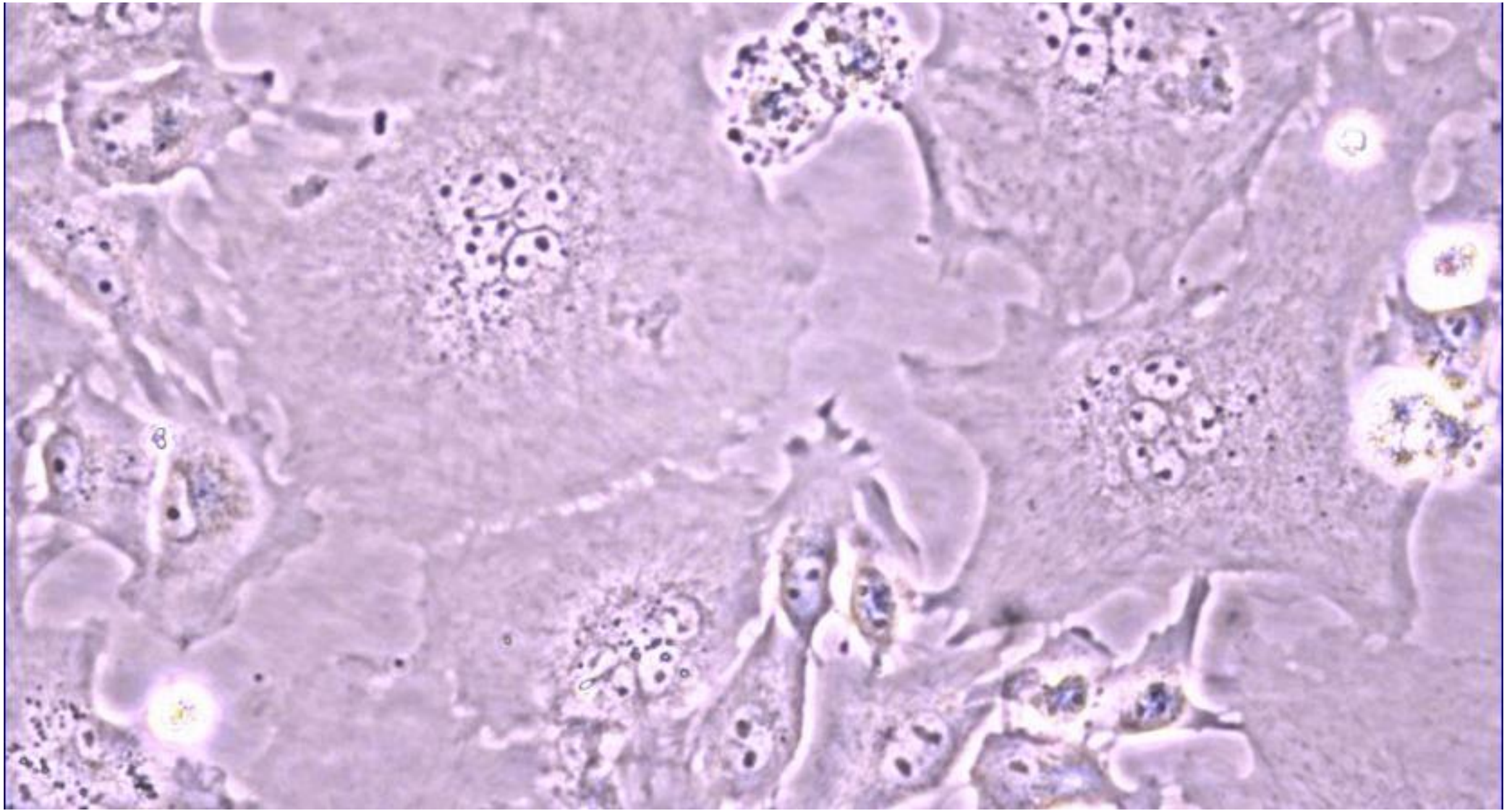
Bldg 8, Dr. Bob Huffaker, Biosafety Director, conducting a leak test on one of the glove box cabinets.

Bldg. 8, Dr. Bill Gary at an autoclave and the pass-through box, used as communications device

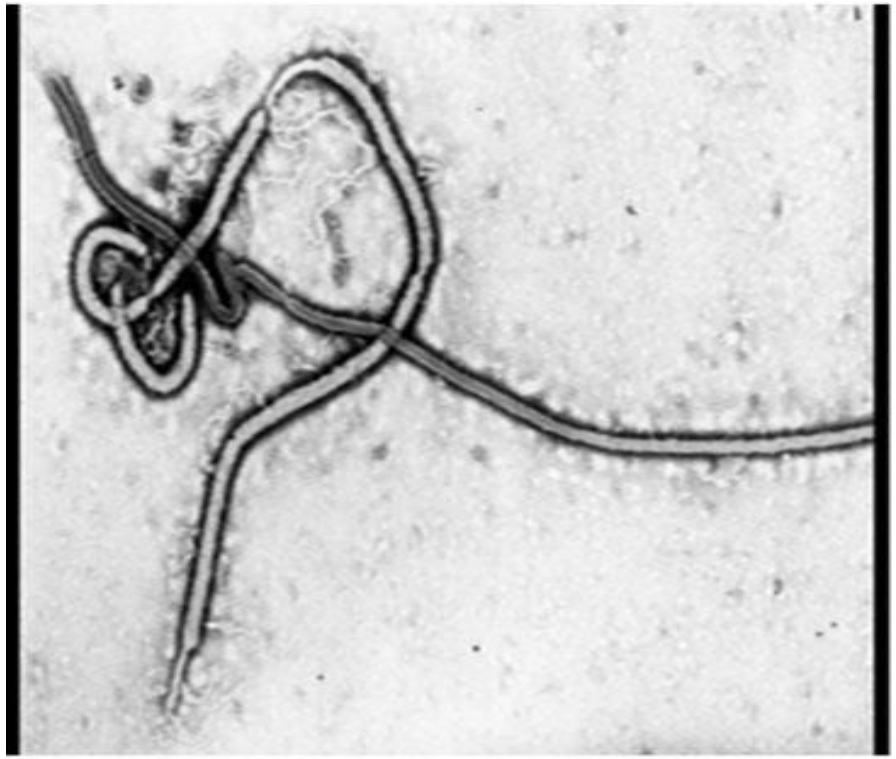
Normal Cells



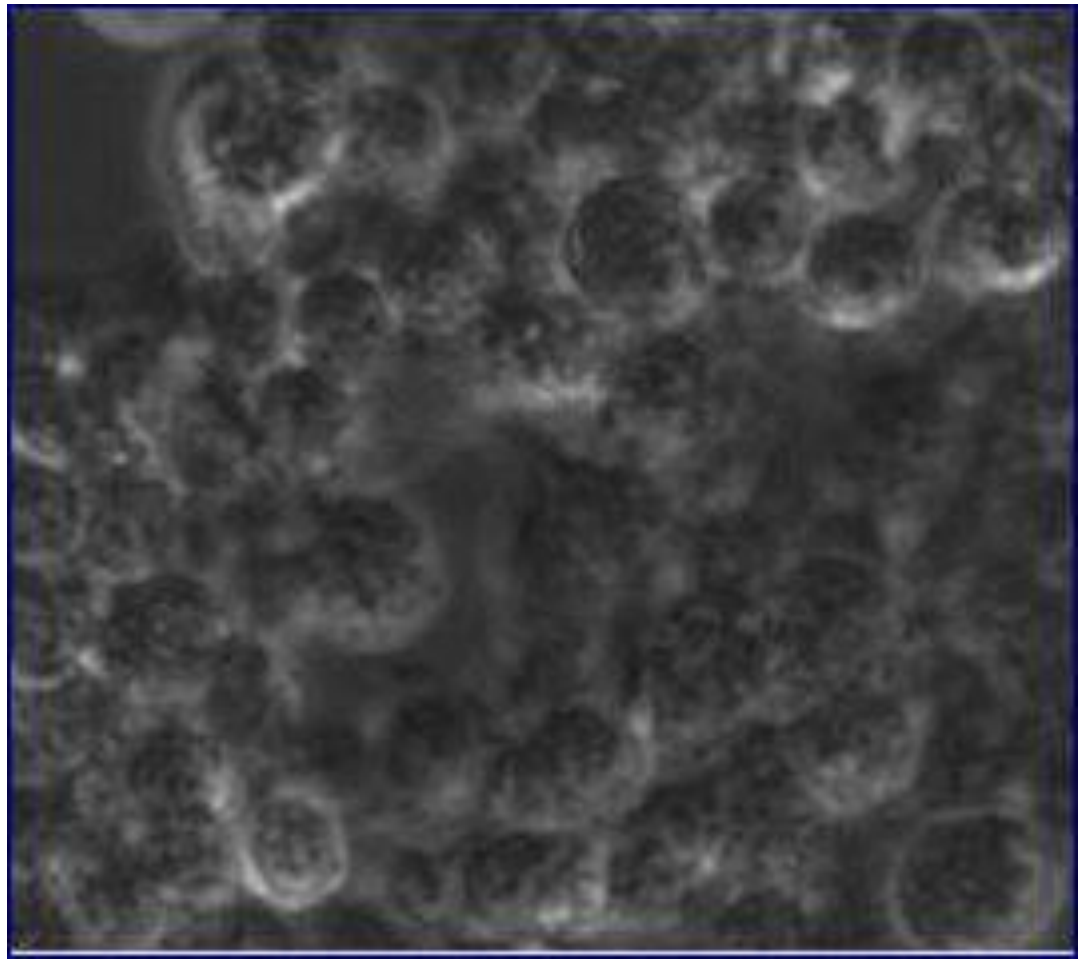
Cells Ruptured After Growth with Ebola



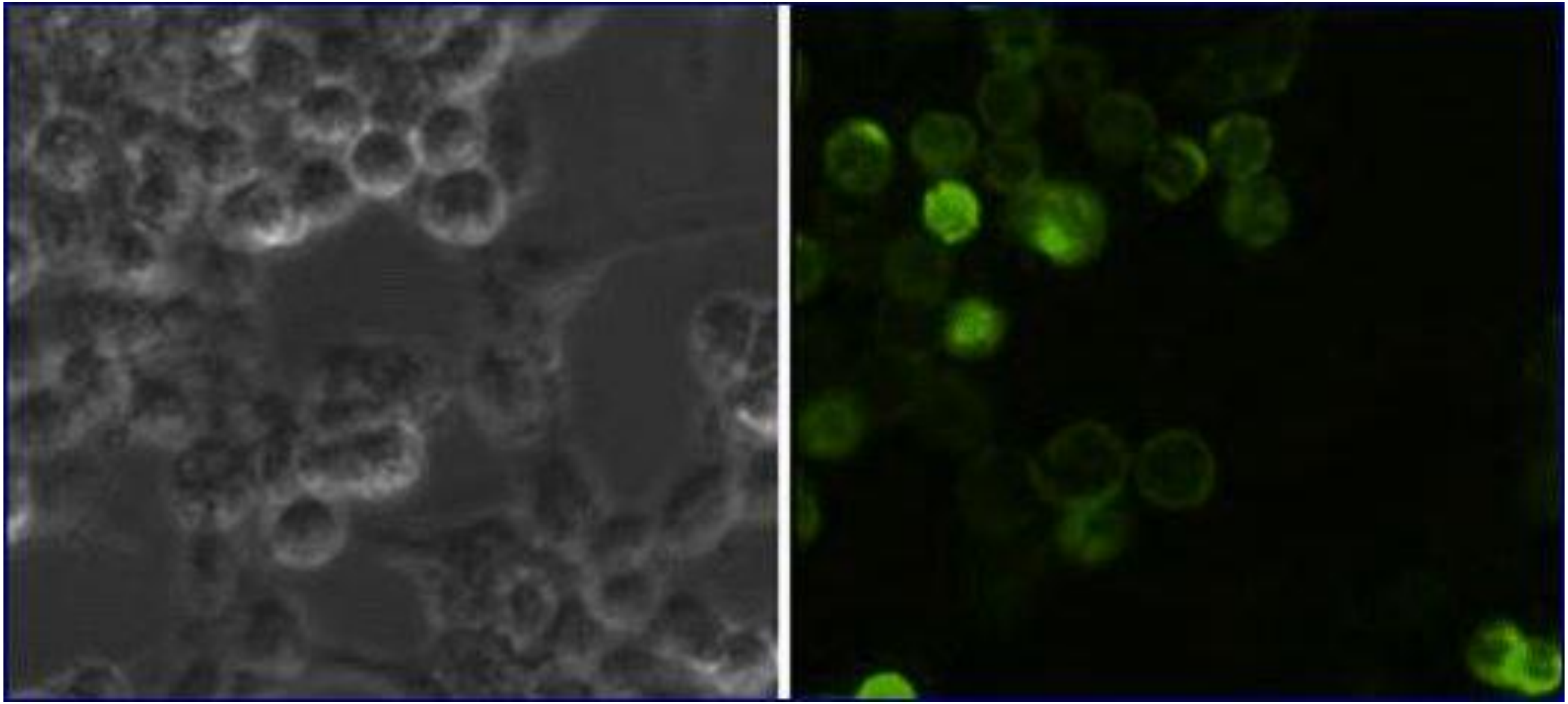
Marburg Virus



Center for Disease Control
Viral Pathology Branch
Atlanta, Georgia 30333
Negative No. 15917
Specimen Marburg '76
Preparation
Magnification 49200
Date 10/13, 19 76
Source: Fred Murphy



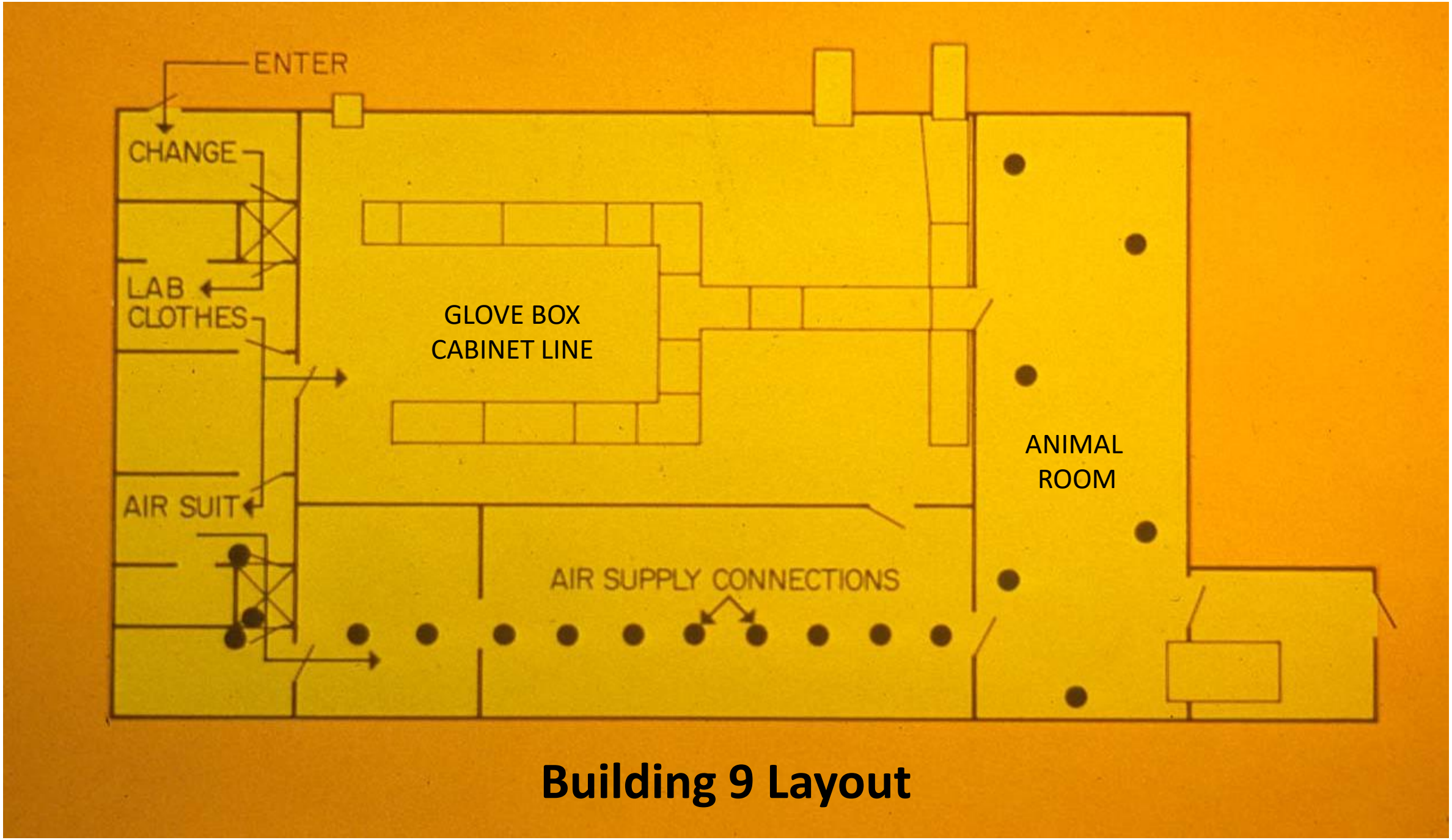
CAPT Patricia Ann Webb



No Immunofluorescence on New Sample

Immunofluorescence on Prior Marburg Sample


1975–1978
9



Building 9 Layout

Sierra Leone

Ebola in Zaire, 1976

Joel Breman, MD, DTPH
Fogarty International Center, NIH
Bethesda, MD 20892

CDC, September 5, 2019

Fogarty International Center

An Electron Micrograph of Marburg Virus, Obtained on October 13, 1976 at the Centers for Disease Control and Prevention

Unfixed diagnostic specimen from
Vero cell passage:
Sodium phosphotungstate x 90,000
(Fred Murphy)

Center for Disease Control
Viral Pathology Branch
Atlanta, Georgia 30333
Negative No. 15917
Specimen Marburg '76
Preparation
Magnification 49200
Date 10/13, 19 76
Source: Fred Murphy

Flying along the Zaire River to Yambuku, DR Congo (Zaire), October 1976

Goals: Determine

- Limits
- Active disease
- Convalescents
- Local needs

Photo: J. Breman

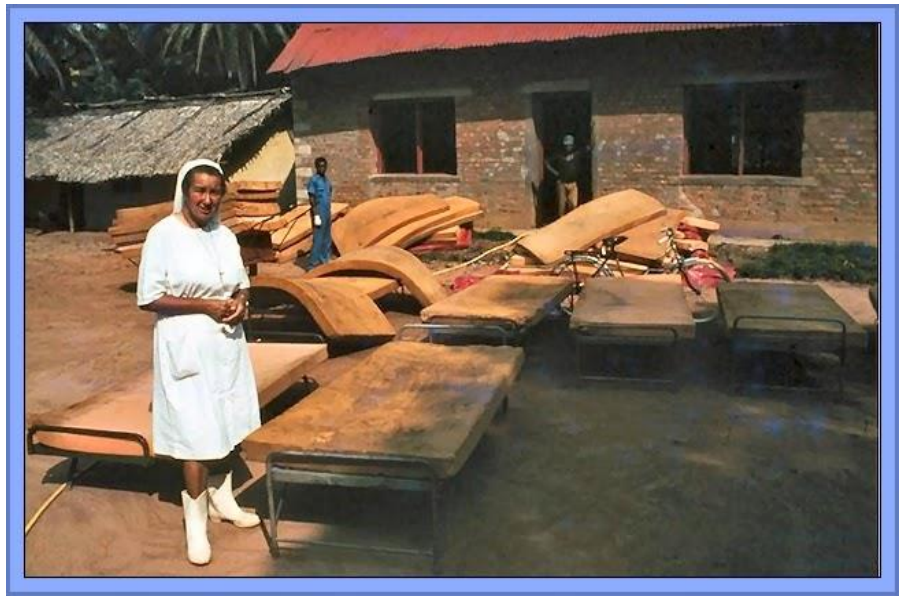
Villages on the Bumba to Yambuku Road:
Transport, DR Congo (Zaire), October–December, 1976

