#### Vector-borne (insect borne) infectious diseases.







Christopher Whitty Gresham College 2021 Route of transmission is key to understanding and combatting infectious diseases.

- Vector-borne (insects etc).
- Food, water.
- Sexual (& bloodborne).
- Respiratory.
- Touch.
- Usually one route dominant. Sometimes secondary routes.
- Infections very seldom change their route of transmission even if they jump species.



### Many major diseases are entirely or largely vector-borne.

- Plague (also respiratory). Flea
- Malaria. Anopheles mosquito
- Dengue, Zika, Yellow fever. Aedes mosquito
- Sleeping sickness. Tsetse fly
- River blindness. Blackfly
- Trachoma (also touch). Fly
- Chagas. Reduviid (assassin) bug
- Lyme, tick typhus, tick-borne encephalitis. Tick
- Also mites, sandflies, body lice.











Vector-borne diseases need different control measures from other transmission methods.

- Making it harder.
- Often very efficient at infection.
- You do not need to meet the person or animal who infects you.
- Can be over large distances, or extended time.



Chigger (mite) of scrub typhus in pinhead

- Making it easier.
- They often have a specific geographical range.
- If you can kill the insect vector you can prevent transmission.



TseTse Fly. Patrick Manson

# Vector-borne epidemics gone (for now) in UK but remain a major global risk.

- Vector-borne epidemics were a serious threat in England when Gresham College was founded.
- Plague (flea + respiratory)
- Epidemic typhus (body lice)
- Malaria (mosquito)
- UK currently has few vectors with epidemic potential- ticks, midges.
- Global warming could change that, but not for a long time.



Plague an example of the power of vector-borne infectious disease to shape human history- and human capacity to respond.

- Plague reduced the world population from an estimated 450 million down to 350–375 million in the 14th century.
- 30-60% of Europe's population died.
- Great Plague of London 1665-6. Official record 68,596 people died out of 460,000 estimated population.
- Risk of a plague pandemic now zero (WHO) although outbreaks occur.



#### Plague reservoir rats and other mammals. Fleas pass them on.

- Rats travel widely.
- Fleas bite the rat, get infected with plague bacteria.
- Flea bites humans, cause bubonic plague.
- Septicaemic spread in blood to lungs- secondary pneumonia.
- Spread human-to-human mainly via respiratory route- pneumonic plague.





## Epidemic typhus and trench fever. Body lice.

- Passed human-to-human via insect vector.
- Crowded, limited hygiene environments.
- Common in wars, gaols, refugee camps, concentration camps.
- Epidemic typhus (gaol fever) fatality over 10%. Major epidemics in history.
- Trench fever (bartonella) less severe but can be prolonged.
- Killing lice, eg via hot water washing of clothes or DDT (R) key intervention.





Janice Carr CDC,

### Malaria by the mid 19<sup>th</sup> Century.

- Marsh fever / ague was well known from ancient times.
- Malaria was a major problem globally, including much of Europe (inc. UK), USA, Australia.
- Land use changes had reduced it especially in parts of Europe but still a major threat.



# The discovery of the lifecycle of malaria- one of the great breakthroughs in medicine.

- The female Anopheles mosquito sucks up malaria parasites when it feeds.
- These mature in the mosquito gut over around 9-11 days.
- Then injected into any person it bites.
- Sir Ronald Ross rightly received the second Nobel Prize in Medicine (1902) for discovering this although many involved.









