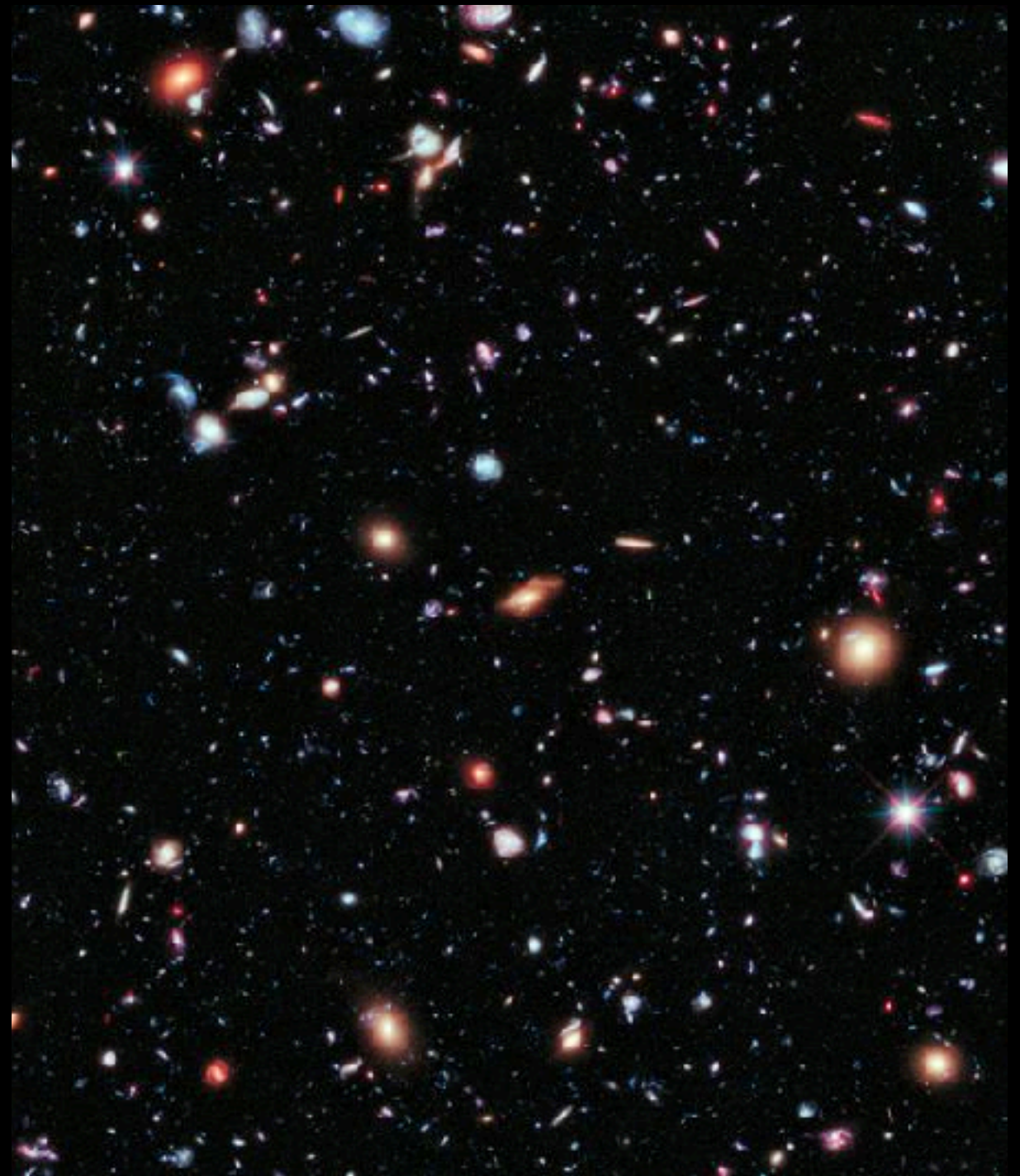# R as a tool for complex systems modelling

Caitlin Adams
R-Ladies Melbourne — 19/09/18

About me

- PhD Student at Swinburne's Centre for Astrophysics and Supercomputing

- Use the statistical properties of many galaxies to understand the Universe

- Mostly program in C++ and Python for my research

About Mezo
(not the soup!)

- Small company that works on mathematical modelling and statistical analysis

- Founders have backgrounds in science and ecological modelling

- Systems thinking, resource management and decision making

- Program primarily in R!

Plan for this talk

Complex Systems

Plan for this talk

Complex Systems I.

Plan for this talk
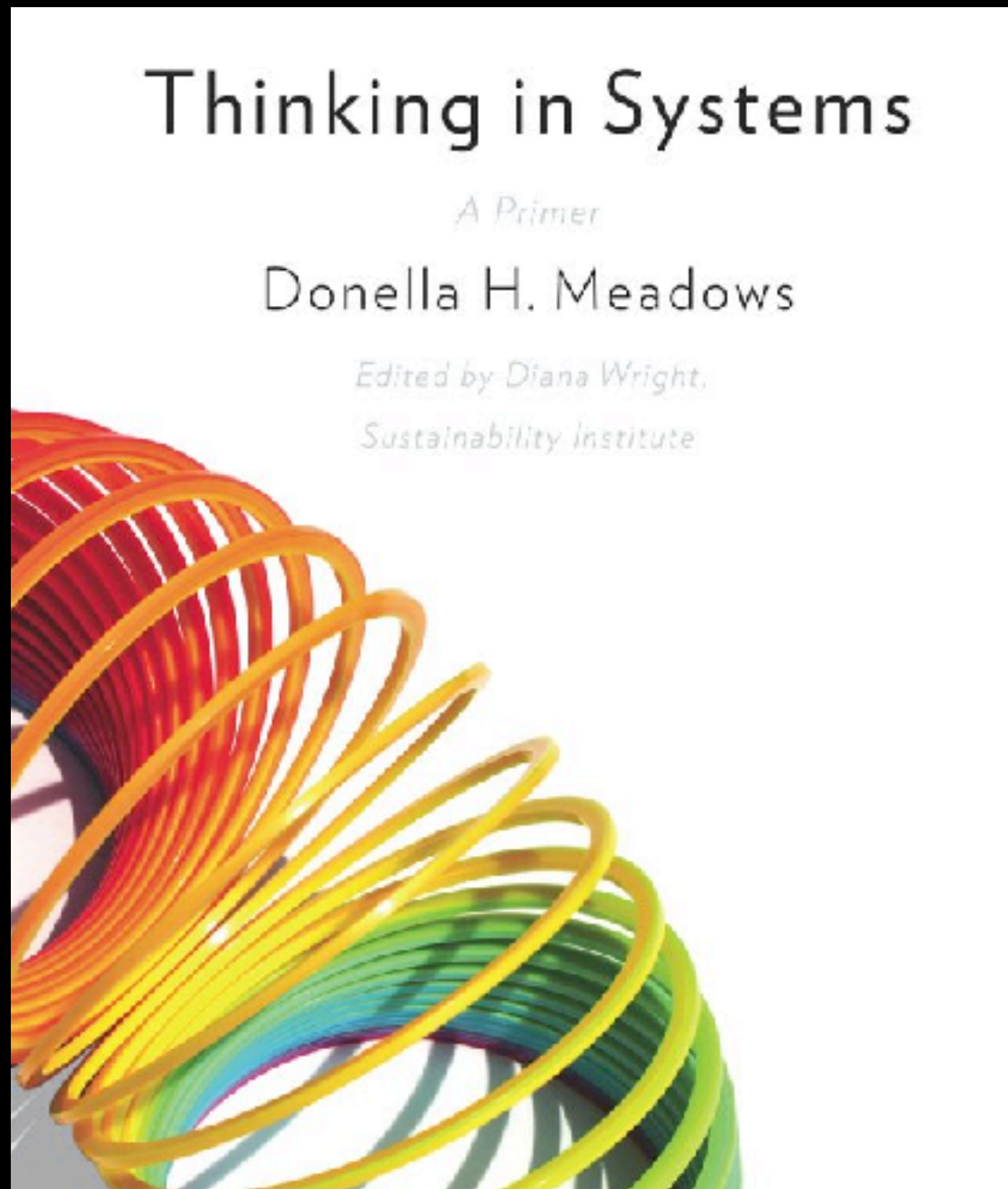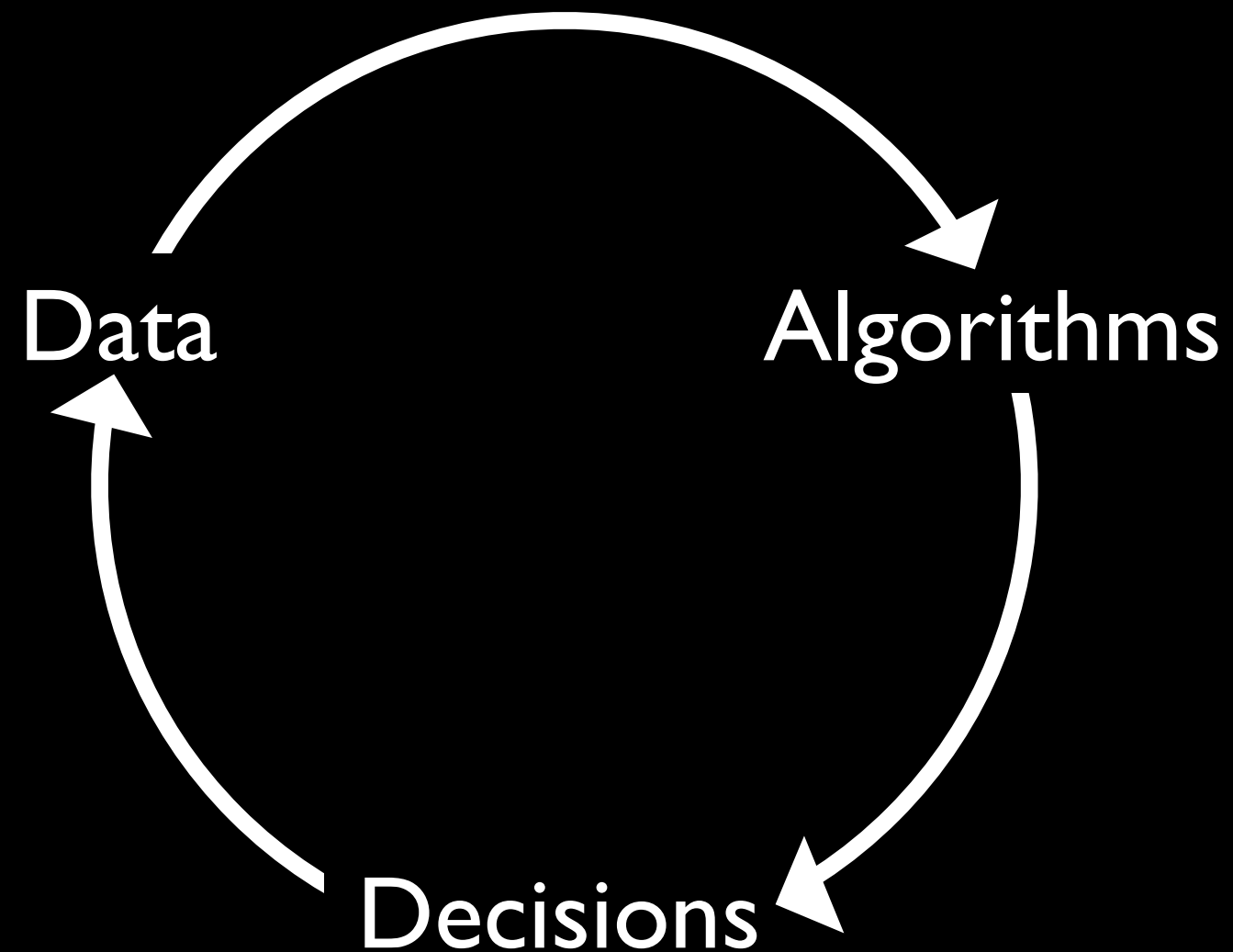
Complex Systems