Photo: J. Breman

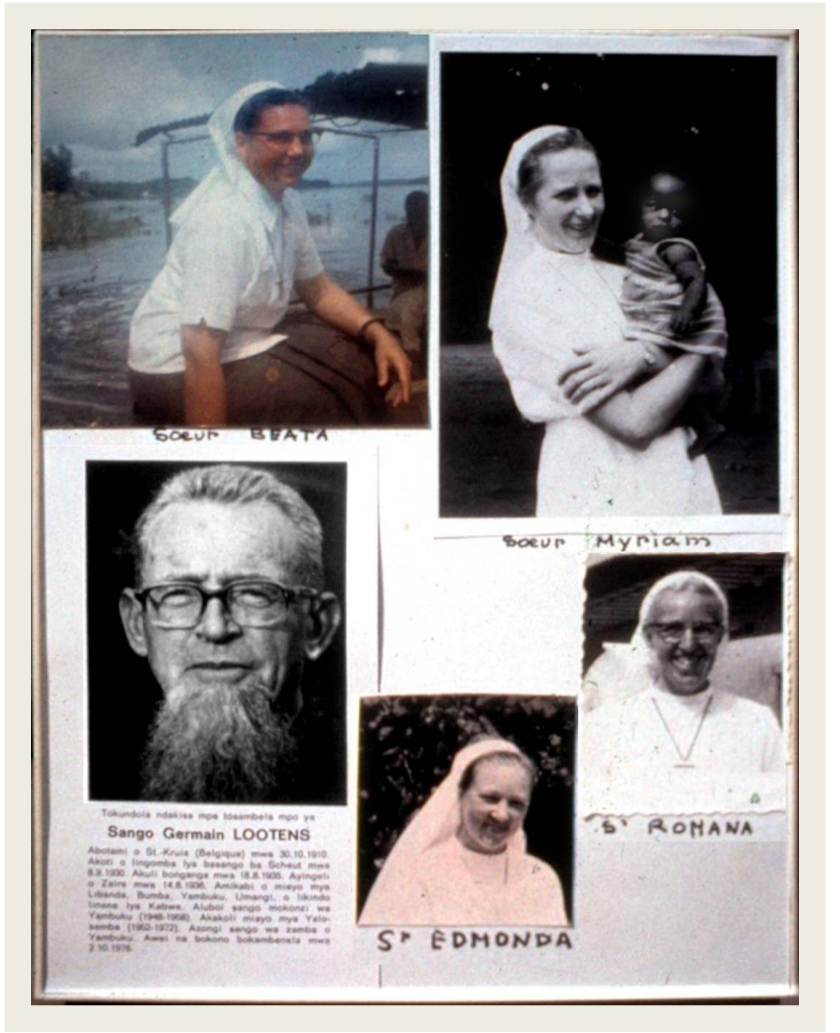
Photo: Joe McCormick

Yambuku Mission Church, 1976

The Belgian Missionaries Who Died of Ebola, Yambuku, Zaire, 1976



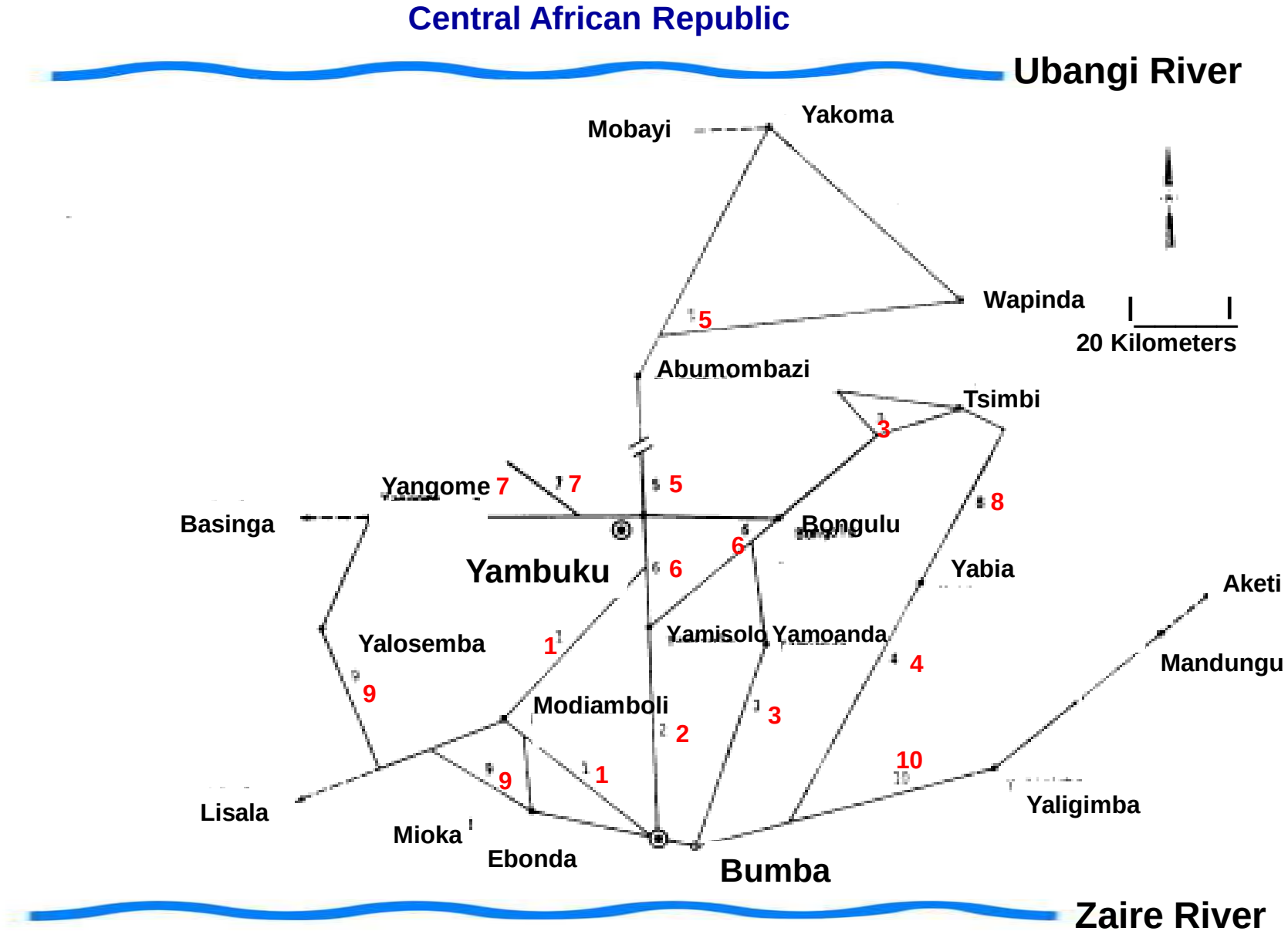
Sister Superior Marcella Photo: P. Piot



From CDC slide set, 1977

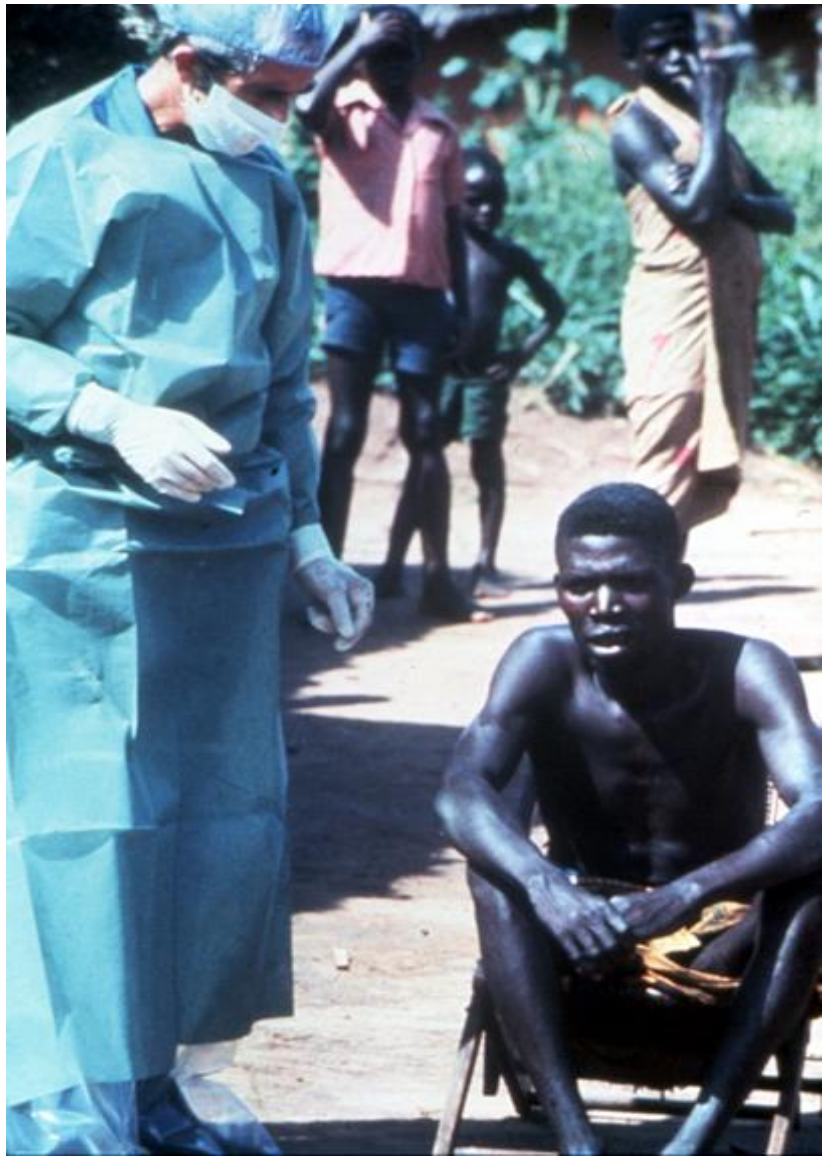
Hospital Staff: 17
- EHF 13
- Died 11
Closed Sept. 30

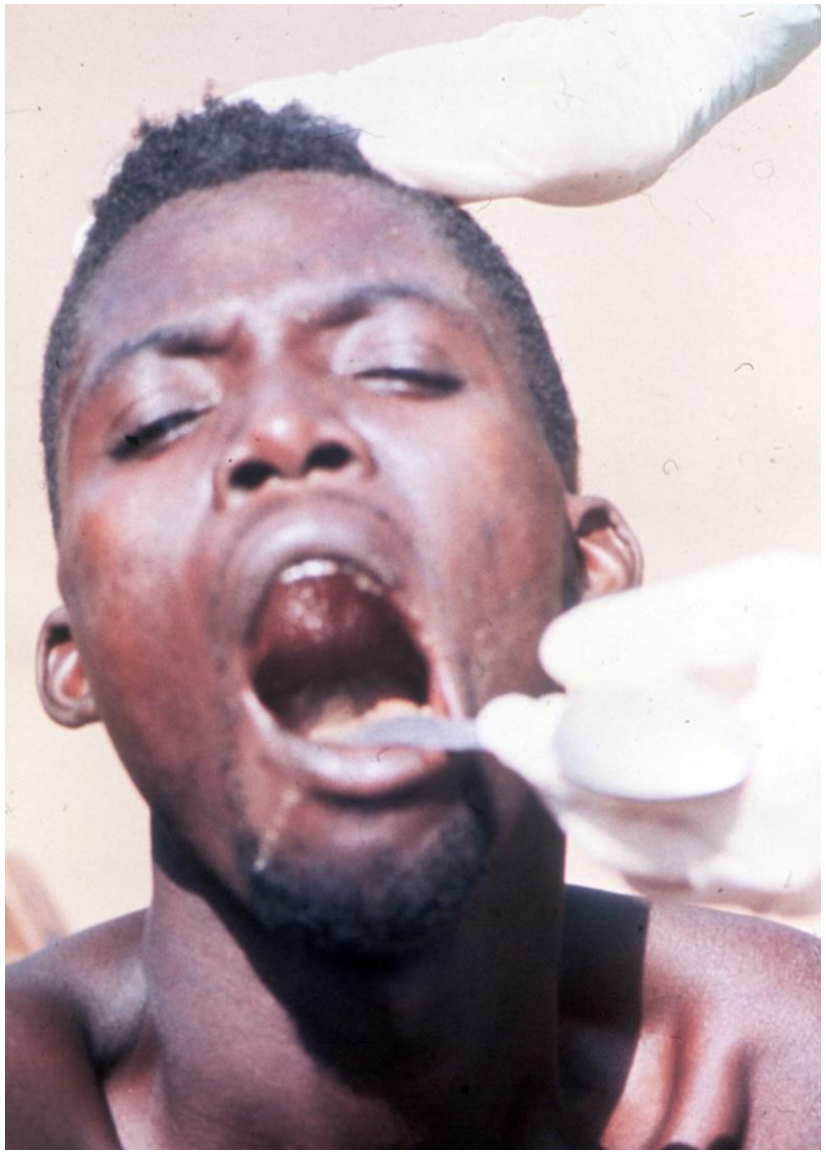
Numbered Routes Followed by the Surveillance Teams, DRC Congo (Zaire), 1976



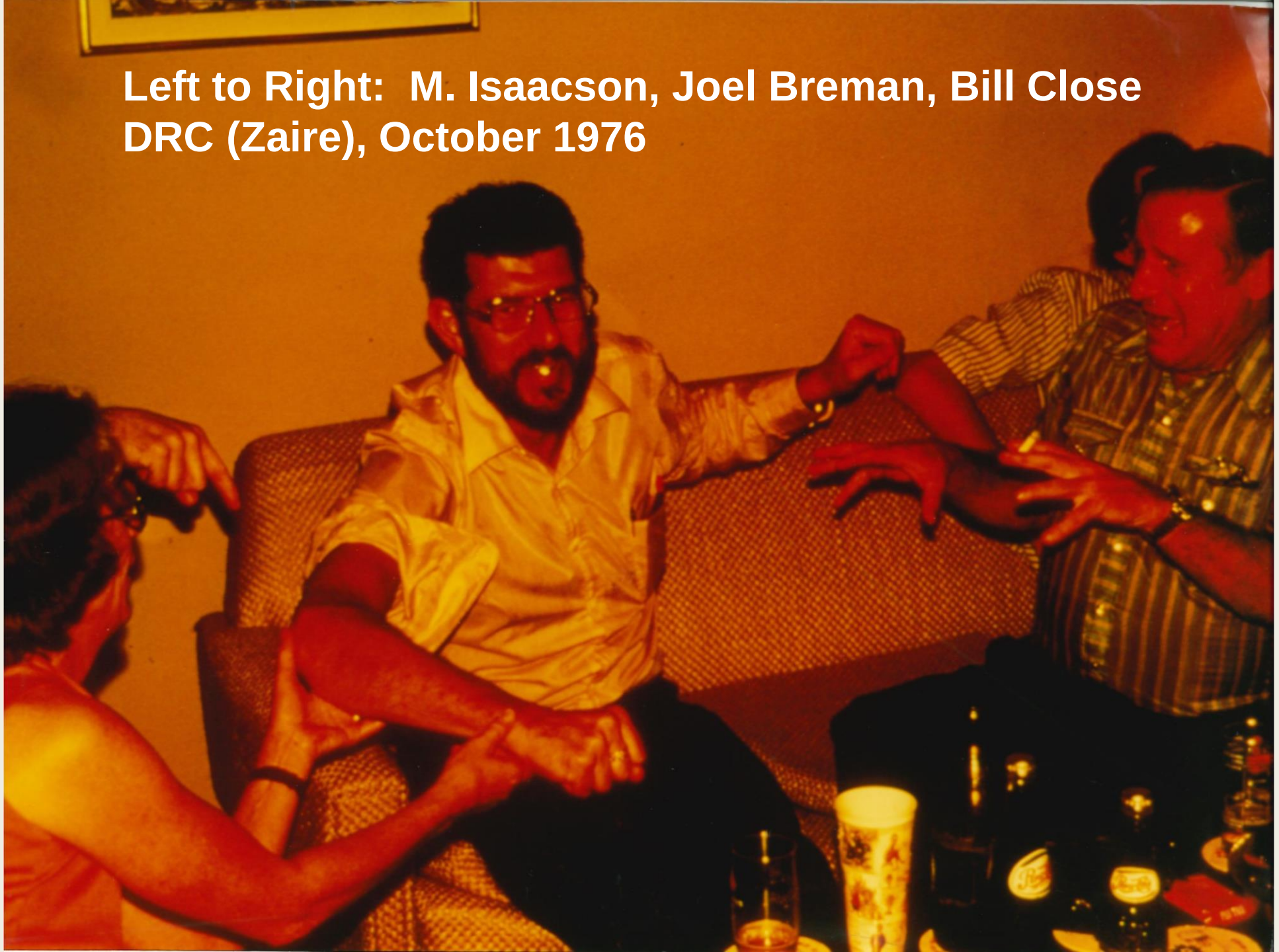
International Commission, *Bull Wld Hlth Org*, 1978.

Patient with Ebola Hemorrhagic Fever, Bumba Zone, Equateur Province, DR Congo (Zaire), October 1976





Pierre Sureau (France) and patient, 1976. Photos: J. Breman


Left to Right: M. Isaacson, Joel Breman, Bill Close
DRC (Zaire), October 1976

Investigations of EHF Cases in Villages, Equateur Province, DR Congo (Zaire), October-December 1976

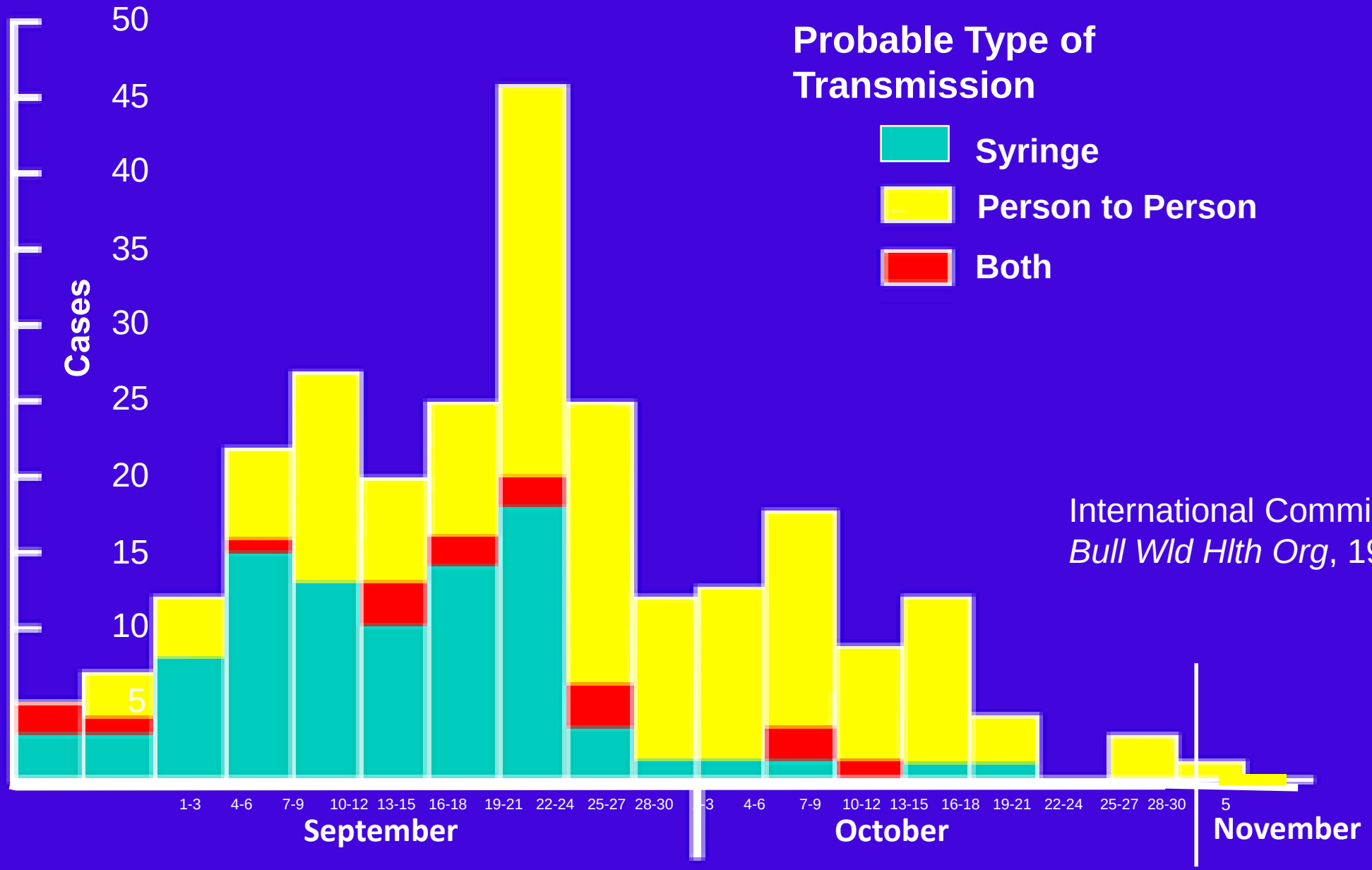
Dr. M. Mbuyi & Nurse Sukato interviewing mourning family member

Cases/Deaths, Ebola Hemorrhagic Fever in Sudan and DRC (Zaire), 1976

		Deaths/Cases	Case-fatality rate
1976	Zaire	280/318	88%
1976	Sudan	150/284	53%

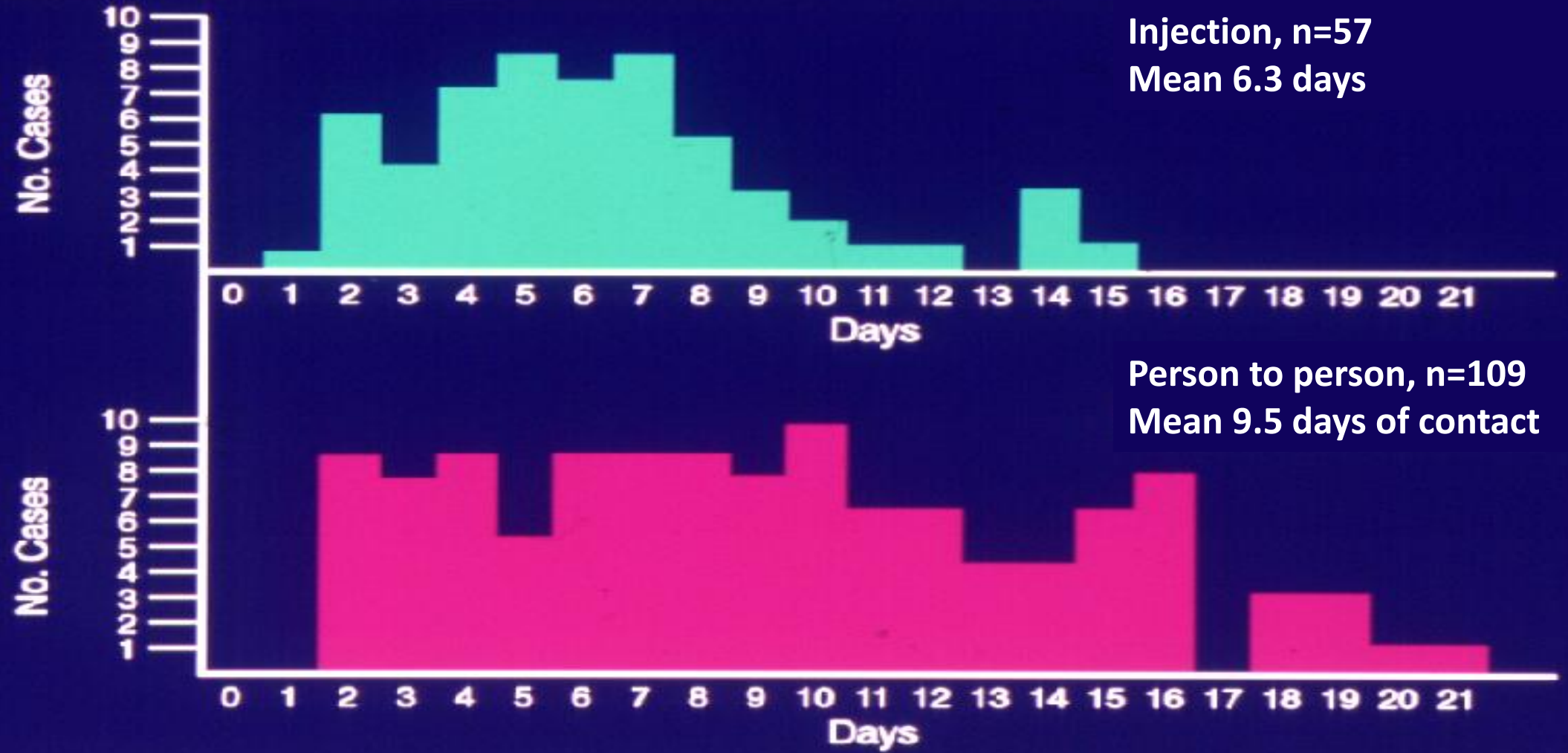
Report of an International Commission, *Bull Wld Hlth Org*, 1978.
WHO Commission, *Bull Wld Hlth Org*, 1978.

Number of Cases of Ebola Hemorrhagic Fever in the Equator Region, by Day of Onset and Probable Type of Transmission, 1976



International Commission, *Bull Wld Hlth Org*, 1978.

Time of Onset of Ebola Hemorrhagic Fever by Transmission Type (after initial contact with source), DR Congo (Zaire), 1976



International Commission, *Bull Wld Hlth Org*, 1978.

Major Clinical Manifestations of Persons Dying and Recovering Ebola Hemorrhagic Fever, DRC, (Zaire), 1976

	Death (n = 178-231)		Recovered (n = 9-34)*
	%	Duration (days)	%
Symptoms			
Fever	98%	7	59
Headache	96	7	59
Abdominal pain	81	6	50
Sore throat	79	6	32
Myalgia	79	7	47
Nausea	66	5	33
Arthritis	53	6	38
Other	5		
Signs	**(n = 208-228)**		
Diarrhea	79	5	44
Bleeding	78	4	18
Oral lesions	74	6	27
Vomiting	65	4	35
Conjunctivitis	58	5	6
Cough	36	7	7
Abortion	25	1	
Jaundice	5		
Other (including rash)	5		

* IFA = ≥ 1:64.

