# Efficient contact tracing

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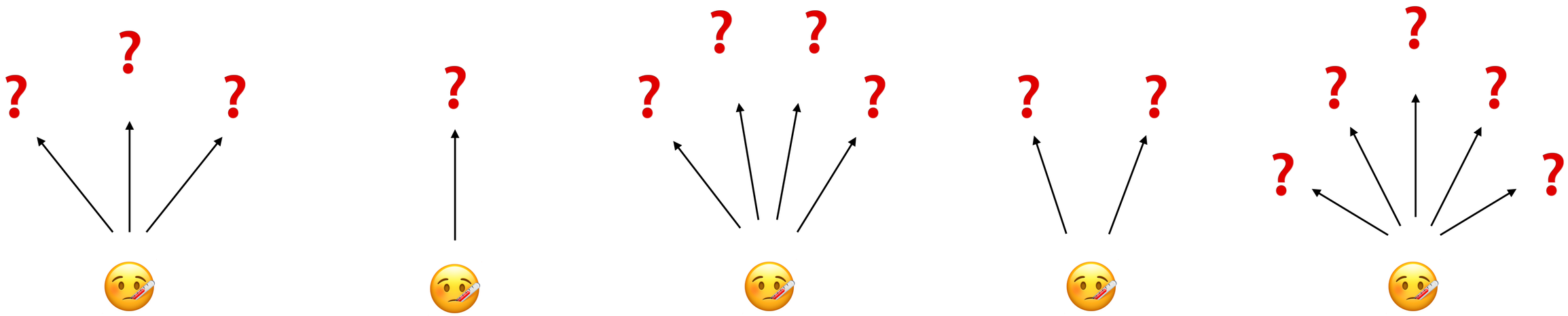
# Contact tracing

We have a list of people infected with a disease.
They may have passed on this infection to others.



# Contact tracing

Goal: maximize number of infected people we identify.
Limited number of tests.

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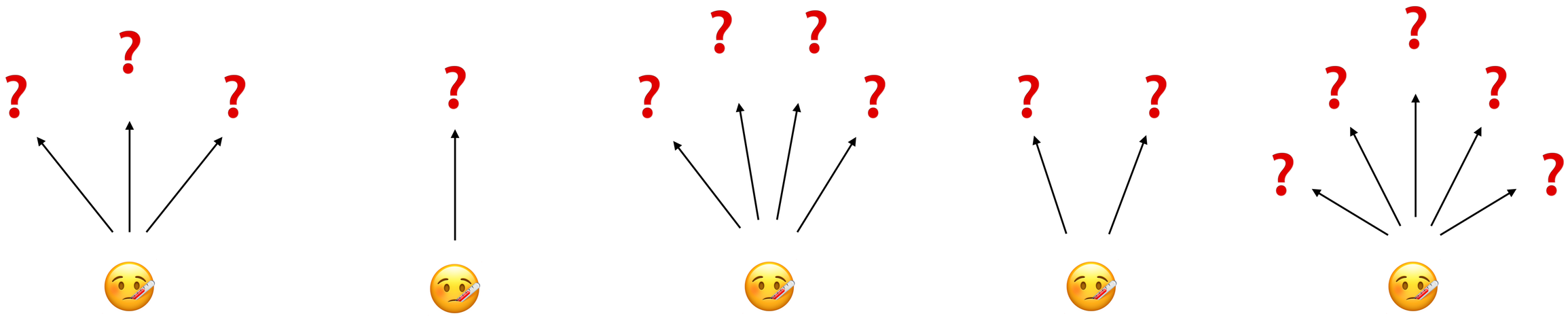

