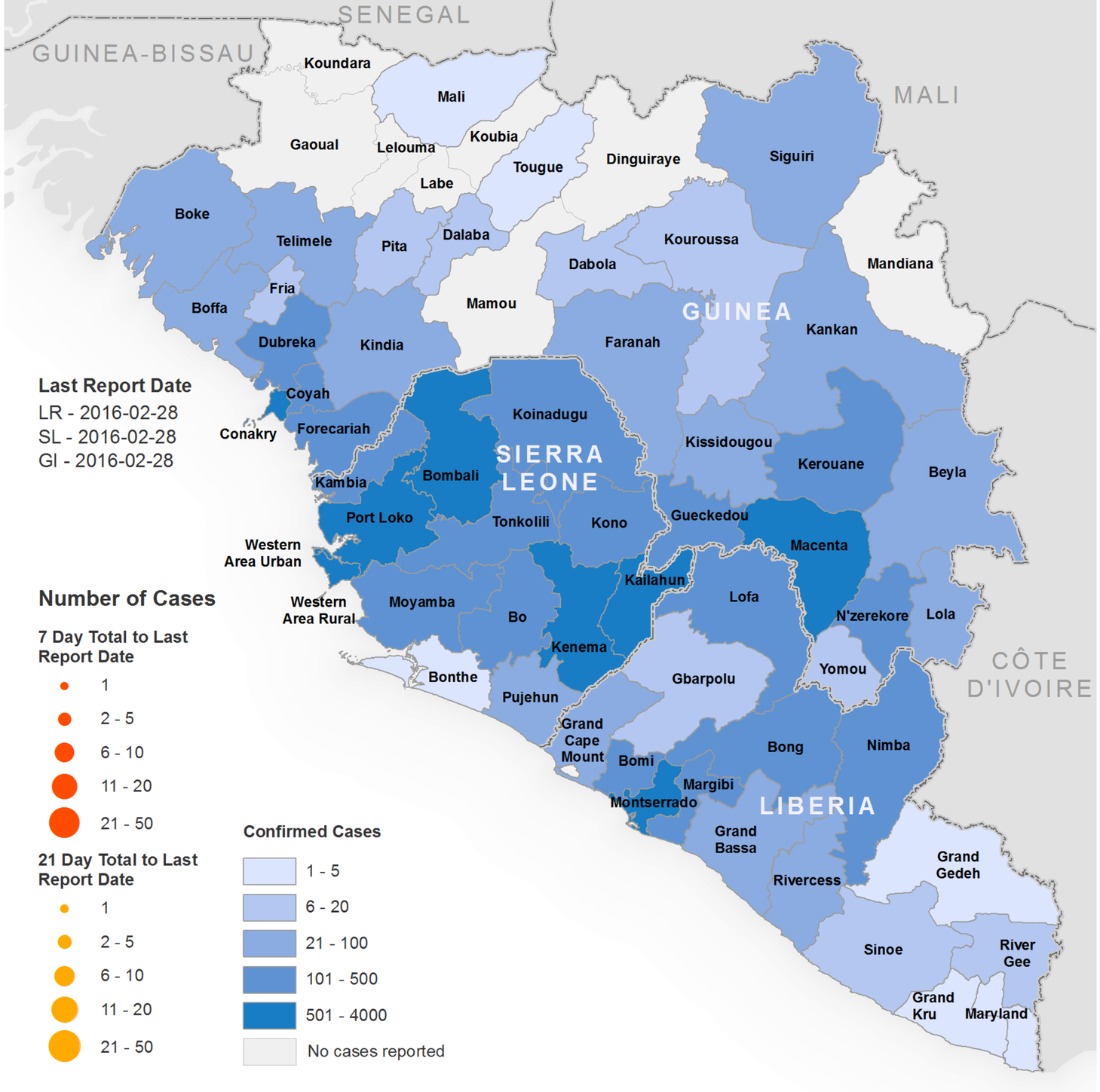

SENEGAL
GUINEA-BISSAU
MALI
GUINEA
SIERRA LEONE
LIBERIA
CÔTE D'IVOIRE
Koundara
Mali
Gaoual
Lelouma
Koubia
Tougue
Dinguiraye
Siguiri
Labe
Boke
Telimele
Pita
Dalaba
Kouroussa
Dabola
Mandiana
Fria
Boffa
Mamou
Faranah
Kankan
Dubreka
Kindia
Coyah
Conakry
Forecariah
Koinadugu
Kissidougou
Kerouane
Beyla
Kambia
Bombali
Port Loko
Tonkolili
Kono
Gueckedou
Macenta
Western Area Urban
Kailahun
Lofa
Western Area Rural
Moyamba
Bo
N'zerekore
Lola
Kenema
Yomou
Bonthe
Gbarpolu
Pujehun
Grand Cape Mount
Bong
Nimba
Bomi
Margibi
Montserrado
Grand Bassa
Rivercess
Grand Gedeh
Sinoe
River Gee
Grand Kru
Maryland
Last Report Date
LR - 2016-02-28
SL - 2016-02-28
GI - 2016-02-28
Number of Cases
7 Day Total to Last Report Date
1
2 - 5
6 - 10
11 - 20
21 - 50
21 Day Total to Last Report Date
1
2 - 5
6 - 10
11 - 20
21 - 50
Confirmed Cases
1 - 5
6 - 20
21 - 100
101 - 500
501 - 4000
No cases reported

Isobel Blake, Anne Cori, Christl A Donnelly, Ilaria Dorigatti, Neil M Ferguson, Tini Garske, Gemma Nedjati Gilani, Wes Hinsley, Thibaut Jombart, Harriet Mills, Pierre Nouvellet, Steven Riley, Maria Van Kerkhove

Alex Hill

Carol Brickley

Emma Russell

Giovanni Charles

Lekan Anifowoshe

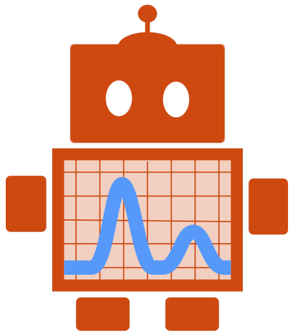
Mark Woodbridge

Nick Dolan

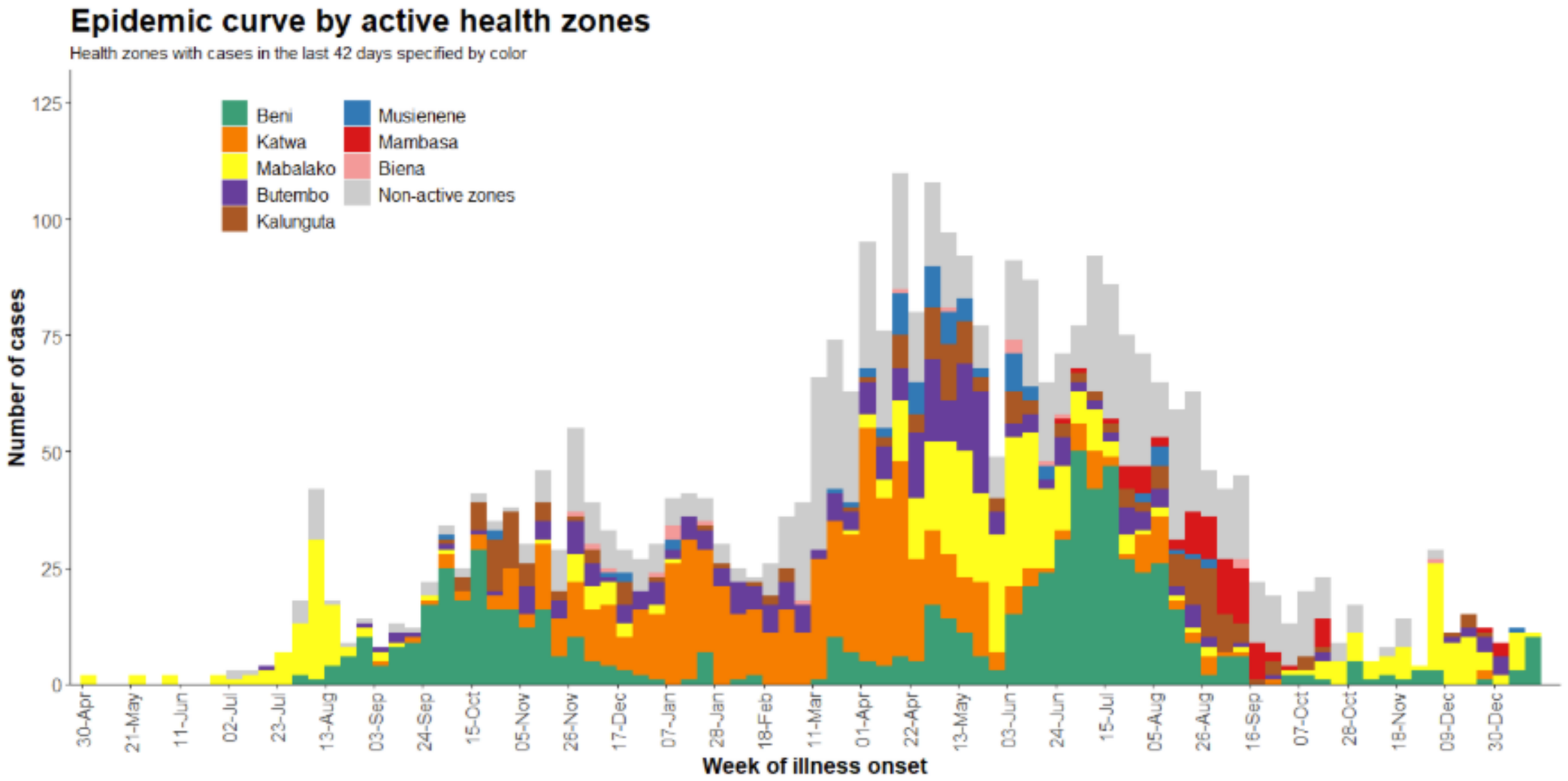
Rob Ashton

Wes Hinsley

RESIDE@IC



reside-ic.github.io



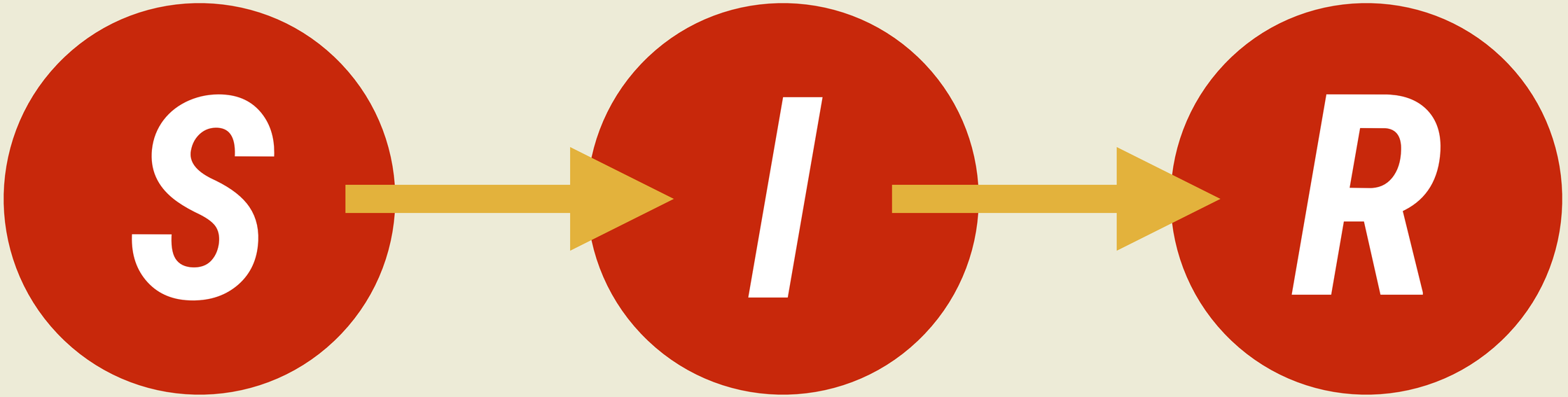
Ebola cases over time in Democratic Republic of Congo 2018-2019