International Commission, *Bull Wld Hlth Org*, 1978.

Distribution of Number of Cases in Villages
Ebola Hemorrhagic Fever, DRC, (Zaire), 1976

Number of Cases	Number of Villages	% of total Villages	Cumulative
1	17	31%	31%
2 – 5	18	33	64
6 – 9	12	22	85
10 – 14	4	7	93
15 – 19	1	2	95
20 – 29	1	2	96
>30	2	4	100
	55		

International Commission, *Bull Wld Hlth Org*, 1978.

Age and Sex Distribution
Ebola Hemorrhagic Fever, DRC, (Zaire), 1976

Age (Years)	Male		Female		Total (n = 318)	
Newborns and <12 months	10	3%	14	4%	24	8%
1 – 14	18	6%	22	7 %	40	13%
15 – 29	31	10%	60	19%	91	29%
30 – 49	57	18%	52	16%	109	34%
>50	23	7%	26	8%	49	15%
Unknown	2	1%	3	1 %	5	2%
	141	44%	177	56%	318	100%

International Commission, *Bull Wld Hlth Org*, 1978.

Factors Associated with Person-to-Person Spread of EHF, DR Congo (Zaire), 1976

Risk	Case (% Yes) (n = 104-126	Controls (% Yes) Family (74-98)	Controls (% Yes) Village (n = 22)
Touched case	86%	84%	68%
Cared for case	71	71	68
Slept in room	69	66	23
Prepared cadaver	59	58	55
Attended funeral	86	86	96
Aided in delivery of newborn	18*	10	5

* < 0.05

Family Contact Attack Rates of Ebola Virus Disease by Generation of Illness, Democratic Republic of Congo, 1976

Generation	Families			Attack Rate (%)
	Number	Exposures	Cases	
1 (injection)	61	498	38	7.6
2 (person-to-person)	62	459	20	4.4
3 (person-to-person)	18	117	3	2.6
4 (person-to-person)	5	29	1	3.4
Total	146	1,103	62	5.6
Delivered fetus or was caregiving spouse				27.0

Serosurveys and Plasmapheresis in Yambuku, DR Congo, 1976

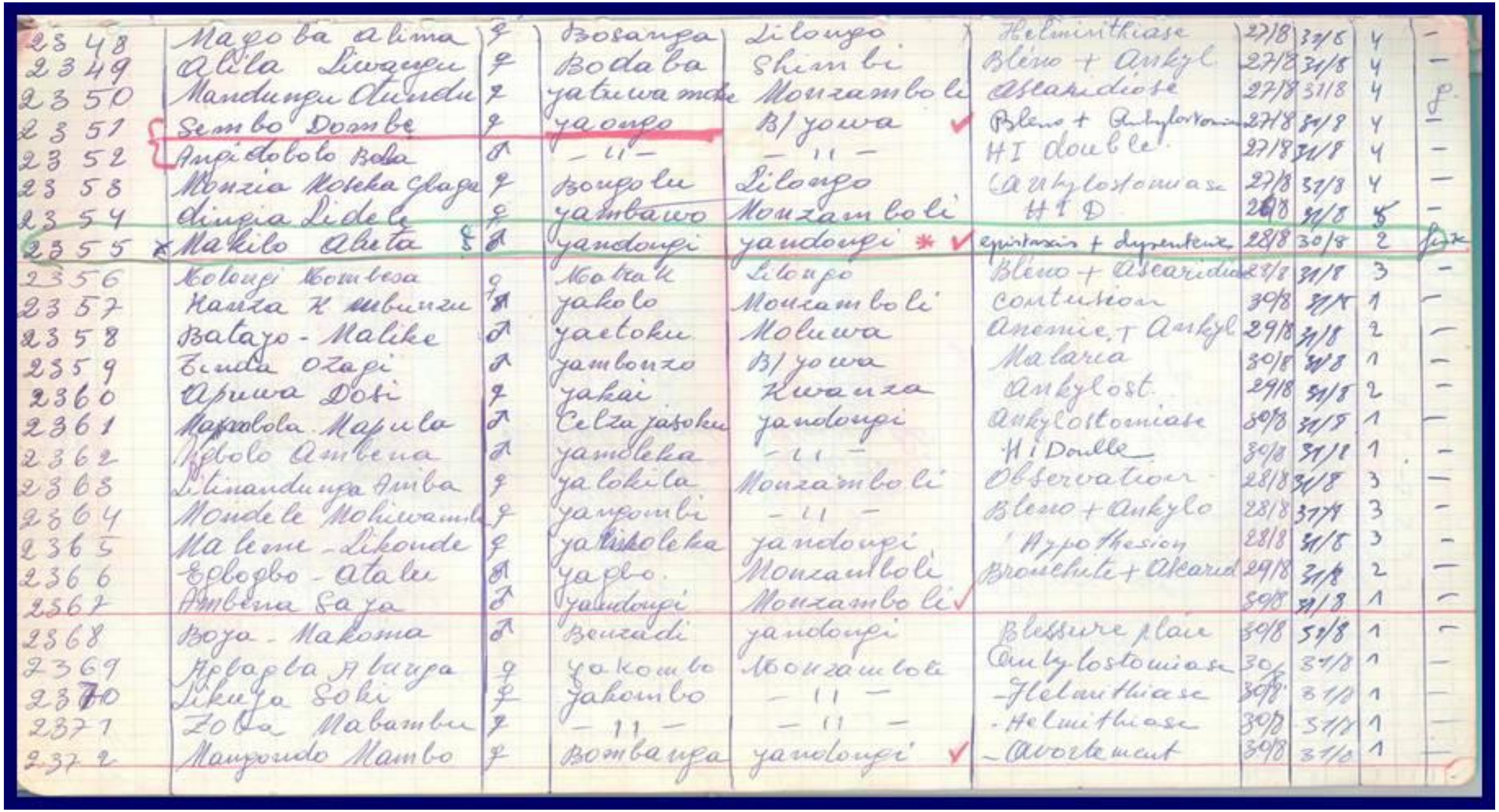
Dell Conn (PCV, US), Serosurveys

Denis Courtois (France), Margaretha Isaacson (RSA) and convalescent patient, 1976

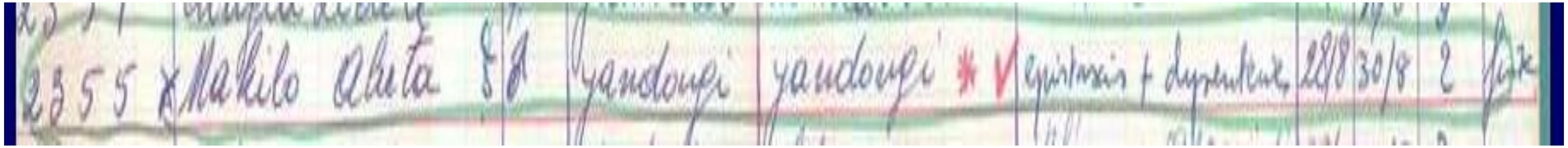
Photos: J. Breman

Evacuation of EHF Commission Member from Yambuku, DR Congo (Zaire), to Johannesburg, December 1976

From Inpatient Register, Yambuku Hospital, August 1976



2348	Magoba Alima	♀	Bosanga	Lilongo	Helminthiase	27/8	31/8	4	—
2349	Alila Liwangu	♀	Bodaba	Shimbi	Bleno + Ankyl	27/8	31/8	4	—
2350	Mandungu Atundu	♀	yatuwa mde	Mouzamboli	Ascaridiose	27/8	31/8	4	g.
2351	Sembo Dombe	♀	yaongo	B/ yowa ✓	Bleno + Ankylostom	27/8	31/8	4	—
2352	Angidobolo Bola	♂	— " —	— " —	HI double	27/8	31/8	4	—
2353	Monzia Moteka Gbaga	♀	Bongolu	Lilongo	Ankylostomiase	27/8	31/8	4	—
2354	Dingia Lidele	♀	yambawo	Mouzamboli	HID	28/8	31/8	3	—
2355	x Makilo Aleta	♂	yandongi	yandongi * ✓	epistaxis + dysenterie	28/8	30/8	2	[illegible]
2356	Bolongi Bombesa	♀	Mokali	Lilongo	Bleno + Ascaridiase	28/8	31/8	3	—
2357	Hanza K. Mbunzu	♂	yakolo	Mouzamboli	contusion	30/8	31/8	1	—
2358	Batayo - Malike	♂	yaetoku	Moluwa	Anemie + Ankyl	29/8	31/8	2	—
2359	Binda Ozagi	♂	yambonzo	B/ yowa	Malaria	30/8	31/8	1	—
2360	Apuwa Doti	♀	yakai	Kwanza	Ankylost	29/8	31/8	2	—
2361	Mapumbola Mapula	♂	Celza yasoku	yandongi	Ankylostomiase	30/8	31/8	1	—
2362	Ndolo Ambena	♂	yamoleka	— " —	HI Double	30/8	31/8	1	—
2363	Litinandunga Amba	♀	yalokila	Mouzamboli	Observation	28/8	31/8	3	—
2364	Mondele Mokiwamb	♀	yangombi	— " —	Bleno + Ankylo	28/8	31/8	3	—
2365	Malemu - Likonde	♀	yaliboleka	yandongi	Hypothesion	28/8	31/8	3	—
2366	Egbogbo - Atalu	♂	yagbo	Mouzamboli	Bronchite + Ascarid	29/8	31/8	2	—
2367	Ambena Saya	♂	yandongi	Mouzamboli ✓		30/8	31/8	1	—
2368	Boya - Makoma	♂	Beuzadi	yandongi	Blessure plaie	30/8	31/8	1	—
2369	Agbagba Alunga	♀	yakombo	Mouzamboli	Ankylostomiase	30/8	31/8	1	—
2370	Likuya Soki	♀	Jakombo	— " —	Helminthiase	30/8	31/8	1	—
2371	Zoba Mabambu	♀	— " —	— " —	Helminthiase	30/8	31/8	1	—
2372	Mangondo Mambo	♀	Bombanga	yandongi ✓	Avortement	30/8	31/8	1	—



2355 x Makilo Aleta ♂ yandongi yandongi * ✓ epistaxis + dysenterie 28/8 30/8 2

Ebola Hemorrhagic Fever, DRC (Zaire)
Major Findings, 1976

Clinical
- Manifestations
- Incubation period
- Plasmapheresis of convalescents

Epidemiology
- Geographic extent
- Persons at risk
- Mode of transmission
- Transmissibility

Control
- Area quarantine
- Identify, isolate patients
- Rapid burial
- Rule out other diseases

Laboratory
- Basic lab tests
- IFA for Ebola
- Virus culture

Ecological studies

Ebola Hemorrhagic Fever, DRC (Zaire)

Major Unknowns, Unsolved, 1976

- Animal reservoir
- Transmission to humans
- Treatment
- Vaccine
- Extent globally

Ebola Hemorrhagic Fever Team in Yambuku, DR Congo (Zaire), 1976

Left to Right, Back Row: Del Conn (obscured), Michael White, Karl Johnson, Guido van der Groen, Sister Mariette. Middle Row: G. Dujeu, Denis Courtois, Sister Marcella, Peter Piot, Stefan Pattyn, M. Miatudila. Front Row: Unidentified, Joel Breman.

Summary Lessons from the Ebola 1976 Outbreak

Administrative

1. Leadership
2. Organization
3. Communications
4. Transparency
5. Partnerships
6. Coordination
7. Logistics (supplies)
8. Transport (mobility)
9. Quarantine (selective)
10. Isolation
11. Survivor assistance

Dr. Karl Johnson: Checking Possible Sudan-Zaire Link and the Historical Naming of Ebola, November 1976

Ebola River, DRC

Spectrum of Emotion and Activity of Population and Investigative Team, Ebola in Democratic Republic of Congo (Zaire), 1976

High — Anxiety → Low

Emotion	Terror Fear Confusion	Uncertainty Anger Sorrow Shock	Understanding Trust Focus	Confidence Comfort Camaraderie Worry	Clarity Celebration 
Activity	Flight Chaos Local investigations Specimens collected	Isolation and Quarantine Virus identified Commission formed	Rapid surveillance Quick investigations Rapid burial	Patient management Detailed field investigations Data analyzed	Active case detection and tracing Plasmapheresis Quarantine lifted

Low — Information Sharing → High

J. Breman, 50th EIS Anniversary, CDC, 2001

Ebola Hemorrhagic Fever, DR Congo (Zaire), 1976: Team Members, Antwerp, 1996

Left to right: Joe McCormick, Guido van der Groen, David Heymann, Stefan Pattyn, Muyembe Tamfun, Karl Johnson, Joel Breman, Simon van Niewvenhove, Patricia Webb, Peter Piot

International Commission for the Investigation and Control of Ebola Hemorrhagic Fever

Democratic Republic of the Congo (Zaire), 1976-77

dedicated to the people who were afflicted and

Our Collaborators

Belgium

Democratic Republic of the Congo (Zaire)

Canada

France

South Africa

United States

World Health Organization

Ebola in Zaire, ‘76 – From Then Until Now

Jonathan S. Towner, PhD

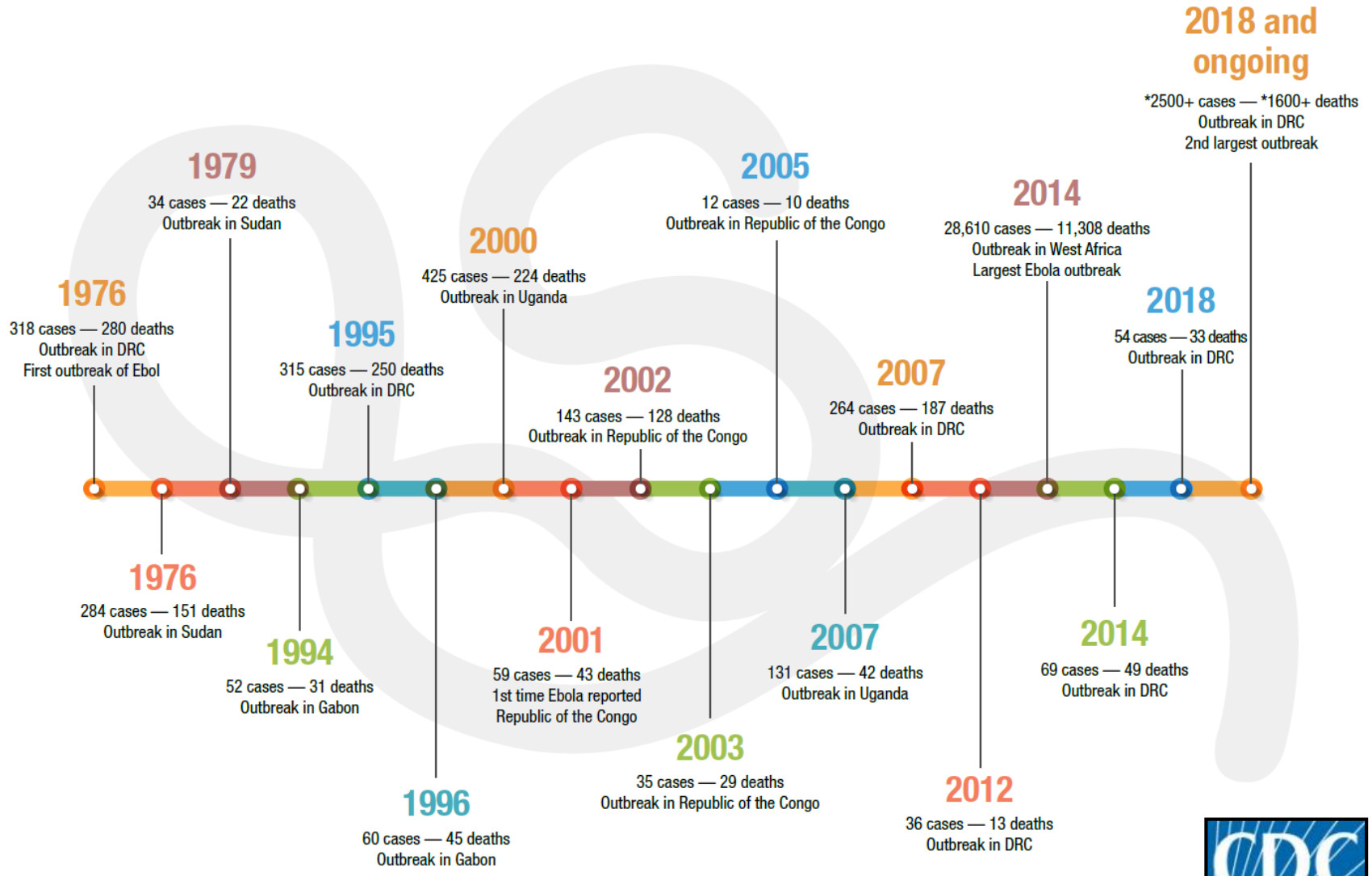
Viral Special Pathogens Branch,

Division of High-Consequence Pathogens and Pathology,

National Center for Emerging Zoonotic Diseases

The findings and conclusions in this presentation are those of the author(s) and do not necessarily represent the views of the Centers for Disease Control and Prevention

Timeline of Ebola Outbreaks 1976-Present

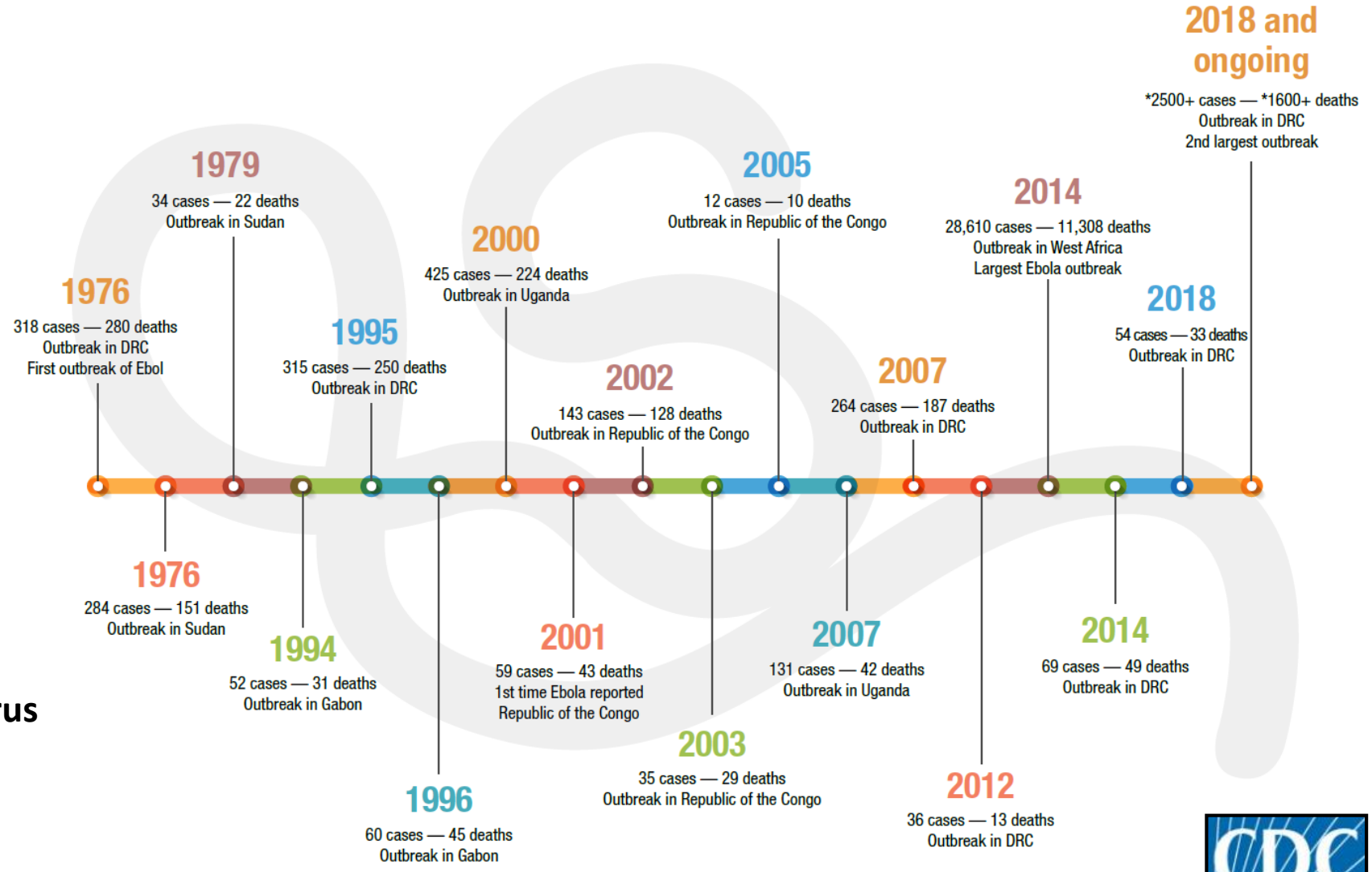


* As of July 15, 2019.
Note: Not a complete list of all outbreaks

Timeline of Ebola Outbreaks 1976-Present

Family *Filoviridae*

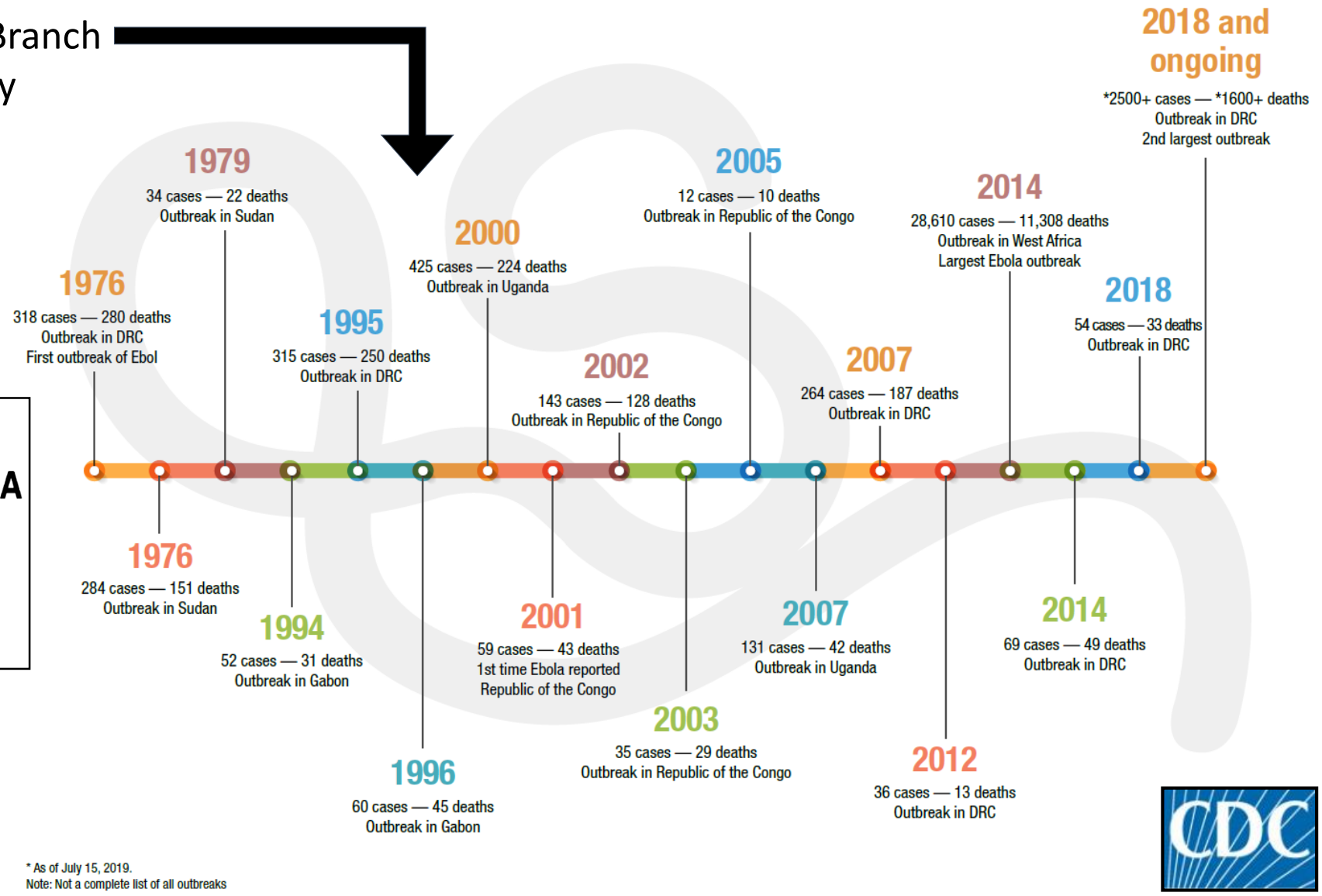
- Genus *Marburgvirus*
  - Species *Marburg marburgvirus*
    - virus: **Marburg virus**
    - virus: **Ravn virus**
- Genus Ebolavirus
  - Species *Zaire ebolavirus*
    - virus: **Ebola virus**
  - Species *Sudan ebolavirus*
    - virus: **Sudan virus**
  - Species *Reston ebolavirus*
    - virus: **Reston virus**
  - Species *Tai Forest ebolavirus*
    - virus: **Tai Forest virus**
  - Species *Bundibugyo ebolavirus*
    - virus: **Bundibugyo virus**
  - Species *Bombali ebolavirus*
    - virus: **Bombali virus**