2.

Plan for this talk

3.

Complex Systems

Systems thinking

- System: connected elements interacting to produce particular behaviours

- A system is more than the sum of its parts

- Systems thinking works well for non-linear, non-intuitive systems
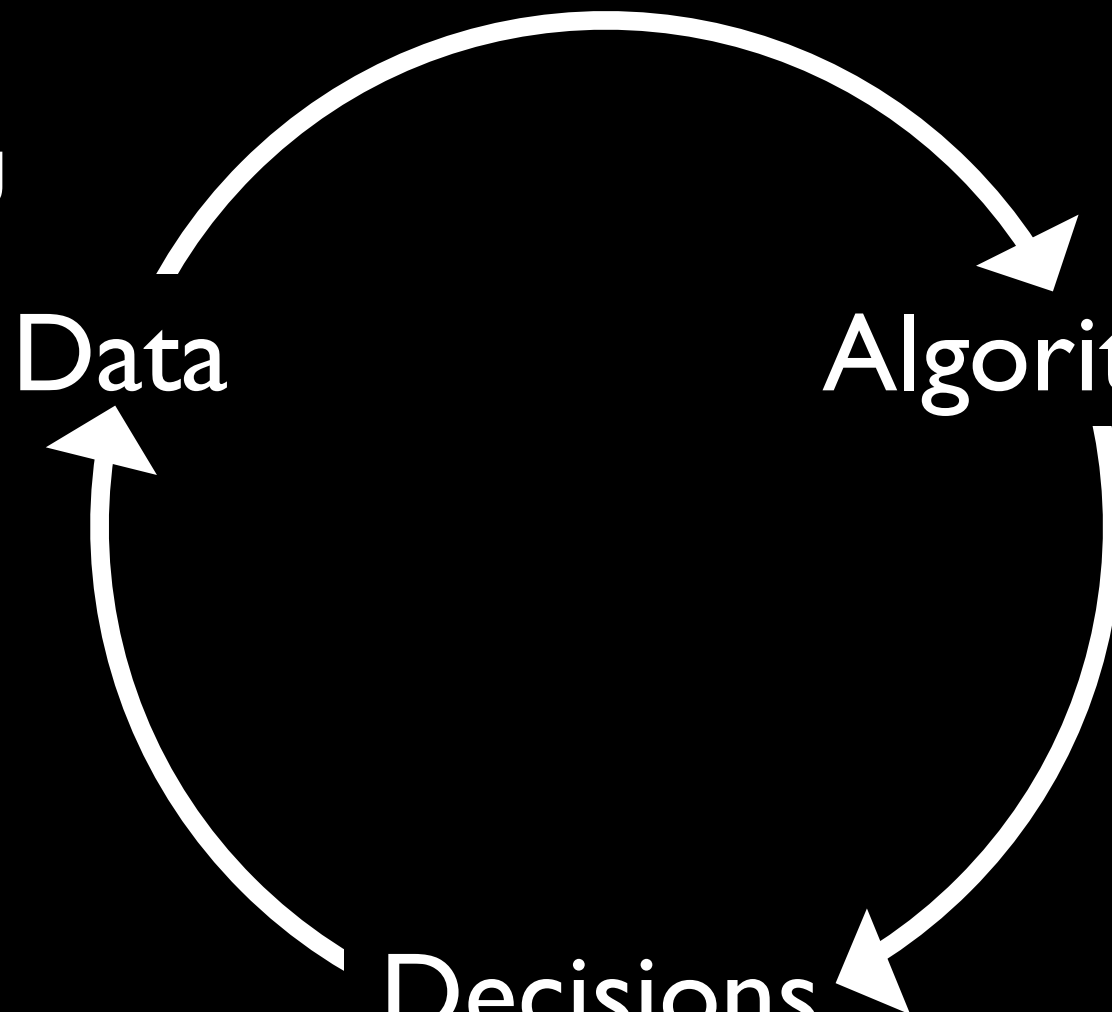
Systems thinking in R