Research Software Engineering and the COVID-19 pandemic response

Rich FitzJohn
Imperial College London

rgfitzjohn

richfitz
mrc-ide
vimc
reside-ic



$$\frac{dS}{dt} \qquad \frac{dI}{dt} \qquad \frac{dR}{dt}$$

PHE
NHS
CHESS
CO-CIN
ONS

(nightly)

Contact matrices
Demography

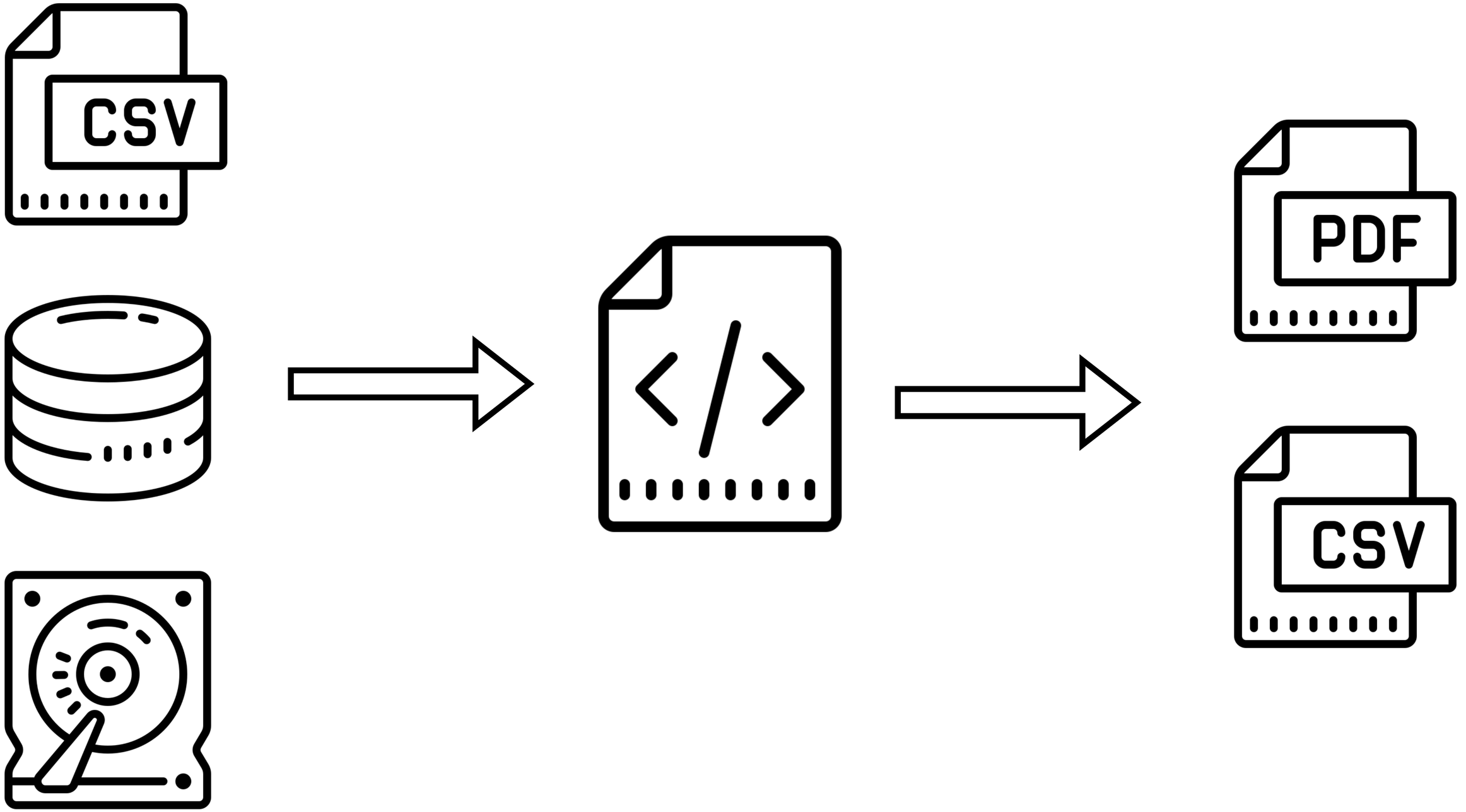
Severity data
Delay distributions

S → I → R

Serology
REACT

Our tools for collaborative data workflows are pretty rubbish

```
$ git checkout d686e90
$ npm install model@2.12.4
$ docker pull redis:5
$ pip install pkg==1.2.3
```


CSV
PDF
CSV

Go To Statement Considered Harmful

Key Words and Phrases: go to statement, jump instruction, branch instruction, conditional clause, alternative clause, repetitive clause, program intelligibility, program sequencing
CR Categories: 4.22, 5.23, 5.24

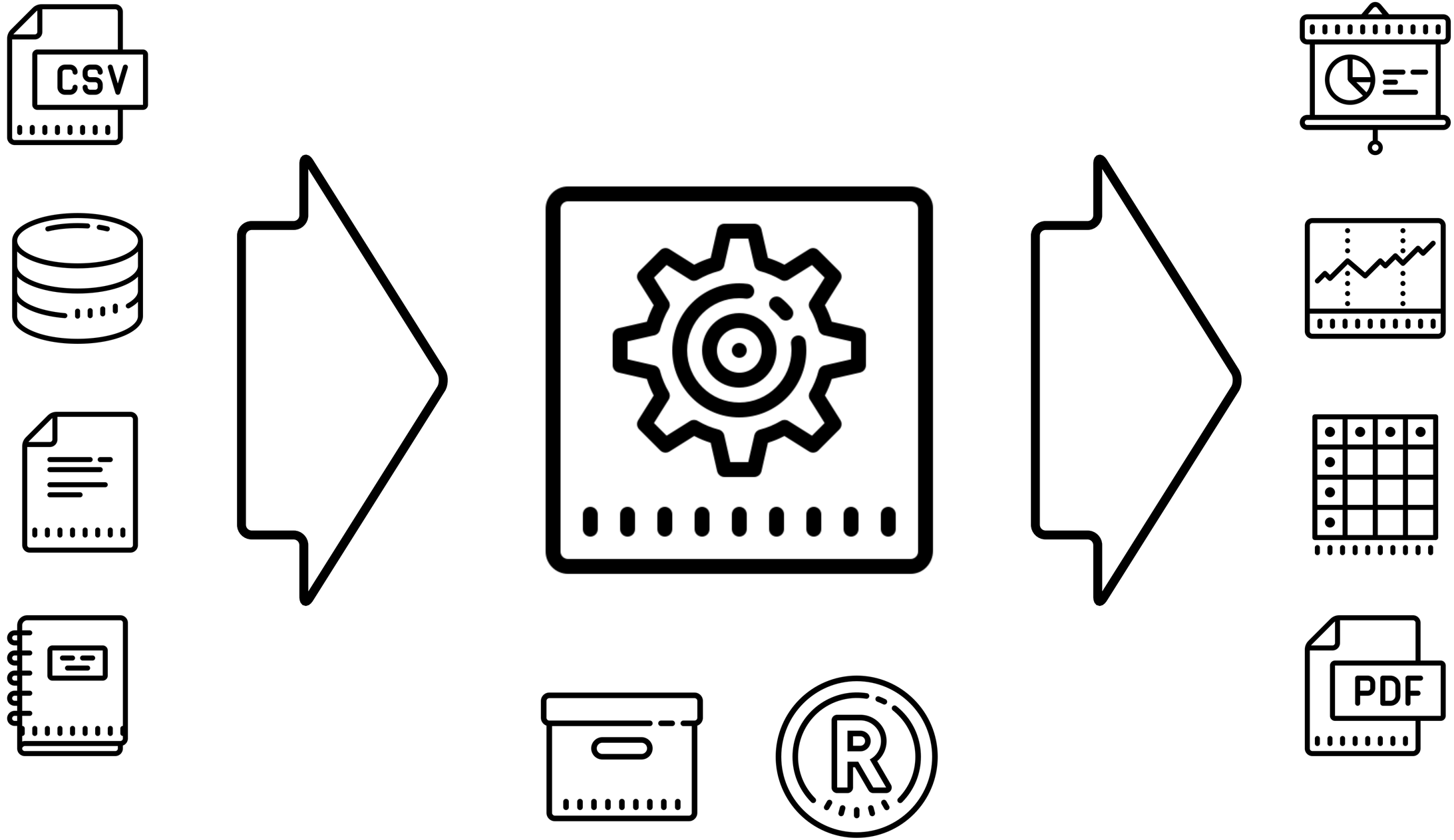
EDITOR:

For a number of years I have been familiar with the observation that the quality of programmers is a decreasing function of the density of **go to** statements in the programs they produce. More recently I discovered why the use of the **go to** statement has such disastrous effects, and I became convinced that the **go to** statement should be abolished from all "higher level" programming languages (i.e. everything except, perhaps, plain machine code).

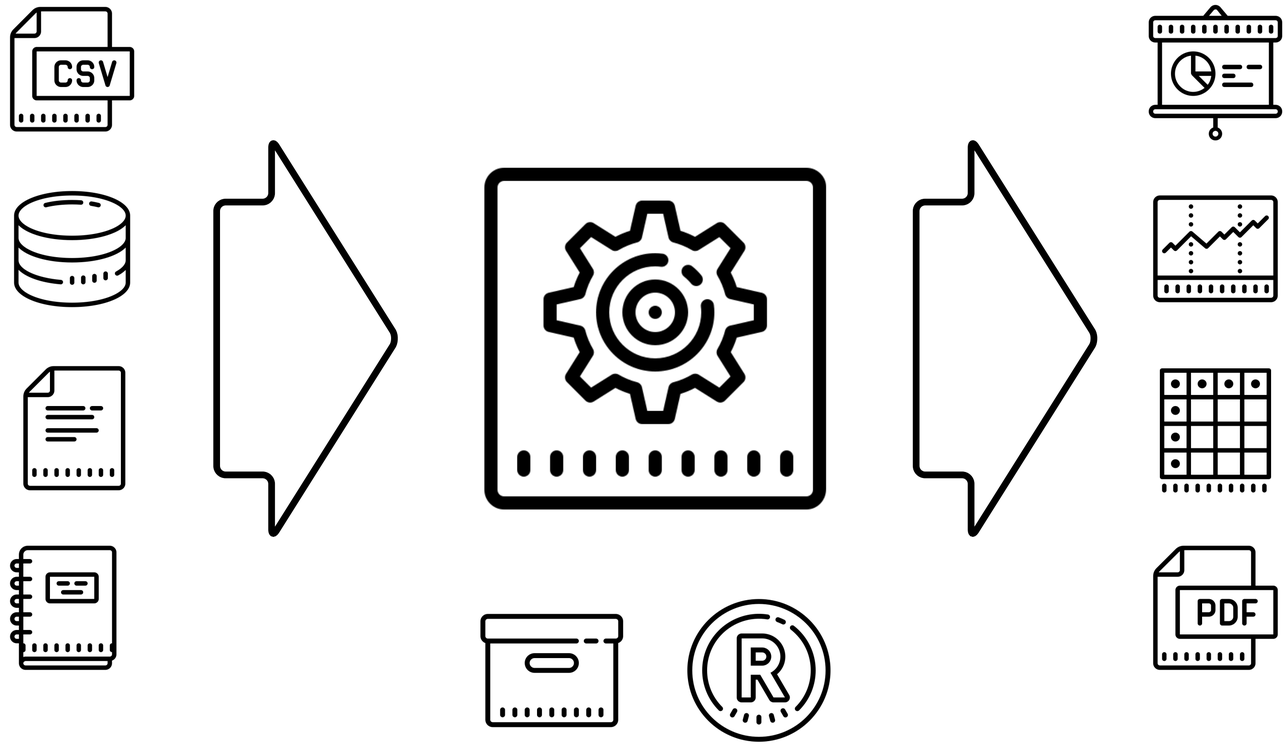
```
add <- function(a, b) {
  a + b
}
```