* As of July 15, 2019.
Note: Not a complete list of all outbreaks

Timeline of Ebola Outbreaks 1976-Present

1997 - Arrive at Special Pathogens Branch to develop a genetic system to study determinants Ebola virus virulence



The EMBO Journal vol.13 no.18 pp.4195–4203, 1994

Infectious rabies viruses from cloned cDNA

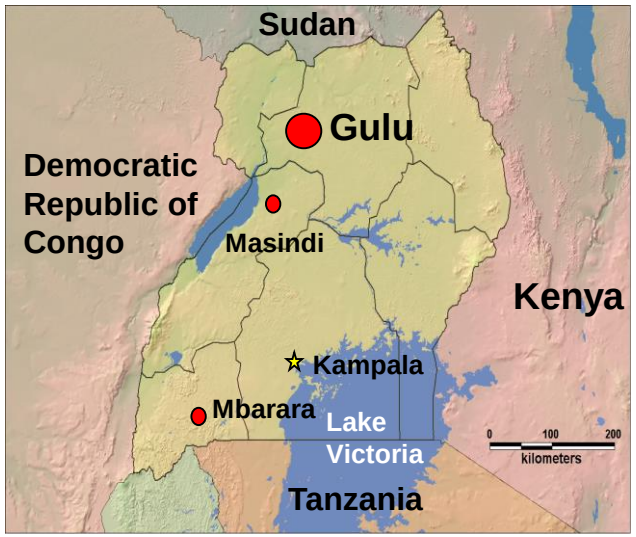
Matthias J.Schnell, Teshome Mebatsion and Karl-Klaus Conzelmann[1]

Institute of Clinical Virology, Federal Research Centre for Virus Diseases of Animals, Paul-Ehrlich-Strasse 28, D-72076 Tübingen, Germany

Special Pathogens Branch

CDC

Ebola (Sudan) Outbreak, Uganda 2000–2001 (425 cases, 53% CFR)



CDC team members who participated in the initial response to the Ebola outbreak in Uganda were (L-R) Daniel Bausch, Scott Harper, Scott Dowell, Pierre Rollin, Jonathan Towner, and Anthony Sanchez.

1976
318 cases — 280 deaths
Outbreak in DRC
First outbreak of Ebol

1976
284 cases — 151 deaths
Outbreak in Sudan

1979
34 cases — 22 deaths
Outbreak in Sudan

1994
52 cases — 31 deaths
Outbreak in Gabon

1995
315 cases — 250 deaths
Outbreak in DRC

1996
60 cases — 45 deaths
Outbreak in Gabon

2000
425 cases — 224 deaths
Outbreak in Uganda

2001
59 cases — 43 deaths
1st time Ebola reported
Republic of the Congo

2002
143 cases — 128 deaths
Outbreak in Republic of the Congo

2003
35 cases — 29 deaths
Outbreak in Republic of the Congo

2005
12 cases — 10 deaths
Outbreak in Republic of the Congo

2007
131 cases — 42 deaths
Outbreak in Uganda

2007
264 cases — 187 deaths
Outbreak in DRC

2012
36 cases — 13 deaths
Outbreak in DRC

2014
28,610 cases — 11,308 deaths
Outbreak in West Africa
Largest Ebola outbreak

2014
69 cases — 49 deaths
Outbreak in DRC

2018
54 cases — 33 deaths
Outbreak in DRC

2018 and ongoing
*2500+ cases — *1600+ deaths
Outbreak in DRC
2nd largest outbreak

* As of July 15, 2019.
Note: Not a complete list of all outbreaks

Special Pathogens Branch

CDC

Field-able Diagnostic Assays, circa 2000

ELISA Based

- Antigen capture
- IgM
- IgG

PCR-Based

- Traditional electrophoresis
  - Primary
    - -Filo L-primers
  - Nested
    - -EboS/EboZ NP
    - -Marb VP35

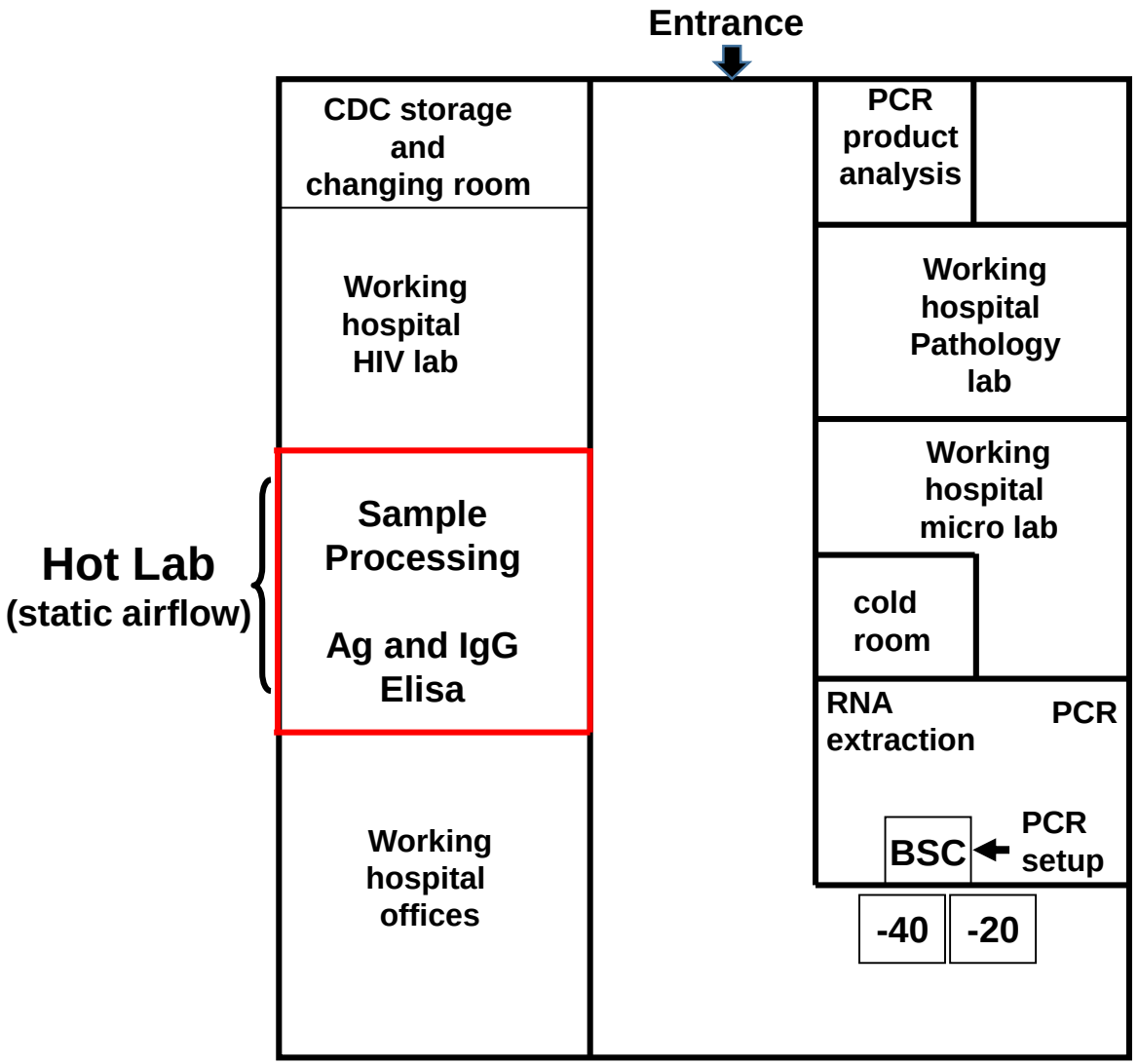
Special Pathogens Branch

CDC

Diagnostic Lab Set-up at St. Mary's Lacor Hospital, Gulu, Uganda

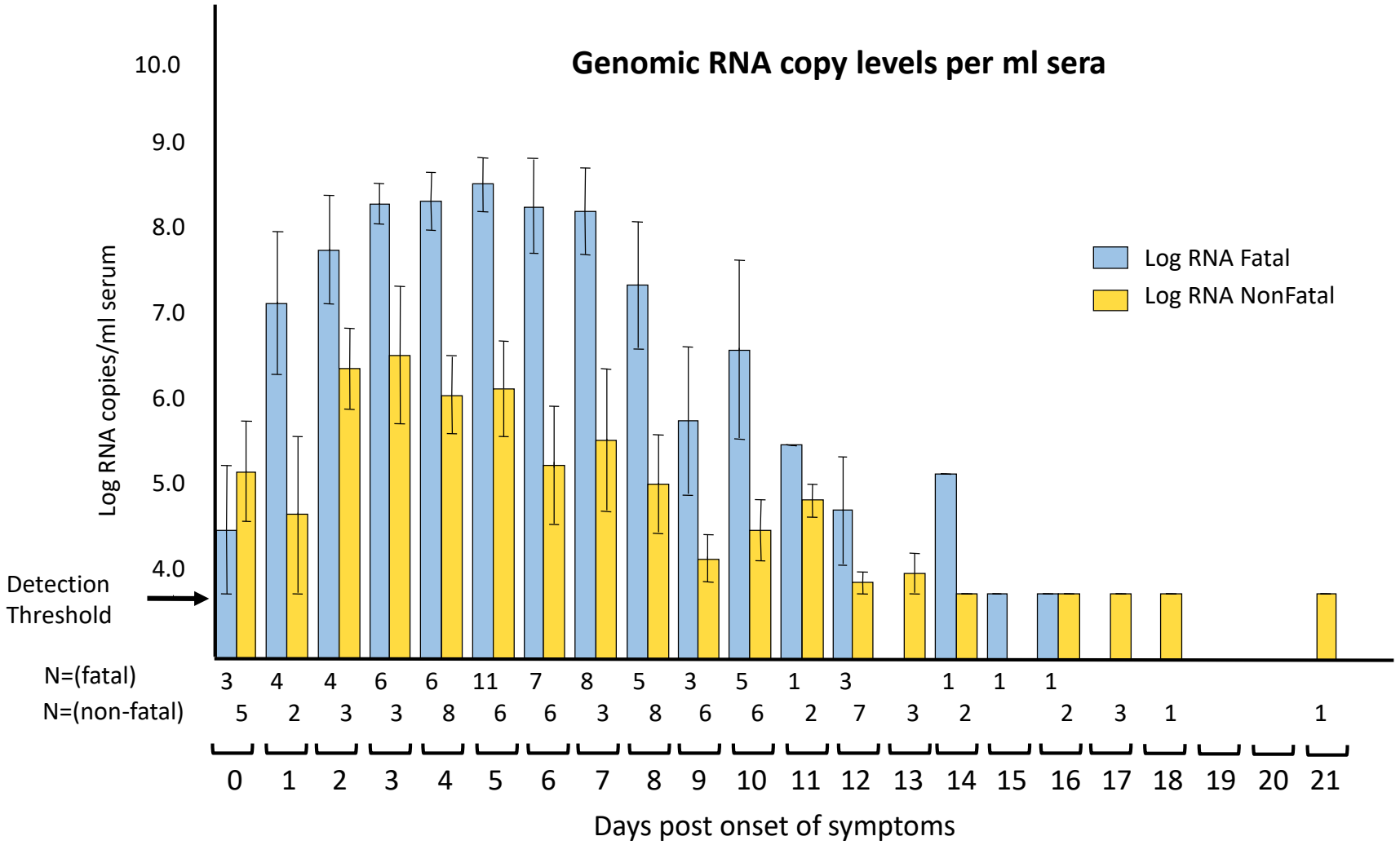
Antigen Capture, IgG, IgM in hot lab

Nested RT-PCR



Tested over 1000 clinical samples, Oct, 2000–Jan, 2001 (3 teams total)

Quantitation of genomic-sense Ebola Sudan RNA in patient sera

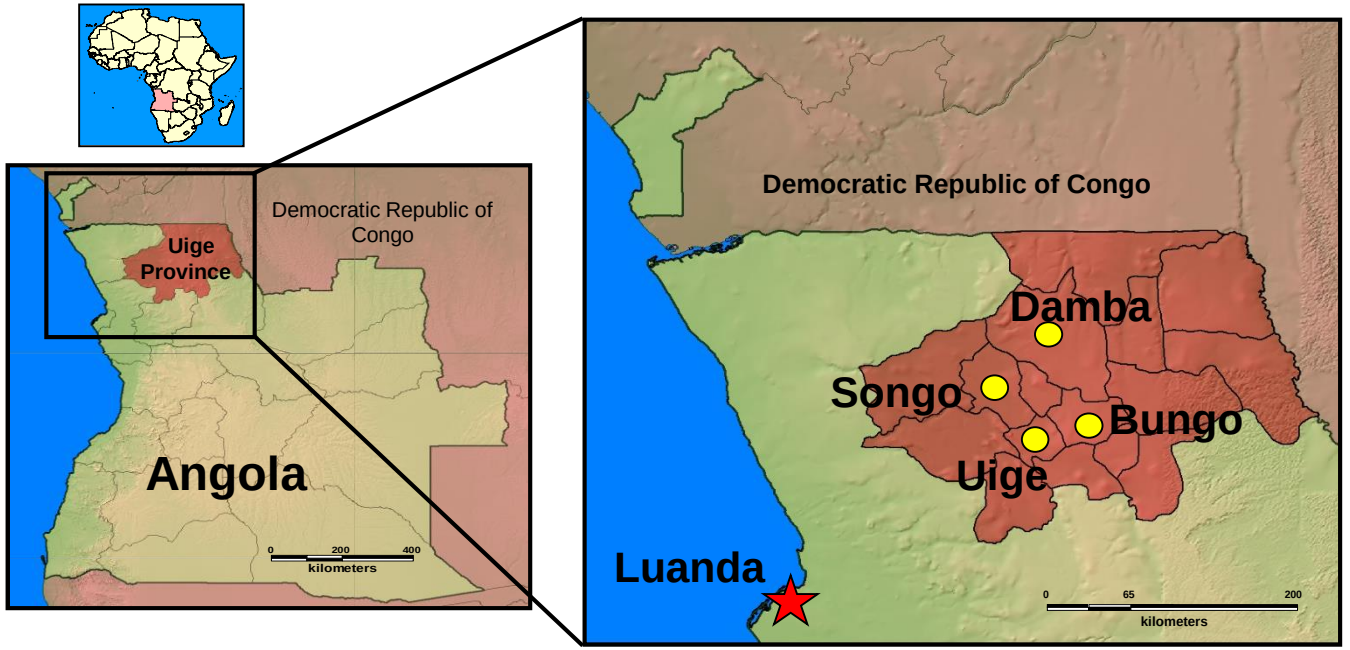


Special Pathogens Branch

CDC

Marburg outbreak, Angola 2005 (252 cases, 90% CFR)

"Marburg Disease"



Field-able Diagnostic Assays, circa 2005

ELISA Based

- Antigen capture
- IgM
- IgG

PCR-Based

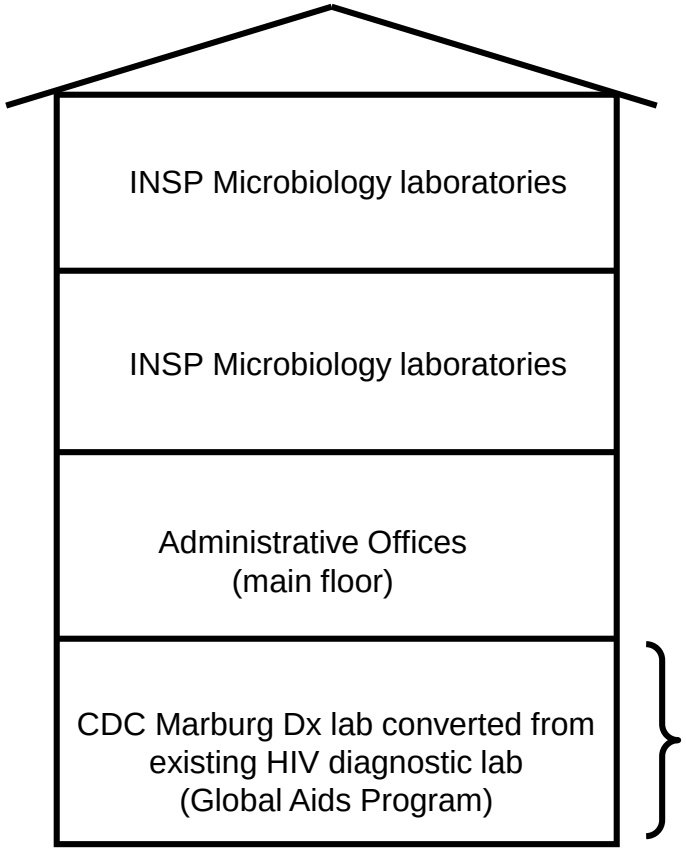
- Traditional electrophoresis
  - Primary
    - -filo L-primers
  - Nested
    - -EboS/EboZ NP
    - -Mbg VP35

- Real-time RT-PCR
  - Probe-based
    - -EboZ (Zaire ’76, ’95, ’94, ’96)
    - -EboS (Sudan ’76, ’79, 00)
    - -Mbg (’67, ’75, ’80, ’87, ’98-00)

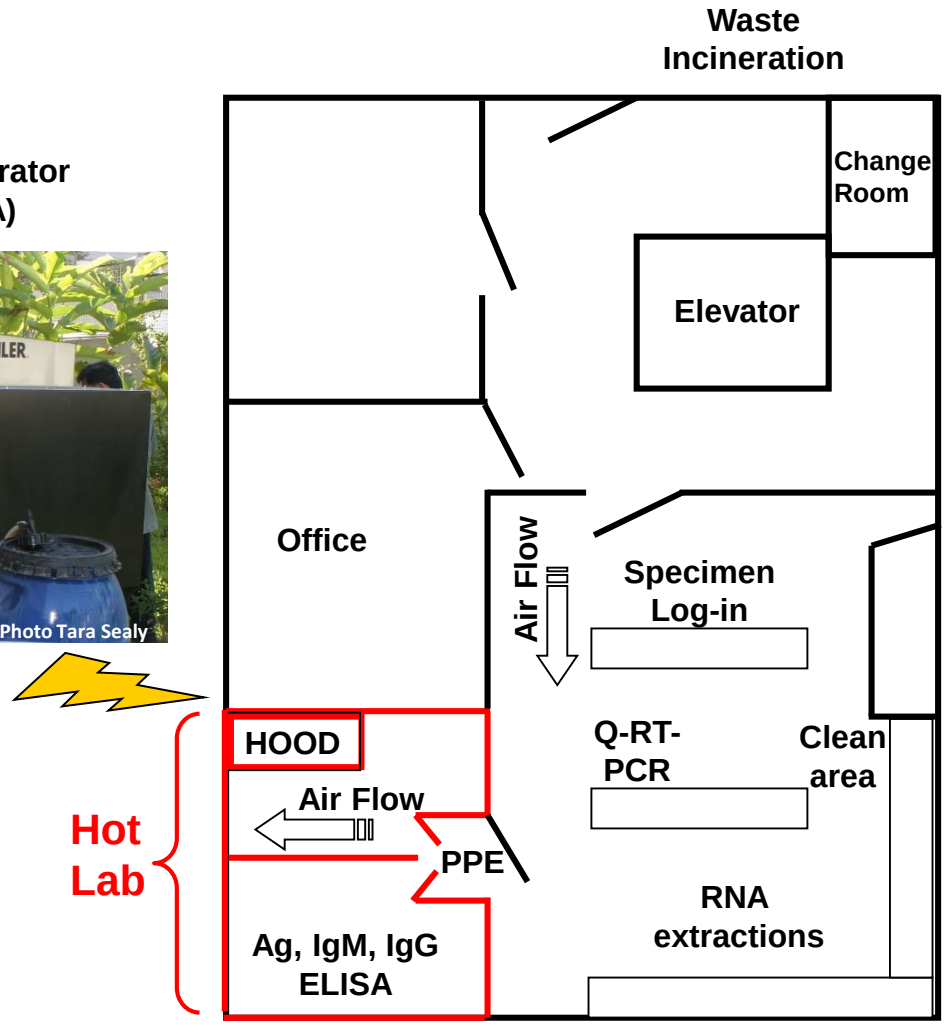
Special Pathogens Branch

CDC

Diagnostic lab setup at INSP Luanda, Angola



Diesel generator
(100 kVA)



Basement Floor Diagram

Marburg virus field diagnostics in Angola 2005

Hot Lab

Donning PPE for hot lab

RNA extraction station-96 well

Sample types processed:

Breast milk	4
Blood/Serum	175
Swabs	326
Total	505

Q-RT-PCR assay
180 / 505 were positive
(131 positives were swabs*)

