

# Finding Patient Zero: How graph databases help us understand, trace and prevent emerging epidemics

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# CONTENT WARNING

There will be no graphic images, but there will be discussion of death, dying and sometimes fairly horrible ways to do so. If this makes you uncomfortable, please leave now.



# A little bit about me...

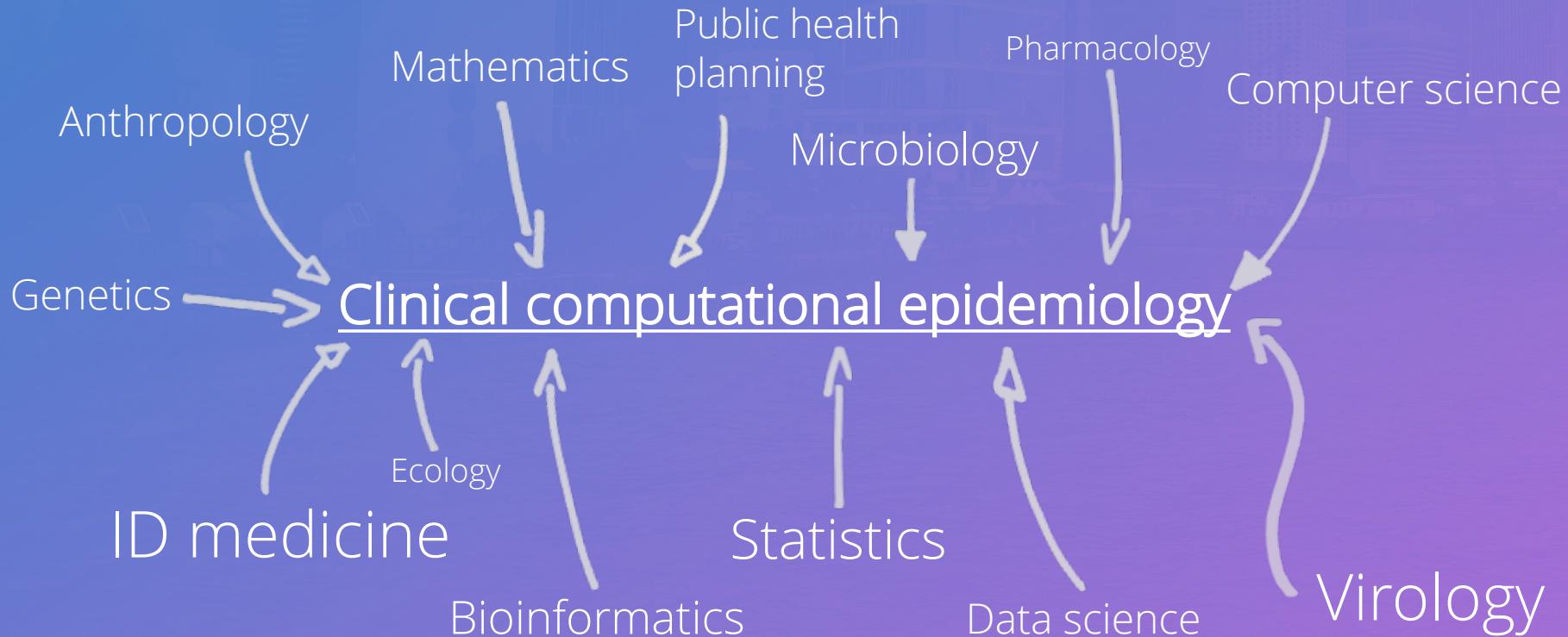
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- Born 1986 in beautiful **Budapest**
- Educated at **Oxford, Leiden and Cardiff**
- Married to **Katie (@kisroka\_inks)**, an art historian and illustrator
- **Clinical computational epidemiologist** for a US population health company



# Wait, clinical what?

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# Wait, clinical what?

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## Clinical computational epidemiology

is the use of **computational** methods to improve **clinical** care using the quantitative awesomeness stolen from **epidemiology**.



