Malaria- An evolutionary arms race

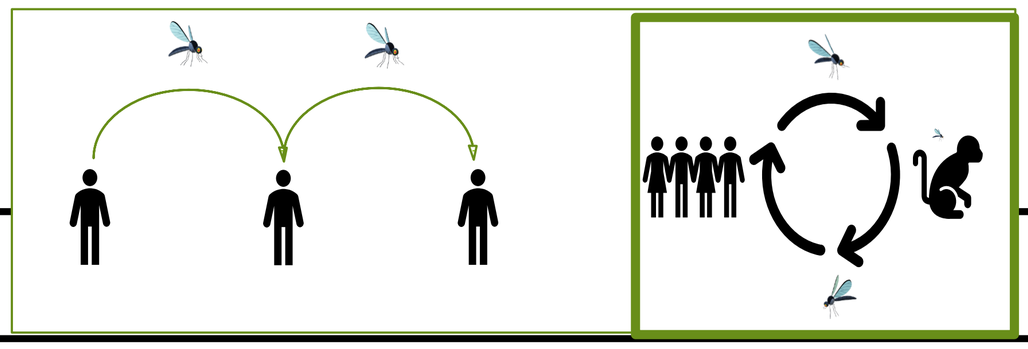
Viruses

- Viruses are the most common biological entity on the planet. There are 10^33 viruses on Earth and are present within all species.
- Viruses are unable to replicate autonomously and so most do not consider them to be organisms
- They are parasitic, relying on organisms to survive and replicate
- Viruses have large populations and short generation times, resulting in rapid evolution. (Buckling, Craig Maclean, Brockhurst and Colegrave, 2009)
- They are a living matter and share genetic information with living organisms.
- The majority of virus species are not pathogens but are important to the functioning of life. (Moelling and Broecker, 2019)
- Yet pathogen viruses remain one of the greatest threats to human life. One of the greatest is Malaria.

Host/s	Vector	Virus
		Malaria

Malaria

- Malaria infected 207 million people and killed 0.63 million in 2012 (WHO) . It can be endemic and costs people their health and ability to work. (Loy et al., 2017)
- 58% of Malaria deaths occur in the poorest 20% (WHO). It is the most unequally distributed of illnesses(Loy et al., 2017)
- Many people in malaria prevalent areas have a high immunity and so act as reservoirs to the virus (Loy et al., 2017)
- Treatment and burden of malaria to society diverts resources from poverty relief and other key issues (Loy et al., 2017)
- The transmission of malaria is complex and dependant on the interconnection of three species; the virus, vector and host.
- Malaria's vector is the means by which it reaches its host. Malaria has multiple species and each uses a different mosquito species as vector.. Hosts become infected though being bitten when the mosquito extracts blood.
- Malaria is selected in ways which can be unpredictable. Complex factors determine its evolutionary trend , alongside the malaria that evolved along with people, many species are evolved for other organism species and have infected people despite not being specialised to do so.

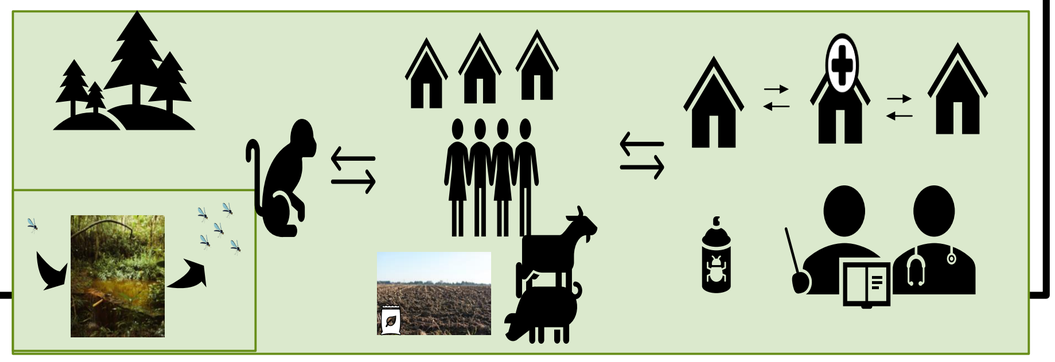


Co-evolution

- Malaria species that afflict people can also infect other species. Some of these originated as zoonotic diseases but then continued in the human population, due to our close relation it is easy for malaria to cross into other primates (Loy et al., 2017).
- Virus, vector and host share the drive to survive and reproduce (replicate for the virus). Each needs to pass on its genetic information to the next generation. The problem with a pathogen like Malaria is that the virus and host do so at the expense of the other. Malaria also needs to be well evolved for other factors like vector transmission
- The relationship between the microparasites and host is implicated as a driver of `evolution and events such as speciation. Studies have shown this coevolution can be rapid and persistent (Buckling, Craig Maclean, Brockhurst and Colegrave, 2009)
- Each is driven in different directions by evolution. With a usual virus this can be as simple as when the hosts immune system becomes stronger, the virus adapts to avoid it, so in turn the hosts immune system becomes stronger again. This creates a genetic arms race to combat each other.
- Populations more exposed to a virus become more resistant to it, however those unexposed may be left more vulnerable.