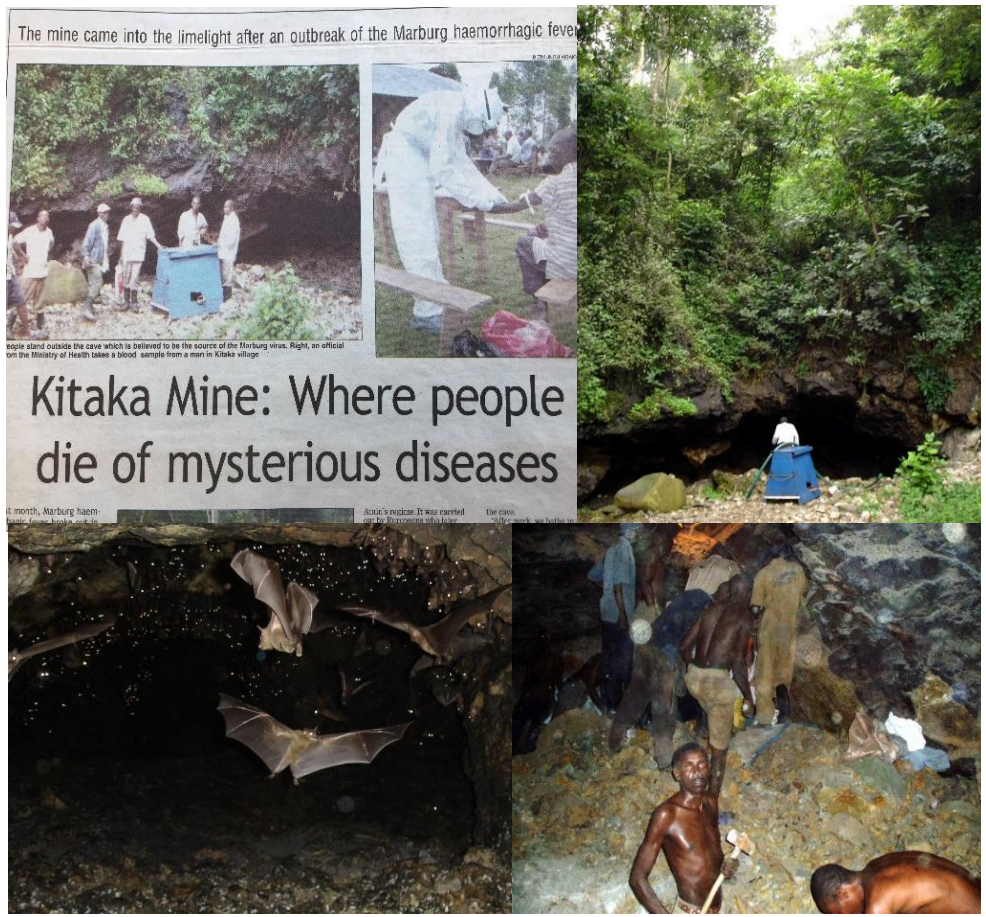
- **First field use of high-throughput nucleic acid extraction platform**
- **First wide spread use of swabs for filovirus diagnosis**

Special Pathogens Branch

CDC

Banner years of filovirus activity

July - Marburg Virus, Kitaka mine, Uganda
(3 cases, 1 fatal)



2007

Aug - Ebola, Luebo, Kasai Occidental, DRC
(264 cases, 71% CFR)

Sept – 2nd Marburg (Ravn) Virus, Kitaka mine, Uganda
(1 case, non-fatal)

Nov - Ebola (Bundibugyo), Uganda
(131 cases, 32% CFR)

Banner years of filovirus activity

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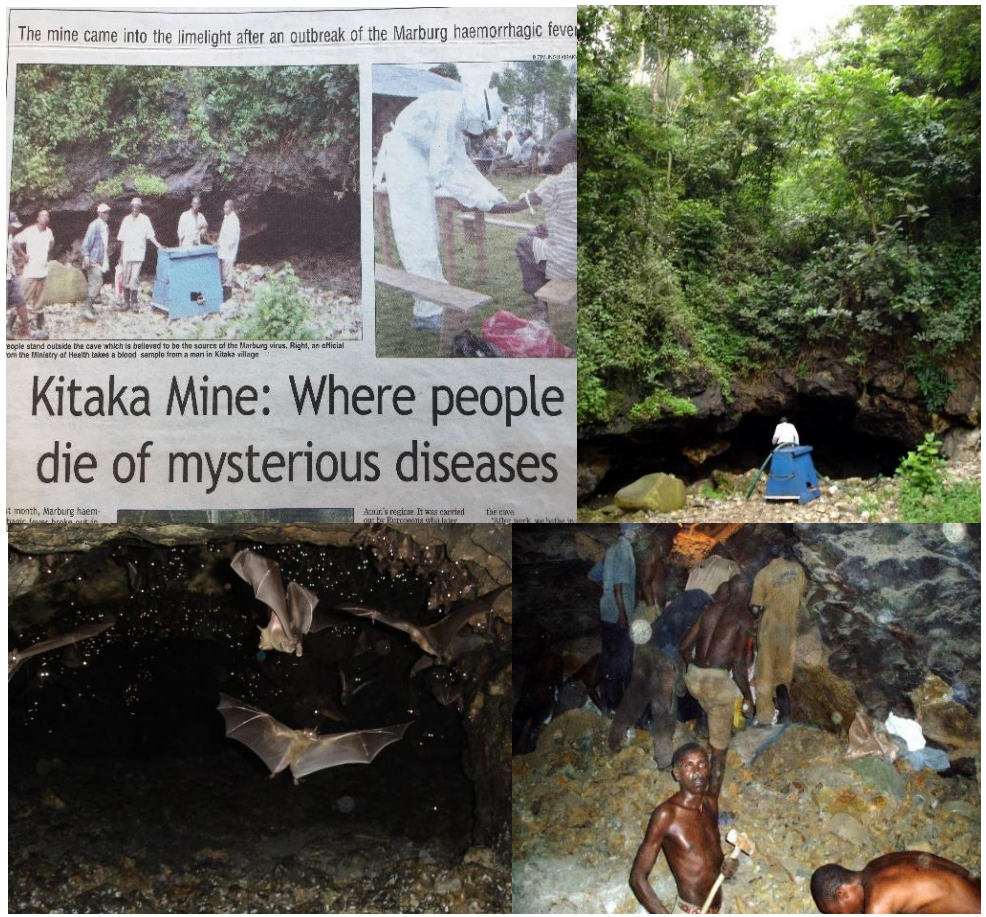

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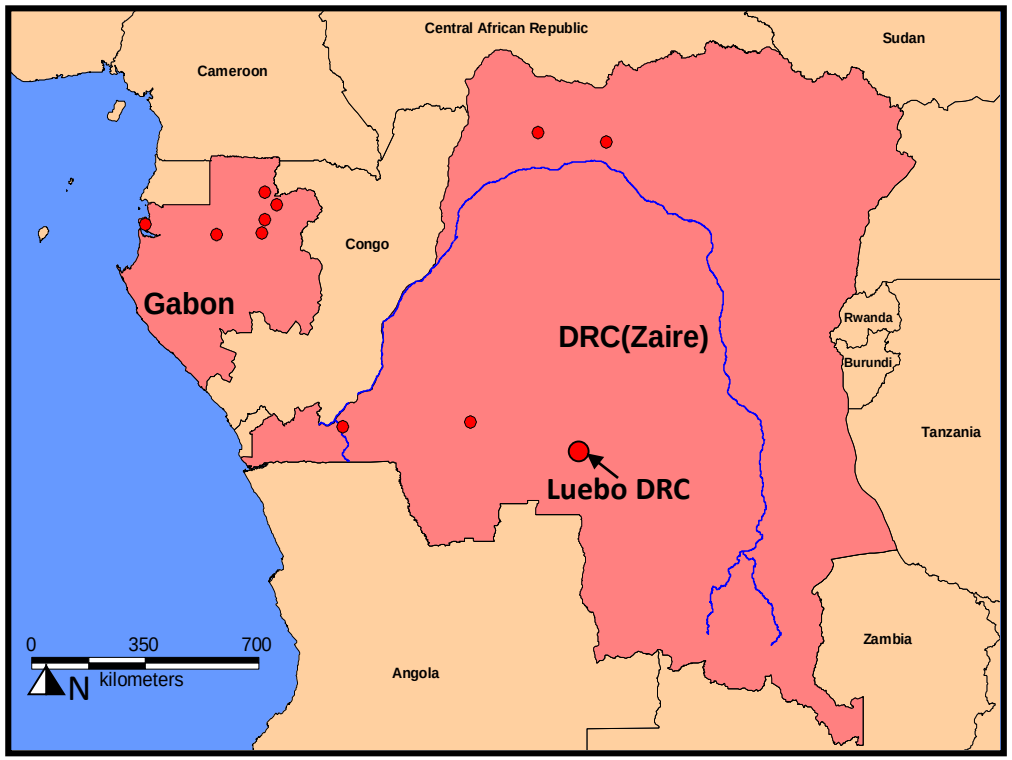

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Negative
Airflow…

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2007

OPEN ACCESS Freely available online

PLoS PATHOGENS

Newly Discovered Ebola Virus Associated with Hemorrhagic Fever Outbreak in Uganda

Jonathan S. Towner[1], Tara K. Sealy[1], Marina L. Khristova[2], César G. Albariño[1], Sean Conlan[3], Serena A. Reeder[1], Phenix-Lan Quan[3], W. Ian Lipkin[3], Robert Downing[4], Jordan W. Tappero[4], Samuel Okware[5], Julius Lutwama[6], Barnabas Bakamutumaho[6], John Kayiwa[6], James A. Comer[1], Pierre E. Rollin[1], Thomas G. Ksiazek[1], Stuart T. Nichol[1]*

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Banner years of filovirus activity

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Aug - Ebola, Luebo, Kasai Occidental, DRC
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- **Newest species of human pathogenic Ebolavirus**
- **First use of NGS to characterize new filovirus**

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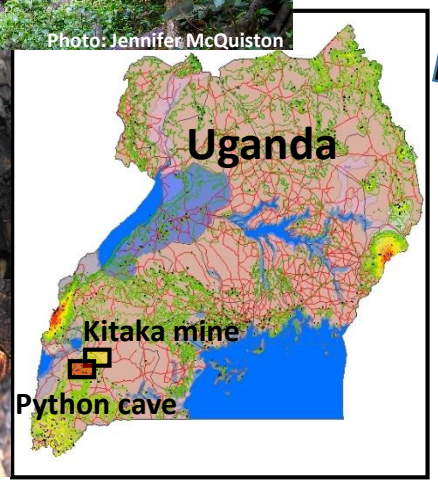

2008

Marburg, Colorado, ex Uganda Python cave (1 case, non-fatal)

Oct – Ebola (Reston, Pigs), Bulacan, Philippines (6 cases, 0% CFR)

Dec – Encore Ebola, Luebo, Kasai Occidental, DRC (32 case, 47% CFR)

Banner years of filovirus activity

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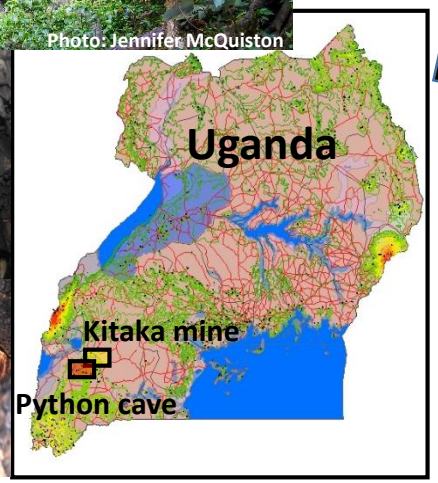

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Discovery of Swine as a Host for the *Reston ebolavirus*

Roger W. Barrette,[1] Samia A. Metwally,[1]* Jessica M. Rowland,[1] Lizhe Xu,[1] Sherif R. Zaki,[2] Stuart T. Nichol,[2] Pierre E. Rollin,[2] Jonathan S. Towner,[2] Wun-Ju Shieh,[2] Brigid Batten,[2] Tara K. Sealy,[2] Consuelo Carrillo,[1] Karen E. Moran,[1] Alexa J. Bracht,[1] Gregory A. Mayr,[1] Magdalena Sirios-Cruz,[3] Davinio P. Catbagan,[3] Elizabeth A. Lautner,[1] Thomas G. Ksiazek,[2,1] William R. White,[1] Michael T. McIntosh[1]*

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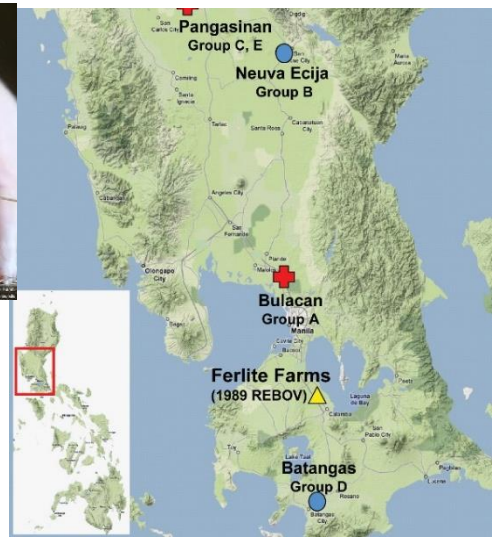

Arch Virol (2014) 159:1129–1132
DOI 10.1007/s00705-012-1477-6

BRIEF REPORT

Reston virus in domestic pigs in China

Yangyang Pan · Wen Zhang · Li Cui ·
Xiuguo Hua · Meng Wang · Qiaoying Zeng

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(1 case, non-fatal)

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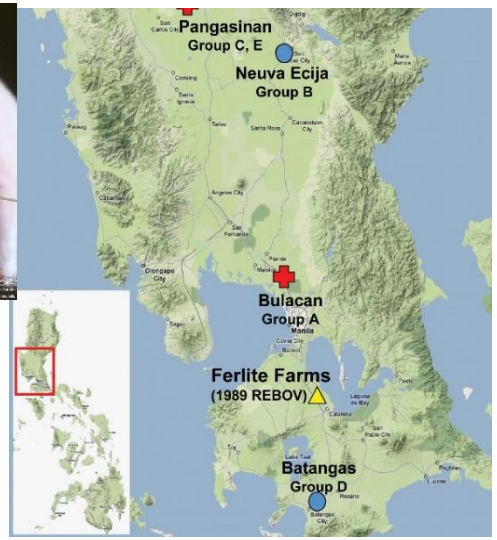

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July – Ebola (Sudan), Kibaale, Uganda
(11 cases, 36% CFR)

2012

Aug – Ebola (Bundibugyo), Isiro, DRC
(36 cases, 36% CFR))

Sept – Marburg, Ibanda (near Kitaka mine), Uganda
(15 case, 27% CFR)

Nov – Ebola (Sudan), Luwero, Uganda
(6 cases, 50% CFR)

Banner years of filovirus activity

June – Ebola (Sudan), Kibaale, Uganda
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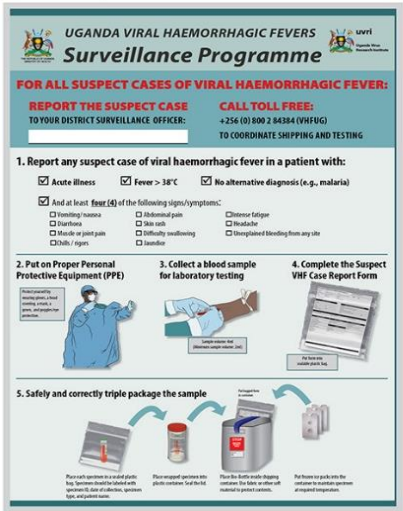
(6 cases, 50% CFR)

VHF training, surveillance, diagnostics, and health education activities in Uganda:

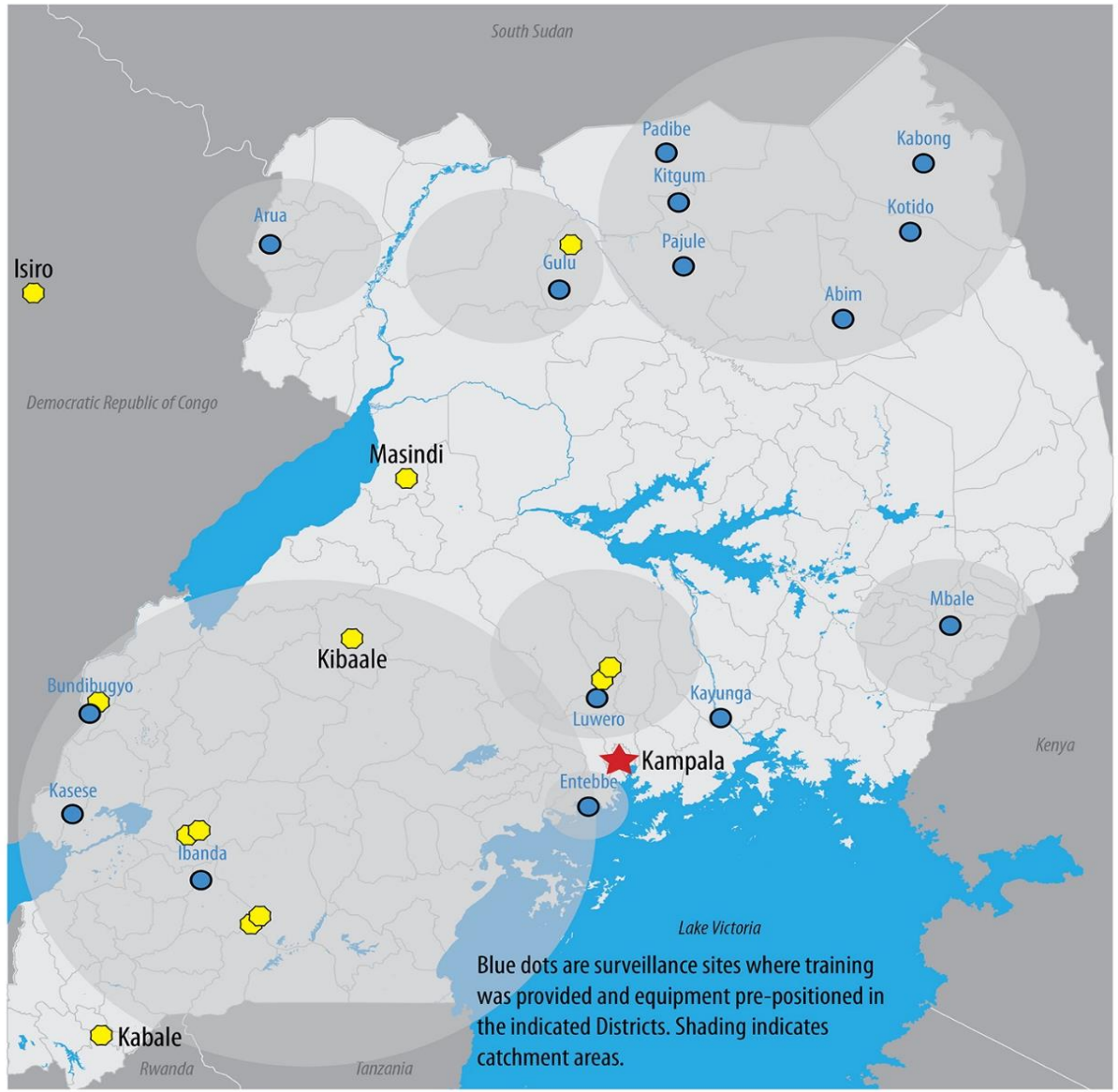
outbreak response, epidemiology, ecology, pathogen discovery

VSPB's Trevor Shoemaker replenishes a District hospital's VHF cabinet with materials needed in the event of a suspect VHF case.



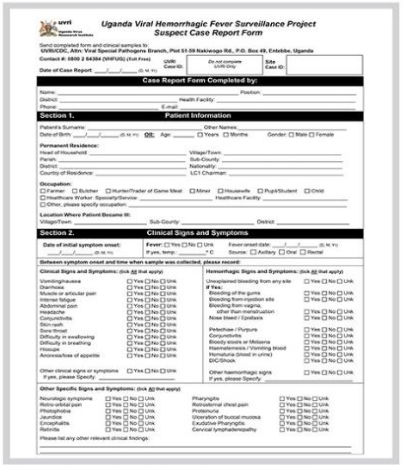
Poster describing VHF symptoms, collecting samples, and safe packing and transport for diagnostics.

VSPB Branch Chief Stuart Nichol and Trevor Shoemaker confer with MoH and village members on case finding during Luwero outbreak.



Ebola and Marburg virus disease outbreaks in Uganda

Entebbe's renovated UVRI lab runs rapid diagnostics on suspect VHF samples.



The newly-updated Form for suspect VHF cases.

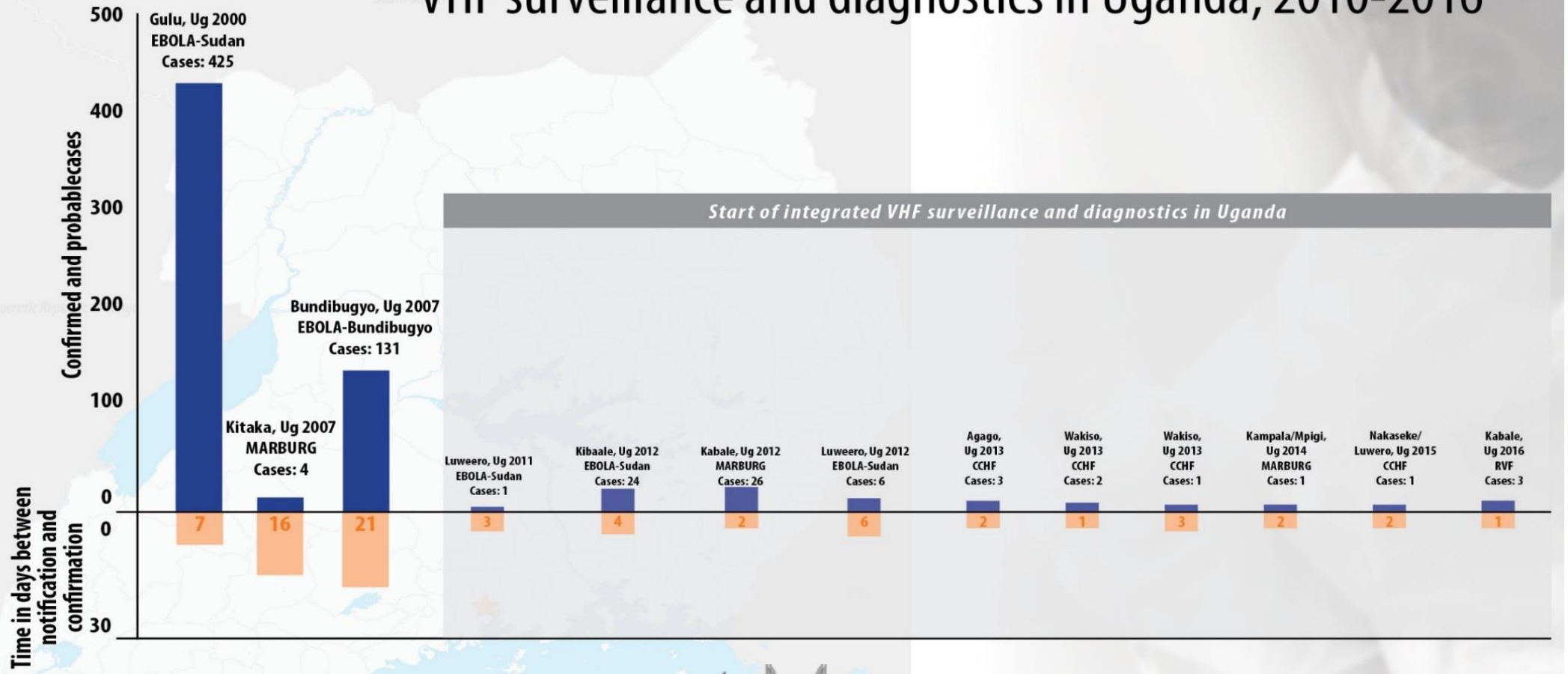
Uganda District Health Educators at a VSPB-sponsored workshop on health education and VHFs.