# Wait, clinical what?

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## Clinical computational epidemiology

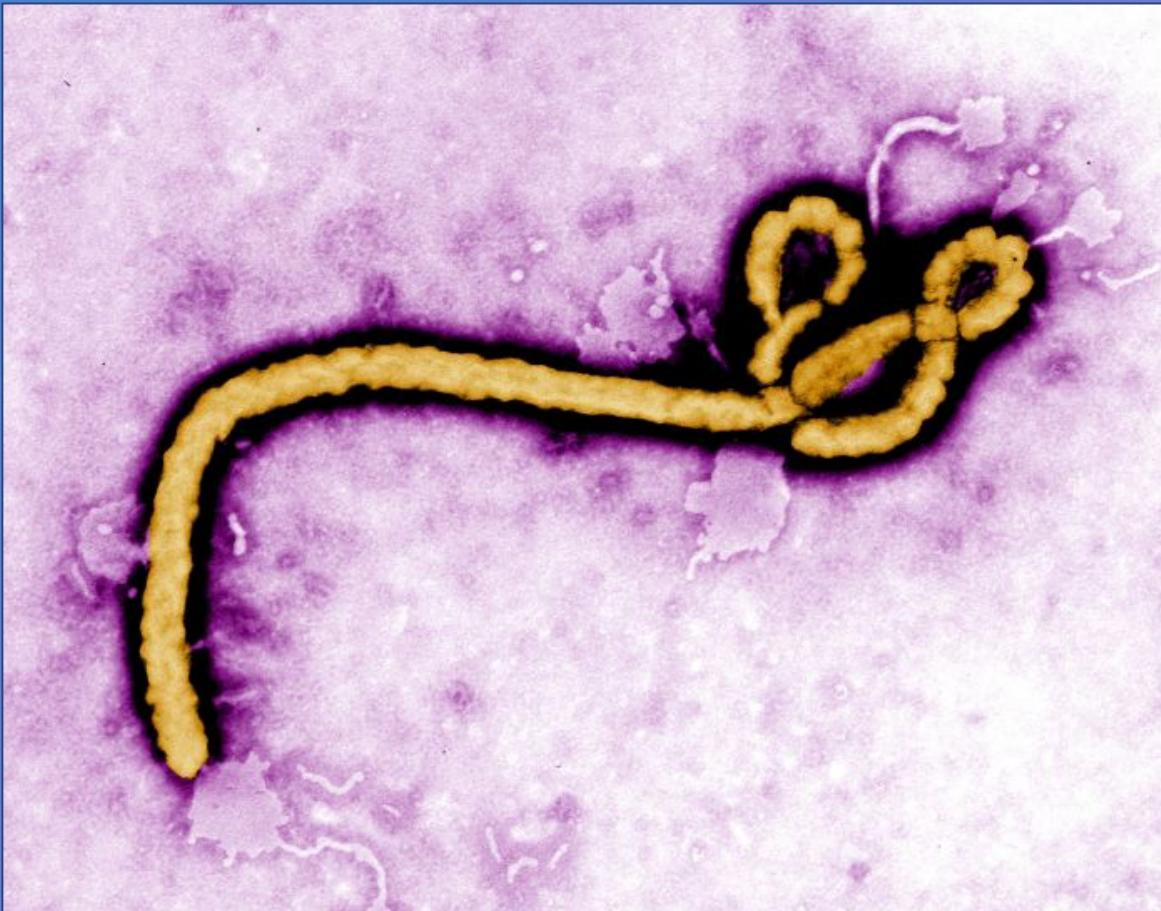
is the use of **computational** methods to improve **clinical** care using the quantitative awesomeness stolen from **epidemiology**.



# A little bit about me...

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- Likes:
  - Katie
  - marsupials
  - **graph theory**
  - old school (circa WW II) cryptanalysis
  - **clinically useful models that save lives**
  - **filoviridae**



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# Bad news wrapped in a protein.

Sir Peter Medawar, British biologist  
Nobel Prize for Medicine and Physiology, 1960



# EBOV and EVD (Ebola Virus Disease)

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- Absolutely, thoroughly, almost preternaturally nasty.
- No cure, SoC is supportive treatment – rehydration, hemostasis
  - ZMapp, a monoclonal antibody, showed some promise
  - Trials on an EBOV vaccine underway
- Untreated mortality 100%, mortality with treatment ~40-70% depending on strain
- Zoonotic disease, reservoir host: probably some fruit bat



The other ones aren't much  
nicer, either.