#### Malaria transmission is very variable. Three sites in Tanzania.



#### Also varies over time due to rainfall. Nigeria.



Kenneth Whitty

Niger Chad Sokoto Katsina Daura Nguru • Gashua Monguno Gumel \star Garki • Anka • Gusau Kano Kamba Maiduguri • Damaturu Potiskum • Funtúa • Dabai • Zaria Birnin Gwari Bin Yauri. Benin Biu • Kaduna Babana ♦Kontagorá • Bauchi • Gombe Tegina ( Jos Minna 📀 Kaiama Jebba Suleja • Langtang Bida Wamba Jalingo Number of months ●llorin 📀 Lafia of suitable climate ●Isantu Ogbomosho No transmission ● Iseyin Wukari • Beli Lokoja 1 month • Makurd Ilesha • Okene 2 months • Ibadan Akure Oturkpo 3 months Abeokuta 0 4 months ♦ ljebu-Øde ♦ Ore Enugu 5 months •-LAGOS Benin City Abakalik 6 months Onitsha Cameroon 7 months Afikpo OIKOM 8 months • Warri MARA • Owérri 9 months Country boundaries • Aba 10 months 🔿 Calal Administrative boundaries • Port Harcourt 11 months Kilometers Perennial water bodies All year transmission ARMA

Nigeria: Duration of the Malaria Transmission Season

#### Vectorial capacity- R for vector-borne diseases.

VC≈ m a<sup>2</sup> p<sup>n</sup>

m= mosquito density

- a= human biting habit (anthrophilia)
- p= probability of mosquito surviving a full day
  after being infected

n=how many days before mosquito infectious



#### Ways to attack the mosquito stage.

- Remove their breeding sites
- Kill them as larvae
- Kill them before they bite a human
- Kill them after they bite a human\*

Speculative

- Sterile males
- Genetically engineer mosquitoes





#### Malaria distribution 1948 (L) and 1977 (R)





#### Malaria's reach has gradually shrunk. (Gething et al, Nature 2010)



### Malaria current approximate range.



Treating malaria early essential. Saves lives, reduces transmission. Based on two plants with long medical histories.





#### Malaria deaths are steadily dropping.

- Mortality rate over halved since 2000.
- Deaths, mainly in children reduced from 736 000 in 2000 to 409 000 in 2019.
- 7.6 million malaria deaths have been averted in the period 2000– 2019 (WHO). Most are children.



#### Imported and travellers malaria in UK: 2000-2019.

- Malaria remains a major risk to travellers to endemic areas.
- More common than 'flu in many areas.
- Largely preventable-
- Sleeping under a treated bednet.
- Prophylactic antimalarial drugs.



PHE Malaria Reference Laboratory

#### The recent announcement by WHO in favour of a malaria vaccine.

- The RTS,S malaria vaccine has been long in development.
- Provides around 30% reduction against severe malaria (WHO).
- A moderate reduction in a large risk is still a significant advance.
- Will be third pillar of control, with anti-mosquito measures and drugs.



## Lymphatic filariasis (elephantiasis).

- Worm species transmitted by mosquitos in Africa and Asia.
- Cause inflammation of the lymphatic system.
- Result can be substantial swelling of appendages- limb, breast, scrotal swelling.
- Control of mosquitoes.
- Mass drug administration to kill baby worms (microfilaria) in humans.



#### Control of lymphatic filariasis. Steady reduction over time.

Local Burden of Disease Neglected Tropical Diseases Collaborators. Lancet GH 2020



A group of serious viral infections transmitted by one mosquito genus, Aedes are currently spreading.

- Dengue
- Zika
- Chikungunya
- Yellow Fever (we have a vaccine)
- Aedes is well adapted to peri-urban living.
- Day-time feeder.





#### Global dengue cases (WHO). Reported cases risen from 0.4M 1996 to 5.2M by 2021



## Aedes adapted to peri-urban living. Dengue spread in the Americas. Globally 70% of the dengue burden in Asia.



San Martin JL et el 2010 JASTMH. Incidence/100,000

#### Dengue can be a severe disease.

- Dengue haemorrhagic disease.
- Dengue shock syndrome.
- Symptoms can be prolonged.
- Producing a vaccine has proved difficult- some progress for those with prior infection.



WHO/TDR/STI/Hatz

#### Zika. Notified cases of microcephaly in Brazil, November 2015.





#### Baby with Severe Microcephaly

Typical Head Size



#### Zika gradually travelled round the world until first epidemic.



Sources: LANCASTER UNIVERSITY, WHO, CENTRES FOR DISEASE CONTROL AND PREVENTION ST GRAPHICS

Potential for spread limited to vector distribution (CDC). Aedes albopictus spreading to and in Europe, often via tyres.