Systems thinking in R
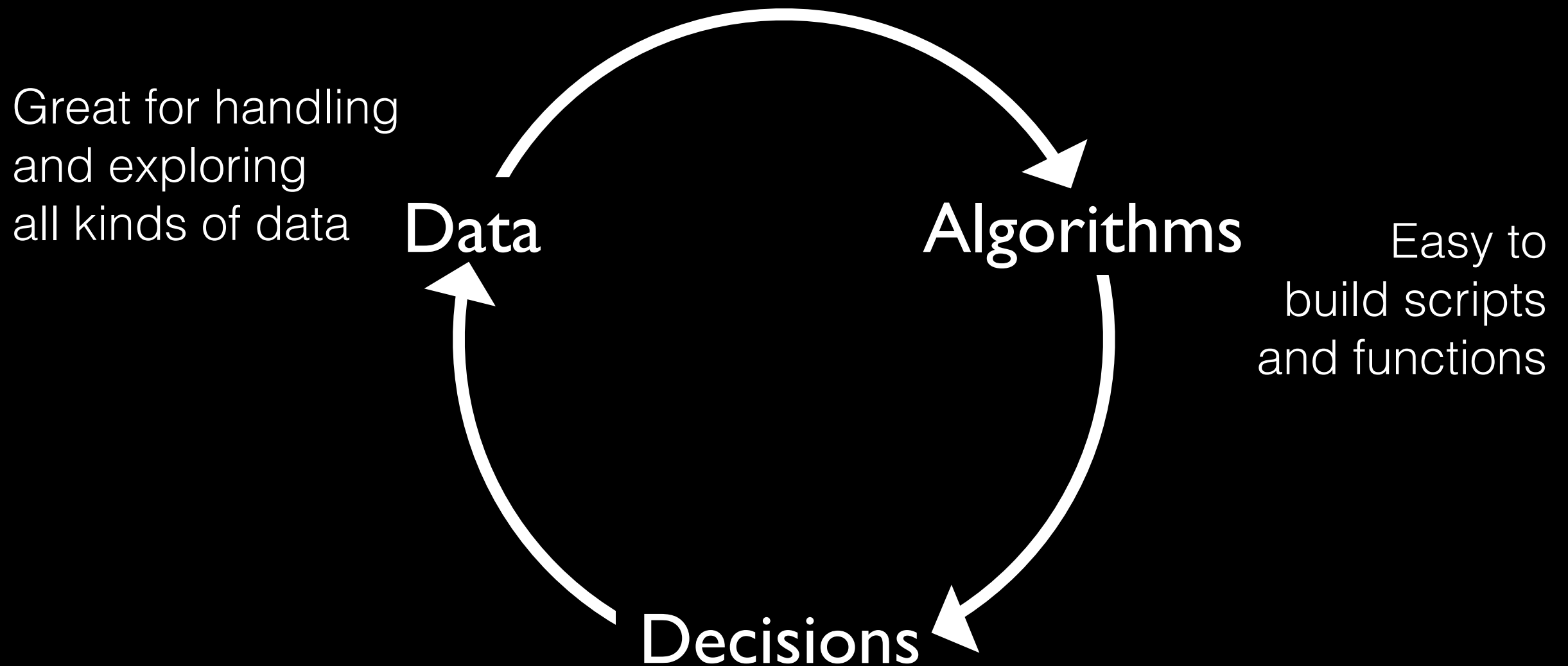
Great for handling
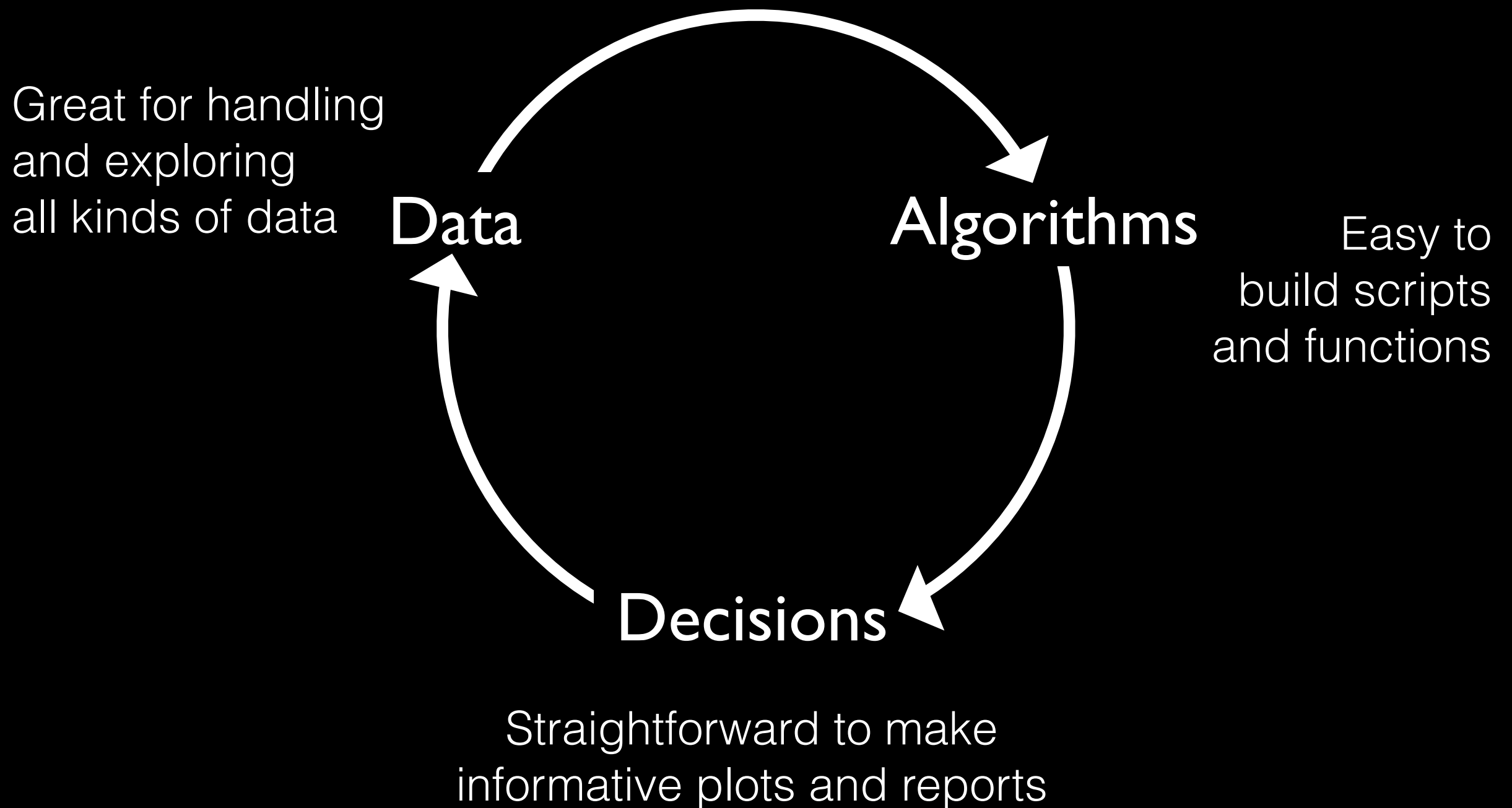and exploring
all kinds of data

Data   Algorithms

Decisions

Systems thinking in R

Great for handling
and exploring
all kinds of data

Data

Algorithms

Easy to
build scripts
and functions

Decisions

Systems thinking in R

Great for handling
and exploring
all kinds of data

Data

Algorithms

Easy to
build scripts
and functions

Decisions

Straightforward to make
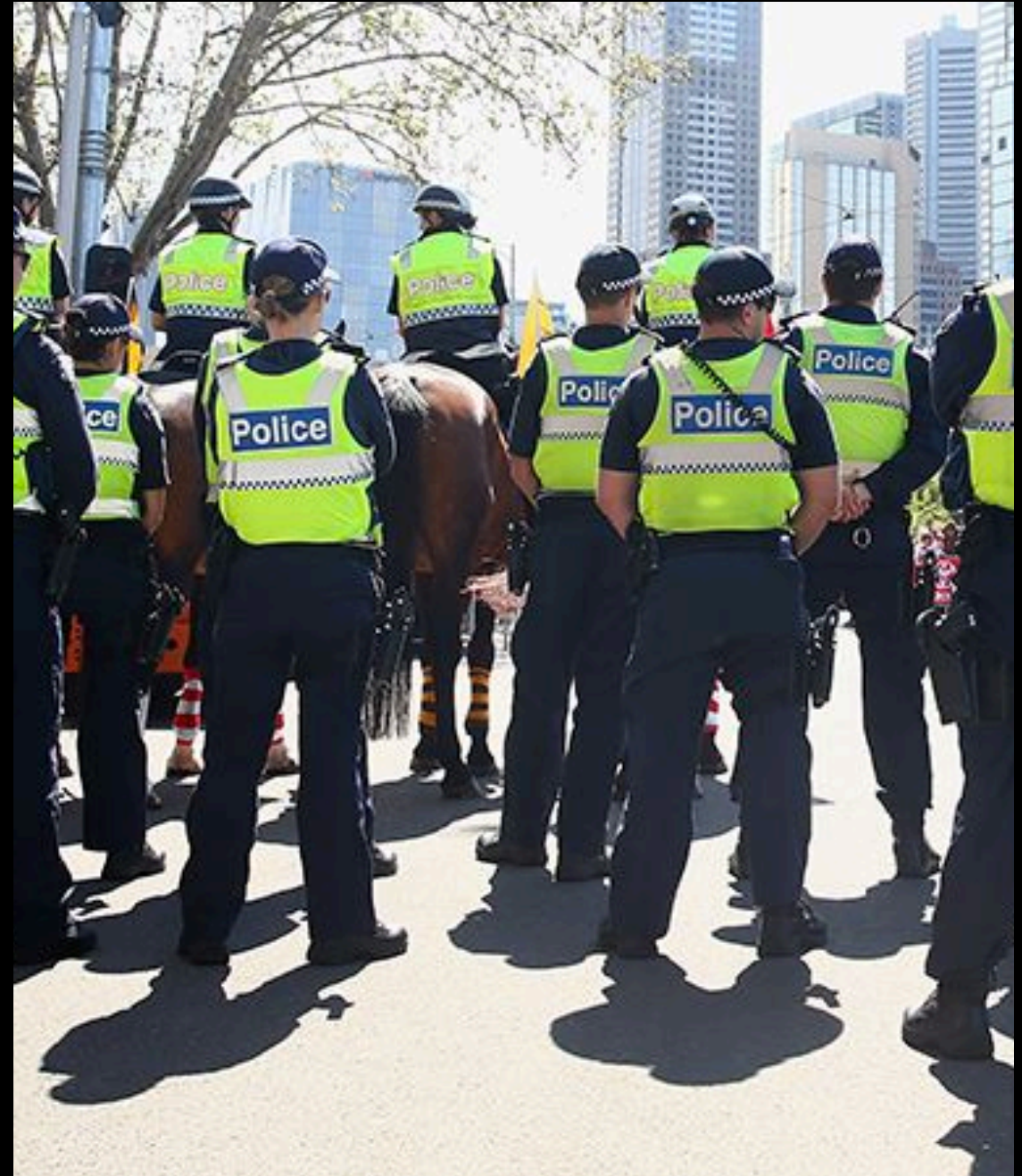informative plots and reports