# Anthroponotic vs zoonotic diseases

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# Anthroponotic vs zoonotic diseases

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- **Anthroponoses** spread from people to people only.
- **Therefore**, once everybody is dead, immune or inoculated (vaccinated), the outbreak will die off. In fact, if sufficient numbers are vaccinated, it won't even start.
- **Anthroponoses can be defeated.** They have nowhere to run.
- Examples:
  - *Morbillivirus* (measles),
  - ~~*Variola* spp. (smallpox)~~,
  - poliovirus (poliomyelitis)



# Anthroponotic vs zoonotic diseases

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Human-to-human  
transmission

*Index case  
("Patient Zero")*

Reservoir host:  
Carries virus but does not get sick  
(suspected: one or more species of fruit bat)

Typical zoonosis: EBOV



How do we find the index case,  
trace the course of the  
infection, and what do we do  
once we've done that?

# Contact tracing

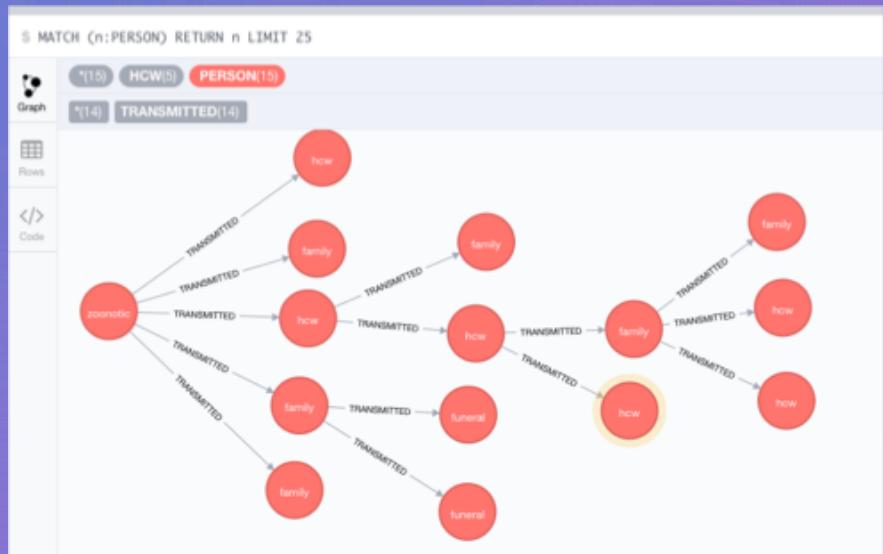
- The bane of field epidemiology: **hot, risky and exhausting.**
- However, it is **absolutely essential.**
- It helps us **understand**
  - **how the epidemic is moving,**
  - **where it started, and**
  - **how it is transmitted.**



# Contact tracing with Neo4j

Graph databases are **naturals** when it comes to contact tracing.

- Fast to operate on complex linkages
- Easy to trace connections
- A more 'natural' way of representing what is, in reality, a graph rather than a neat table
- Can accommodate marginal cases (multiple infections, multiple patient zeros)