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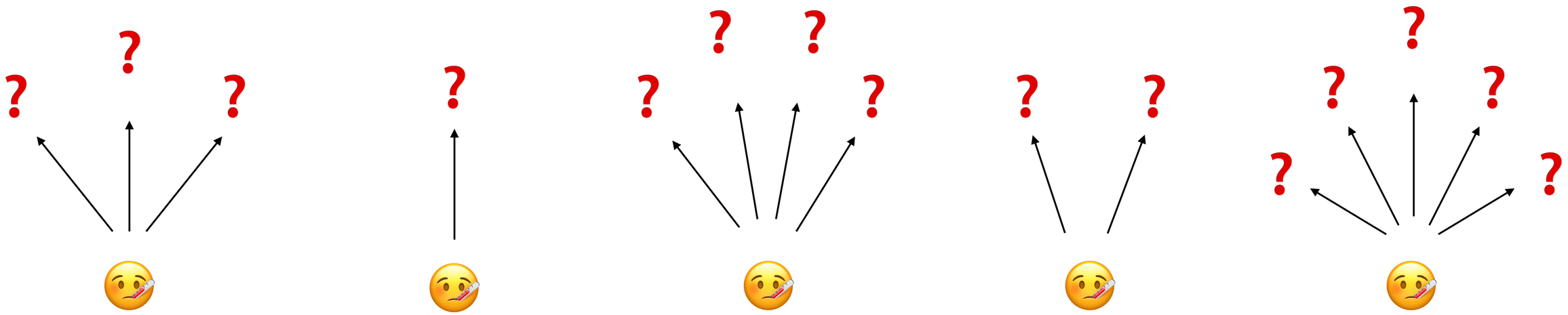
Goal: maximize number of infected people we identify.
There is heterogeneity in infectiousness.

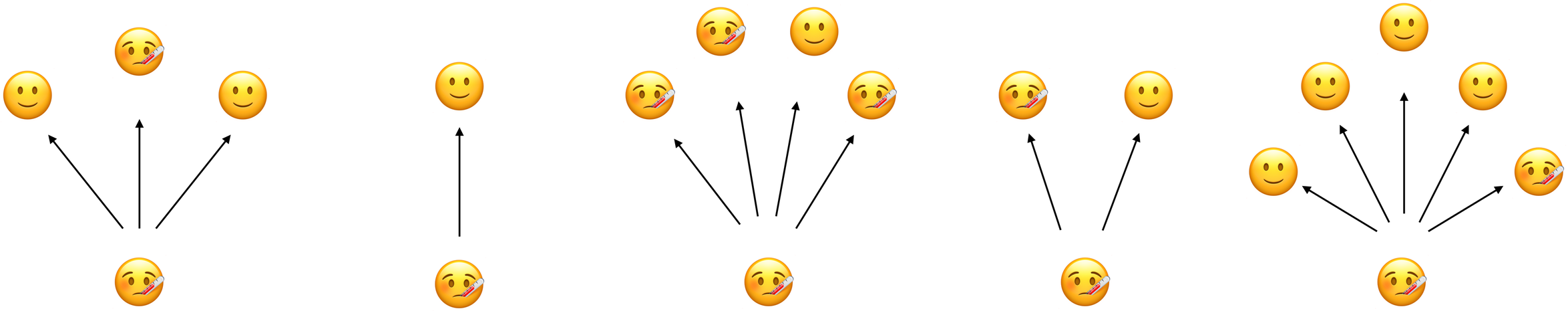


# Contact tracing

Goal: maximize number of infected people we identify.

There is heterogeneity in infectiousness.

Each person infects their contacts at a different rate.