Working for Victoria Police
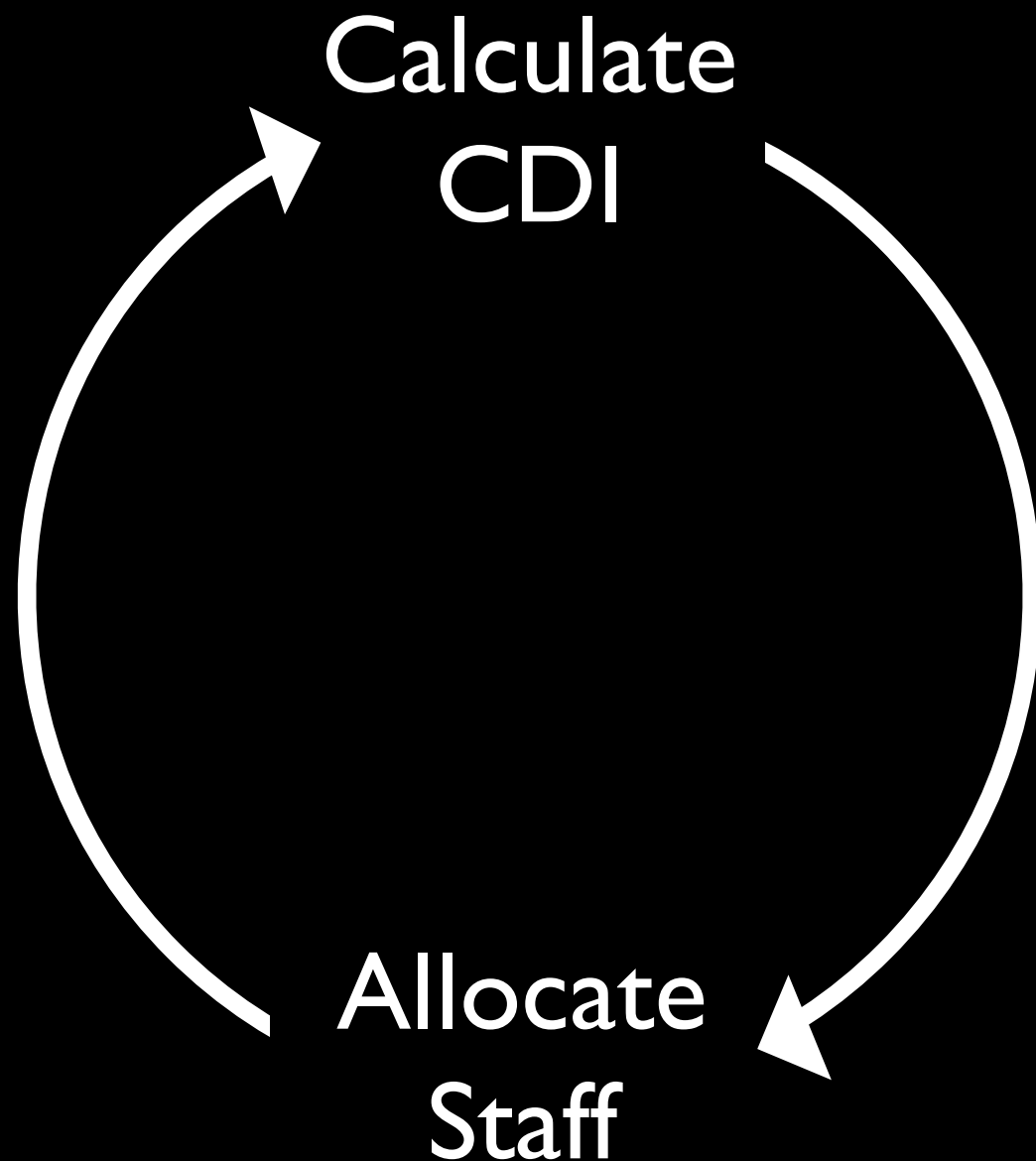
How many recruits do they need?

Where should they put them?

Data

- Over 30 different data sources

- Crime, 000 calls, event management, traffic incident reports

- Use an R script to clean and process data

- Key packages: the Tidyverse (dplyr, tidyr, tibble, ggplot2, lubridate…)

- `saveRDS` for data compression and ease of use

Algorithms

Calculate CDI

Allocate Staff

- Victoria Police's questions can be tied to understanding demand

- Mezo developed the composite demand index (CDI) by understanding and combining different types of data

- The CDI per staff rate is calculated and the model recommends an allocation to the place most in need

- This can be repeated as necessary

Most of the <u>complexity</u> comes from determining the CDI!
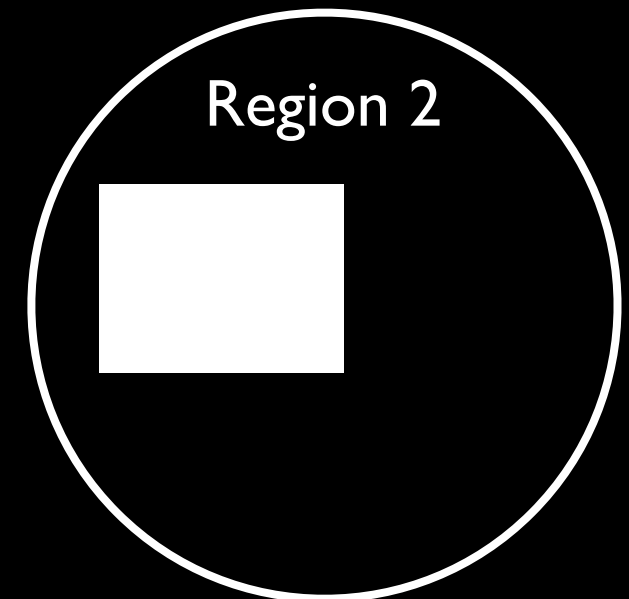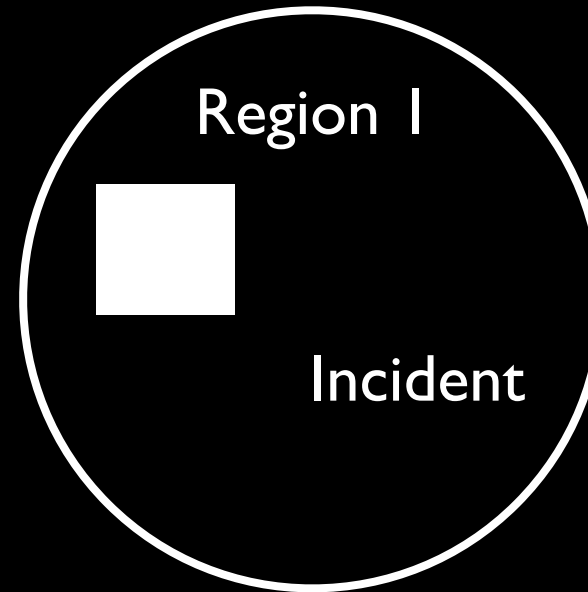
I'll now cover two examples

