

First, an introduction

Hello! I'm Jess.

I'm a lecturer in computing at the University of Glasgow.

I like:

- ▶ Graphs and networks
- ▶ D&D and many other nerd things
- ▶ Dogs
- ▶ Rugby

I dislike:

- ▶ Pandemics



The Plan

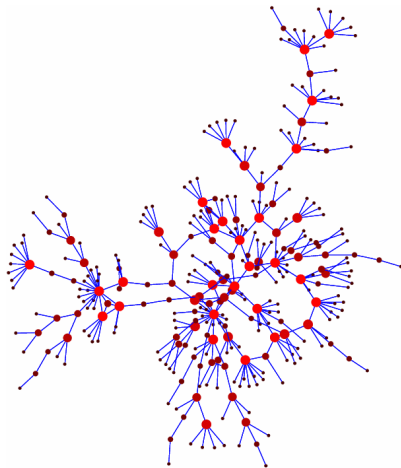
Welcome!

This lecture will be mostly by example:

- Examples of networks relevant to epidemiology
- Examples of networks being confusing or confounding
- Examples of the sorts of things we might want to compute or measure
- Examples of some complex features of networks - space, time, and character

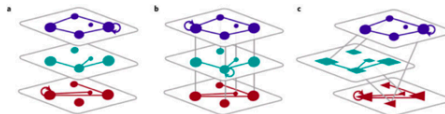
What do I mean by networks? (or graphs?)

I mean a set of dots connected by lines.

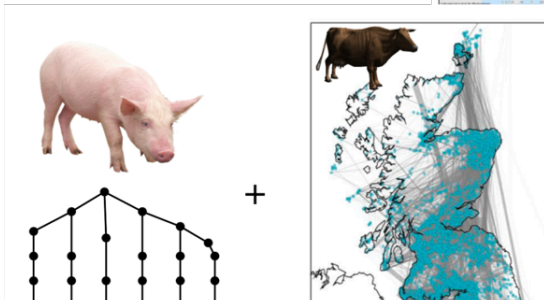


What do I mean by networks? (or graphs?)

They might be in different 'layers'

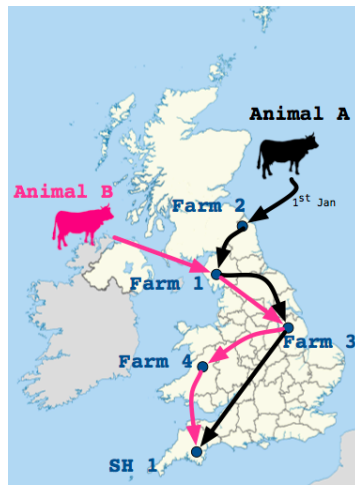


(from De Domenico, Granule, Porter, Arenas, 2006. The physics of spreading processes in multilayer networks, Nature Physics)



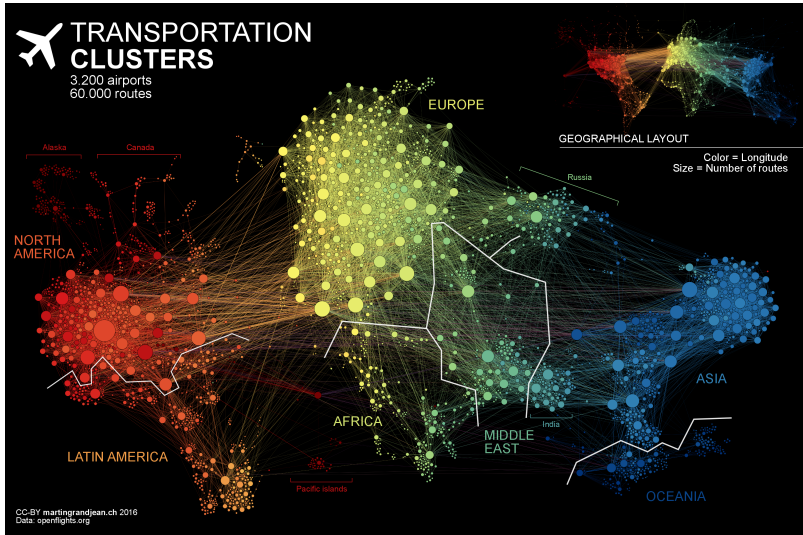
What do I mean by networks? (or graphs?)