$p = \frac{1}{3}$ $\quad$ $p = 0$ $\quad$ $p = \frac{3}{4}$ $\quad$ $p = \frac{1}{2}$ $\quad$ $p = \frac{1}{5}$

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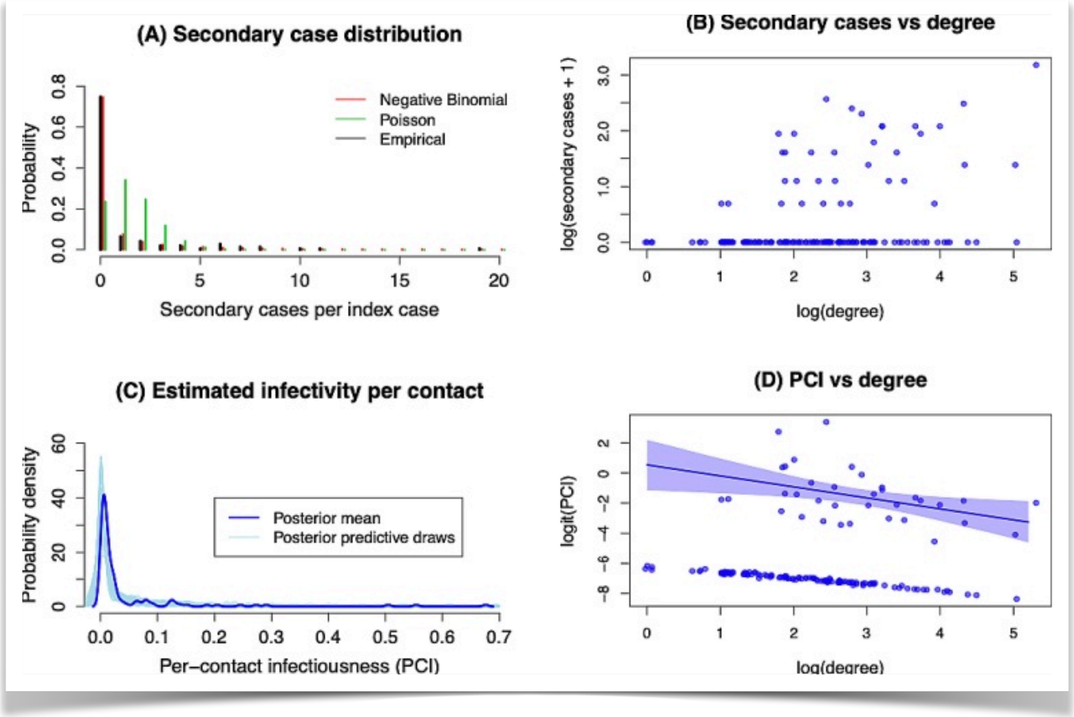


Arinaminpathy, Nimalan, et al. "Quantifying heterogeneity in SARS-CoV-2 transmission during the lockdown in India." Epidemics (2021)

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Can we extract information from this uncertainty to devise better strategies?

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Prior to March 2020, we were commonly exposed to
infections that spread slowly
infections that are contained within a region

# Outline

1. The problem
2. Mortal multi-armed bandit
3. Data and results

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1. There is heterogeneity in infectiousness

This is called the multi-armed bandit problem.

We play a slot machine by pulling arms.
Each arm gives a random reward.
Our goal is to maximize this reward.

# The problem

Goal: maximize number of infected people we identify.

1. There is heterogeneity in infectiousness.
2. There is heterogeneity in number of contacts.
   Each person comes into contact with a different number of people.

# The problem

Goal: maximize number of infected people we identify.

1. There is heterogeneity in infectiousness.
2. There is heterogeneity in number of contacts.
3. Set of people whose contacts we want to test changes.
   We add new people to trace when we find a new infection.
   We remove people when we finish testing all of their contacts.

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This is called the mortal multi-armed bandit problem.