Responding or Attending?
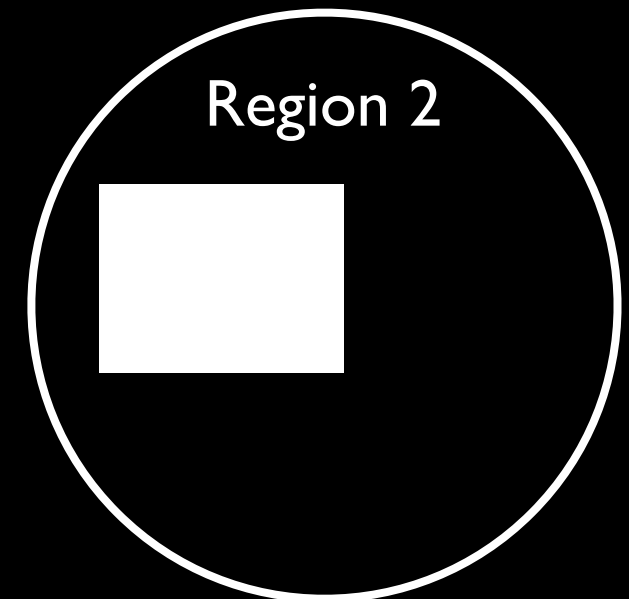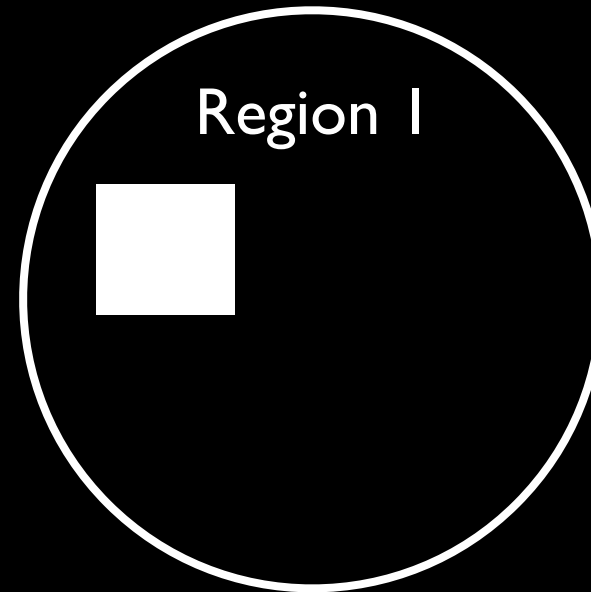
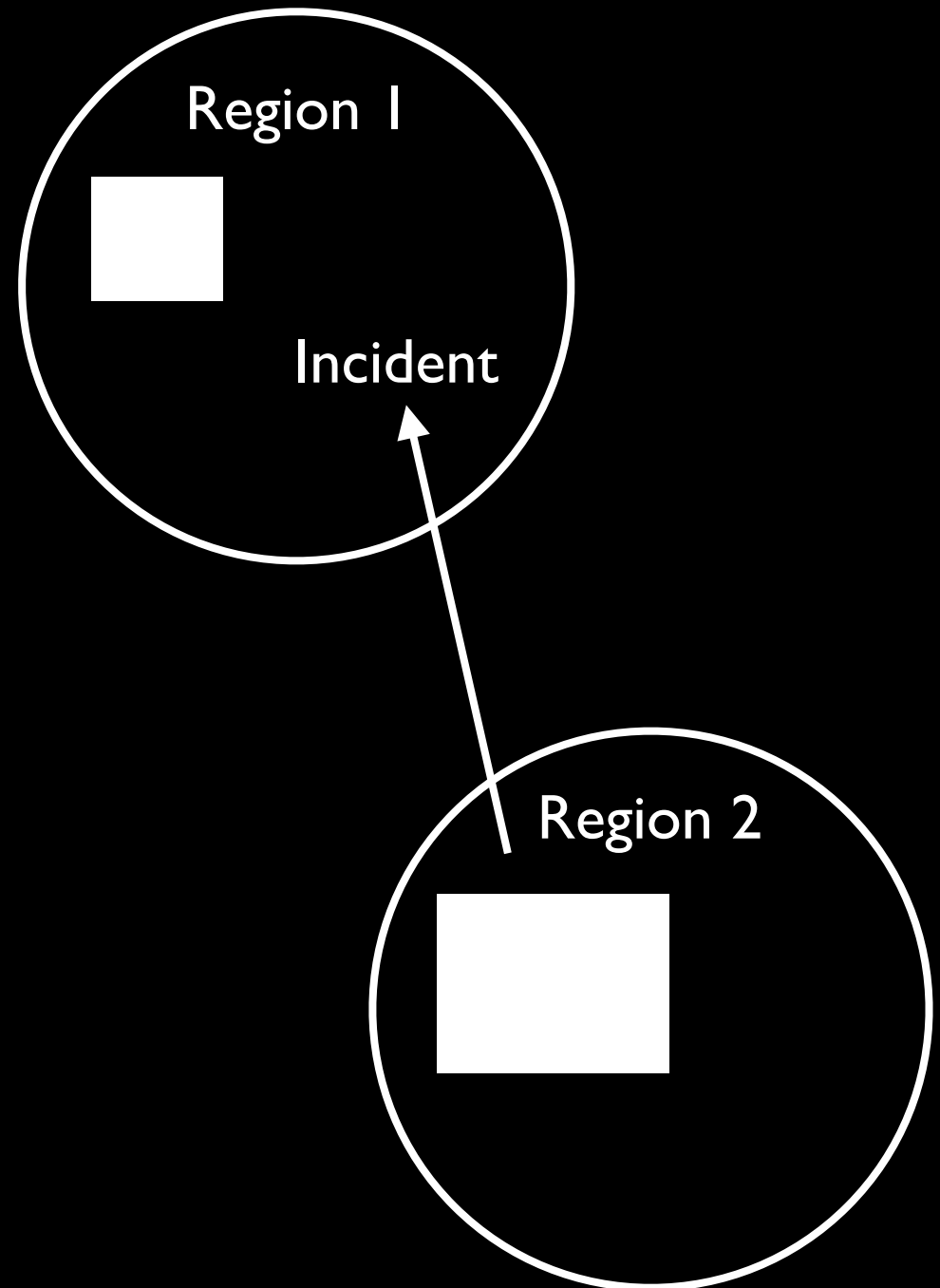- Imagine two regions, where Region 2 has a slightly larger station

Region 1

Region 2

Responding or Attending?

- Imagine two regions, where Region 2 has a slightly larger station

- There is then an incident in Region 1

Region 1

Incident

Region 2

Responding or Attending?

- Imagine two regions, where Region 2 has a slightly larger station

- There is then an incident in Region 1

- The station in Region 1 is too busy to respond, so the station in Region 2 attends
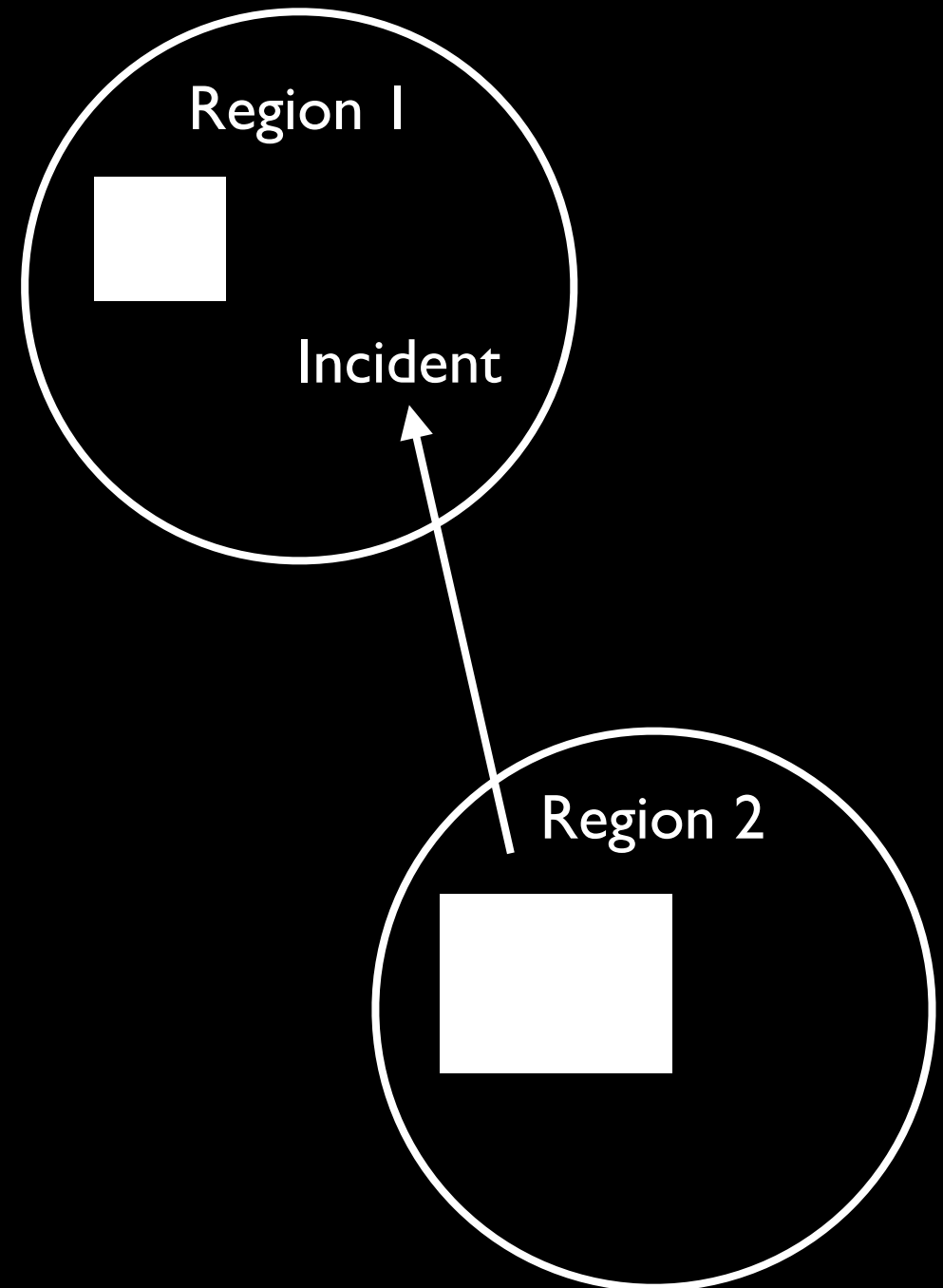
Region 1

Incident

Region 2

Responding or Attending?

