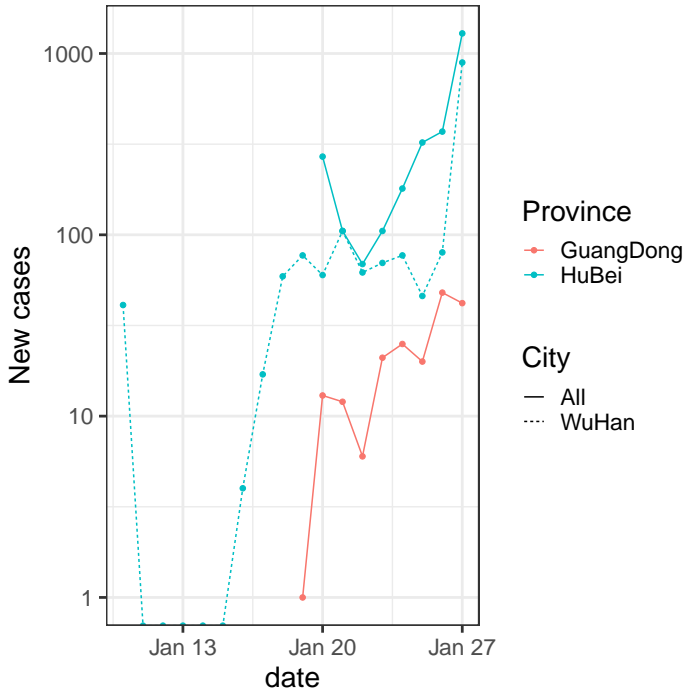
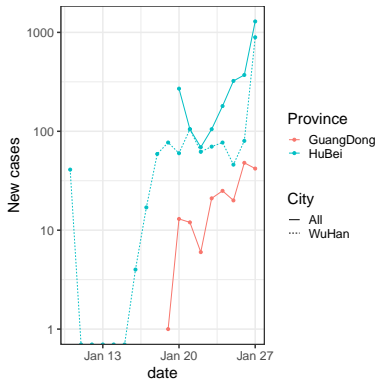
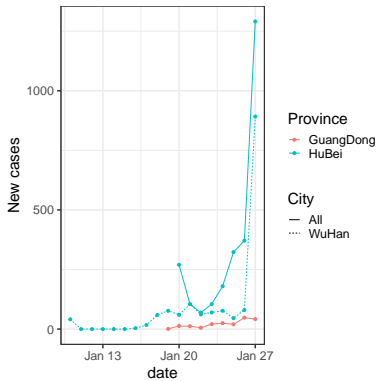


# UNIT X Novel coronavirus







# Scales

- ▶ Which scale should we look at?

# Scales

- ▶ Which scale should we look at?



# Scales

- ▶ Which scale should we look at?
  - ▶ \* Both, but the log scale is more relevant

# Scales

- ▶ Which scale should we look at?
  - ▶ \* Both, but the log scale is more relevant
    - ▶ \*



# Scales

- ▶ Which scale should we look at?
  - ▶ \* Both, but the log scale is more relevant
    - ▶ \* Focus on what individual cases are doing

# Scales

- ▶ Which scale should we look at?
  - ▶ \* Both, but the log scale is more relevant
    - ▶ \* Focus on what individual cases are doing
  - ▶ \*

# Scales

- ▶ Which scale should we look at?
  - ▶ \* Both, but the log scale is more relevant
    - ▶ \* Focus on what individual cases are doing
  - ▶ \* A slowdown on the log scale would be progress

# Scales

- ▶ Which scale should we look at?
  - ▶ \* Both, but the log scale is more relevant
    - ▶ \* Focus on what individual cases are doing
  - ▶ \* A slowdown on the log scale would be progress

# Population biology

- ▶ What quantities do we want to look at?

# Population biology

- ▶ What quantities do we want to look at?