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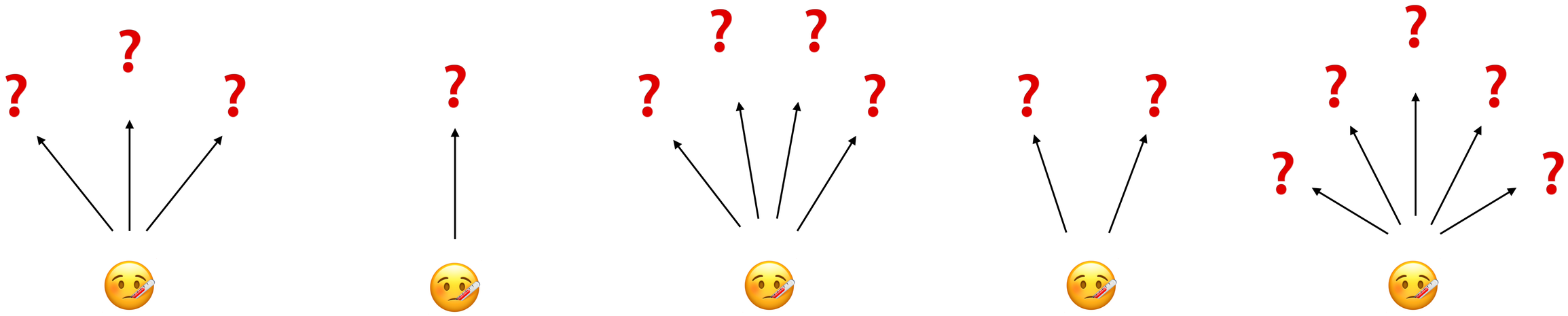
# Mortal multi-armed bandit



# Mortal multi-armed bandit

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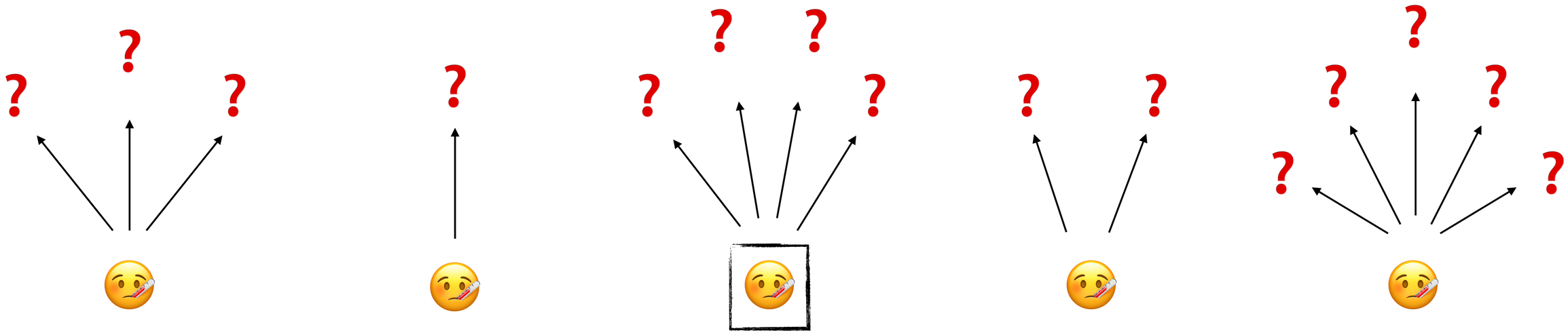

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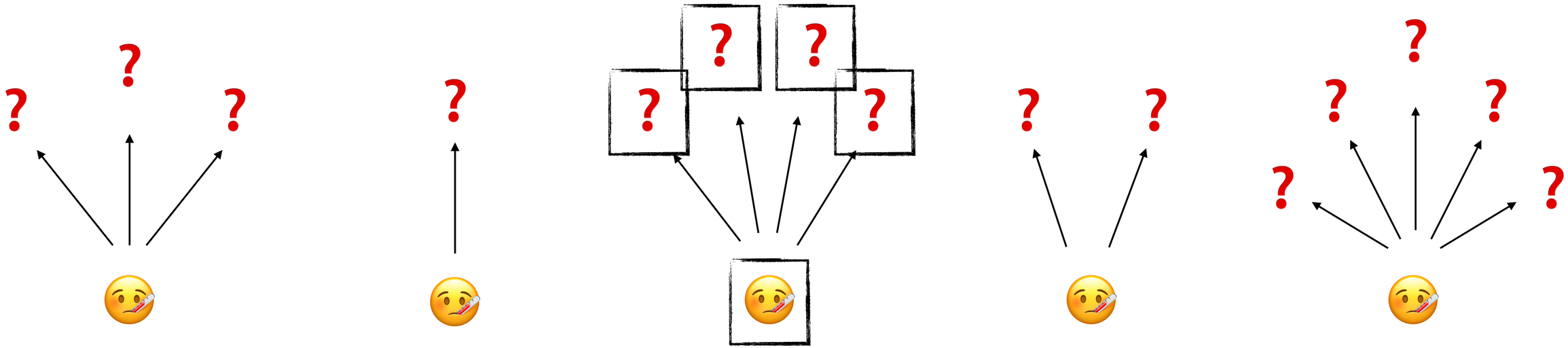