- Imagine two regions, where Region 2 has a slightly larger station

- There is then an incident in Region 1

- The station in Region 1 is too busy to respond, so the station in Region 2 attends

- Who needs more staff?

Responding or Attending?

- The data will show most of the work being done by Region 2

- However, giving more resources to Region 2 creates a feedback loop

- If we give the resources to Region 1, they're able to attend their own incidents

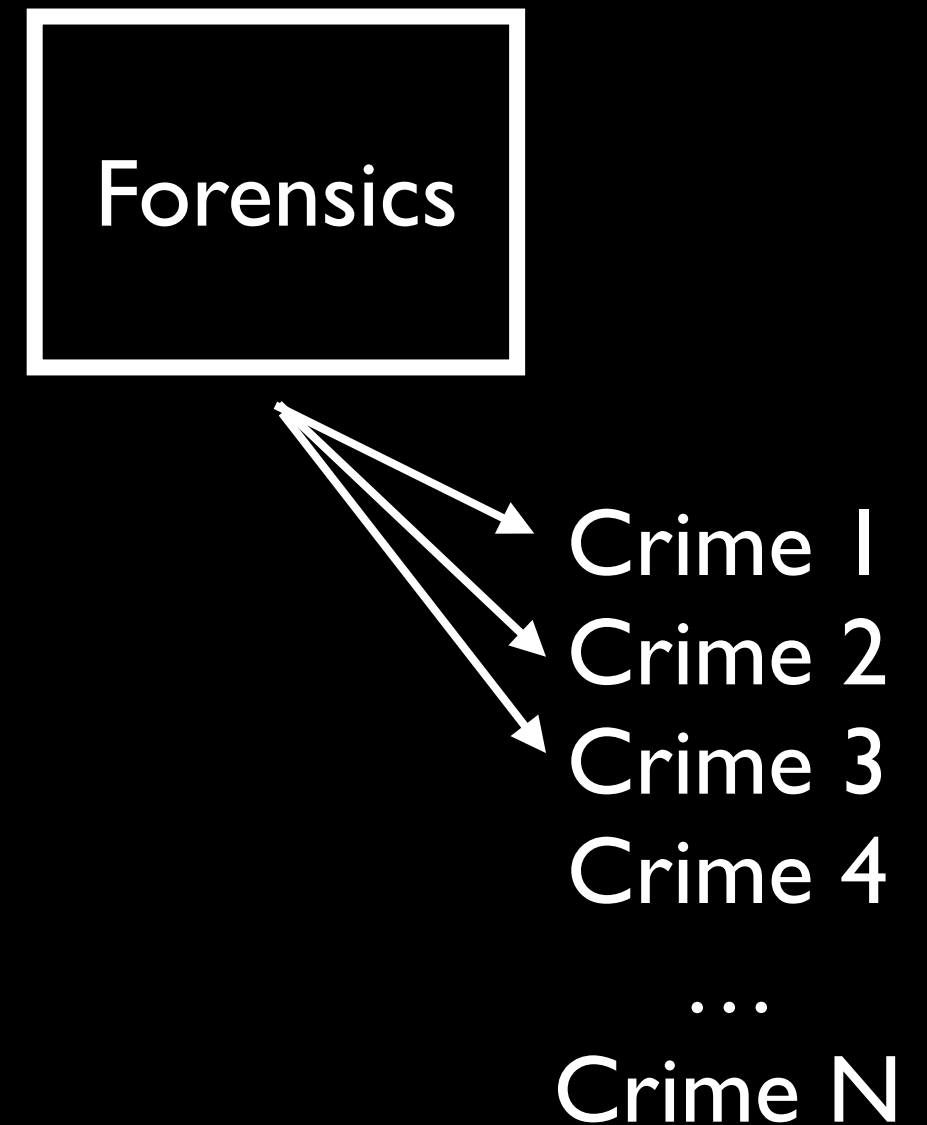- Understanding feedback loops is a key aspect of systems modelling
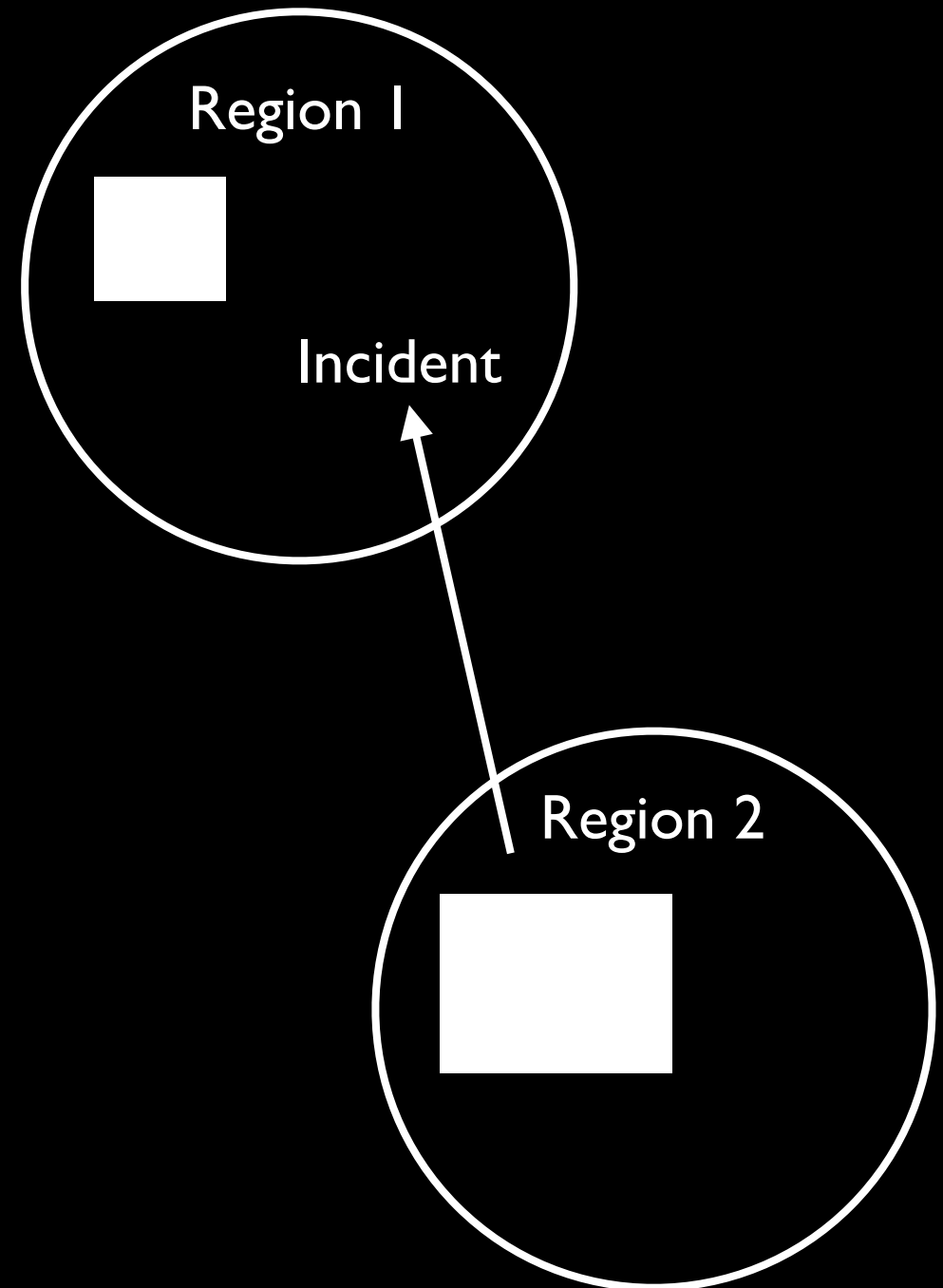
Region 1