orderly

https://github.com/vimc/orderly


CSV
R
PDF

```yaml
resources:
  - support.R
  - metadata.csv

script: script.R

depends:
  - other:
      id: latest
      use:
        incoming.csv: output.csv

artefacts:
  - report:
      description: Summary of results
      filenames: summary.pdf
  - data:
      description: Processed data for further use
      filenames: data.csv
```



```
orderly_config.yml
src/
  myreport/
    orderly.yml
    script.R
    support.R
    metadata.csv
```

```
orderly_config.yml
src/
  myreport/
    orderly.yml
    script.R
    support.R
    metadata.csv
archive/
  myreport/
    20190204-143204-f5aa3bc9/
      orderly.yml
      script.R
      support.R
      metadata.csv
      summary.pdf
      data.csv
      orderly_run.rds
```

orderly run myreport

orderly run myreport

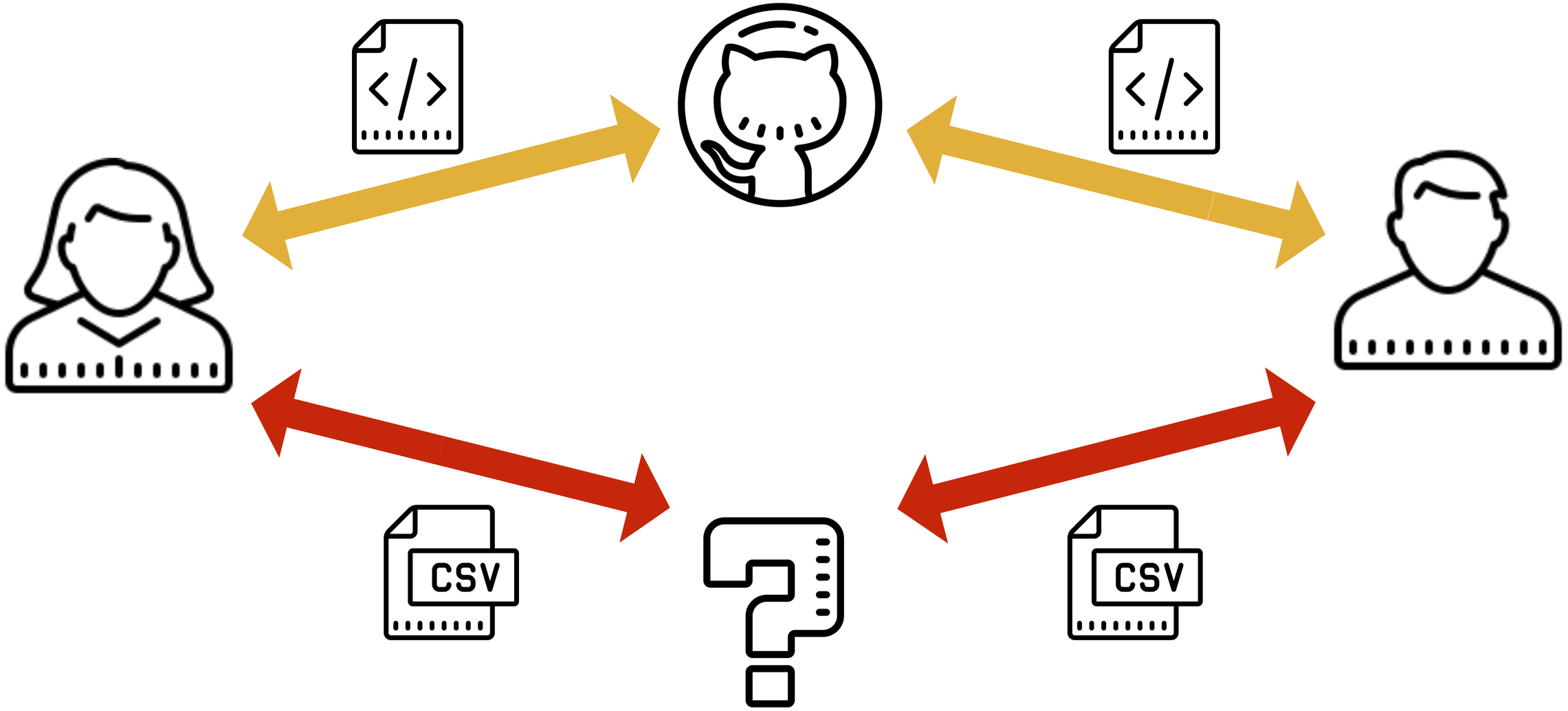
```
orderly_config.yml
src/
  myreport/
    orderly.yml
    script.R
    support.R
    metadata.csv
archive/
  myreport/
    20190204-143204-f5aa3bc9/
    20190204-192249-3bc9f5aa/
      orderly.yml
      script.R
      support.R
      metadata.csv
      summary.pdf
      data.csv
      orderly_run.rds
```

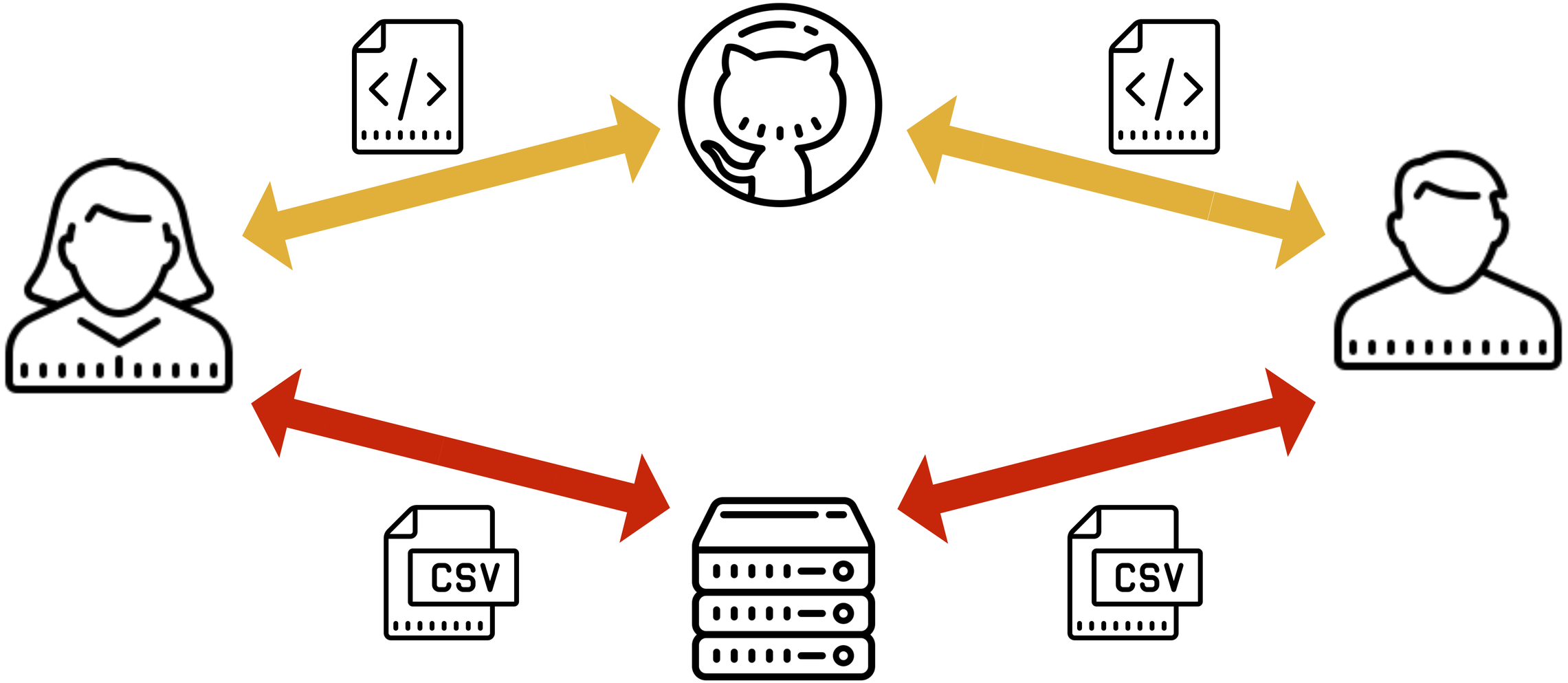
VACCINE IMPACT MODELLING CONSORTIUM

BILL & MELINDA GATES *foundation*

Gavi The Vaccine Alliance

https://vaccineimpact.org


CSV
CSV


CSV
CSV

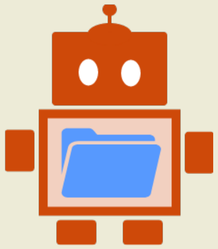
Kotlin

Vue.js

plumber

R



https://github.com/vimc/orderly-web

```
$ orderly_pull_archive("rtm_incoming_data")
$ orderly_pull_archive("rtm_incoming_data",
    "20201109-195633-02085ffb")
$ orderly_pull_dependencies()
$ orderly_pull_dependencies(remote = "staging")
```

orderly

Not a workflow manager
Asychronous collaborative analysis
Everything auditable, re-runnable
Analysis treated as blackbox, with interface

https://github.com/vimc/orderly

PHE
NHS
CHESS
CO-CIN
ONS

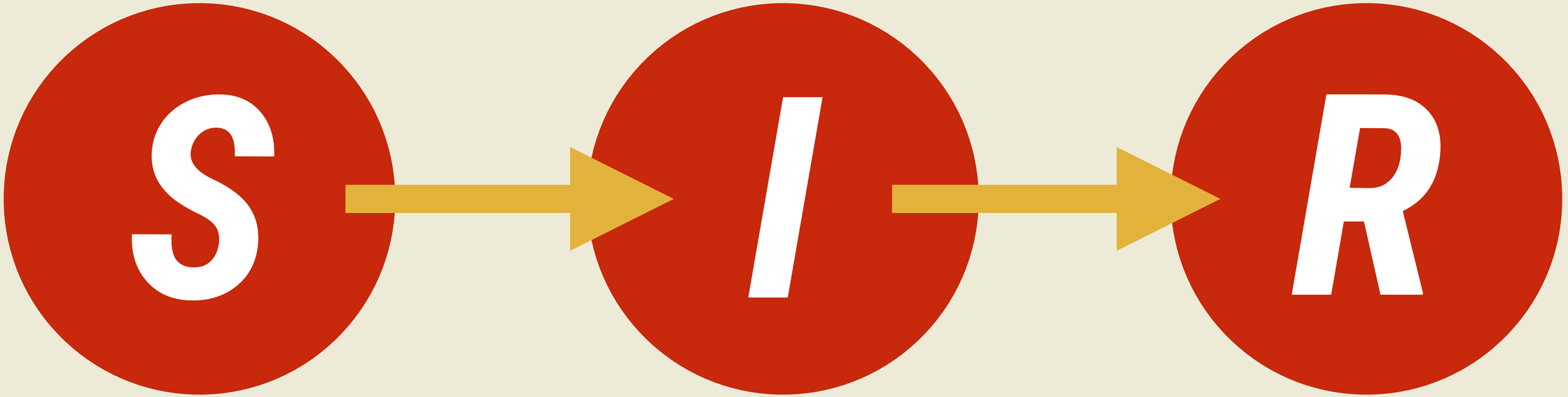
(nightly)