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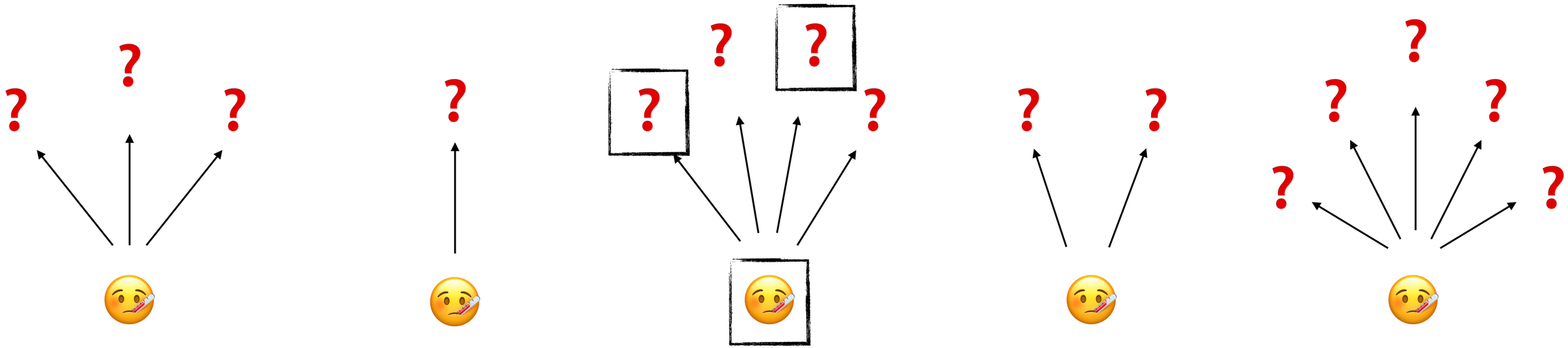

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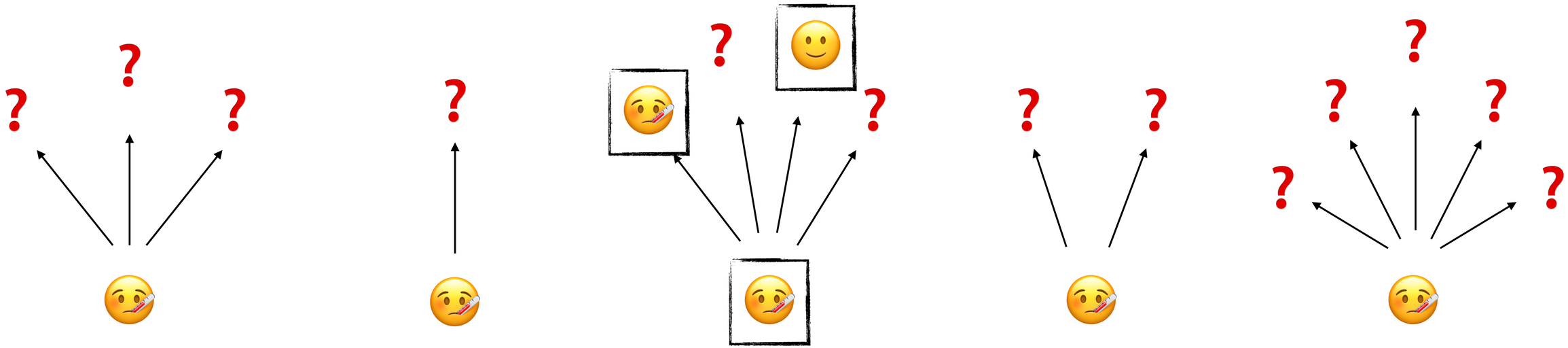