VSPB and UWA team capturing bats at Python Cave, part of long-term Branch/UWA ecology project.

Special Pathogens Branch

CDC

Pre- and post-implementation of enhanced VHF surveillance and diagnostics in Uganda, 2010-2016



Viral Special Pathogens Branch

UVRI

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

The West Africa Ebola virus disease outbreak

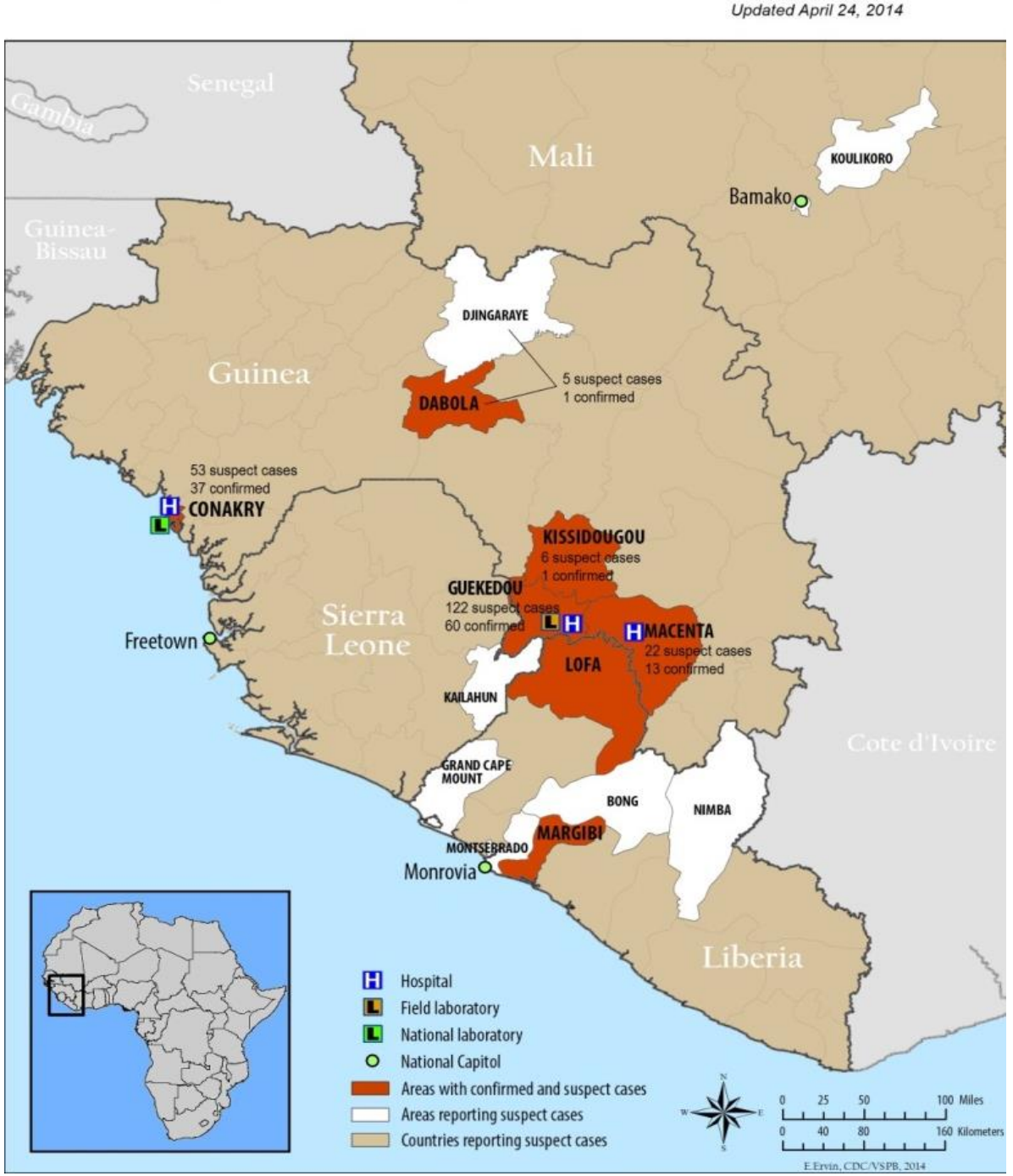
Diagnostic challenges and response

In the beginning……

- **March 25**, Guinea MoH & WHO report Ebola outbreak in Guinea;
- **March 26**, suspect cases reported in Liberia
- **Mid-April** – Cases distributed in 6 districts in Guinea, including Conakry (60 cases), and multiple counties in Liberia

Initial deployed labs to offer Ebola virus real time RT-PCR :

- EU consortium lab (led by Stephan Günther) in Gueckedou, Guinea
- Institute Pasteur Senegal lab in Donka, Conakry, Guinea
- Then as EVD spread in Liberia - LIBR lab in Monrovia supported by DOD and NIH

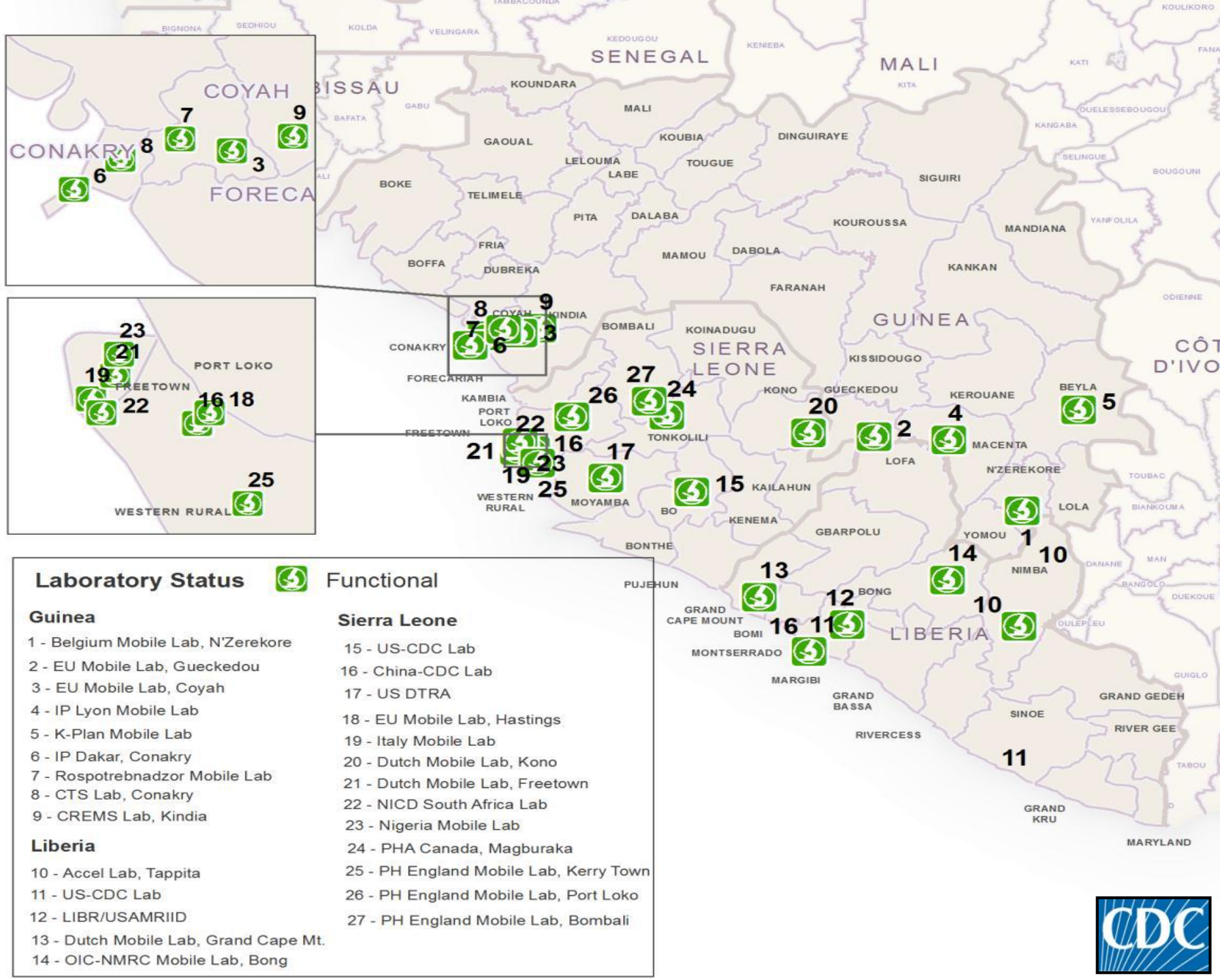


‘United Nations’ of labs

- Labs provided by:
- Germany France Italy Belgium Netherlands England Canada USA Nigeria South Africa China Russia

- US agencies included CDC, NIH and DOD

WHO Ebola Situation Report
Mar 18, 2015



Laboratory Status Functional

Guinea

1 - Belgium Mobile Lab, N'Zerekore
2 - EU Mobile Lab, Gueckedou
3 - EU Mobile Lab, Coyah
4 - IP Lyon Mobile Lab
5 - K-Plan Mobile Lab
6 - IP Dakar, Conakry
7 - Rospotrebnadzor Mobile Lab
8 - CTS Lab, Conakry
9 - CREMS Lab, Kindia

Liberia

10 - Accel Lab, Tappita
11 - US-CDC Lab
12 - LIBR/USAMRIID
13 - Dutch Mobile Lab, Grand Cape Mt.
14 - OIC-NMRC Mobile Lab, Bong

Sierra Leone

15 - US-CDC Lab
16 - China-CDC Lab
17 - US DTRA
18 - EU Mobile Lab, Hastings
19 - Italy Mobile Lab
20 - Dutch Mobile Lab, Kono
21 - Dutch Mobile Lab, Freetown
22 - NICD South Africa Lab
23 - Nigeria Mobile Lab
24 - PHA Canada, Magburaka
25 - PH England Mobile Lab, Kerry Town
26 - PH England Mobile Lab, Port Loko
27 - PH England Mobile Lab, Bombali

Special Pathogens Branch

CDC

CDC Bo
“Hot Lab”

Generator, water and waste disposal provided by MSF

MSF ETU

CDC Bo Lab set up

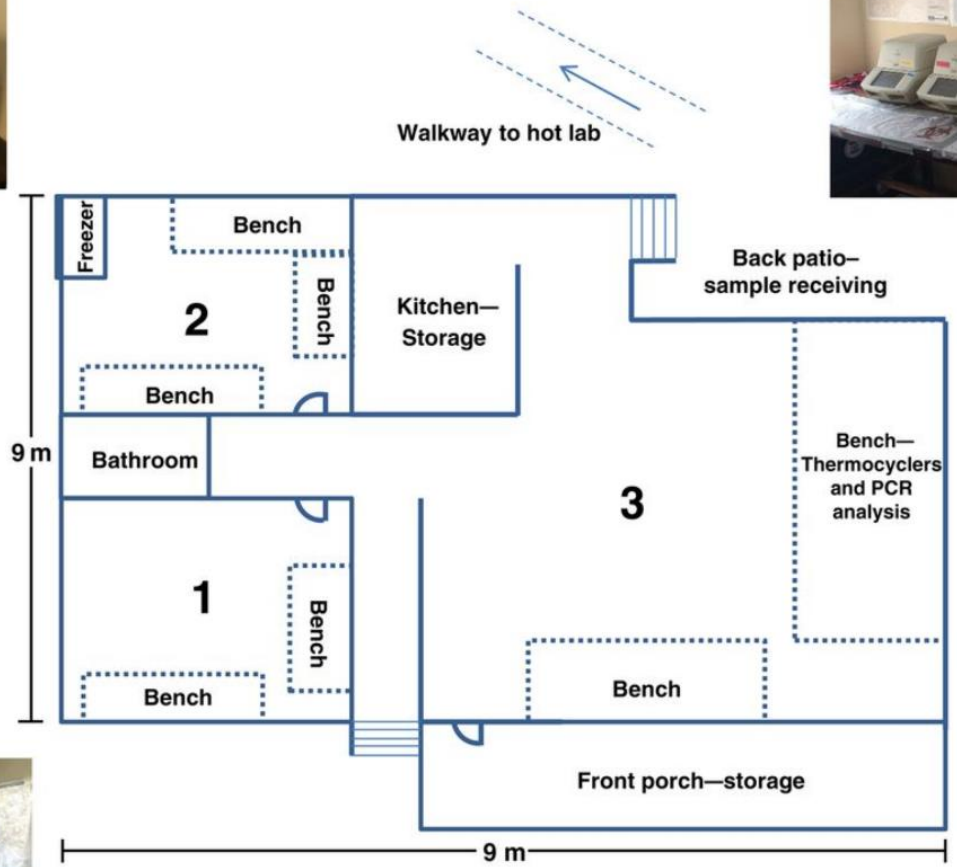
RNA extraction: automated
- Dynal® BeadRetriever™ (15 samples)
- MagMAX™ Express-96 Deep Well Magnetic Particle Processor (96 samples)
- run takes approx. 30’

Real time RT-PCR
- Biorad CFX96 Touch™ Real-Time PCR Detection System
  - run resumes in case of short power loss
  - can operate without a lap top (less instruments requiring power)

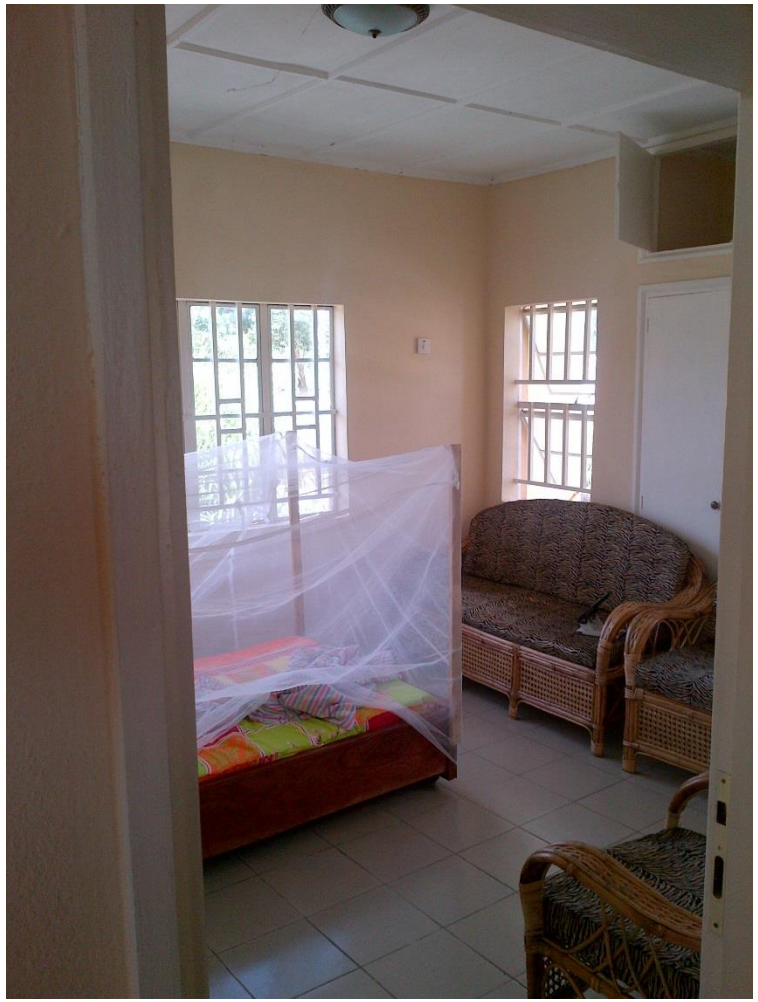
2 targets: Ebola NP & VP40
- cellular gene (β2M) as extraction control
- run takes approx. 90’

Room 2. The 96-well RNA extractor is in the center, 3 Bead Retrievers are on the right. Foil was placed over the window to deflect the heat of the sun

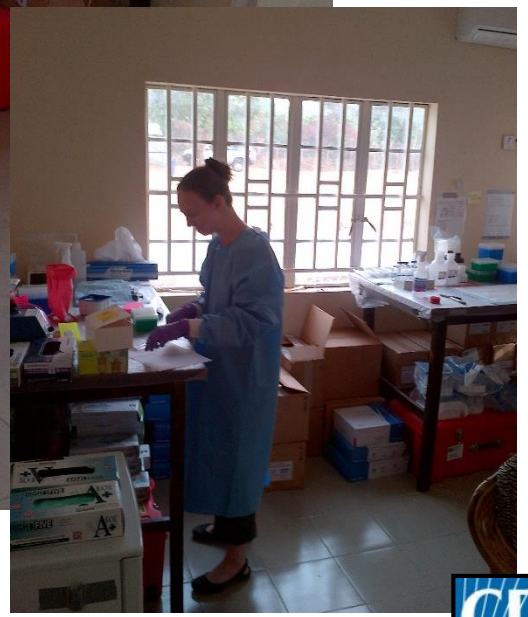
Room 3. Office area with thermocyclers



Clean Room

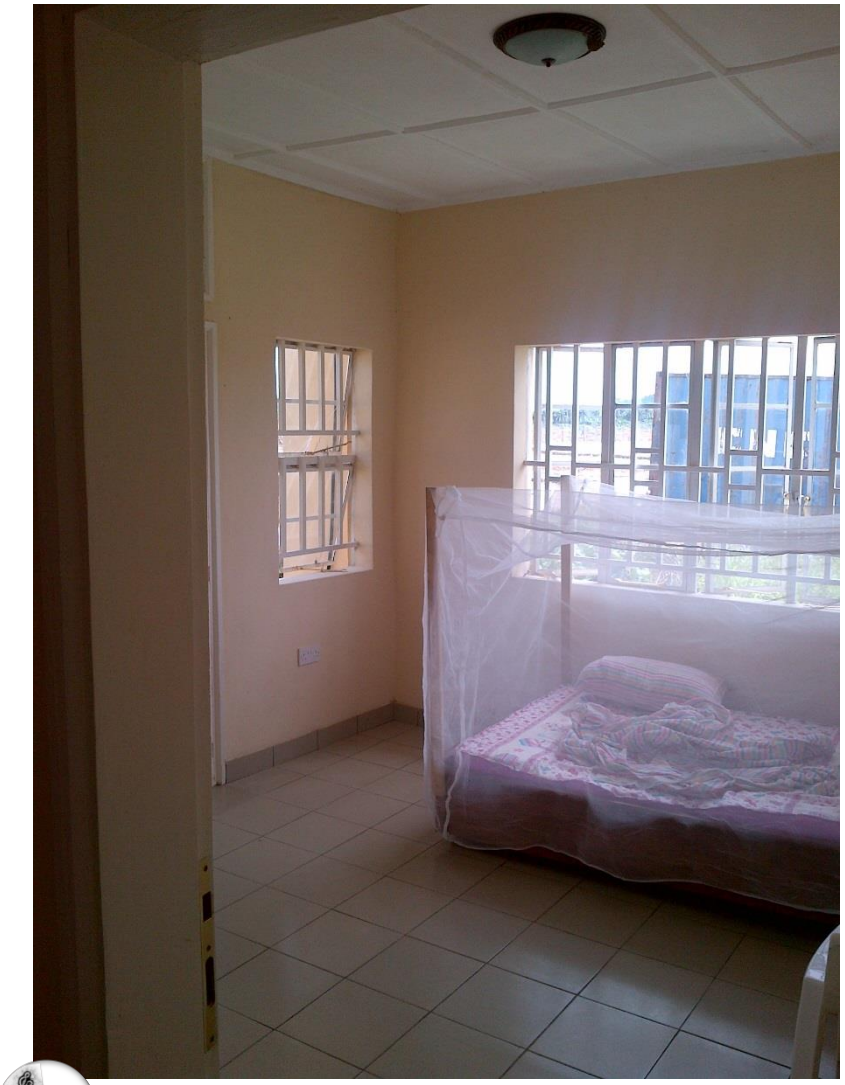


Before



After

RNA Extraction Room



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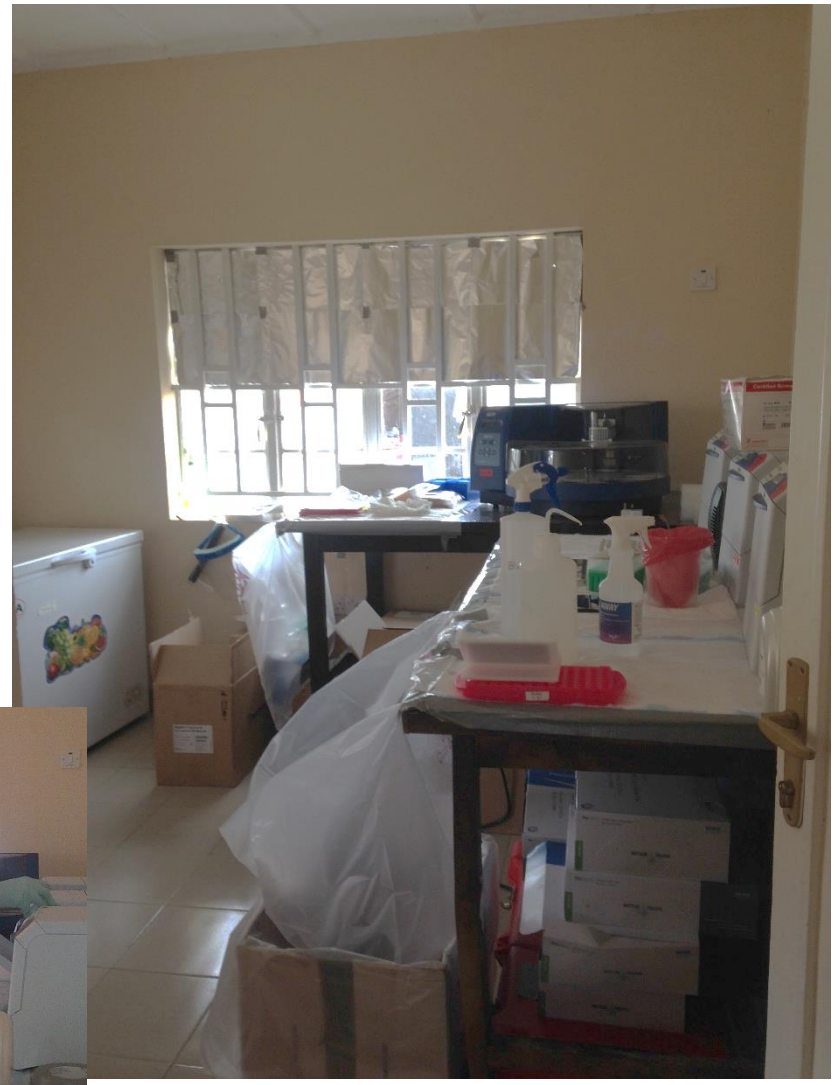