Contact matrices
Demography

Severity data
Delay distributions

S → I → R

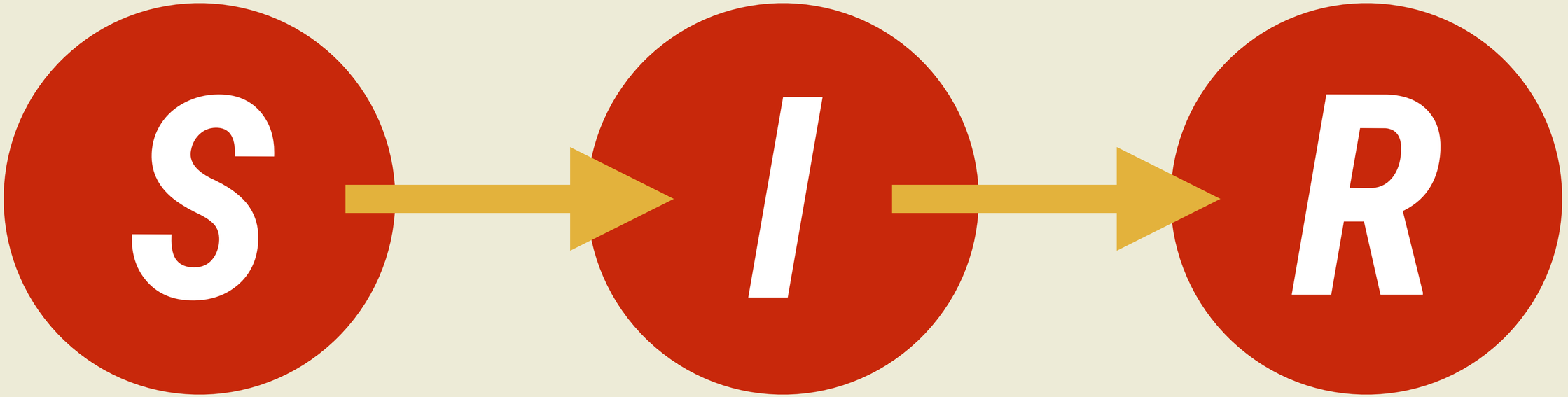
Serology
REACT



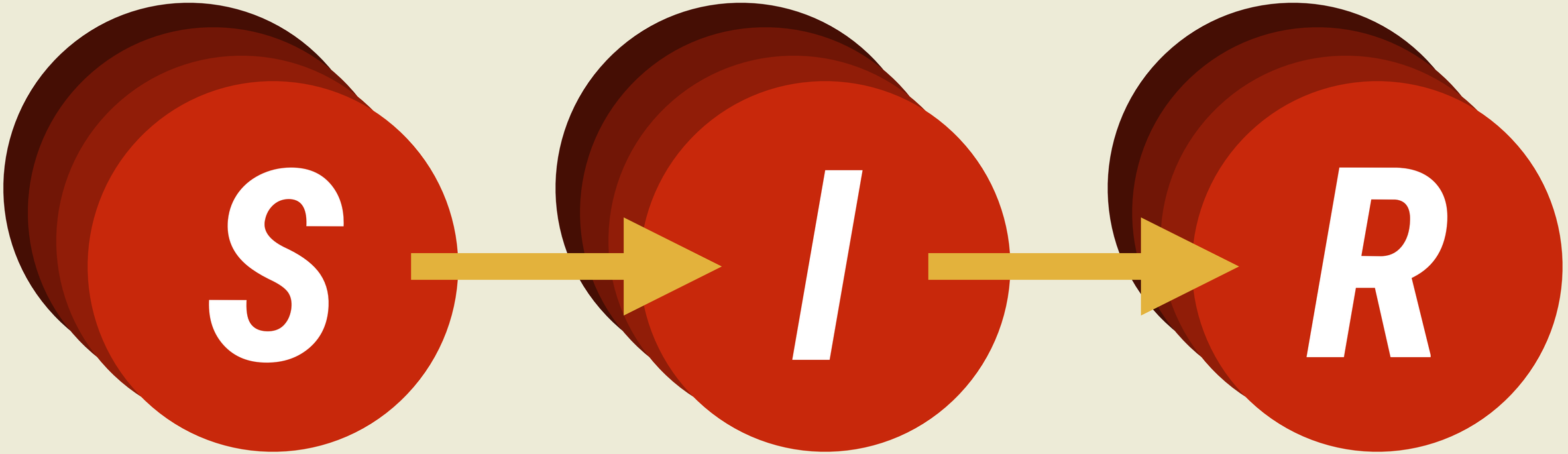
$$\frac{dS}{dt} \qquad \frac{dI}{dt} \qquad \frac{dR}{dt}$$

Things that map neatly to software problems may not be the hard bits

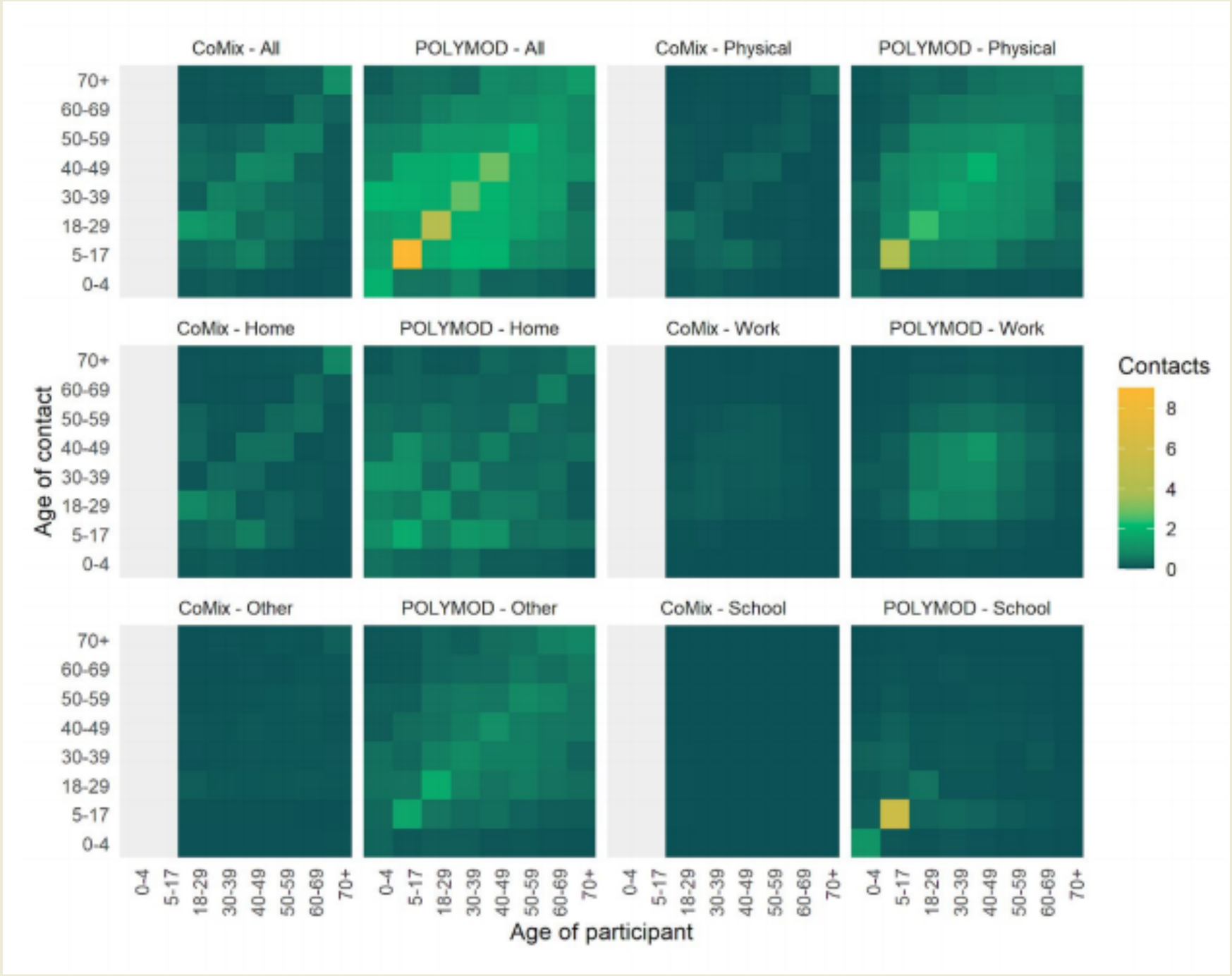
```
sir <- function(S, I, R, beta, sigma, n_steps) {
  history <- matrix(c(S, I, R), 3, n_steps + 1)
  for (i in seq_len(n_steps)) {
    N <- S + I + R
    FOI <- beta * I / N
    nSI <- rbinom(1, S, 1 - exp(-FOI))
    nIR <- rbinom(1, I, 1 - exp(-sigma))
    S <- S - nSI
    I <- I + nSI - nIR
    R <- R + nIR
    history[, i + 1] <- c(S, I, R)
  }
  history
}
```



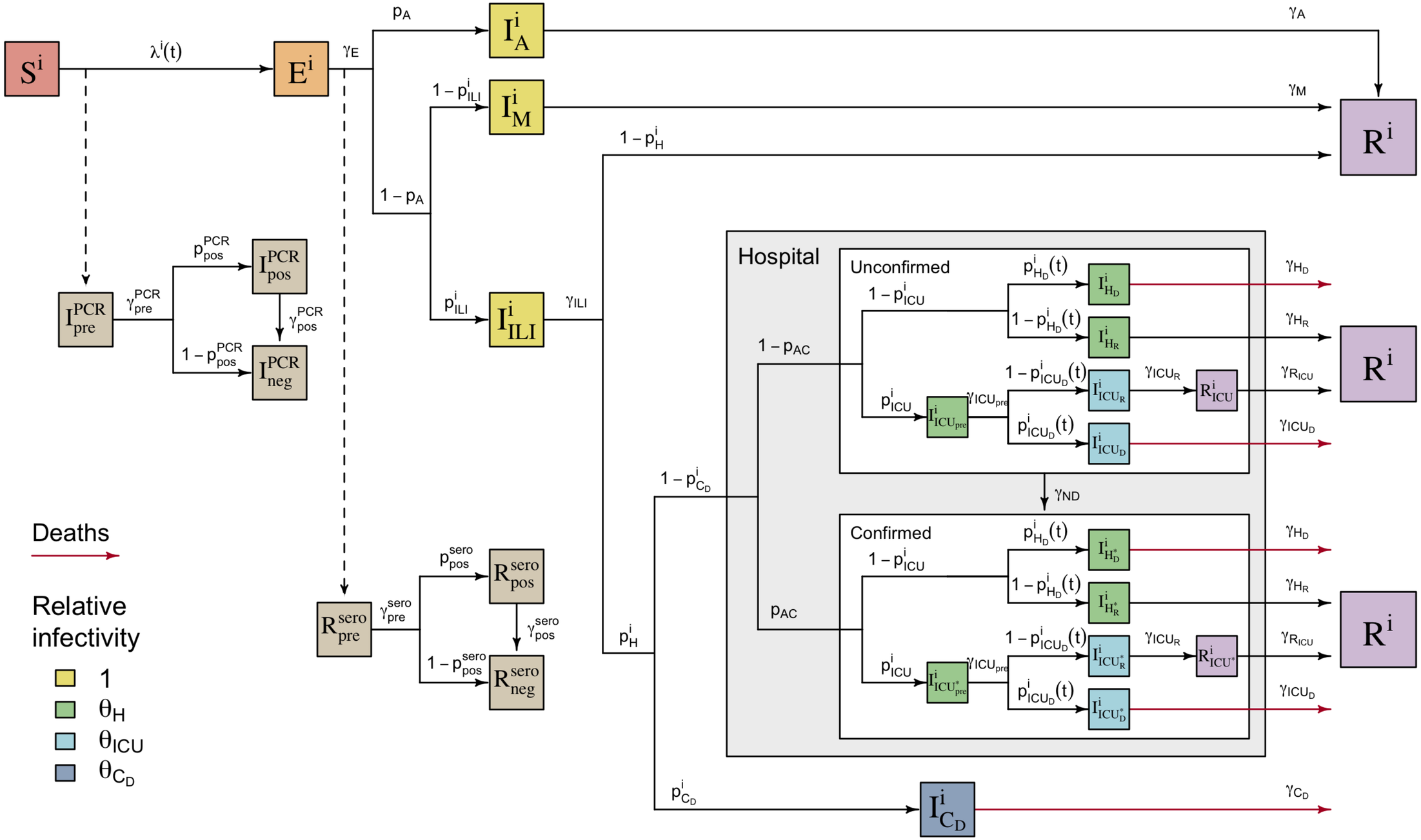
$$\frac{dS}{dt} \qquad \frac{dI}{dt} \qquad \frac{dR}{dt}$$

