

Editorial

# Viruses and Bats

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Bats are a unique but diverse group of mammals in the order *Chiroptera* (meaning “hand-wings” in Greek), which is the second largest order of mammals in terms of species number. Thus far, there are more than 1300 known species of bats across six continents, constituting 20% of the total number of mammalian species. Indonesia, for example, is home of more than 200 bat species, the largest variety in the world. Bats are monophyletic. Traditionally, they were classified into two suborders: *Megachiroptera* (megabats) and *Microchiroptera* (microbats). In general, megabats are larger than microbats, although some large microbats can be larger than some small megabats. Most megabats are frugivorous and eat fruit, nectar or pollen and most microbats are insectivorous. Some microbats also eat small vertebrates or even other bats. Recently, extensive molecular studies and phylogenetic analysis have led to a revision of the classification of bats into two suborders, *Yinpterochiroptera* and *Yangochiroptera*, of which *Yinpterochiroptera* includes the megabats and a number of microbat species. In general, bats are nocturnal animals that are mainly active during night time, dusk or dawn. They roost in caves, trees, mines and water tunnels and most rest and sleep in an upside-down position. They usually live in groups known as colonies, with hundreds to thousands of individuals, which may facilitate intraspecies transmission of viruses. They are capable of echolocation, which help them to locate themselves as well as their food.

The high diversity of bats, and hence the highly diversified cell types and receptors, have facilitated this group of animals to harbor a myriad of viruses. Bats are well recognized to be the hosts of a number of highly pathogenic viruses, such as rabies virus, Hendra virus, Nipah virus and Ebola virus, for a long time. Since the discovery of bats as the reservoir of Severe Acute Respiratory Syndrome (SARS) coronavirus [1,2], there has been a surge of interests in research on various aspects of bat viruses as well as bat-virus interactions. Using coronavirus as an example, there have been a total of at least 30 bat coronaviruses discovered in the last 15 years after the SARS epidemic in 2003 [3–15], and bats are now recognized as the gene source of *Alphacoronavirus* and *Betacoronavirus* in the current model of coronavirus evolution, the only two coronavirus genera with coronaviruses that are known to infect humans [16]. The discovery of *Tylonycteris* bat CoV HKU4 and *Pipistrellus* bat CoV HKU5 in *Tylonycteris pachypus* and *Pipistrellus abramus*, respectively, have also greatly facilitated the study of the Middle East Respiratory Syndrome coronavirus when it emerged in the Middle East in 2012 [9,17]. In fact, among the ~1900 papers on [bat virus] indexed in PubMed, two-thirds of them were published after the SARS epidemic in 2003 and half of them were published in the last seven years. In 2013, bats were the known reservoirs of more than 60 viruses that can infect humans.

In addition to its diversity, the capability to fly also facilitate bats to disseminate the viruses they harbor, and hence, increases the chance of both intraspecies and interspecies transmission, which involves two bat species or one bat species and another kind of animal. With their forelimbs adapted as wings, bats are the only mammals that are capable of sustained flight. Echolocation enables

bats to fly in dark places. Bats have long finger-like bones in their wings, and hence are more maneuverable than the wings of birds. However, unlike birds, they do not have a lot of lift. Furthermore, the fact that they are nocturnally active helps them avoid direct competition with birds. The ability to fly makes bats important vehicles for the dissemination of seeds and pollens, as well as viruses.

Contacts between human and bats or bat products are not uncommon. Huge bat caves, such as the Batu Caves in Malaysia, are major tourist attractions. Caves explorers are sometimes bitten by bats, and their mucous membranes or wounds may contact the saliva, urine, etc. of bats, resulting in virus transmission. In addition to these direct contacts, bats are used as food in southern China and some parts of Asia such as Indonesia. A variety of bat dishes, minced bat meat, and even hot pot with the whole bat cooked in a pot of soup are available in restaurants in southern China. Dried bat droppings are used as traditional Chinese medicine, for the treatment of diseases such as night blindness. Bat dung that is mined in caves as guano can be used as organic fertilizers. All these uses of bats and their derived products have created countless opportunities of human-bat interaction, and hence, have increased the chance of virus transmission.

In the recent few years, numerous novel bat viruses have been discovered and other downstream studies performed. In this special issue, a number of novel bat viruses, including coronavirus, poxvirus, paramyxovirus and orbivirus, were described [18–24]. In addition, molecular surveillance studies have improved our understanding on the epidemiology of a number of virus families in bats, as for example, adenovirus, coronavirus, mobatvirus, rubulavirus and rotavirus [15,25–31]. Furthermore, a number of studies on bat-virus interaction have provided insights into the innate immune response of bats developed upon encountering bat viruses [32–39]. All these have helped us better understand the diversity, epidemiology, intraspecies and interspecies transmission, host-virus interaction, etc. in various virus families in this unique group of animals.

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