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#### Aedes aegypti mosquito



#### Aedes albopictus mosquito



#### Control of Aedes-transmitted diseases.

• Vector control of Aedes not easy.

Conventional, moderately effective include

- Covering water sources.
- Screens on windows, doors.
- 'Fogging' with insecticide during outbreaksseveral disadvantages.

Experimental

- Sterile male mosquitoes.
- Genetically modified mosquitoes.
- Wolbachia-infected Aedes less able to transmit.



#### Mosquito-borne viruses from birds and animals.

#### Examples

- Japanese encephalitis, most common encephalitis in Asia. Pigs and water birds to humans via Culex mosquito. Vaccines available.
- West Nile virus most common mosquito-borne infection in North America. Usually Culex mosquito from birds.



Culex mosquito CDC.

## Fly-borne diseases. Sleeping sickness (African trypanosomiasis).

- Main form (gambiense) human-tohuman.
- Tsetse fly- bites humans, transmits the parasite.
- Untreated almost always fatal, chronic neurological disease.
- Several large epidemics.
- Control: find and treat patients (vector control). Several new drugs.
- Less than 1000 cases reported 2019 (WHO). Around 500,000 cases in 1990s.





### Zoonotic (animal) form human African trypanosomiasis.

- *T. rhodesiense-* from animals.
- Therefore eliminating human reservoir does not work.
- Tsetse control more important.





#### Onchocerciasis- river blindness in Africa and Latin America.

- Due to a worm transmitted by the blackfly *Similium damnosum*.
- Causes vision loss (over 1M-GBD) and skin inflammation.
- Some vector control by spraying larvicide in breeding sites of blackfly.
- Mass drug administration of ivermectin, an antiparasitic drug.





#### Other fly-transmitted infections affecting eye.

Loa loa (eyeworm) via chrysops fly.



Trachoma via touch and fly.

1.9M people blind or visually impaired (WHO).



Lichtinger A, Caraza M, Halpert M Am.J.Trop.Med.Hy P. Emerson R. Bailey. Bazaar fly and follicular trachoma

# Ticks and mites (arachnids). Tick-borne typhus and other spotted fever diseases.

- African tick typhus, Rocky Mountain Spotted Fever, Queensland tick typhus and other varieties.
- Form of bacteria- Rickettsia.
- Fever and rash.
- Treated antibiotics.
- Mite-borne typhus SE Asia.

Alan Walker/JMK/Peterwchen /Bjørn Christian Tørrissen





#### Lyme disease. Tick-borne, geographically concentrated.



1 dot placed randomly within county of residence for each confirmed case



#### Tulloch et al / PHE. Lab proven Lyme. 2018

#### Lyme disease reported cases USA 2019. CDC.

### Neuroborreliosis (neurological Lyme).

- Lyme disease can cause neurological inflammation in a minority.
- Can be difficult to diagnose. In most cases antibiotic treatment very effective.
- Controlled studies suggest outlook usually good. For example recent study of 2,067 people proven neuro Lyme and 20,670 general Danish population.
- Almost identical hospitalisations, employment, income, disability, children.



Obel et al, BMJ 2018

#### Tick-borne viral encephalitis.

- Tick-borne encephalitis across much of Europe and Asia.
- Inflammation of the brain. In some cases can cause lifelong neurological complications.
- An effective vaccine available.
- Remove ticks if you find them.



NaTHNaC/NHS.



#### Control of vector-borne diseases.

- Vector-borne diseases are common, varied, and can be very dangerous.
- Depend on the local vectors- highly geographically varied.
- Three approaches to control:
- -Kill the vectors, or stop them biting humans.
- -Early treatment, to cure and prevent transmission.

-Vaccines.

Relative importance of these depends on the disease and the vector.