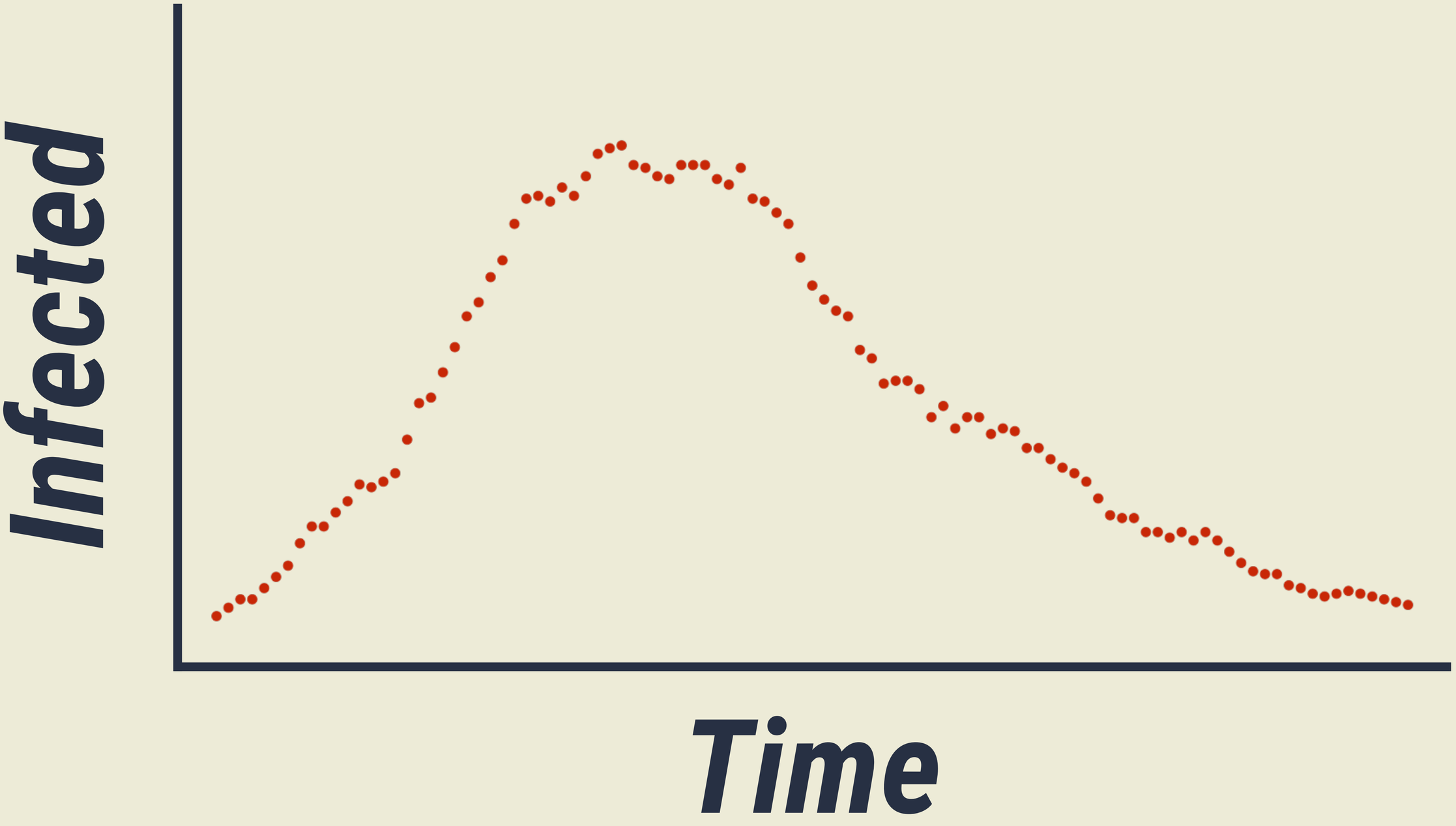


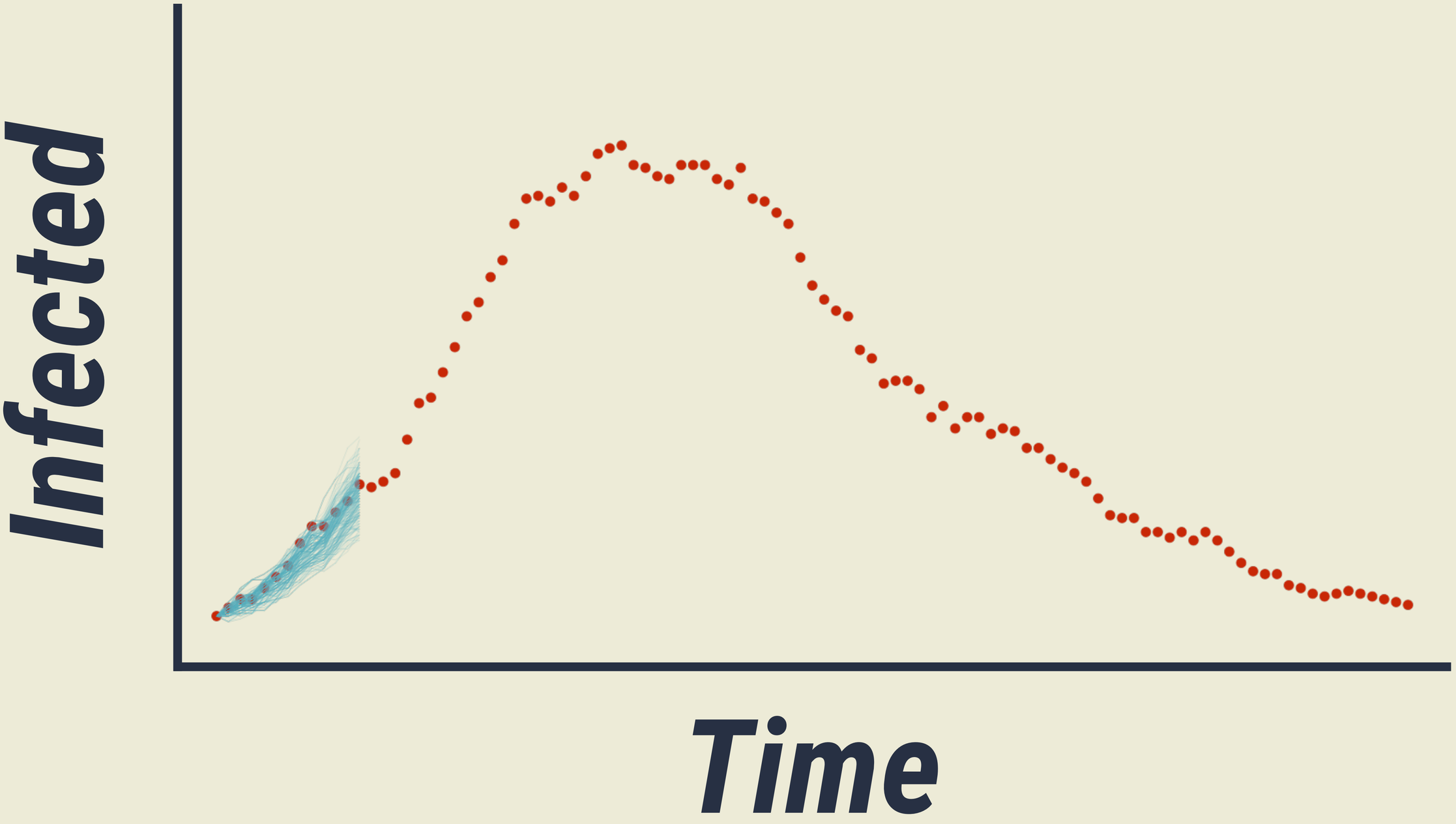
$$\frac{dS_i}{dt} \qquad \frac{dI_i}{dt} \qquad \frac{dR_i}{dt}$$