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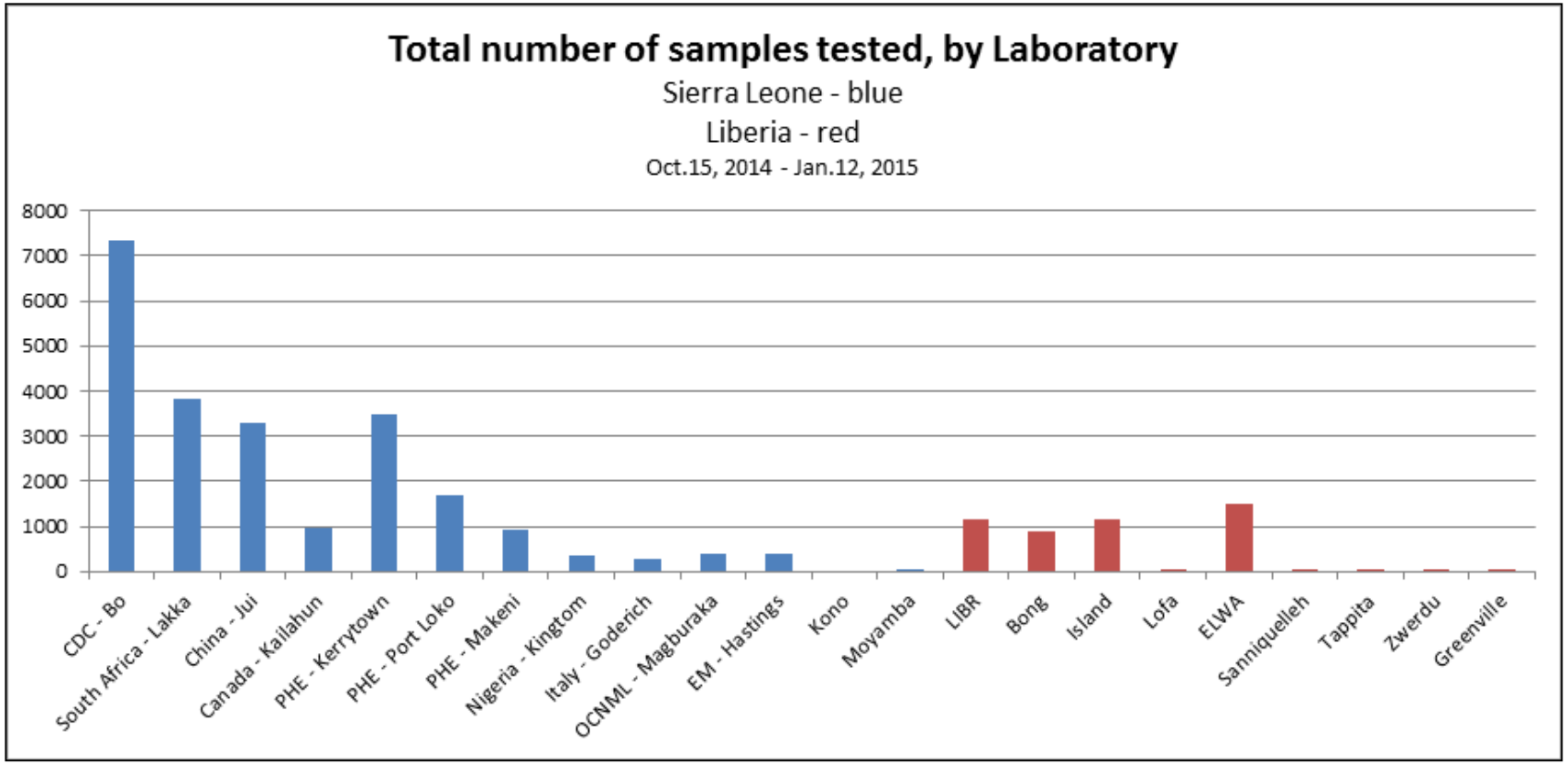


CDC Sierra Leone lab contribution

- At height of outbreak processed 2,000 clinical specimens in a 3-week period

Types of Specimens

Special Pathogens Branch

CDC

Sample transport in Sierra Leone

UNMEER helicopters moving samples within Sierra Leone

Special Pathogens Branch

CDC

Bo lab accomplishments

- **>27,000** samples tested
- The lab remained continuously operational for **406 days**
- Viral persistence in male survivors: testing of >500 semen samples
- STRIVE (Sierra Leone vaccine trial) testing began on May 24th and we tested 51 samples from 30 participants
- **28 teams** of personnel from **17 different branches** throughout CDC were trained and deployed to operate Bo lab

50th Anniversary of CDC's High Containment Laboratory: Major virus discoveries along the way…

Dr. Karl Johnson

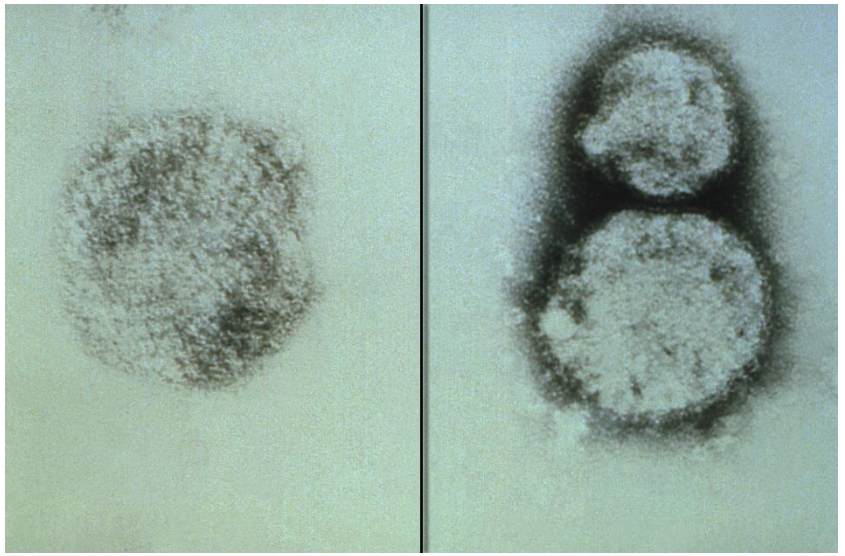
50th Anniversary of CDC's High Containment Laboratory: Major virus discoveries along the way…

- **1993 – Identification and isolation of Sin Nombre virus (4 corners virus)**

Genetic Identification of a Hantavirus Associated with an Outbreak of Acute Respiratory Illness

Stuart T. Nichol,* Christina F. Spiropoulou, Sergey Morzunov, Pierre E. Rollin, Thomas G. Ksiazek, Heinz Feldmann, Anthony Sanchez, James Childs, Sherif Zaki, Clarence J. Peters

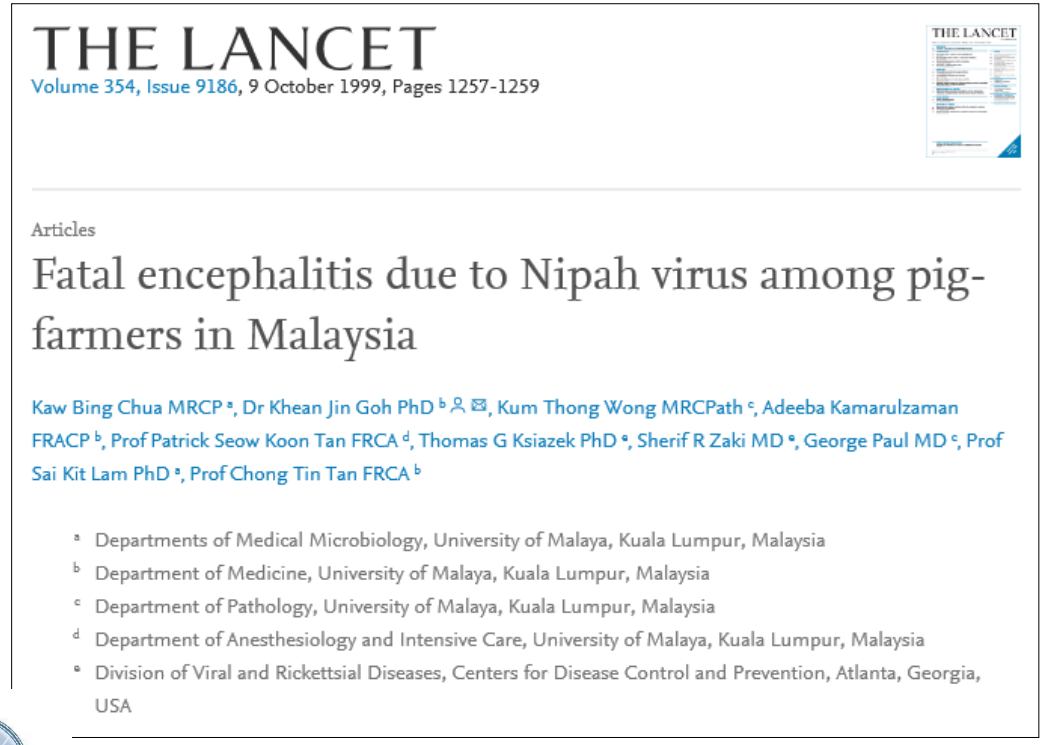
A mysterious respiratory illness with high mortality was recently reported in the southwestern United States. Serologic studies implicated the hantaviruses, rodent-borne RNA viruses usually associated elsewhere in the world with hemorrhagic fever with renal syndrome. A genetic detection assay amplified hantavirus-specific DNA fragments from RNA extracted from the tissues of patients and deer mice (*Peromyscus maniculatus*) caught at or near patient residences. Nucleotide sequence analysis revealed the associated virus to be a new hantavirus and provided a direct genetic link between infection in patients and rodents.



SCIENCE • VOL. 262 • 5 NOVEMBER 1993

50th Anniversary of CDC's High Containment Laboratory: Major virus discoveries along the way…

- **1999 – Identification and isolation of Nipah virus**



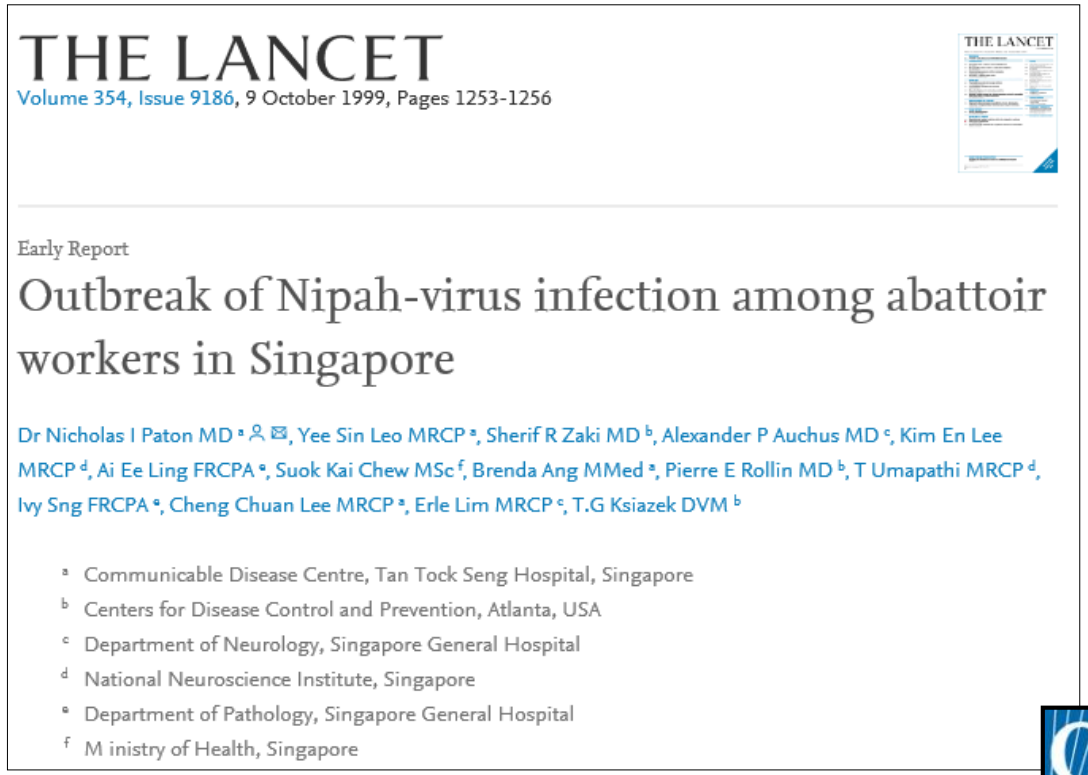
THE LANCET
Volume 354, Issue 9186, 9 October 1999, Pages 1257-1259

Articles

Fatal encephalitis due to Nipah virus among pig-farmers in Malaysia

Kaw Bing Chua MRCP [a], Dr Khean Jin Goh PhD [b] ✉, Kum Thong Wong MRCPath [c], Adeeba Kamarulzaman FRACP [b], Prof Patrick Seow Koon Tan FRCA [d], Thomas G Ksiazek PhD [e], Sherif R Zaki MD [e], George Paul MD [c], Prof Sai Kit Lam PhD [a], Prof Chong Tin Tan FRCA [b]

[a] Departments of Medical Microbiology, University of Malaya, Kuala Lumpur, Malaysia
[b] Department of Medicine, University of Malaya, Kuala Lumpur, Malaysia
[c] Department of Pathology, University of Malaya, Kuala Lumpur, Malaysia
[d] Department of Anesthesiology and Intensive Care, University of Malaya, Kuala Lumpur, Malaysia
[e] Division of Viral and Rickettsial Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia, USA



THE LANCET
Volume 354, Issue 9186, 9 October 1999, Pages 1253-1256

Early Report

Outbreak of Nipah-virus infection among abattoir workers in Singapore

Dr Nicholas I Paton MD [a] ✉, Yee Sin Leo MRCP [a], Sherif R Zaki MD [b], Alexander P Auchus MD [c], Kim En Lee MRCP [d], Ai Ee Ling FRCPA [e], Suok Kai Chew MSc [f], Brenda Ang MMed [a], Pierre E Rollin MD [b], T Umapathi MRCP [d], Ivy Sng FRCPA [e], Cheng Chuan Lee MRCP [a], Erle Lim MRCP [c], T.G Ksiazek DVM [b]

[a] Communicable Disease Centre, Tan Tock Seng Hospital, Singapore
[b] Centers for Disease Control and Prevention, Atlanta, USA
[c] Department of Neurology, Singapore General Hospital
[d] National Neuroscience Institute, Singapore
[e] Department of Pathology, Singapore General Hospital
[f] M inistry of Health, Singapore

50th Anniversary of CDC's High Containment Laboratory: Major virus discoveries along the way…

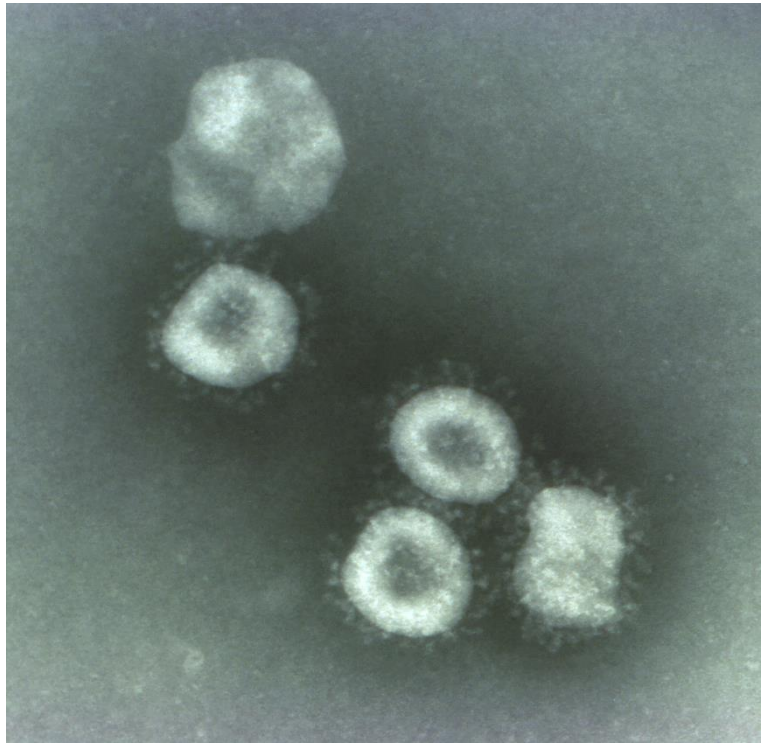
- **2003 – Identification and isolation of SARS**

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 MAY 15, 2003 VOL. 348 NO. 20

A Novel Coronavirus Associated with Severe Acute Respiratory Syndrome

Thomas G. Ksiazek, D.V.M., Ph.D., Dean Erdman, Dr.P.H., Cynthia S. Goldsmith, M.S., Sherif R. Zaki, M.D., Ph.D., Teresa Peret, Ph.D., Shannon Emery, B.S., Suxiang Tong, Ph.D., Carlo Urbani, M.D.,* James A. Comer, Ph.D., M.P.H., Wilina Lim, M.D., Pierre E. Rollin, M.D., Scott F. Dowell, M.D., M.P.H., Ai-Ee Ling, M.D., Charles D. Humphrey, Ph.D., Wun-Ju Shieh, M.D., Ph.D., Jeannette Guarner, M.D., Christopher D. Paddock, M.D., M.P.H.T.M., Paul Rota, Ph.D., Fields, Ph.D., Joseph DeRisi, Ph.D., Jyh-Yuan Yang, Ph.D., Nancy Cox, Ph.D., James M. Hughes, M.D., ıes W. LeDuc, Ph.D., William J. Bellini, Ph.D., Larry J. Anderson, M.D., and the SARS Working Group†



50th Anniversary of CDC's High Containment Laboratory: Major virus discoveries along the way…

- **2007 – Identification and isolation of Bundibugyo ebolavirus**

OPEN ACCESS Freely available online

PLoS PATHOGENS

Newly Discovered Ebola Virus Associated with Hemorrhagic Fever Outbreak in Uganda

Jonathan S. Towner[1], Tara K. Sealy[1], Marina L. Khristova[2], César G. Albariño[1], Sean Conlan[3], Serena A. Reeder[1], Phenix-Lan Quan[3], W. Ian Lipkin[3], Robert Downing[4], Jordan W. Tappero[4], Samuel Okware[5], Julius Lutwama[6], Barnabas Bakamutumaho[6], John Kayiwa[6], James A. Comer[1], Pierre E. Rollin[1], Thomas G. Ksiazek[1], Stuart T. Nichol[1]*

1 Special Pathogens Branch, Centers for Disease Control and Prevention, Atlanta, Georgia, United States of America, **2** Scientific Resources Program, Centers for Disease Control and Prevention, Atlanta, Georgia, United States of America, **3** Center for Infection and Immunity, Mailman School of Public Health, Columbia University, New York, New York, United States of America, **4** Global AIDS Program, Centers for Disease Control and Prevention, Entebbe, Uganda, **5** Ministry of Health, Republic of Uganda, Kampala, Uganda, **6** Uganda Virus Research Institute, Entebbe, Uganda

50th Anniversary of CDC's High Containment Laboratory: Major virus discoveries along the way…

- **2009 – Identification and isolation of Lujo virus**

OPEN ACCESS Freely available online

PLoS PATHOGENS

Genetic Detection and Characterization of Lujo Virus, a New Hemorrhagic Fever–Associated Arenavirus from Southern Africa

Thomas Briese[1,9]*, Janusz T. Paweska[2,9], Laura K. McMullan[3], Stephen K. Hutchison[4], Craig Street[1], Gustavo Palacios[1], Marina L. Khristova[5], Jacqueline Weyer[2], Robert Swanepoel[2], Michael Egholm[4], Stuart T. Nichol[3], W. Ian Lipkin[1]*

1 Center for Infection and Immunity, Mailman School of Public Health, Columbia University, New York, New York, United States of America, **2** Special Pathogens Unit, National Institute for Communicable Diseases of the National Health Laboratory Service, Sandringham, South Africa, **3** Special Pathogens Branch, Division of Viral and Rickettsial Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia, United States of America, **4** 454 Life Sciences, Branford, Connecticut, United States of America, **5** Biotechnology Core Facility Branch, Centers for Disease Control and Prevention, Atlanta, Georgia, United States of America

Nosocomial Outbreak of Novel Arenavirus Infection, Southern Africa

Janusz T. Paweska, Nivesh H. Sewlall, Thomas G. Ksiazek, Lucille H. Blumberg, Martin J. Hale, W. Ian Lipkin, Jacqueline Weyer, Stuart T. Nichol, Pierre E. Rollin, Laura K. McMullan, Christopher D. Paddock, Thomas Briese, Joy Mnyaluza, Thu-Ha Dinh, Victor Mukonka, Pamela Ching, Adriano Duse, Guy Richards, Gillian de Jong, Cheryl Cohen, Bridget Ikalafeng, Charles Mugero, Chika Asomugha, Mirriam M. Malotle, Dorothy M. Nteo, Eunice Misiani, Robert Swanepoel, Sherif R. Zaki, and members of the Outbreak Control and Investigation Teams[1]

Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 15, No. 10, October 2009

50th Anniversary of CDC's High Containment Laboratory: Major virus discoveries along the way…

- **2012 – Identification and isolation of Heartland virus**

The NEW ENGLAND JOURNAL of MEDICINE

BRIEF REPORT

A New Phlebovirus Associated with Severe Febrile Illness in Missouri

Laura K. McMullan, Ph.D., Scott M. Folk, M.D., Aubree J. Kelly, M.S., Adam MacNeil, Ph.D., Cynthia S. Goldsmith, M.G.S., Maureen G. Metcalfe, B.S., Brigid C. Batten, M.P.H., César G. Albariño, Ph.D., Sherif R. Zaki, M.D., Ph.D., Pierre E. Rollin, M.D., William L. Nicholson, Ph.D., and Stuart T. Nichol, Ph.D.

50th Anniversary of CDC's High Containment Laboratory: Major virus discoveries along the way…

- 2014 – Identification and isolation of Sosuga virus

Novel Paramyxovirus Associated with Severe Acute Febrile Disease, South Sudan and Uganda, 2012

César G. Albariño, Michael Foltzer, Jonathan S. Towner, Lory A. Rowe, Shelley Campbell, Carlos M. Jaramillo, Brian H. Bird, DeeAnn M. Reeder, Megan E. Vodzak, Paul Rota, Maureen G. Metcalfe, Christina F. Spiropoulou, Barbara Knust, Joel P. Vincent, Michael A. Frace, Stuart T. Nichol, Pierre E. Rollin, and Ute Ströher

Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 20, No. 2, February 2014

Ebola in Zaire ‘76 – Where are we now?