Incident

Region 2

Picking the right driver

- When a crime occurs, the forensics unit attends and collects evidence

```
+------------------+
|                  |
|   Forensics      |
|                  |
+------------------+
         \
          \
           v
           Crime 1
```
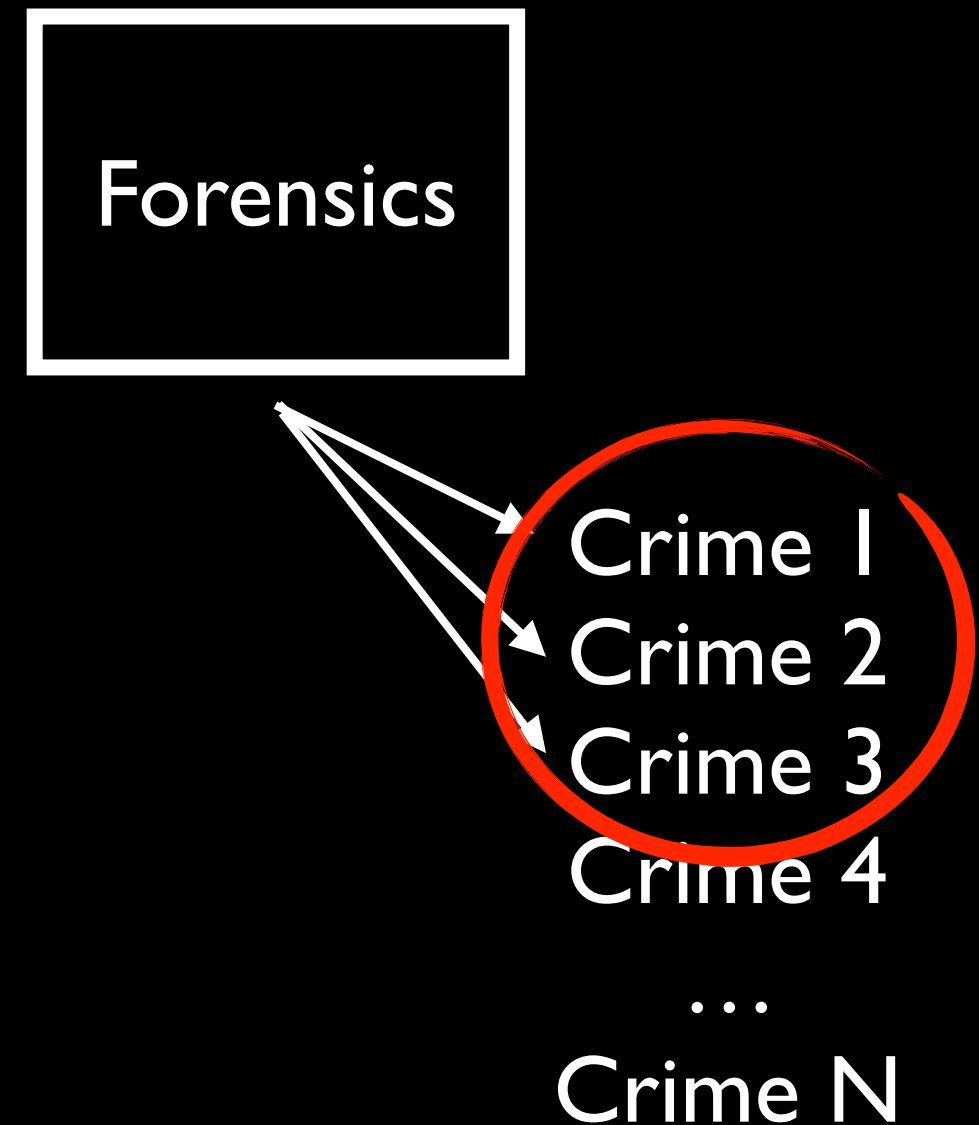
Picking the right driver

- When a crime occurs, the forensics unit attends and collects evidence
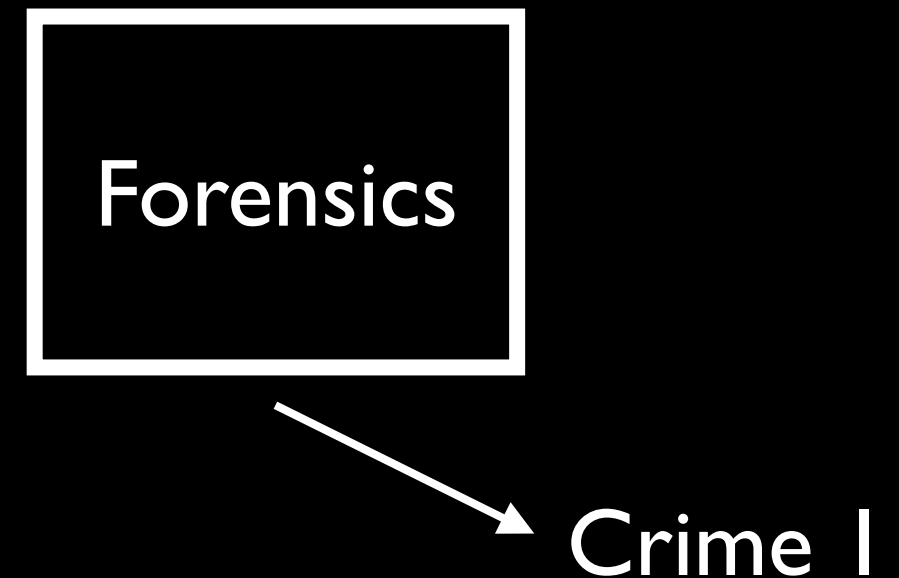
- However, there is prioritisation based on the available resources

Forensics

Crime 1
Crime 2
Crime 3
Crime 4
…
Crime N

Picking the right driver

- When a crime occurs, the forensics unit attends and collects evidence

- However, there is prioritisation based on the available resources

- The data say how many crime scenes were attended

- If we make demand proportional to attendance, groups with more ability to attend get more resources.

- This is a positive feedback loop

Forensics

Crime 1
Crime 2
Crime 3
Crime 4
…
Crime N

Picking the right driver

- Instead, we cross-reference other data sources to get the number of crimes that forensics could have attended if they had enough resources

- This means that forensics units will get resources if they don't have enough staff to respond to demand

- Identifying the underlying cause of feedback loops often requires looking at the bigger picture

Forensics

Crime 1
Crime 2
Crime 3
Crime 4
…
Crime N
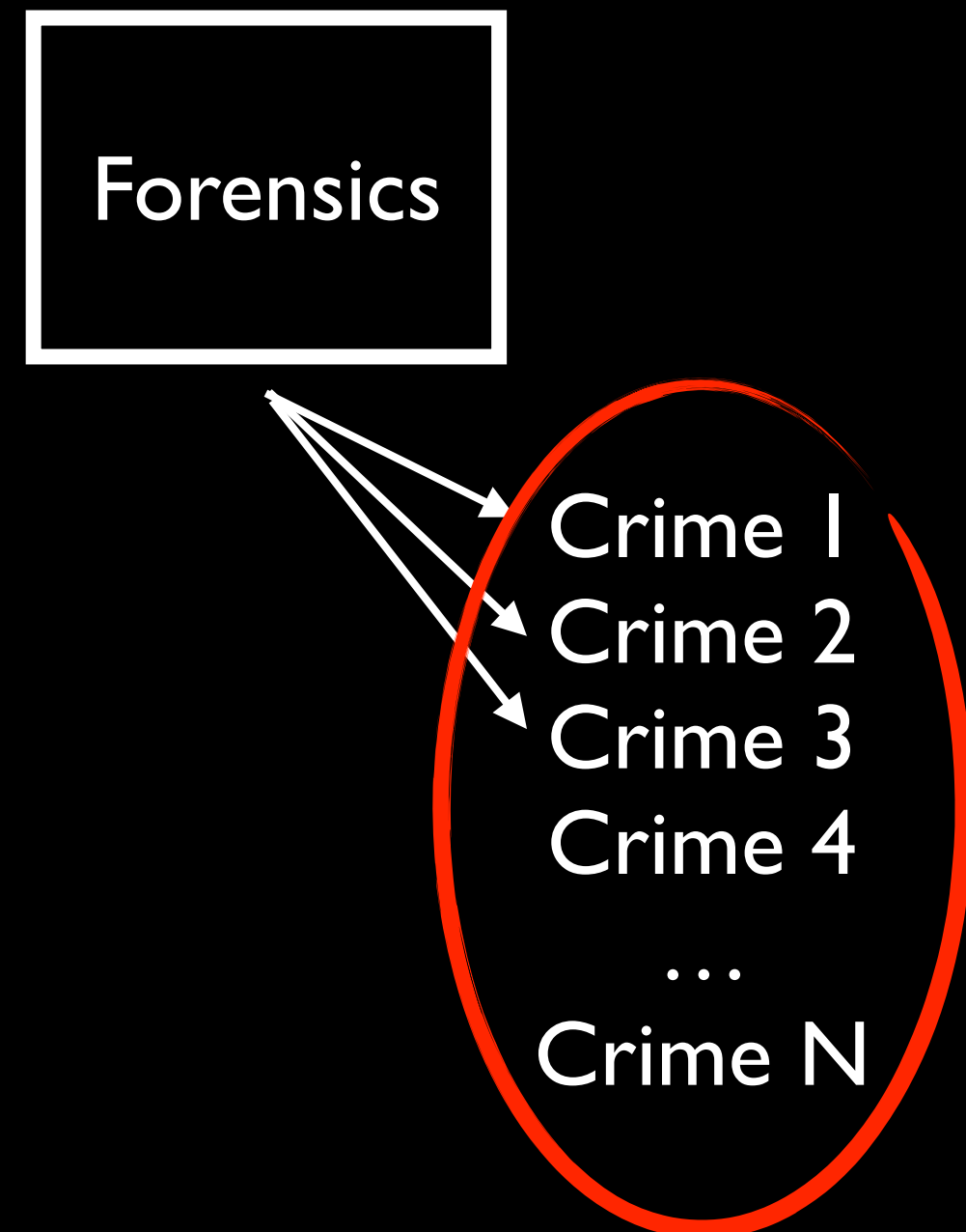
What about product delivery?

