The forest, the fly, and the virus?

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Ebola hemorrhagic fever, named after the Ebola River in equatorial Africa, first appeared in June, 1976, during an outbreak of 284 cases in Nzara and Maridi, Southern Sudan with a fatality rate of 53%. In September 1976, another outbreak of 318 cases happened in Yambuku, Democratic Republic of the Congo (DRC), in which 88% of the affected died. Residual outbreaks occurred in the same areas over the next 2-3 years.

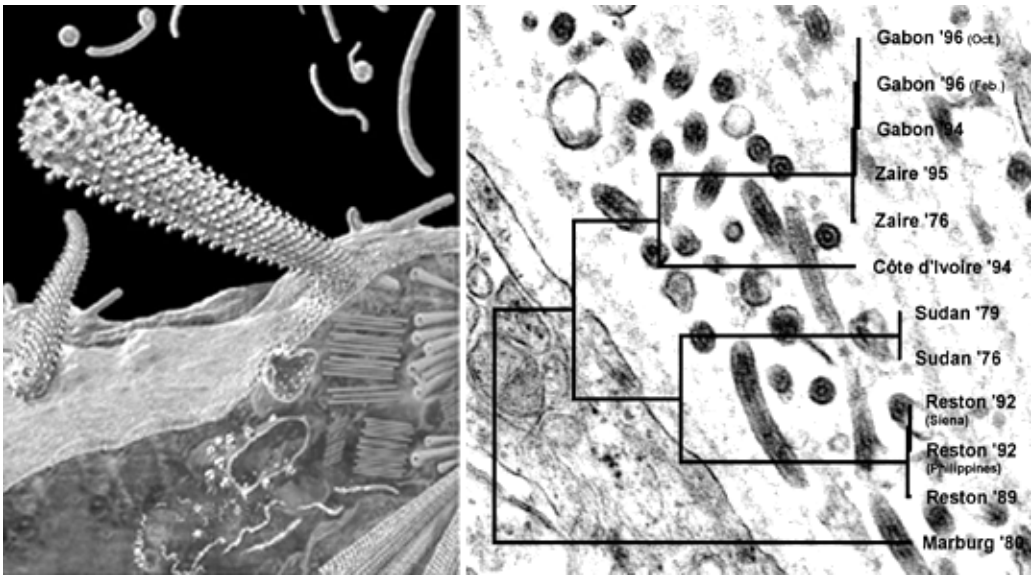

Figure 1. Artist's view of Ebola virus after Russell Kightley Media www.rkm.com.au on left and the phylogenetic tree of the various sequenced Ebola viruses strains and outbreak dates on the right.

Ebola hemorrhagic fever was not reported again until the end of 1994, when three outbreaks occurred within a relatively short time. In October, an outbreak was identified in a chimpanzee group in Tai, Cote d'Ivoire (12 chimpanzee cases, all chimps died) with one human infection that was not fatal. Forty-nine cases (59% fatal) were reported the following month in northeast Gabon in the gold panning camps of Mekouka, Andock, and Minkebe. Later that same month, 315 cases (77% were fatal) were reported at Kikwit, DRC, through unknown initial exposure thought to have occurred to men working in a

charcoal pit. Residual outbreaks were reported in February and July, 1996 in which 67% of those infected perished. Subsequent outbreaks have occurred in August 2000 and December 2001 in Uganda and Gabon and adjacent areas of Congo, respectively.

The emergence of Ebola hemorrhagic fever in equatorial Africa is enigmatic. It is thought to result from, or to be facilitated by, human intrusion into previously uninhabited tropical areas, changes in the ecology of the Ebola virus, or its natural reservoir, mutation of the Ebola virus, and possibly severe climatic conditions, which could serve as a "trigger" event. No reservoir or vector has yet been found.

All known outbreaks of Ebola have been linked to tropical forests. We undertook a study of environmental conditions associated with Ebola hemorrhagic fever after preliminary reports strongly suggested that simultaneous outbreaks occurred, during two limited time periods in the 1970s and 1990s, immediately following sudden transitions between dry and wet seasons.

Ebola hemorrhagic fever outbreaks were identified from documented, clinically described, and serologically confirmed cases. The date of the first documented Ebola case was used to define the start of each outbreak. We assume the first or index case had come into contact with Ebola virus up to 25 days prior to the onset of the illness. This includes an incubation period of 21 days plus additional time spent between onset of symptoms and subsequent appearance at a clinic (Peters and LeDuc, 1999).

Landsat data of the Ebola outbreak areas showed the vegetation ranged from primary tropical forest in a continuum of tropical forest (Gabon, Zaire/Congo, and Uganda sites), isolated primary tropical forest surrounded by human activities (Cote d'Ivoire site), or gallery tropical forest in a savanna matrix (Sudan sites).

Advanced Very High Resolution Radiometer normalized difference vegetation index data were used as a surrogate for photosynthetic capacity, which is directly influenced by rainfall. We found the most marked transitions between dry and wet seasons were closely associated with emergence of the Ebola virus for 2 of the 3 1994 outbreak sites investigated. Additional outbreaks are needed to test our hypothesis of a possible Ebola "trigger" event (Tucker et al., 2002). These have occurred in 2000 and 2001 and we are

presently expanding our study to include these most recent Ebola hemorrhagic fever outbreaks.

References

Peters, C. J. and J. W. LeDuc, 1999. An introduction to Ebola: The virus and the disease. *Journal of Infectious Diseases* 179:ix-xvi.

Tucker, C. J., Wilson, J. M., Mahoney, R., Anyamba, A., Linthicum, K., and Myers, M., 2002. Climatic and ecological context of the 1994-1996 Ebola outbreaks. *Photogrametric Engineering and Remote Sensing* 68:147-152.