# Population biology

- ▶ What quantities do we want to look at?
  - ▶ \* Speed of exponential growth  $r$

# Population biology

- ▶ What quantities do we want to look at?
  - ▶ \* Speed of exponential growth  $r$
  - ▶ \*



# Population biology

- ▶ What quantities do we want to look at?
  - ▶ \* Speed of exponential growth  $r$
  - ▶ \* Finite rate of increase  $\lambda$

# Population biology

- ▶ What quantities do we want to look at?
  - ▶ \* Speed of exponential growth  $r$
  - ▶ \* Finite rate of increase  $\lambda$
  - ▶ \*

# Population biology

- ▶ What quantities do we want to look at?
  - ▶ \* Speed of exponential growth  $r$
  - ▶ \* Finite rate of increase  $\lambda$
  - ▶ \* Lifetime reproduction

# Population biology

- ▶ What quantities do we want to look at?
  - ▶ \* Speed of exponential growth  $r$
  - ▶ \* Finite rate of increase  $\lambda$
  - ▶ \* Lifetime reproduction

# Instantaneous rate of growth $r$

- ▶ What are the components?

# Instantaneous rate of growth $r$

- ▶ What are the components?

▶ \*

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate

# Instantaneous rate of growth $r$

- ▶ What are the components?

- ▶ \* Birth rate

- ▶ \*



# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \*

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \*

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!
    - ▶ \*



# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!
    - ▶ \* Rate of death, recovery, or effective quarantine

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!
    - ▶ \* Rate of death, recovery, or effective quarantine
- ▶ How do you think we estimate?

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!
    - ▶ \* Rate of death, recovery, or effective quarantine
- ▶ How do you think we estimate?
  - ▶ \*

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!
    - ▶ \* Rate of death, recovery, or effective quarantine
- ▶ How do you think we estimate?
  - ▶ \* People are estimating  $r$  right now from the population-level increase in disease

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!
    - ▶ \* Rate of death, recovery, or effective quarantine
- ▶ How do you think we estimate?
  - ▶ \* People are estimating  $r$  right now from the population-level increase in disease
    - ▶ \*

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!
    - ▶ \* Rate of death, recovery, or effective quarantine
- ▶ How do you think we estimate?
  - ▶ \* People are estimating  $r$  right now from the population-level increase in disease
    - ▶ \* Then using that to estimate  $b$

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!
    - ▶ \* Rate of death, recovery, or effective quarantine
- ▶ How do you think we estimate?
  - ▶ \* People are estimating  $r$  right now from the population-level increase in disease
    - ▶ \* Then using that to estimate  $b$
- ▶ \*

# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!
    - ▶ \* Rate of death, recovery, or effective quarantine
- ▶ How do you think we estimate?
  - ▶ \* People are estimating  $r$  right now from the population-level increase in disease
    - ▶ \* Then using that to estimate  $b$
  - ▶ \* Models go both directions!



# Instantaneous rate of growth $r$

- ▶ What are the components?
  - ▶ \* Birth rate
    - ▶ \* Instantaneous rate of a case producing new cases
    - ▶ \*  $[\text{case}/(\text{case} \cdot \text{time})]$
  - ▶ \* Death rate
    - ▶ \* Virus-centered!
    - ▶ \* Rate of death, recovery, or effective quarantine
- ▶ How do you think we estimate?
  - ▶ \* People are estimating  $r$  right now from the population-level increase in disease
    - ▶ \* Then using that to estimate  $b$
  - ▶ \* Models go both directions!

# Finite rate of growth $\lambda$

- Why do we want this?

# Finite rate of growth $\lambda$

► Why do we want this?

► \*

# Finite rate of growth $\lambda$

- ▶ Why do we want this?
  - ▶ \* to communicate with policy-makers or the public

# Finite rate of growth $\lambda$

- ▶ Why do we want this?
  - ▶ \* to communicate with policy-makers or the public
  - ▶ \*

# Finite rate of growth $\lambda$

- ▶ Why do we want this?
  - ▶ \* to communicate with policy-makers or the public
  - ▶ \* maybe to make concrete predictions, though we could use  $r$

# Finite rate of growth $\lambda$

- ▶ Why do we want this?
  - ▶ \* to communicate with policy-makers or the public
  - ▶ \* maybe to make concrete predictions, though we could use  $r$
- ▶ How do we calculate it?

# Finite rate of growth $\lambda$

- ▶ Why do we want this?
  - ▶ \* to communicate with policy-makers or the public
  - ▶ \* maybe to make concrete predictions, though we could use  $r$
- ▶ How do we calculate it?
  - ▶ \*



# Finite rate of growth $\lambda$

- ▶ Why do we want this?
  - ▶ \* to communicate with policy-makers or the public
  - ▶ \* maybe to make concrete predictions, though we could use  $r$
- ▶ How do we calculate it?
  - ▶ \* Pick a time step (week? year?)