The dots or lines might have direction or qualities or time



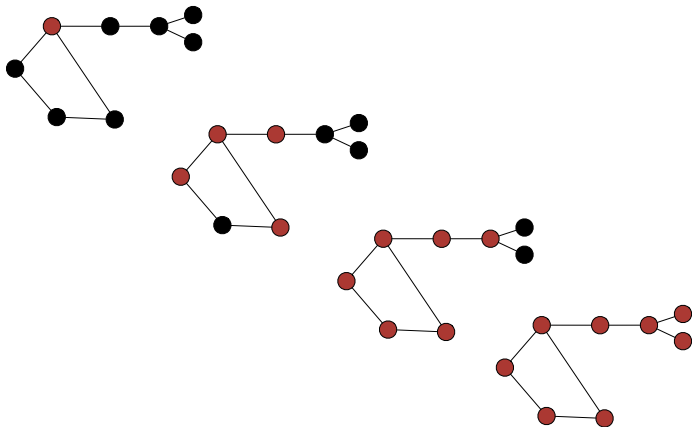
(more about time and scale later!)

Reminder: humans move too!

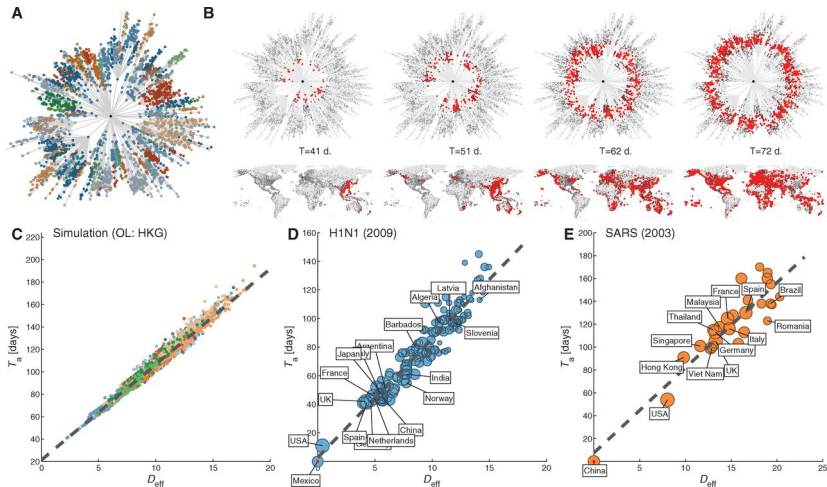


CC-BY martingrandjean.ch 2016
Data: openflights.org

Ultimately, I'm talking about agents (dots) that can catch a contagion, and contacts (lines) that can spread that contagion.



Do we have evidence that networks spread disease?



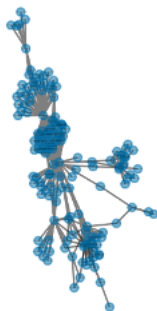
(Brockmann and Helbing, 2013 - Science) Videos of simulation:
<http://rocs.hu-berlin.de/projects/hidden/index.html>

Which network drives our disease?

We need to understand disease spread to predict it or simulate interventions, lots of cases where multiple networks are involved!