Victoria Police need clear model
outputs to inform their decisions

How do we use R to communicate these?

Automated report

- Victoria Police desired a word document with tables, plots and explanations

- We perform similar analyses for them year-to-year, so auto-generating such a report is extremely useful

- I built a Word template, then `knitr` converts `rmarkdown` to docx

Automated report

Style markdown headings →
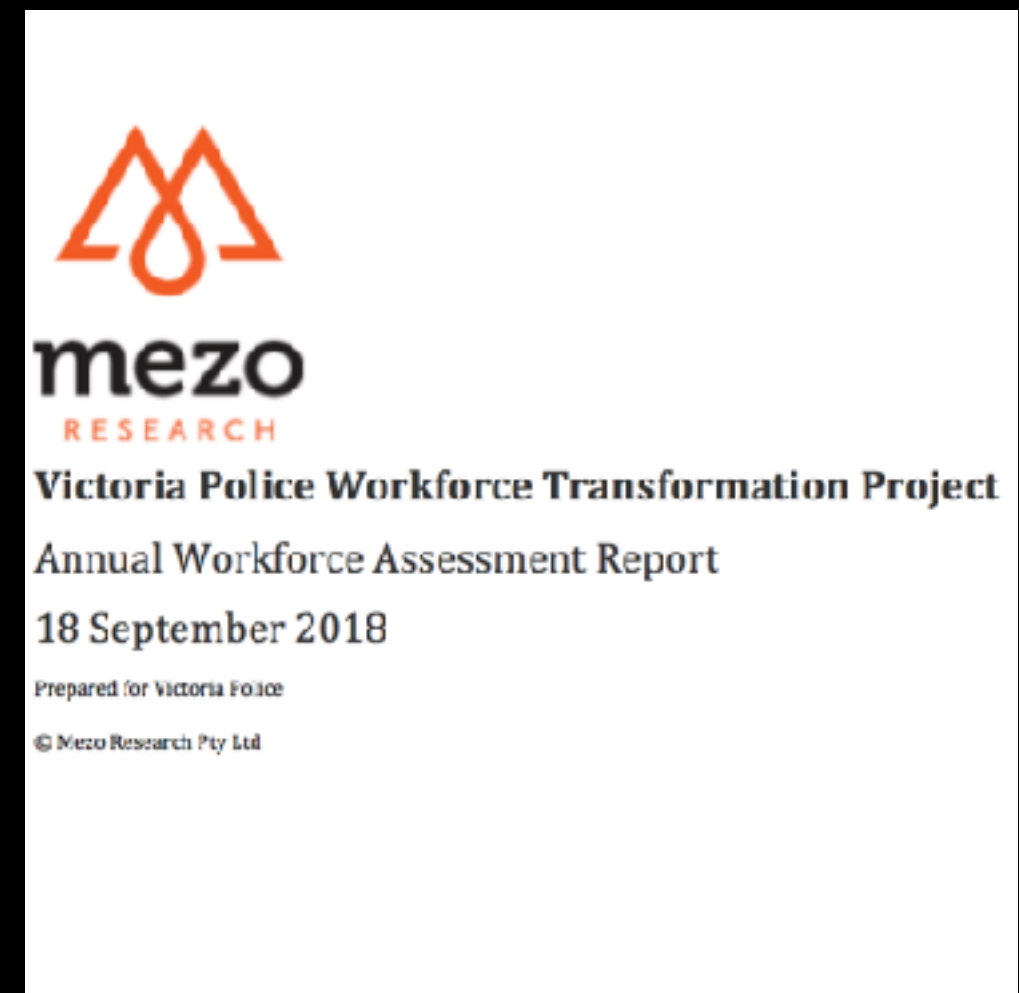
Map markdown commands to page gap and page breaks →

Auto-populate date →

Format TOC →

Automated report

Control application

- The Staff Allocation Model (SAM) is controlled by a series of switches

- E.g. whether to attribute demand to the responding or attending station

- I built a Shiny app that allows Victoria Police to change the switches and run the model

- See the R-Ladies git page for a tutorial!

Ongoing work

- Modelling is an ongoing task!

- Every year we collect more data from Victoria Police, and the model grows in complexity

- We're also constantly improving our product delivery to increase usability for non-technical users

Data → Algorithms → Decisions → Data
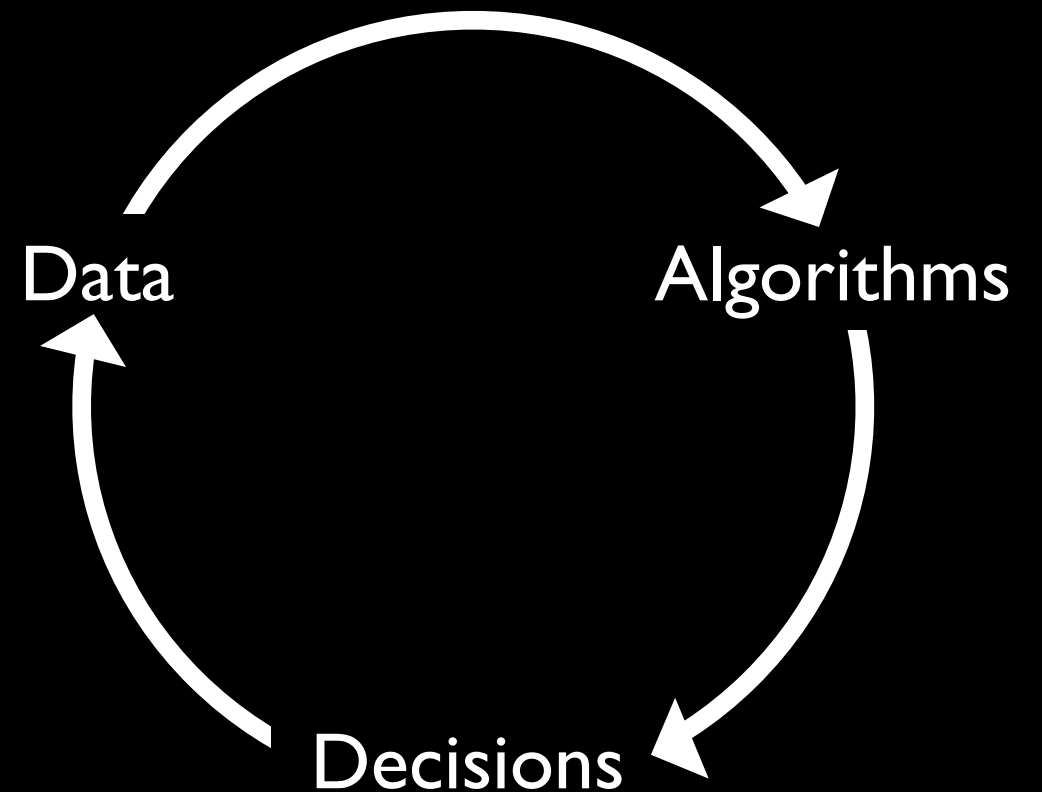
Summing up

- R is great for complex systems modelling

- It's easy to go from data to algorithms to decisions within one environment

- R packages play nicely together — simple packages can be combined to create an amazing product

- Victoria Police use our system regularly to inform their decision making around recruitment and allocation of staff