# Finite rate of growth $\lambda$

- ▶ Why do we want this?
  - ▶ \* to communicate with policy-makers or the public
  - ▶ \* maybe to make concrete predictions, though we could use  $r$
- ▶ How do we calculate it?
  - ▶ \* Pick a time step (week? year?)
  - ▶ \*

# Finite rate of growth $\lambda$

- ▶ Why do we want this?
  - ▶ \* to communicate with policy-makers or the public
  - ▶ \* maybe to make concrete predictions, though we could use  $r$
- ▶ How do we calculate it?
  - ▶ \* Pick a time step (week? year?)
  - ▶ \* Use a formula  $\lambda = \exp(r\Delta t)$

# Finite rate of growth $\lambda$

- ▶ Why do we want this?
  - ▶ \* to communicate with policy-makers or the public
  - ▶ \* maybe to make concrete predictions, though we could use  $r$
- ▶ How do we calculate it?
  - ▶ \* Pick a time step (week? year?)
  - ▶ \* Use a formula  $\lambda = \exp(r\Delta t)$

# Example

►  $r \approx 0.14/\text{day}$

# Example

▶  $r \approx 0.14/\text{day}$

▶ What is  $\lambda$ ?

# Example

- ▶  $r \approx 0.14/\text{day}$
- ▶ What is  $\lambda$ ?
  - ▶ At a time scale of a day?

# Example

- ▶  $r \approx 0.14/\text{day}$
- ▶ What is  $\lambda$ ?
  - ▶ At a time scale of a day?
  - ▶ At a time scale of a week?



# Example

- ▶  $r \approx 0.14/\text{day}$
- ▶ What is  $\lambda$ ?
  - ▶ At a time scale of a day?
  - ▶ At a time scale of a week?

# Reproductive number $\mathcal{R}$

- ▶ What is it?

# Reproductive number $\mathcal{R}$

► What is it?

► \*

# Reproductive number $\mathcal{R}$

- ▶ What is it?
  - ▶ \* Expected number of new cases per case over the lifetime of a case

# Reproductive number $\mathcal{R}$

- ▶ What is it?
  - ▶ \* Expected number of new cases per case over the lifetime of a case
- ▶ Why do we want this?

# Reproductive number $\mathcal{R}$

- ▶ What is it?
  - ▶ \* Expected number of new cases per case over the lifetime of a case
- ▶ Why do we want this?
  - ▶ \*

# Reproductive number $\mathcal{R}$

- ▶ What is it?
  - ▶ \* Expected number of new cases per case over the lifetime of a case
- ▶ Why do we want this?
  - ▶ \* An important measure of how hard the epidemic will be to stop

# Reproductive number $\mathcal{R}$

- ▶ What is it?
  - ▶ \* Expected number of new cases per case over the lifetime of a case
- ▶ Why do we want this?
  - ▶ \* An important measure of how hard the epidemic will be to stop
- ▶ How do we calculate it?



# Reproductive number $\mathcal{R}$

- ▶ What is it?
  - ▶ \* Expected number of new cases per case over the lifetime of a case
- ▶ Why do we want this?
  - ▶ \* An important measure of how hard the epidemic will be to stop
- ▶ How do we calculate it?
  - ▶ \*

# Reproductive number $\mathcal{R}$

- ▶ What is it?
  - ▶ \* Expected number of new cases per case over the lifetime of a case
- ▶ Why do we want this?
  - ▶ \* An important measure of how hard the epidemic will be to stop
- ▶ How do we calculate it?
  - ▶ \*  $\mathcal{R} = b/d$ ; if we can estimate those

# Reproductive number $\mathcal{R}$

- ▶ What is it?
  - ▶ \* Expected number of new cases per case over the lifetime of a case
- ▶ Why do we want this?
  - ▶ \* An important measure of how hard the epidemic will be to stop
- ▶ How do we calculate it?
  - ▶ \*  $\mathcal{R} = b/d$ ; if we can estimate those

# Example

►  $r \approx 0.14/\text{day}$

# Example

- ▶  $r \approx 0.14/\text{day}$
- ▶ What is our estimate of  $\mathcal{R}$ ?