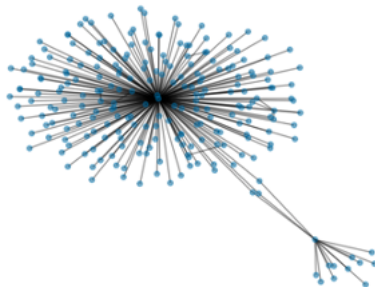
Example: when modelling COVID-19

- Travel-to-work movements differ between the overall flows and essential-worker-only



Mostly essential workers

J. Enright (including work by many others)



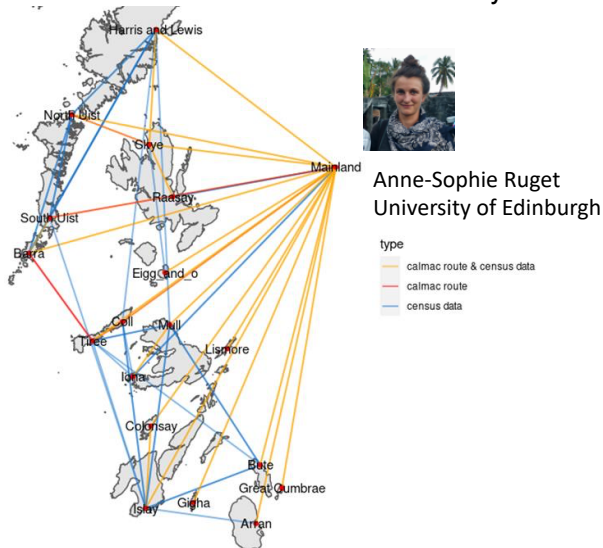
Mostly office workers

Using networks to understand disease spread



Which network drives our disease?

Scottish Islands: travel-to-work vs ferry data



Which network drives our disease?

We need to understand disease spread to predict it or simulate interventions, lots of cases where multiple networks are involved!

Example: when modelling COVID-19

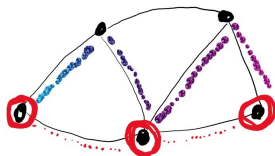
- Travel-to-work movements differ between the overall flows and essential-worker-only
- Geographic adjacencies are different
- Schools catchments are different
- Student movements are yet another set of movements
- What about linkages via carehome company?

What should we use for what timescale, and what evidence can we find?

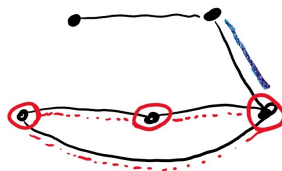
Do we see clustering of infection in these network types? There are a lot of ways to check!

Looking for clustering

One simplistic way to do it: count edges that connect places with similar levels of infection.



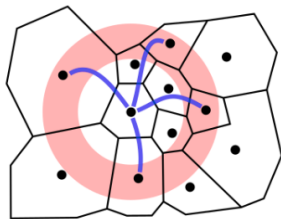
4 border
2 within-red
1 within-black



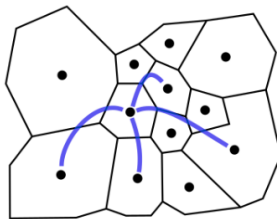
1 border
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Compare between networks,
or to a null model

Looking for clustering



(a) Within range



(b) Randomly rewired

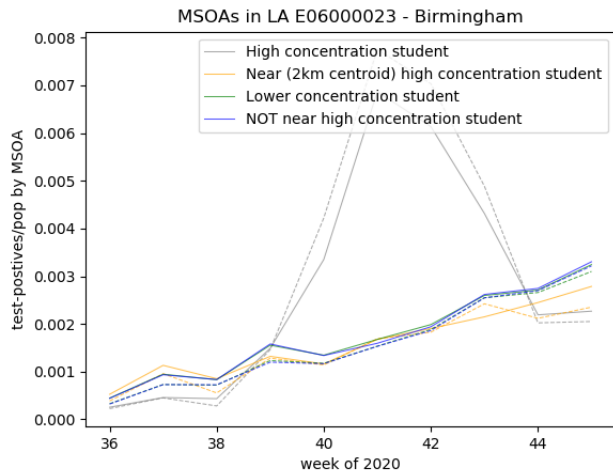
When many places in Scotland had cases in the first wave, cases were correlated up to 20/30 km.