Ebola reverse genetic systems at CDC

Available online at www.sciencedirect.com

SCIENCE DIRECT

VIROLOGY

ELSEVIER

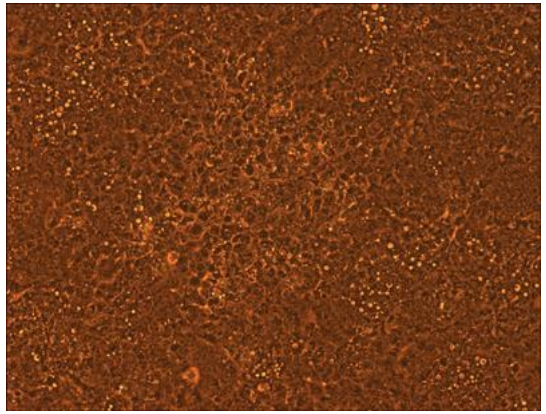
Virology 332 (2005) 20–27

www.elsevier.com/locate/yviro

Rapid Communication

Generation of eGFP expressing recombinant Zaire ebolavirus for analysis of early pathogenesis events and high-throughput antiviral drug screening

Jonathan S. Towner[a], Jason Paragas[b], Jason E. Dover[a], Manisha Gupta[a], Cynthia S. Goldsmith[c], John W. Huggins[b], Stuart T. Nichol[a,*]



Brightfield

THE LANCET

Infectious Diseases

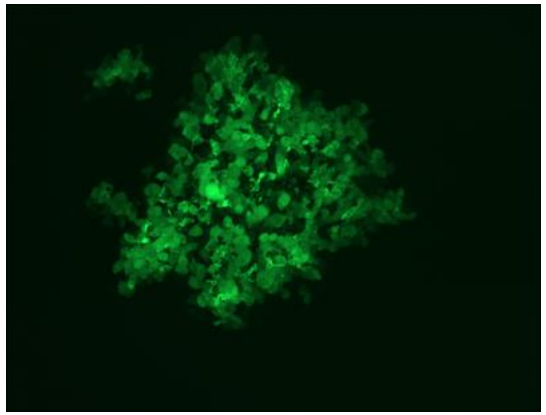
Available online 9 July 2019

In Press, Corrected Proof

Articles

Characterisation of infectious Ebola virus from the ongoing outbreak to guide response activities in the Democratic Republic of the Congo: a phylogenetic and in vitro analysis

Laura K McMullan PhD [a], Mike Flint PhD [a], Ayan Chakrabarti MS [a], Lisa Guerrero MPH [a], Michael K Lo PhD [a], Danielle Porter PhD [b], Stuart T Nichol PhD [a], Christina F Spiropoulou PhD [a], César Albariño PhD [a]



Fluorescent

Special Pathogens Branch

CDC

Ebola in Zaire ‘76 – Where are we now?

Ebola vaccines

Ebola in Zaire ‘76 – Where are we now?

Ebola vaccines

- **In 2000 – 1st demonstration that Ebola infection could be prevented by a vaccine**
- **3 x DNA (GP) + ADV (GP) boost**
- **All vaccinated nonhuman primates asymptomatic after challenge**

nature
International journal of science

Letter | Published: 30 November 2000

Development of a preventive vaccine for Ebola virus infection in primates

Nancy J. Sullivan, Anthony Sanchez, Pierre E. Rollin, Zhi-yong Yang & Gary J. Nabel

Nature **408**, 605–609 (2000)

Vaccine Research Center, National Institutes of Health, 40 Convent Drive, MSC-3005, Bethesda, 20892, Maryland, USA
Nancy J. Sullivan, Zhi-yong Yang & Gary J. Nabel

Special Pathogens Branch, Centers for Disease Control and Prevention, 1600 Clifton Road, Mailstop G14, Atlanta, 30333, Georgia, USA
Anthony Sanchez & Pierre E. Rollin

Ebola in Zaire ‘76 – Where are we now?

Ebola vaccines

- 2 dose ‘Ebola prime boost’
  ADV (GP) + MVA (GP) day 56

INNOVATION

Johnson & Johnson Advances Investigational Ebola Prime-boost Vaccine Regimen with New Partnership

NEW BRUNSWICK, N.J., SEPTEMBER 29, 2017 – Johnson & Johnson (NYSE: JNJ) announced today

Ebola in Zaire ‘76 – Where are we now?

Ebola vaccines

- 2 dose ‘Ebola prime boost’ ADV (GP) + MVA (GP) day 56
- **1 dose Ebola VSV-based (rVSVΔG-ZEBOV-GP)**
  - **>200,000 vaccine doses given in eastern DRC**
  - **97.5% efficacy**

MERCK
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ABOUT US INVENTING FOR LIFE PRODUCTS RESEARCH

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Merck Begins Rolling Submission of Licensure Application for V920 (rVSVΔG-ZEBOV-GP) to U.S. Food and Drug Administration

V920 is the Company's Investigational Vaccine for Ebola Zaire

Tuesday, November 13, 2018 4:35 pm EST

Ebola in Zaire ‘76 – Where are we now?

Ebola therapeutics

As of 12 August 2019, Ebola (Zaire) may be treatable!*

*Pending release and analysis of final data - these numbers from NY Times

- PALM trial = Pamjoa Tulinde Maisha, "Save Lives Together"
- Randomized, multicenter clinical trial in DRC, started Nov 2018
- 4 arms, no placebo - interim mortality data from 499 patients

Remdesivir (Gilead Sciences)

- Small-molecule, nucleotide analogue
- 53% mortality (33% with low viral load)

ZMapp (Mapp BioPharmaceutical)

- Cocktail of 3 chimeric mouse-human mAbs
- Given in West Africa (efficacy unproven)
- 49% mortality (24% with low viral load)

mAb-114 (Ridgeback Biotherapeutics)

- Human mAb from survivor of 1995 Kikwit outbreak
- 34% mortality (**11% with low viral load**)

REGN-EB3 (Regeneron Pharmaceuticals)

- Cocktail of 3 human mAbs
- 29% mortality (**6% with low viral load**)
- Not significantly different from mAb-114

- Trial halted for efficacy, all patients now to be offered mAb-114 or REGN-EB3.

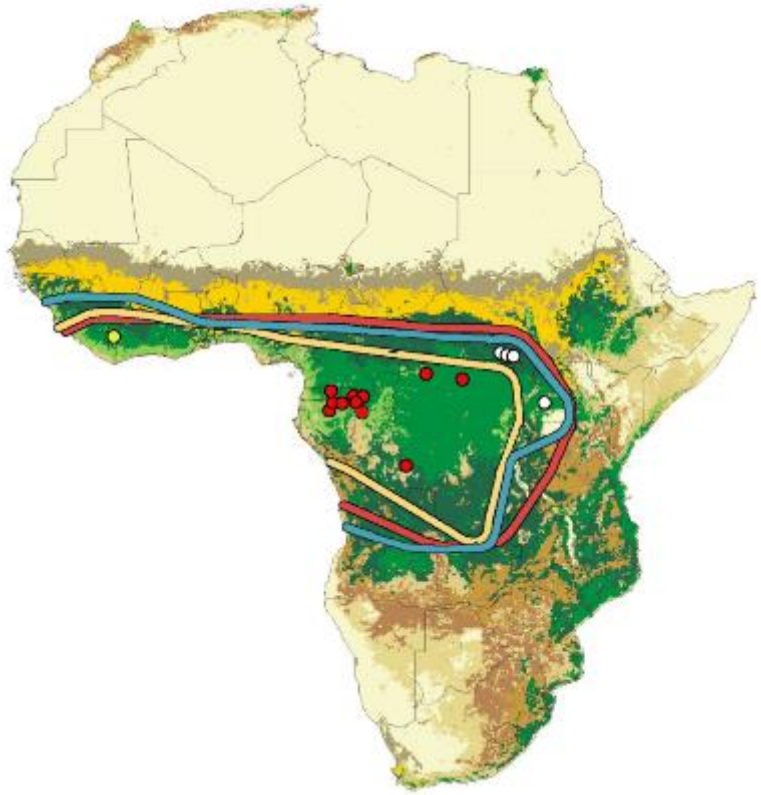
Special Pathogens Branch

Names of specific products are for informational purposes only and do not constitute endorsement by CDC or HHS.

CDC

Ebola – Where does it come from?

Ebola Zaire reservoir search in Gabon, 2002-03



- Only known PCR data to date for Ebola virus, no additional published reports
- Home ranges overlap outbreak locations
- Ebola virus never isolated from a bat

Hypsignathus monstrosus

PCR+	4/21
IgG+	4/17

Epomops franqueti

PCR+	5/117
IgG+	8/117

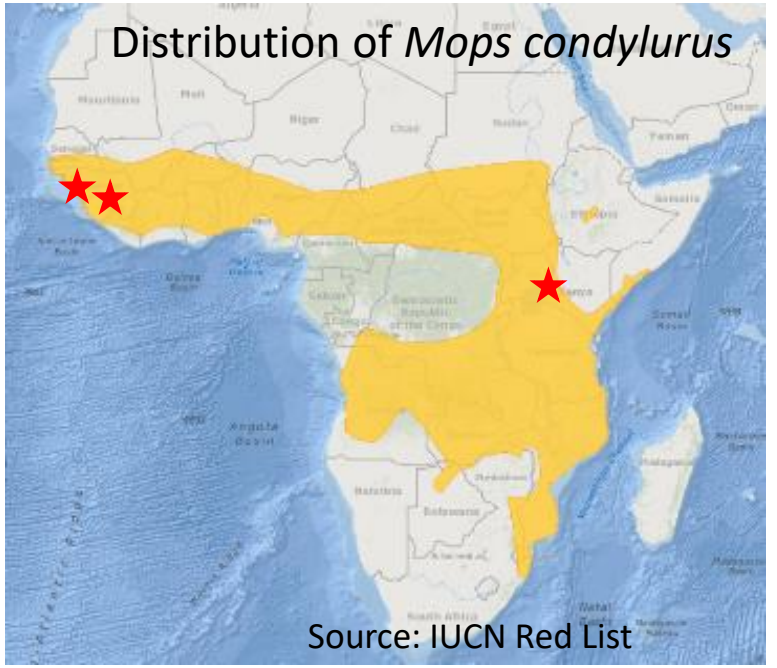
Myonycteris torquata

PCR+	4/141
IgG+	4/58

Eric M. Leroy et al., Fruit bats as reservoirs of Ebola virus *Nature* 438, 575-576 (1 December 2005)

Ebola Zaire reservoir search in Guinea, 2014

Mops condylurus



- **No PCR+ bats found**
- **No linkage to large mammal die-off**
- **Antibody evidence inconclusive**
- **Home range doesn't overlap previous Ebola outbreaks**
- **Secondary host?**
- **Peridomestic**


Published online: December 30, 2014

Report

TRANSPARENT PROCESS OPEN ACCESS

EMBO Molecular Medicine

Investigating the zoonotic origin of the West African Ebola epidemic

Almudena Marí Saéz[1,†], Sabrina Weiss[2,†,‡,§], Kathrin Nowak[2,3,†], Vincent Lapeyre[4,†],

Ebola Zaire reservoir search in Guinea, 2014

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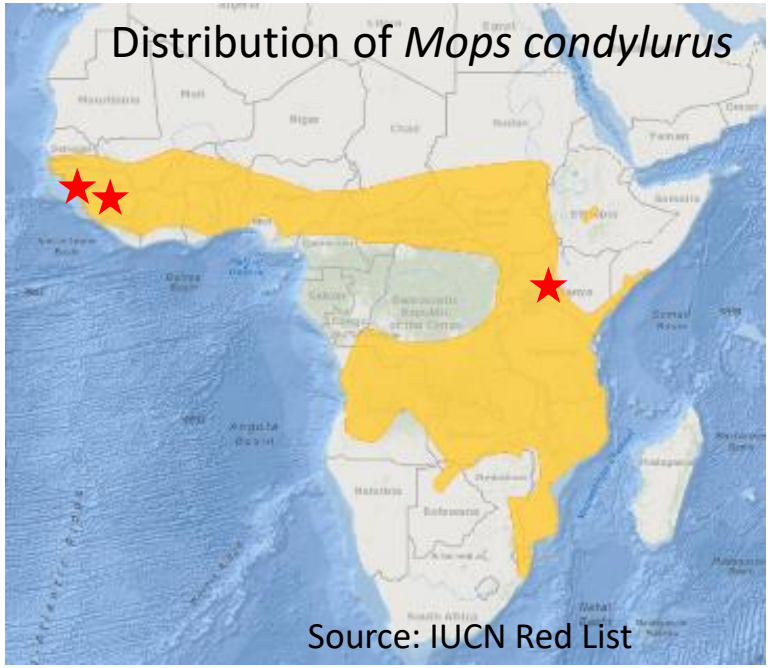

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BRIEF COMMUNICATION

https://doi.org/10.1038/s41564-018-0227-2

nature microbiology

Corrected: Author Correctior

The discovery of Bombali virus adds further support for bats as hosts of ebolaviruses

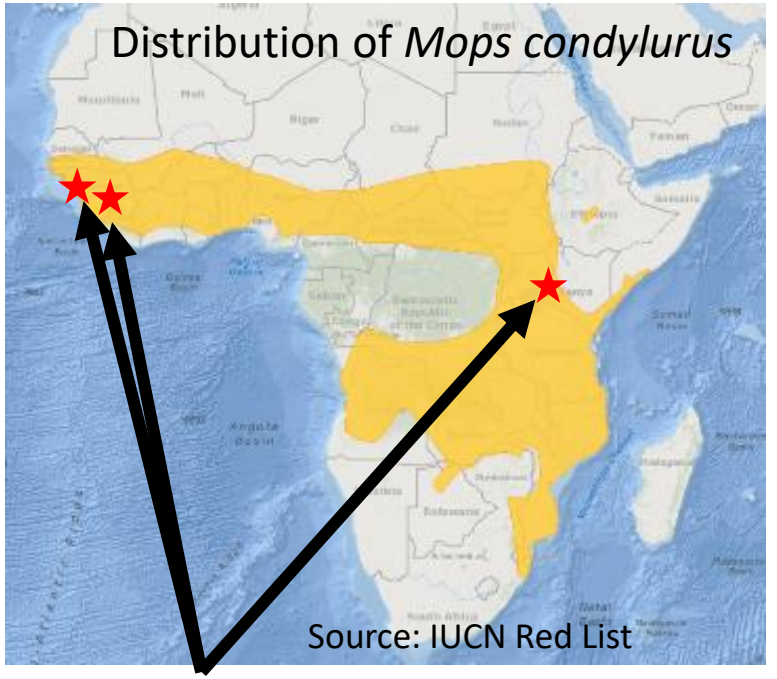
Tracey Goldstein[1,14*], Simon J. Anthony[2,3,4,14*], Aiah Gbakima[5], Brian H. Bird[1], James Bangura[5], Alexandre Tremeau-Bravard[1], Manjunatha N. Belaganahalli[1], Heather L. Wells[2], Jasjeet K. Dhanota[1], Eliza Liang[2,4], Michael Grodus[2], Rohit K. Jangra[6], Veronica A. DeJesus[6], Gorka Lasso[7], Brett R. Smith[1], Amara Jambai[8], Brima O. Kamara[9], Sorie Kamara[10], William Bangura[11], Corina Monagin[1,12], Sagi Shapira[7,13], Christine K. Johnson[1], Karen Saylors[12], Edward M. Rubin[12], Kartik Chandran[6], W. Ian Lipkin[2,3] and Jonna A. K. Mazet[1]

Special Pathogens Branch

CDC

Ebola Zaire reservoir search in Guinea 2014

Mops condylurus



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Special Pathogens Branch

CDC

Egyptian rousette bat (*Rousettus aegyptiacus*) is a natural reservoir for Marburg/Ravn viruses

- 1998-2000: Goroumbwa mine, DRC, Marburg outbreak
  - 9 Marburg virus lineages found in miners and bats
- 2007: Kitaka Mine, Uganda Marburg outbreak
  - 5 Marburg/Ravn virus isolates from Egyptian rousettes
- 2008: Python Cave, Uganda Marburg virus in tourists
  - 7 Marburg/Ravn virus isolates from Egyptian rousettes
- 2012: Ibanda (Kitaka Mine), Uganda Marburg outbreak
  - 9 Marburg isolates from Egyptian rousettes

Tourists + Egyptian rousette bats

Egyptian rousette bats

Photo Jon Towner

Studies of Reservoir Hosts for Marburg Virus

Robert Swanepoel,* Sheilagh B. Smit,* Pierre E. Rollin,† Pierre Formenty,‡ Patricia A. Leman,* Alan Kemp,* Felicity J. Burt,§ Antoinette A. Grobbelaar,* Janice Croft,* Daniel G. Bausch,¶ Hervé Zeller,# Herwig Leirs,** †† L.E.O. Braack,‡‡ Modeste L. Libande,§§ Sherif Zaki,† Stuart T. Nichol,† Thomas G. Ksiazek,† and Janusz T. Paweska,* on behalf of the International Scientific and Technical Committee for Marburg Hemorrhagic Fever Control in the Democratic Republic of the Congo

Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 13, No. 12, December 2007

OPEN ACCESS Freely available online PLoS PATHOGENS

Isolation of Genetically Diverse Marburg Viruses from Egyptian Fruit Bats

Jonathan S. Towner[1], Brian R. Amman[1], Tara K. Sealy[1], Serena A. Reeder Carroll[1], James A. Comer[1], Alan Kemp[2], Robert Swanepoel[2], Christopher D. Paddock[3], Stephen Balinandi[4], Marina L. Khristova[5], Pierre B. H. Formenty[6], Cesar G. Albarino[1], David M. Miller[1], Zachary D. Reed[1], John T. Kayiwa[7], James N. Mills[1], Deborah L. Cannon[1], Patricia W. Greer[3], Emmanuel Byaruhanga[8], Eileen C. Farnon[1], Patrick Atimnedi[9], Samuel Okware[10], Edward Katongole-Mbidde[7], Robert Downing[4], Jordan W. Tappero[4], Sherif R. Zaki[3], Thomas G. Ksiazek[1¤], Stuart T. Nichol[1]*, Pierre E. Rollin[1]*

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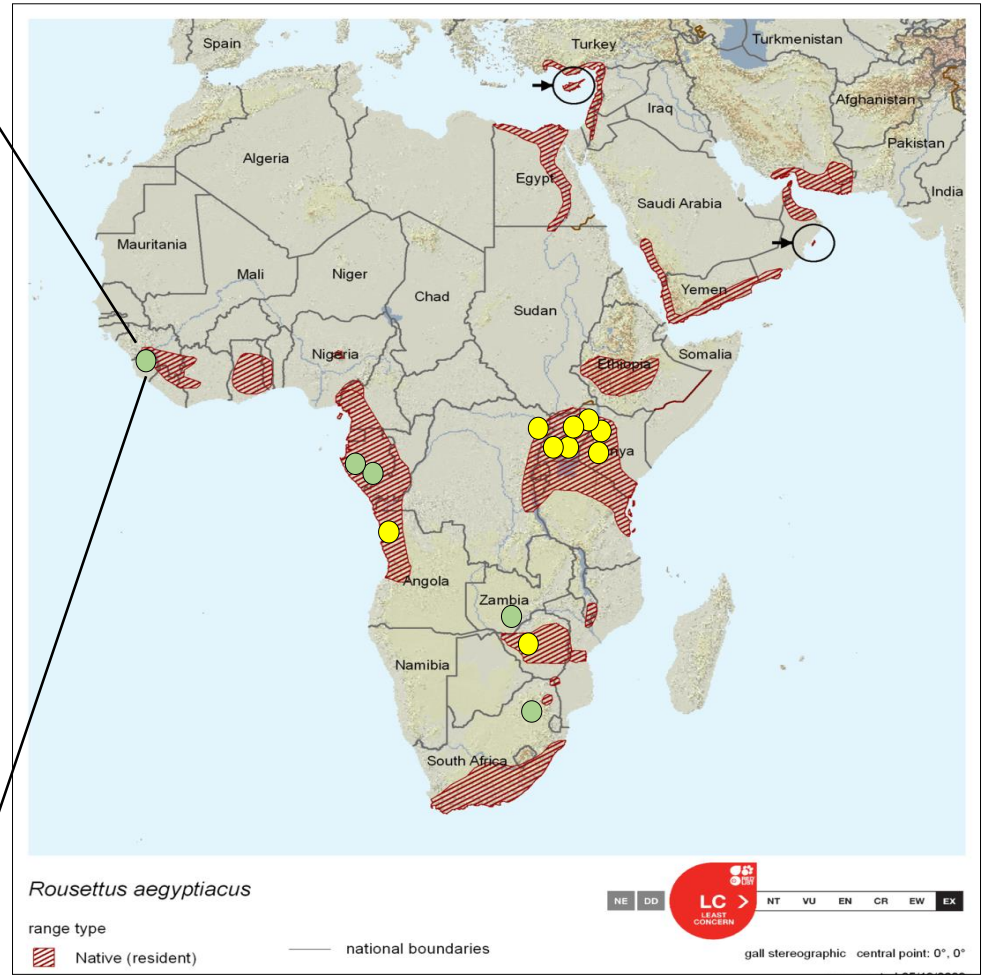
Seasonal Pulses of Marburg Virus Circulation in Juvenile *Rousettus aegyptiacus* Bats Coincide with Periods of Increased Risk of Human Infection

Brian R. Amman[1], Serena A. Carroll[1], Zachary D. Reed[1], Tara K. Sealy[1], Stephen Balinandi[1], Robert Swanepoel[2¤a], Alan Kemp[2], Bobbie Rae Erickson[1], James A. Comer[1], Shelley Campbell[1], Deborah L. Cannon[1], Marina L. Khristova[3], Patrick Atimnedi[4], Christopher D. Paddock[5], Rebekah J. Kent Crockett[6], Timothy D. Flietstra[1], Kelly L. Warfield[7], Robert Unfer[7], Edward Katongole-Mbidde[8], Robert Downing[9], Jordan W. Tappero[9], Sherif R. Zaki[5], Pierre E. Rollin[1], Thomas G. Ksiazek[1¤b], Stuart T. Nichol[1], Jonathan S. Towner[1]*

Isolation of Marburg virus from Egyptian rousette bats in Sierra Leone

- 435 *Rousettus aegyptiacus*
  - *Joint study: CDC, Njala University, UC Davis, University of Makeni*
- 11 bats (2.5%) qRT-PCR+ for Marburg virus
- 4 MARV isolates
  - all MARV Angola-like

Dr. Aiah Lebbie (Njala University) with US Ambassador Brewer



Lessons learned from Marburg: What could we apply to Ebola?

- For Ebola, there is no epidemiologic linkage to a restricted biome (e.g. cave/mine)
- For Marburg virus, the number of actively infected bats is low (2-5%)
  - Africa has >250 bat species: you do the math…
- Reservoir animals typically have inapparent disease
- There may be seasonality to consider such as increased infection in juveniles, birthing
- Expect spillover to secondary bat hosts
- Expect serological cross-reactivity to different ebolaviruses
- For Marburg virus, no evidence of persistent infection (ex. rodent reservoirs of arena- or hantaviruses)
- Virus replication and shedding may be brief; last 1-3 weeks

Thank You!