# Example

- ▶  $r \approx 0.14/\text{day}$
- ▶ What is our estimate of  $\mathcal{R}$ ?
  - ▶ When average length of infection  $L = 5$  day?

# Example

- ▶  $r \approx 0.14/\text{day}$
- ▶ What is our estimate of  $\mathcal{R}$ ?
  - ▶ When average length of infection  $L = 5$  day?
  - ▶ When average length of infection  $L = 10$  day?

# Example

- ▶  $r \approx 0.14/\text{day}$
- ▶ What is our estimate of  $\mathcal{R}$ ?
  - ▶ When average length of infection  $L = 5$  day?
  - ▶ When average length of infection  $L = 10$  day?



# Case fatality proportion

- ▶ If the disease spreads around the world, most of us will get it.

# Case fatality proportion

- ▶ If the disease spreads around the world, most of us will get it.
- ▶ How many will die?

# Case fatality proportion

- ▶ If the disease spreads around the world, most of us will get it.
- ▶ How many will die?
  - ▶ This is a units question!

# Case fatality proportion

- ▶ If the disease spreads around the world, most of us will get it.
- ▶ How many will die?
  - ▶ This is a units question!
- ▶ What proportion of people with the disease are dying?

# Case fatality proportion

- ▶ If the disease spreads around the world, most of us will get it.
- ▶ How many will die?
  - ▶ This is a units question!
- ▶ What proportion of people with the disease are dying?
  - ▶ People are often not careful enough with the denominator of this proportion

# Case fatality proportion

- ▶ If the disease spreads around the world, most of us will get it.
- ▶ How many will die?
  - ▶ This is a units question!
- ▶ What proportion of people with the disease are dying?
  - ▶ People are often not careful enough with the denominator of this proportion
  - ▶ People with (detected) severe disease; people with (detected) recognizable disease; people who develop antibodies

# Case fatality proportion

- ▶ If the disease spreads around the world, most of us will get it.
- ▶ How many will die?
  - ▶ This is a units question!
- ▶ What proportion of people with the disease are dying?
  - ▶ People are often not careful enough with the denominator of this proportion
  - ▶ People with (detected) severe disease; people with (detected) recognizable disease; people who develop antibodies

# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?



# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?



# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour

# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour
  - ▶ \*

# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour
  - ▶ \* People die or become immune

# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour
  - ▶ \* People die or become immune
  - ▶ \*

# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour
  - ▶ \* People die or become immune
  - ▶ \* Vaccination or treatment

# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour
  - ▶ \* People die or become immune
  - ▶ \* Vaccination or treatment
- ▶ Are there any reasons it might go *up*?

# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour
  - ▶ \* People die or become immune
  - ▶ \* Vaccination or treatment
- ▶ Are there any reasons it might go *up*?
  - ▶ \*



# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour
  - ▶ \* People die or become immune
  - ▶ \* Vaccination or treatment
- ▶ Are there any reasons it might go *up*?
  - ▶ \* Evolution

# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour
  - ▶ \* People die or become immune
  - ▶ \* Vaccination or treatment
- ▶ Are there any reasons it might go *up*?
  - ▶ \* Evolution
  - ▶ \*

# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour
  - ▶ \* People die or become immune
  - ▶ \* Vaccination or treatment
- ▶ Are there any reasons it might go *up*?
  - ▶ \* Evolution
  - ▶ \* *One way* evolution sometimes increases  $\mathcal{R}$  is by decreasing the fatality proportion

# Population regulation

- ▶ What are some reasons the virus's reproductive number may go down as it spreads?
  - ▶ \* People react by changing behaviour
  - ▶ \* People die or become immune
  - ▶ \* Vaccination or treatment
- ▶ Are there any reasons it might go *up*?
  - ▶ \* Evolution
  - ▶ \* *One way* evolution sometimes increases  $\mathcal{R}$  is by decreasing the fatality proportion

## Other key questions

- ▶ How is the disease transmitted?

## Other key questions

- ▶ How is the disease transmitted?
- ▶ Can it be transmitted before symptoms start?

## Other key questions

- ▶ How is the disease transmitted?
- ▶ Can it be transmitted before symptoms start?