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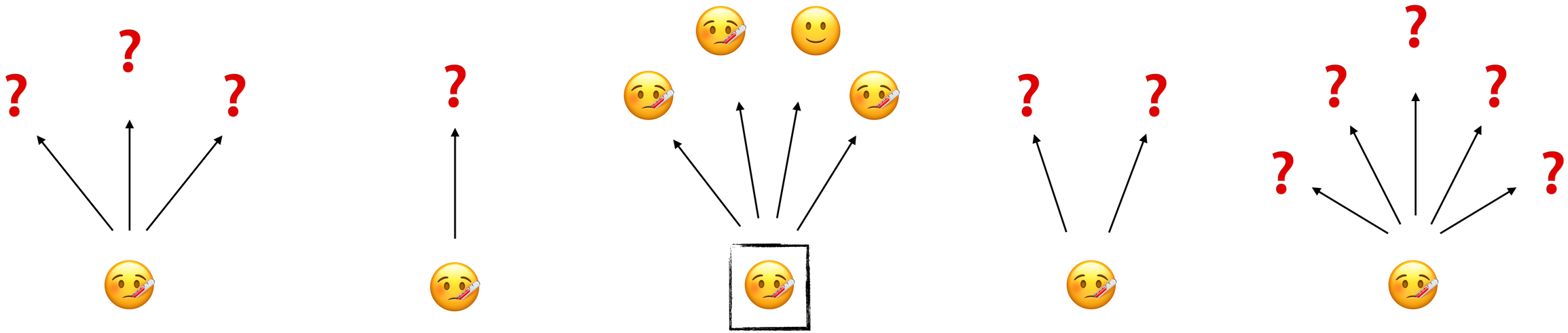

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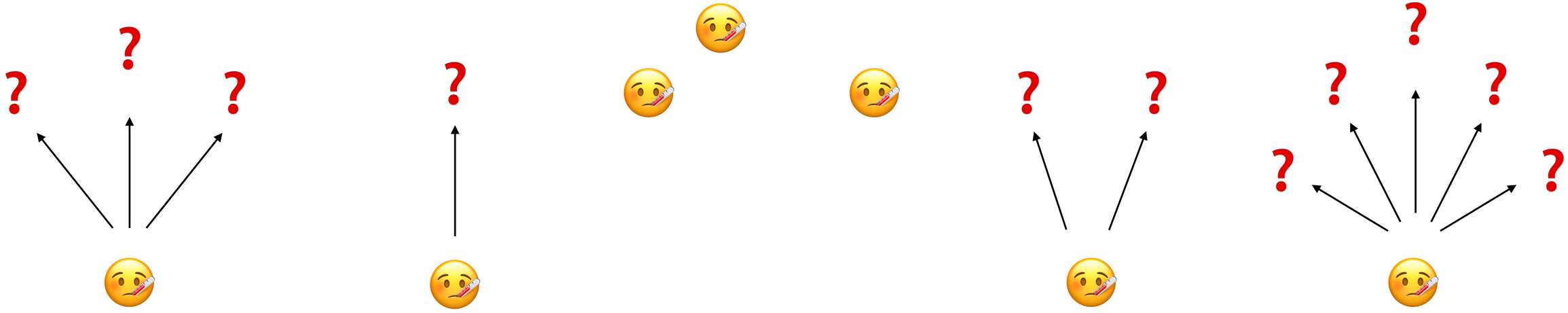

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Chakrabarti, Deepayan, et al. "Mortal multi-armed bandits." Advances in neural information processing systems 21 (2008)

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If infectivity is larger than $k/n$, we test all contacts.