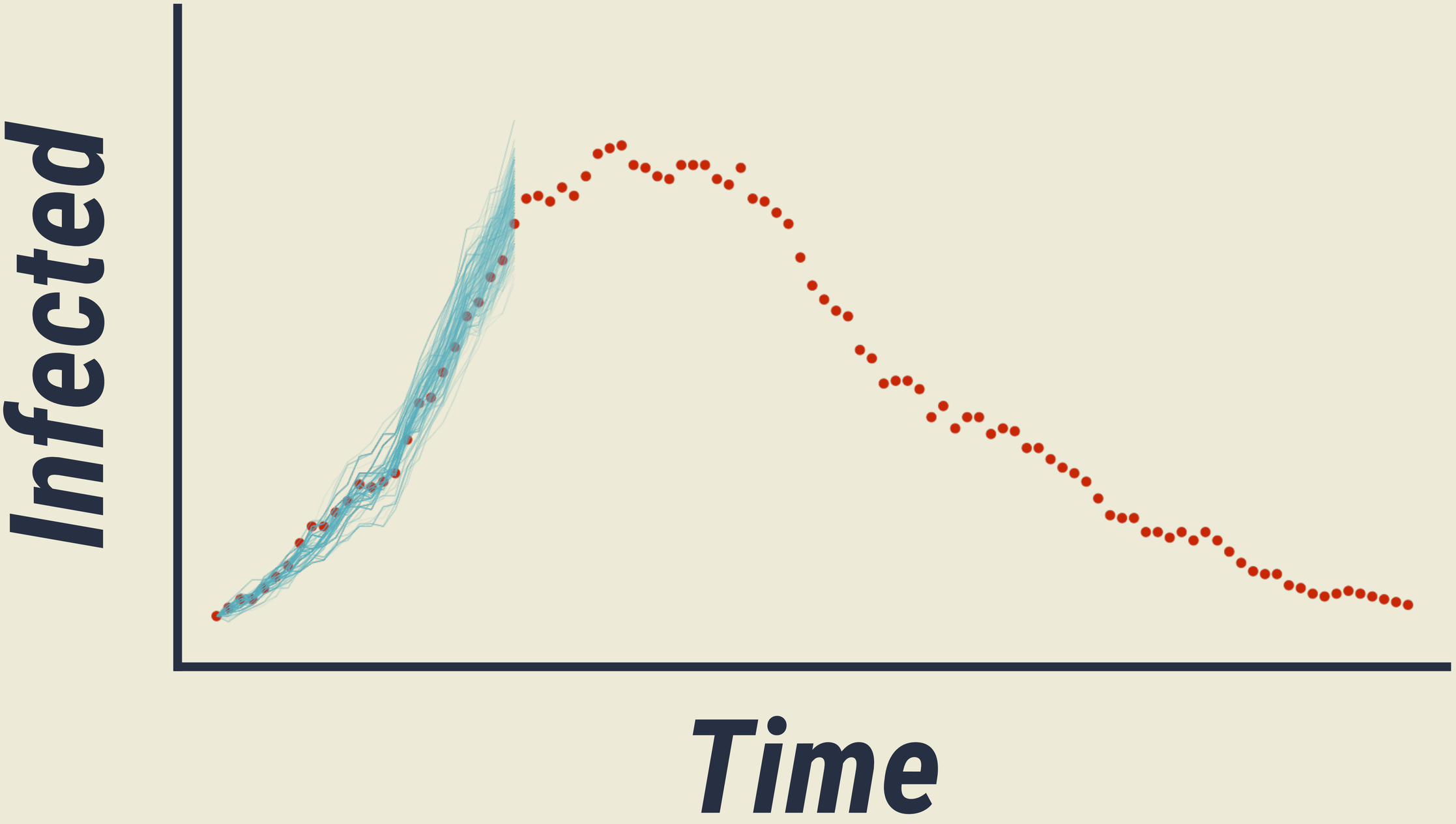


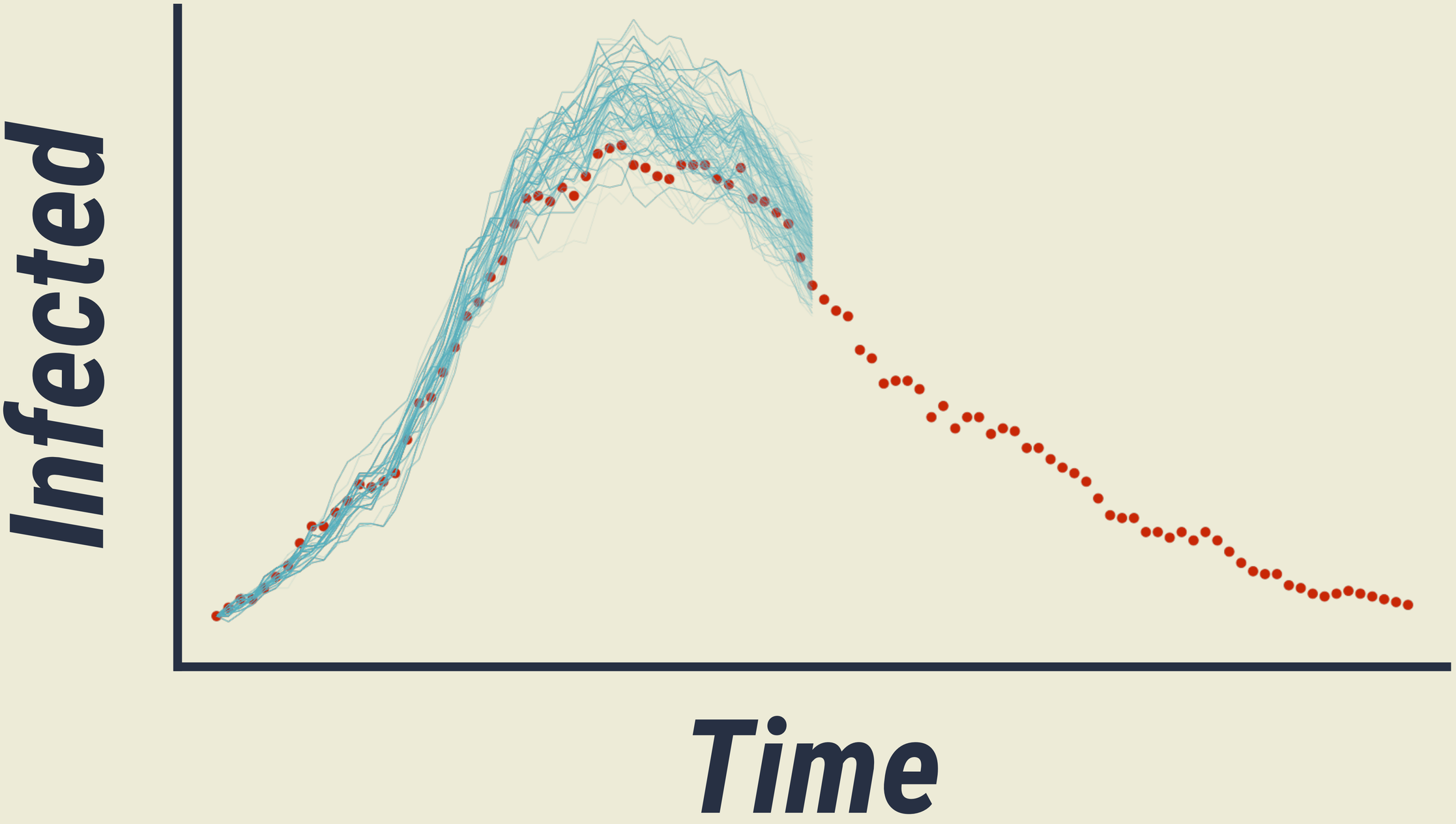
https://cmmid.github.io/topics/covid19/comix-impact-of-physical-distance-measures-on-transmission-in-the-UK.html

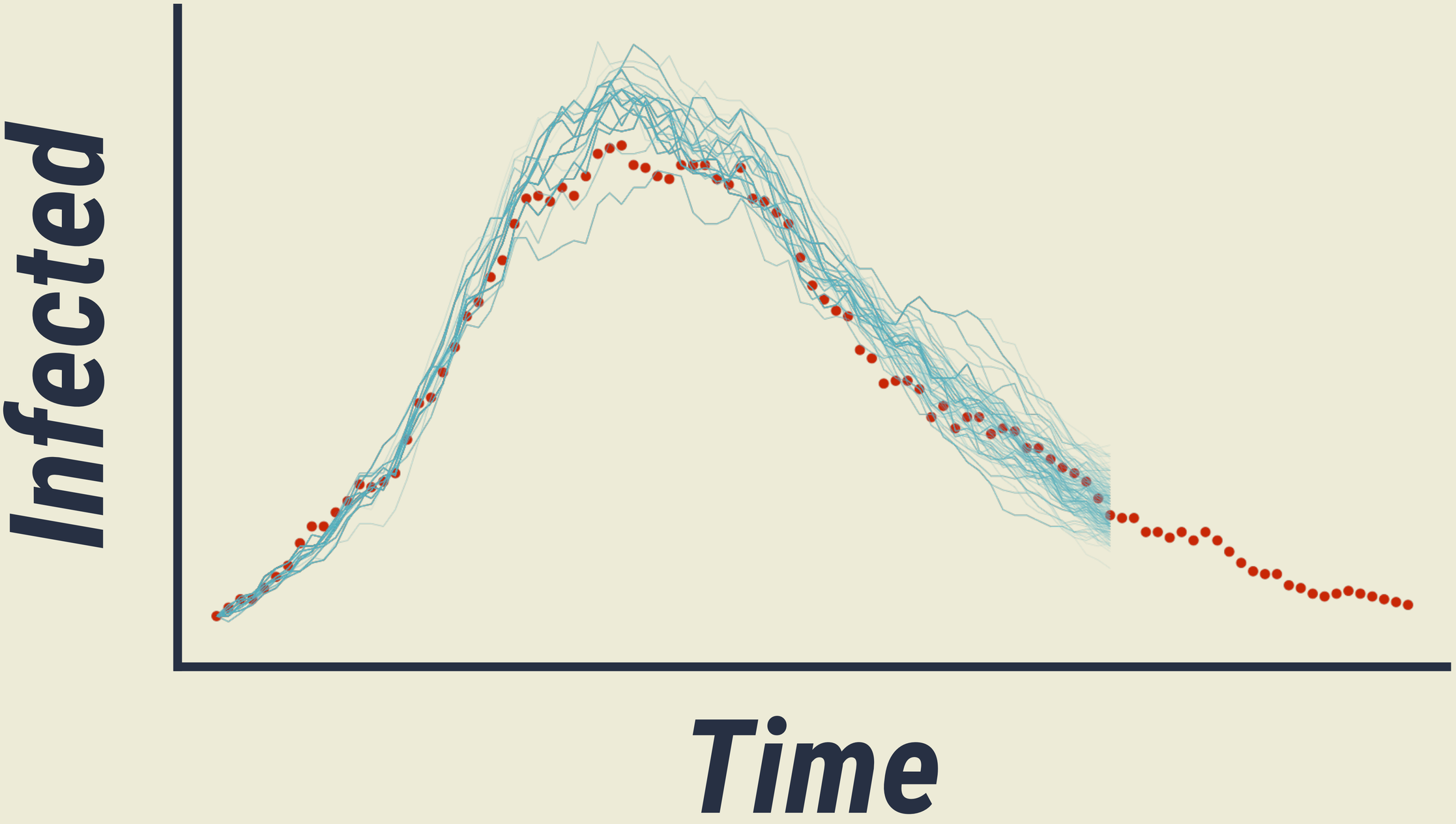

S^i
$\lambda^i(t)$
E^i
γ_E
p_A
I^i_A
γ_A
$1 - p^i_{ILI}$
I^i_M
γ_M
R^i
$1 - p^i_H$
$1 - p_A$
I^{PCR}_{pre}
γ^{PCR}_{pre}
p^{PCR}_{pos}
I^{PCR}_{pos}
γ^{PCR}_{pos}
$1 - p^{PCR}_{pos}$
I^{PCR}_{neg}
p^i_{ILI}
I^i_{ILI}
γ_{ILI}
Hospital
Unconfirmed
$p^i_{H_D}(t)$
$1 - p^i_{ICU}$
$I^i_{H_D}$
$1 - p^i_{H_D}(t)$
$I^i_{H_R}$
γ_{H_D}
γ_{H_R}
$1 - p_{AC}$
$1 - p^i_{ICU_D}(t)$
γ_{ICU_R}
p^i_{ICU}
$I^i_{ICU_{pre}}$
$\gamma_{ICU_{pre}}$
$I^i_{ICU_R}$
R^i_{ICU}
$\gamma_{R_{ICU}}$
$p^i_{ICU_D}(t)$
$I^i_{ICU_D}$
γ_{ICU_D}
$1 - p^i_{C_D}$
γ_{ND}
Confirmed
$p^i_{H_D}(t)$
$1 - p^i_{ICU}$
$I^i_{H^*_D}$
$1 - p^i_{H_D}(t)$
$I^i_{H^*_R}$
γ_{H_D}
γ_{H_R}
p_{AC}
$1 - p^i_{ICU_D}(t)$
γ_{ICU_R}
p^i_{ICU}
$I^i_{ICU^*_{pre}}$
$\gamma_{ICU_{pre}}$
$I^i_{ICU^*_R}$
$R^i_{ICU^*}$
$\gamma_{R_{ICU}}$
$p^i_{ICU_D}(t)$
$I^i_{ICU^*_D}$
γ_{ICU_D}
p^i_H
R^i
R^i
p^{sero}_{pos}
R^{sero}_{pos}
R^{sero}_{pre}
γ^{sero}_{pre}
γ^{sero}_{pos}
$1 - p^{sero}_{pos}$
R^{sero}_{neg}
$p^i_{C_D}$
$I^i_{C_D}$
γ_{C_D}
Deaths
Relative infectivity
1
θ_H
θ_{ICU}
θ_{C_D}