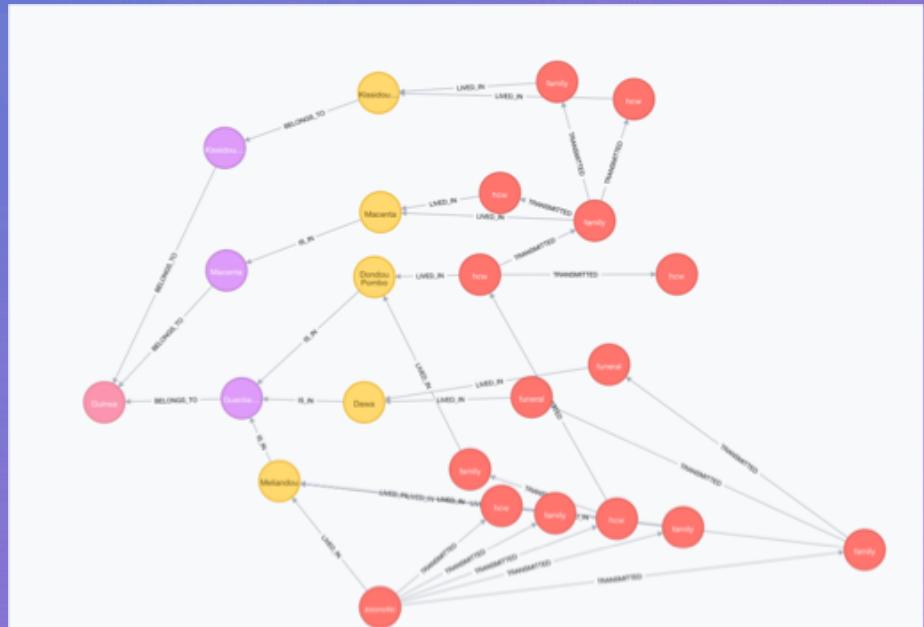


Contact trace of the first fifteen cases – and first five generations – of the W Africa Ebola Outbreak.

# Contact tracing with Neo4j

Graph databases handle diversity of data better.

- In particular, **multiplicity**: e.g. a person living in multiple towns, multiple infections, etc.
- Jumping data types **does not come at a cost** – determining which country Case 12 is coming from would, in a fully normalised RDBMS, require three queries.



Contact trace of the first fifteen cases – and first five generations – of the W Africa Ebola Outbreak, with locations.



# Contact tracing with Neo4j

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In fact, it works so much better, some of us are working on a tool to use it for real time contact tracing.

# CACTI

**Computer Assisted Contact Tracing Instrument**



OK, so?

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You may be wondering how this gets us any closer to the ultimate goal\*.

\* not dying of some horrific contagious disease.



# In three ways.

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## 1. Contact tracing does not end with humans.

Especially not for zoonoses. The only way to deal with zoonoses is to inoculate humans, or kill every last one of its reservoir host with exemplary violence. (Did I say things aren't going great for an EBOV vax?)

The reservoir host of EBOV is not known. It's suspected to be a fruitbat, but we'd like to know for sure before we unnecessarily make their entire species extinct.

-> Contact tracing gets us closer to the right critter to kill.



# In three ways.

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## 2. Contact tracing helps us respond.

It helps us know which cities might be in danger, which air traffic routes to suspend, and other drastic steps. None of these are cheap or easy, and **we owe it to the public to respond based on best evidence.**

For instance, better contact tracing could have avoided the expensive and ultimately futile mass culling of chickens during the SARS-CoV outbreak (the actually culpable agent was, once again, a cave bat).

-> Contact tracing gets us closer to the right thing to do.



# In three ways.

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## 3. Contact tracing helps us understand.

We don't know, among others, why bats are such prolific reservoir hosts for a range of horrific diseases – maybe whatever is lending them immunity can help us?

Contact tracing also helps us understand more about the current strain or, if it's a new pathogen, the whole new pathogen itself: who gets infected, how does it spread, who lives, who dies?

-> Contact tracing gets us closer to the truth.



NEXT

BIG

ONE



# The NBO

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1918

## H1N1 PANDEMIC

Unknown, probably zoonotic.  
Over 50-100m dead worldwide  
Cytokine storm?

1960-

## HIV/AIDS

Almost definitely zoonotic  
>30m cases  
The last true pandemic (that we know of)

2014

## EBOLA (W AFRICA)

Zoonotic, from Guinea, C Africa  
28,616 cases, 11,310 deaths,  
estimated 50% unreported.

mid-20th century

## POLIOMYELITIS

Antrponotic  
Large number of cases worldwide, only recently eradicated in some countries

2002

## SARS

Zoonotic, from the PRC  
8,098 cases, 774 deaths  
Traced back to cave bats in Yunnan.

## THE NBO

We have no idea  
Probably zoonotic  
Probably SE Asia or C Africa

???



Whatever the NBO will be, we need to be well-prepared and well-armed.

That includes geeks like us.

Graph databases and software built on them can play a real, significant role in managing the NBO.

# Thank you for your attention.

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