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Else, we move on to a different person.

We believe this person is not highly infectious. So it is not worth using more tests.

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3. Data and results

# Data and results

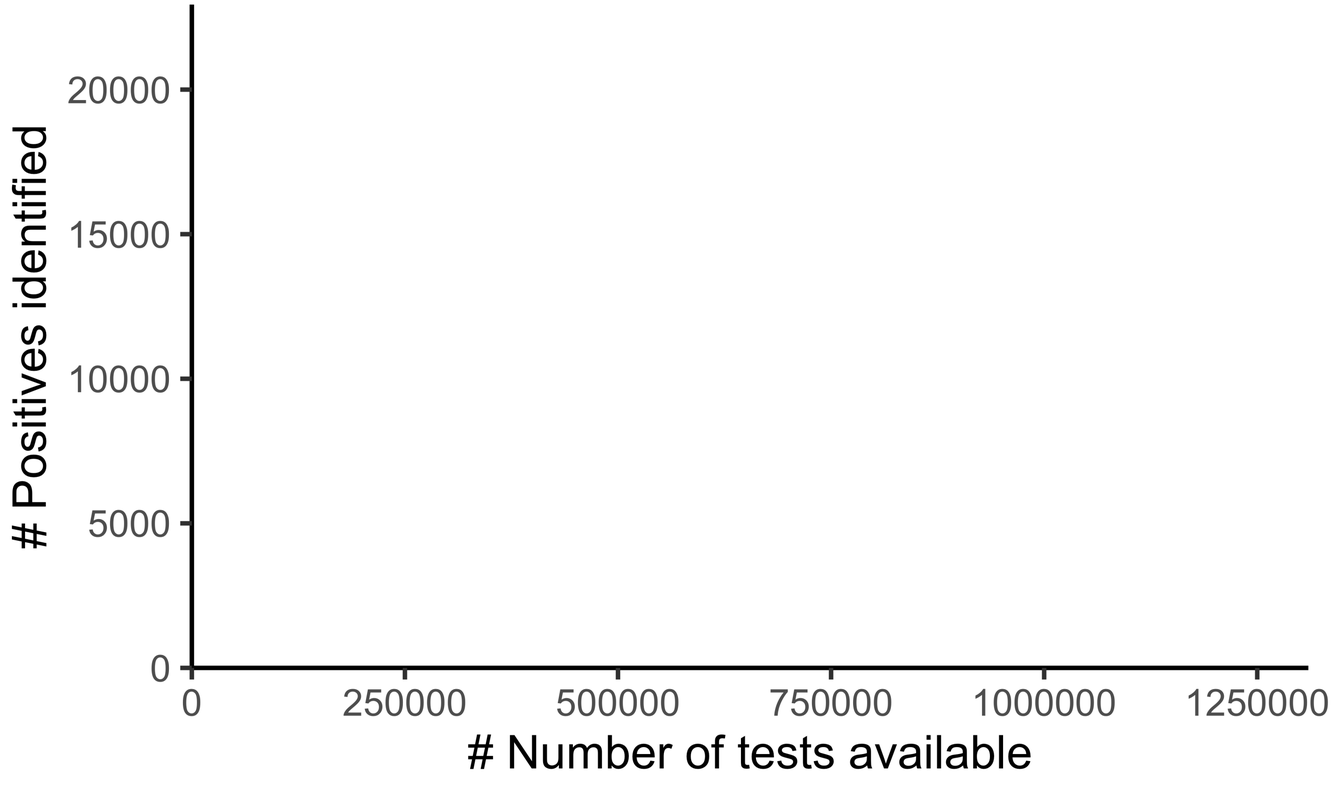
Pakistan

~165,000 people traced
~1.9 million people tested
~30,000 people infected [~0.5 million were awaiting testing and results at time of collection]