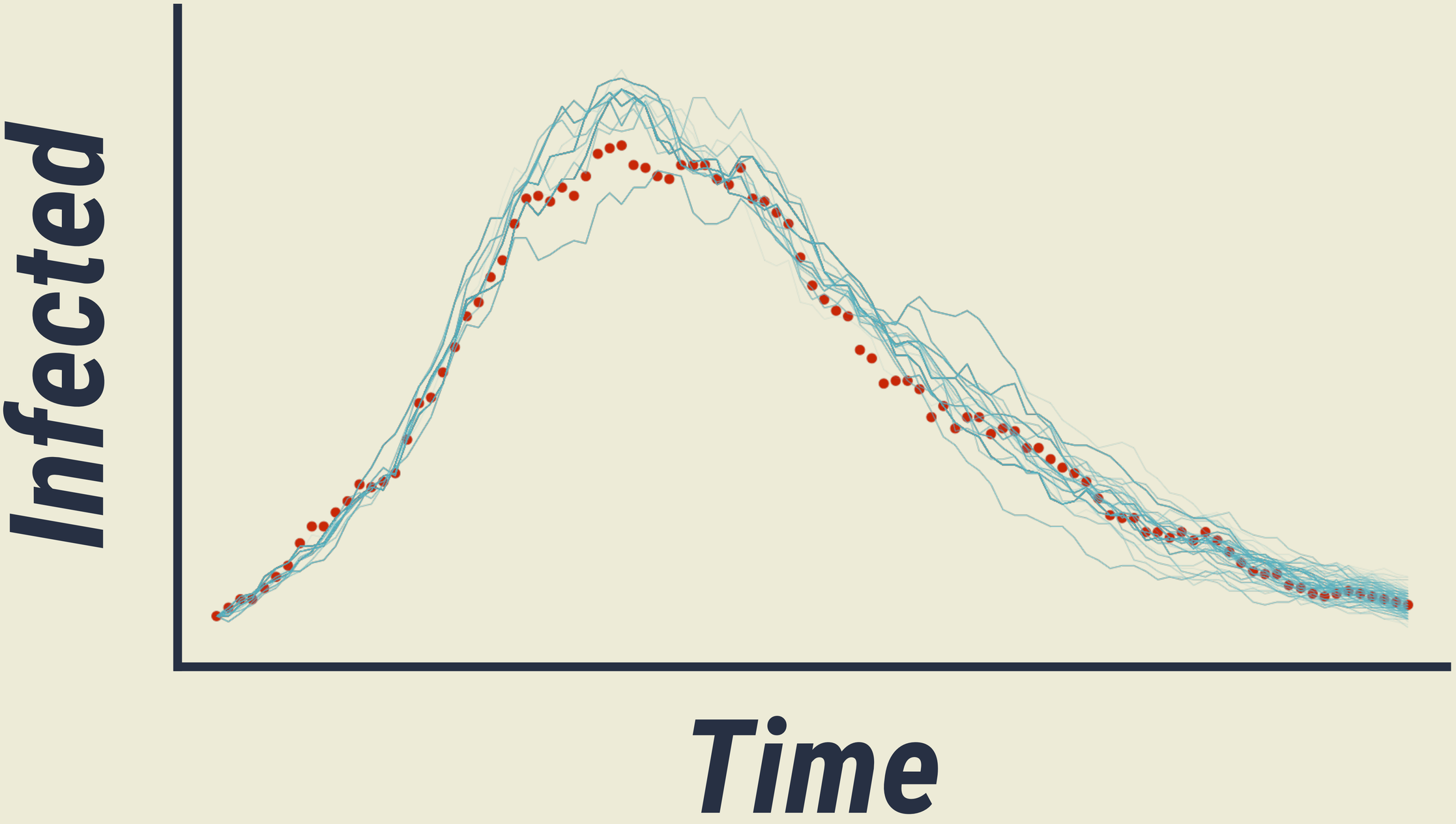

Infected
Time


Infected
Time


Infected
Time


Infected
Time


Infected
Time


Infected
Time

sircovid

Written in 'odin' DSL

Model core, parameter handling

Post-processing (e.g., R_t calculation)

"Science" code

https://github.com/mrc-ide/sircovid

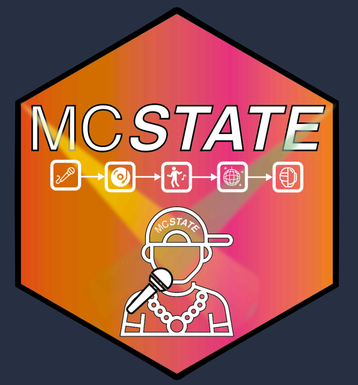

```
n_EE[, , ] <- rbinom(E[i, j, k], p_EE)

## Computes the number of asymptomatic
n_EI_asympt[, ] <- rbinom(n_EE[i, s_E, j], p_asympt[i])

## Computes the number of mild cases - p_sympt_ILI gives the
## proportion of febrile/ILI cases among the symptomatics
n_EI_mild[, ] <-
  rbinom(n_EE[i, s_E, j] - n_EI_asympt[i, j], 1 - p_sympt_ILI[i])

## Computes the number of ILI cases
n_EI_ILI[, ] <- n_EE[i, s_E, j] - n_EI_asympt[i, j] -
  n_EI_mild[i, j]
```

https://github.com/mrc-ide/odin

```
y[, ] = a[i] + b[j]
```

```
for (int i = 1; i <= internal->dim_y_1; ++i) {
  for (int j = 1; j <= internal->dim_y_2; ++j) {
    internal->y[i - 1 + internal->dim_y_1 * (j - 1)] =
      internal->a[i - 1] + internal->b[j - 1]
  }
}
```

mcstate



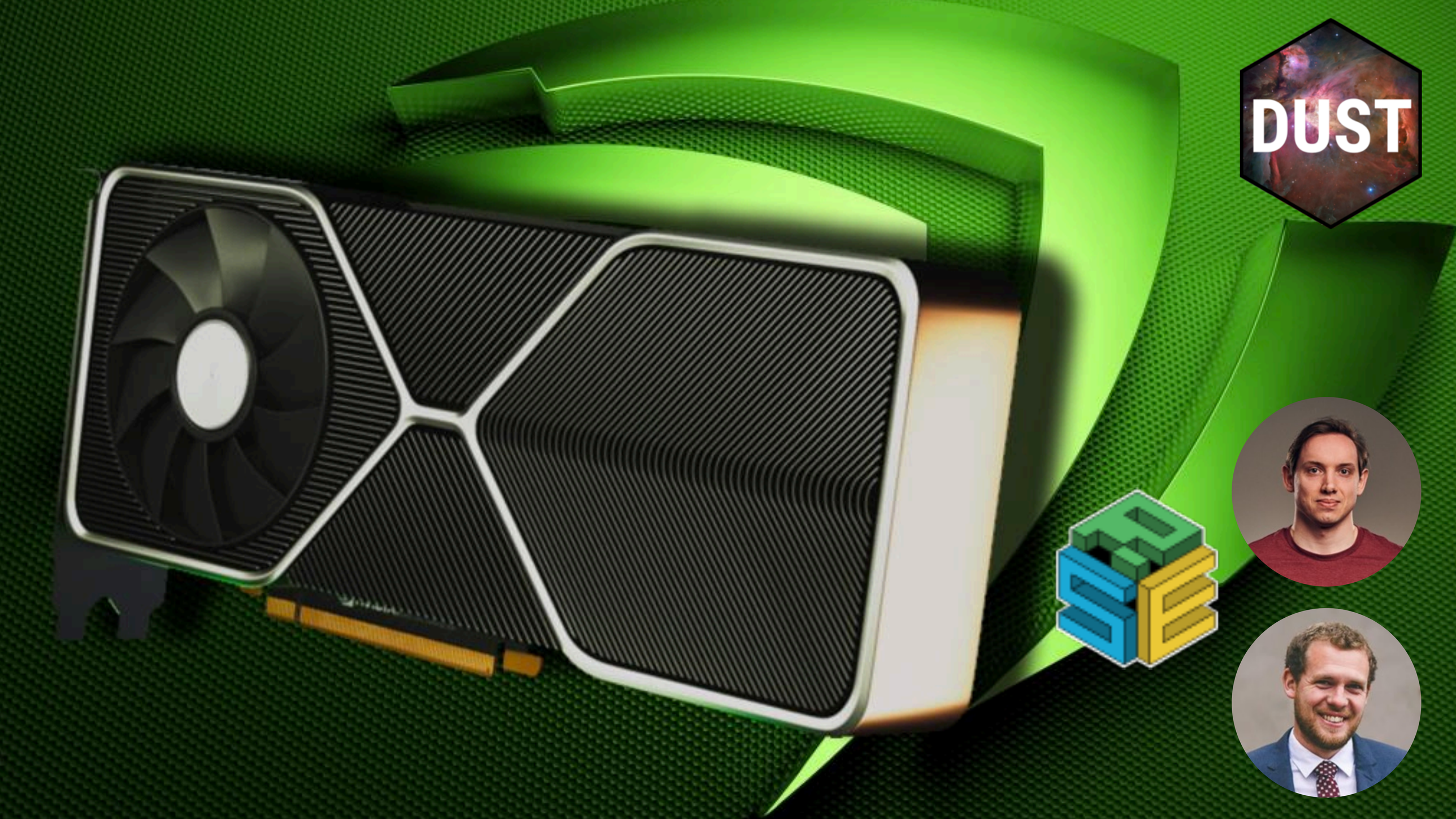
Bootstrap particle filter
Basic MCMC
Special handling of discrete parameters
"Statistics" code

https://github.com/mrc-ide/mcstate

dust

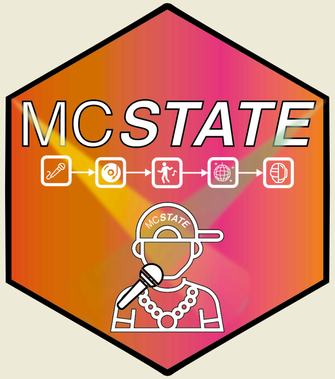
The compilation target for odin
Parallel random numbers (xoshiro)
Provides primatives to support mcstate
"RSE" code