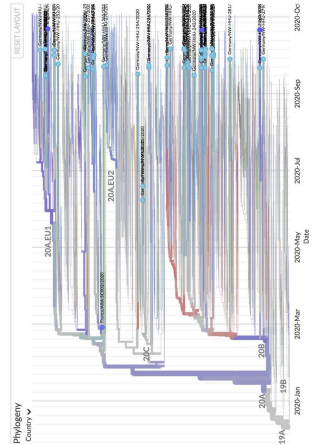
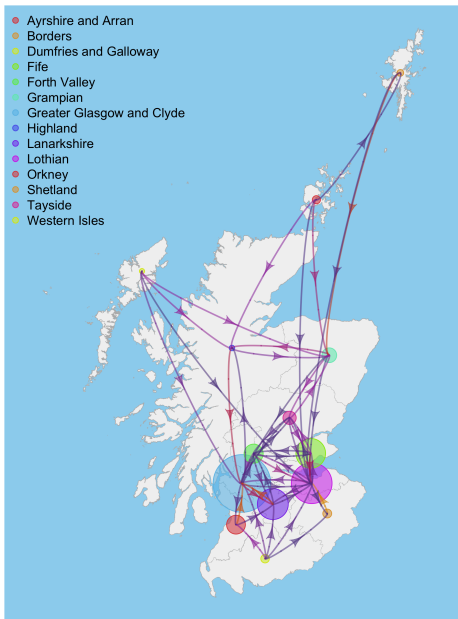


Dr Ewan Colman
University of
Edinburgh
@ewancolman

Many complicating situations!

One complication: a network that is right most of the time, but wrong in very important cases.





<http://129.215.193.110:3838/RiseFallScotCOVID/>

How can we make the network safer?

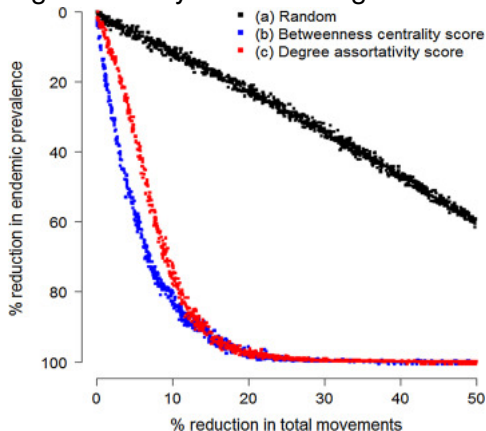
This depends enormously on what we can change and how the disease operates

- If we can limit trade or between-region contact, we can modify edges
- If we can make rules about timing, we can change the times on edges
- If we can protect vertices from infection, we can modify vertices

(For computational complexity enthusiasts, almost all of these problems are NP-Hard, even in situations with full certainty)

How can we make the network safer? - heuristically

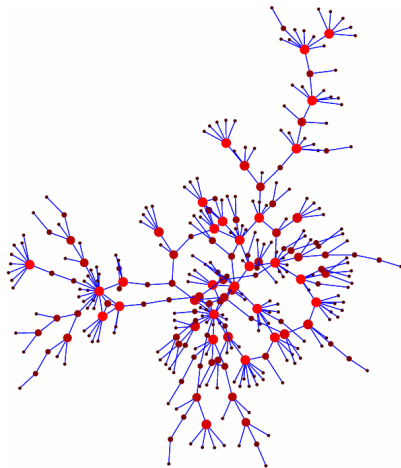
Common approach - simulate impact of removing high-centrality nodes or edges:



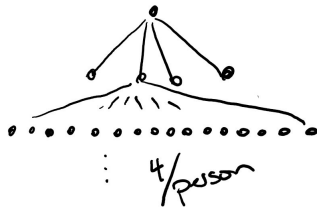
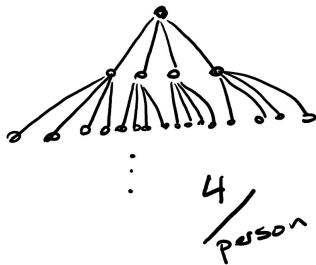
Example on cattle network
(Gates and Woolhouse, 2015 - Epidemics)

How can we make the network safer? - **heuristically**

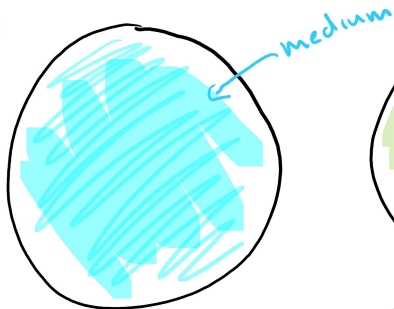
How should we target surveillance testing?