Exposure to malaria

- In Malaysia Malaria is contracted zoonotically. Although the transmission of human strains of the virus may decline people are increasingly exposed to new forms of malaria. (Fornace et al., 2019)
- Risk factors found that contact with the local (malaria contracting) macaques, house elevation and elevation, land use and tree coverage , and access to mosquito replants like sprays and bed nets could all affect chances of infection. (Loy et al., 2017)
- Malaria is limited by the access mosquitos have to the host... Anthropogenic changes to the area could affect the risk of transmission (Loy et al., 2017)
- Land use changes had brought macaques and mosquitos into closer habitation and increased the risk to the human population. (Loy et al., 2017)
- Land use can directly affect how much contact people have with mosquitos, macaques and their natural habitats. Mosquitos rely on pools of water to reproduce, limiting these around people can limit exposure.
- socioeconomic factors relate to malaria risk. They found that the type of housing , proximity to health centres and availability and use of bed nets contribute to better health and disease. (Yadav et al., 2014)
- With poverty comes a lack of access to protection from mosquitos, less protection means more sickness and less agency. This causes increased people in poverty and perpetuating risk of infection.



Exposure to natural sources and access to disease barriers

Adaptation and control

- The more hosts the virus has the more possibility it has for mutating a new strain and reinjecting species. (Buckling, Craig Maclean, Brockhurst and Colegrave, 2009)
- In the medium term it would be good to keep infection rates as low as possible to keep the virus genetically consistent..
- Malaria is greatly limited by many factors. People who have the means and access are able to avoid the mosquitos that carry it.
- If a vaccine could be created the risk of emergence would still exist as the virus would likely continue to circulate among resistant populations and wildlife, leaving the potential opportunity for the disease to evolve resistance to the vaccine and continue in a new form. (Loy et al., 2017)
- Perhaps the best way to combat Malaria is vigilance, continued efforts for a very long time and response early on to protect from natural exposures and continual development of vaccines and treatment for the most at-risk communities, before it can be spread further.
- As such the best way to prevent the virus is to target the causes. Its strong links to the socioeconomic situation of its host suggests that tackling poverty would be a highly effective way of restricting the spread of the virus, along with careful land use management to prevent conditions friendly to the virus.

Overview of Poster

- This poster demonstrates the adaptation and evolution of viruses. Showing how this coincides with the adaptation of its host species. This in turn highlights the risks of not preparing for reintroduction of malaria from other hosts acting as reservoirs. The deep difficulty in vaccinating for malaria in these conditions let alone accessing all creatures with the virus. It is likely that should a vaccine be found that another strain or species may evolve to counter it.

- Evidence suggests that humanity has been affected by malaria for many thousands of years, this time scale makes it difficult to estimate how long. At least one species may have crossed to humanity from gorillas 10,000 years ago. Recent research (Loy et al., 2017) has found that populations of primates in Africa also contract malaria and yet are barely affected by it. The consequences of this is that whatever efforts are made to combat malaria in people there will always be a source of malaria that can be passed zoonotically. This could be very dangerous, however there is limited amounts we can do. The macaques of Malaysia, known for passing the disease are already well adapted for human cohabitation (Fornace et al., 2019), still evidence from this study suggests that land use will reduce the chance of transmission. It is unlikely that you could ever fully stop this natural reservoir of virus, and the virus can go undetected in people as well (Moelling and Broecker, 2019).

- It is effective to target the vector species and prevent the transmission. It has been found that access to bed nets , better housing and location at better land elevations and proximity to health centres decrease malaria transmission. (Yadav et al., 2014), (Fornace et al., 2019). Use of land for agriculture and forest fragmentation had increased risks of infection by bringing people into closer contact with vectors and the carrier macaques and this could be monitored better (Loy et al., 2017)

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- Taubenberger, J. and Kash, J., 2010. Influenza Virus Evolution, Host Adaptation, and Pandemic Formation. *Cell Host & Microbe*, 7(6), pp.440-451.- *Very informative in explaining co-evolution in viruses however was not specific enough or related to malaria, as I needed to focus my narrative I wasn't able to use this source.*