https://github.com/mrc-ide/dust


DUST

sircovid

mrc-ide.github.io/sircovid



mcstate

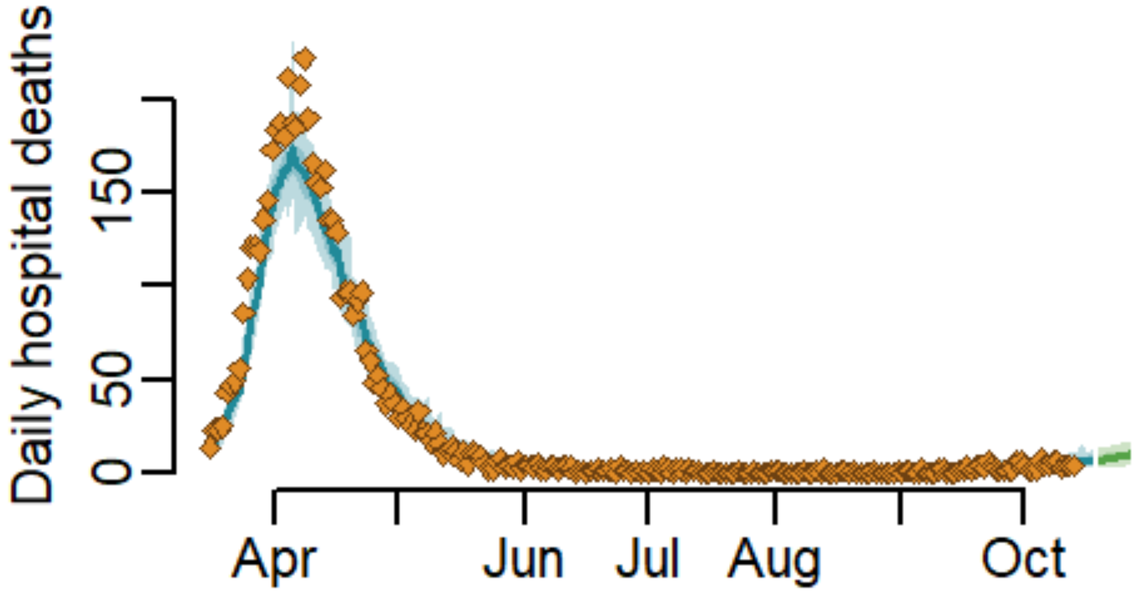
mrc-ide.github.io/mcstate

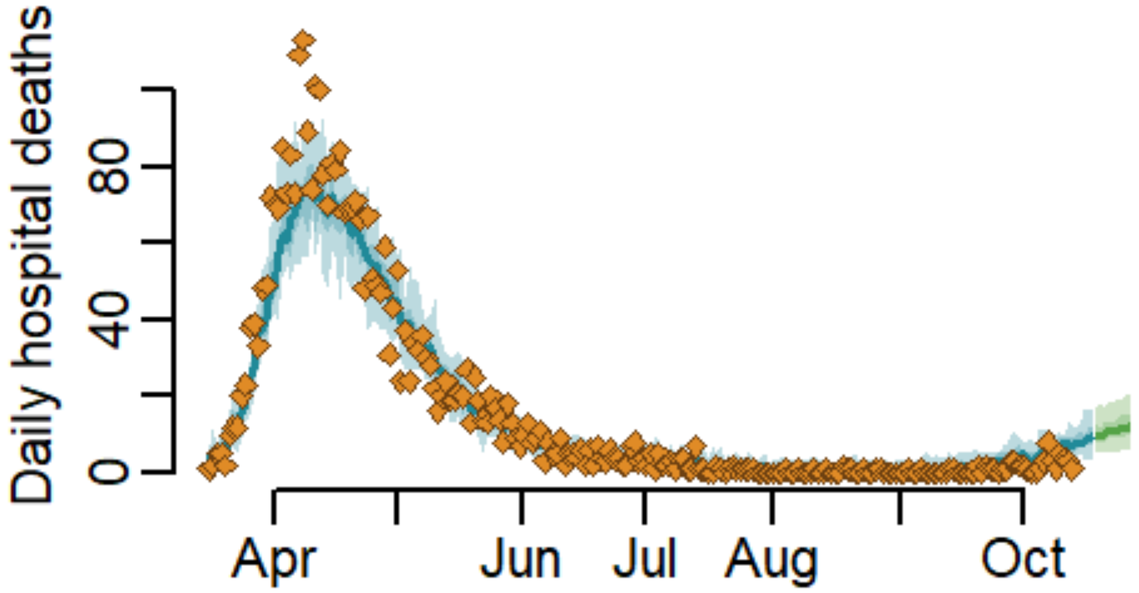
dust

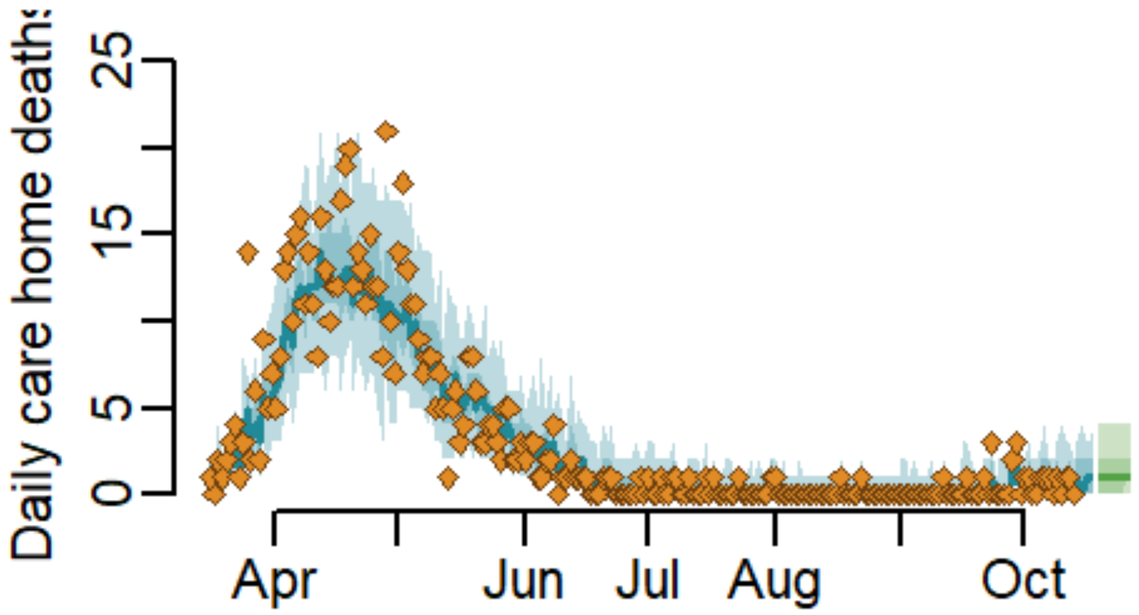
mrc-ide.github.io/dust

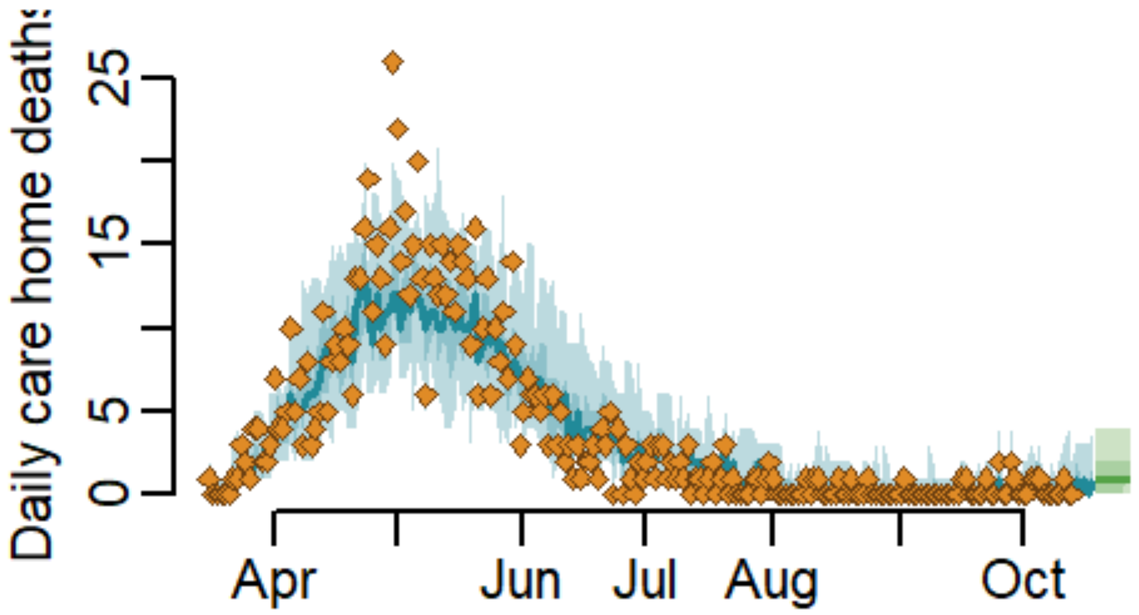
odin

mrc-ide.github.io/odin


Daily hospital deaths
0
50
150
Apr
Jun
Jul
Aug
Oct

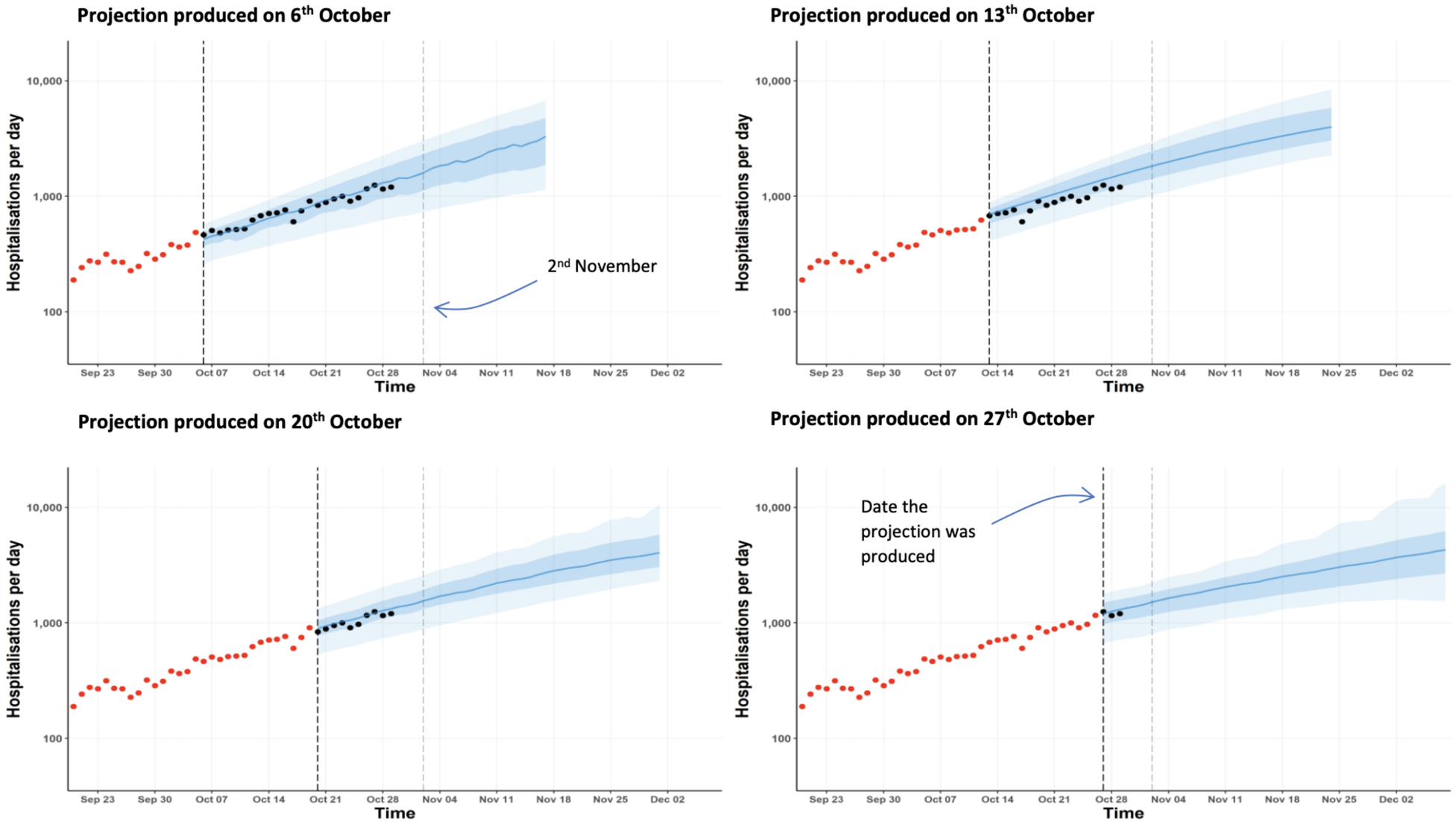

Daily hospital deaths
0
40
80
Apr
Jun
Jul
Aug
Oct


Daily care home deaths
0
5
15
25
Apr
Jun
Jul
Aug
Oct


Daily care home deaths
0
5
15
25
Apr
Jun
Jul
Aug
Oct

Annex: SPI-M-O medium term projections for daily hospital admissions and deaths in England compared to outturn data.

Figure 1: Medium-term projections for daily hospitalisations in England on a *log scale*. Hospitalisations are defined as patients admitted with confirmed COVID-19 and those who test positive in hospital after admission. Blue shows the consensus projection based on current trends, not including the effects of past or future policy or behaviour changes that were yet to be reflected in the data available at the time. The dark blue shows the interquartile range and the light blue the 90% CI. The red dots indicate the data from before the projections begin, and the black dots the number of daily hospitalisations since. Please note some of the data in red has been revised since these projections were produced.



https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/935134/spi-m-o-medium-term-projections-explainer-311020.pdf

PHE
NHS
CHESS
CO-CIN
ONS

Contact matrices
Demography

Severity data
Delay distributions

(nightly)

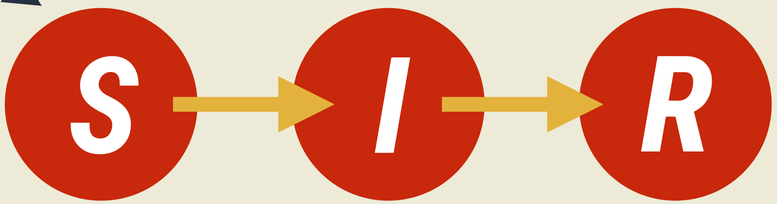
Bob Verity

Wes Hinsley

Katy Gaythorpe

Natsuko Imai

Serology
REACT



John Lees

Pablo Noel Perez Guzman

Anne Cori

Ed Knock

Fernando Guntoro

Marc Baguelin

Lilith Whittles

Neil Ferguson

Take-homes

Interfaces make the difference
Communication is important
It's a collaboration - you're working with experts
Version control and test everything
Our tooling is bad

BETTER SOFTWARE BETTER RESEARCH

www.software.ac.uk

Acknowledgements

MRC Centre for Global Infectious Disease Analysis
COVID response team
Vaccine Impact Modelling Consortium
Bill and Melinda Gates Foundation/GAVI
rOpenSci
Sheffield RSE + NVIDIA

Resources

https://mrc-ide.github.io/odin
https://mrc-ide.github.io/sircovid
https://mrc-ide.github.io/mcstate
https://mrc-ide.github.io/dust
https://vimc.github.io/orderly
https://vimc.github.io/orderly-web

richfitz

rgfitzjohn

reside-ic.github.io