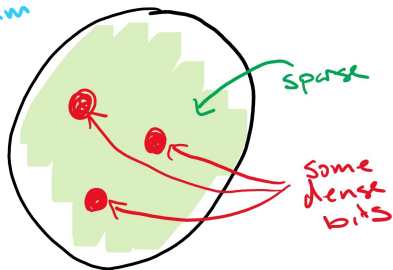
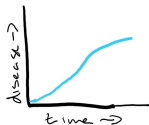
Sneaky networks - heterogeneity and reproductive number



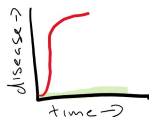
Sneaky networks - heterogeneity and reproductive number



Network medium everywhere



Network patches of density



Sneaky networks - changing over time

Many networks have seasonality - we need to make sure we use the right network!



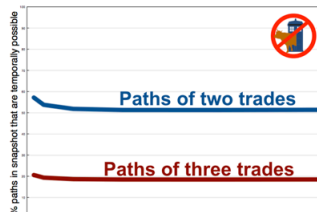
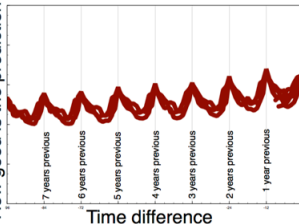
Life Trajectories

Animal A Born, Farm 2, Farm 1, Farm 3, SH 1, Dead
Animal B Born, Farm 1, Farm 3, Farm 4, SH 1, Dead

Bigram Counts

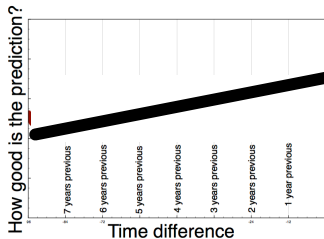
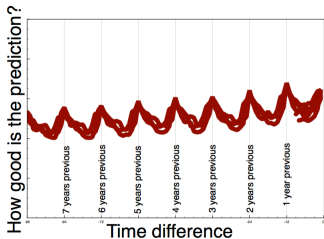
Bigram	Count
Born, Farm 1	1
Born, Farm 2	1
Farm 1, Farm 3	2
Farm 2, Farm 1	1
Farm 3, SH 1	1
Farm 4, SH 1	1
SH 1, Dead	2

How good is the prediction?



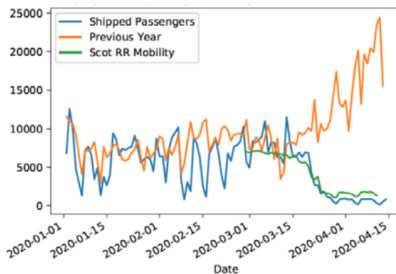
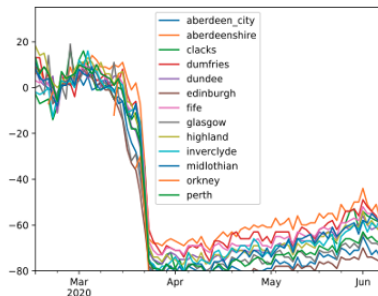
Sneaky networks - changing over time

A large project lead by V. Colizza and E. Valdano comparing cattle trading networks across EU found many differences:



Sneaky networks - changing over time

So how do we deal with shocks?



Cautiously.

Wrap-up

Thank you!

I'm friendly and happy to chat:

- @researcherJess on Twitter
- @magicicada on GitHub
- jessica.enright@glasgow.ac.uk