India [Punjab]

~600 people traced
~18,000 people tested
~1,600 people infected

# Data and results



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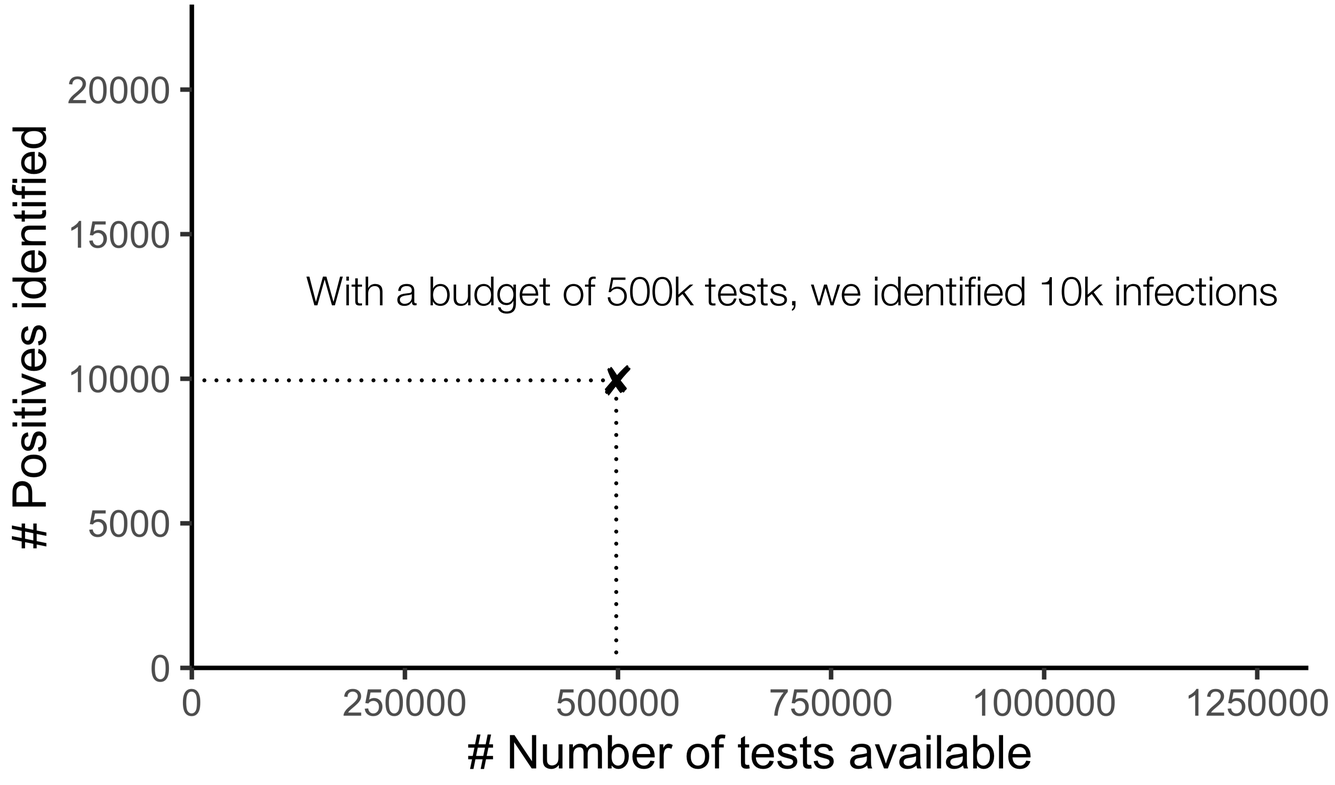
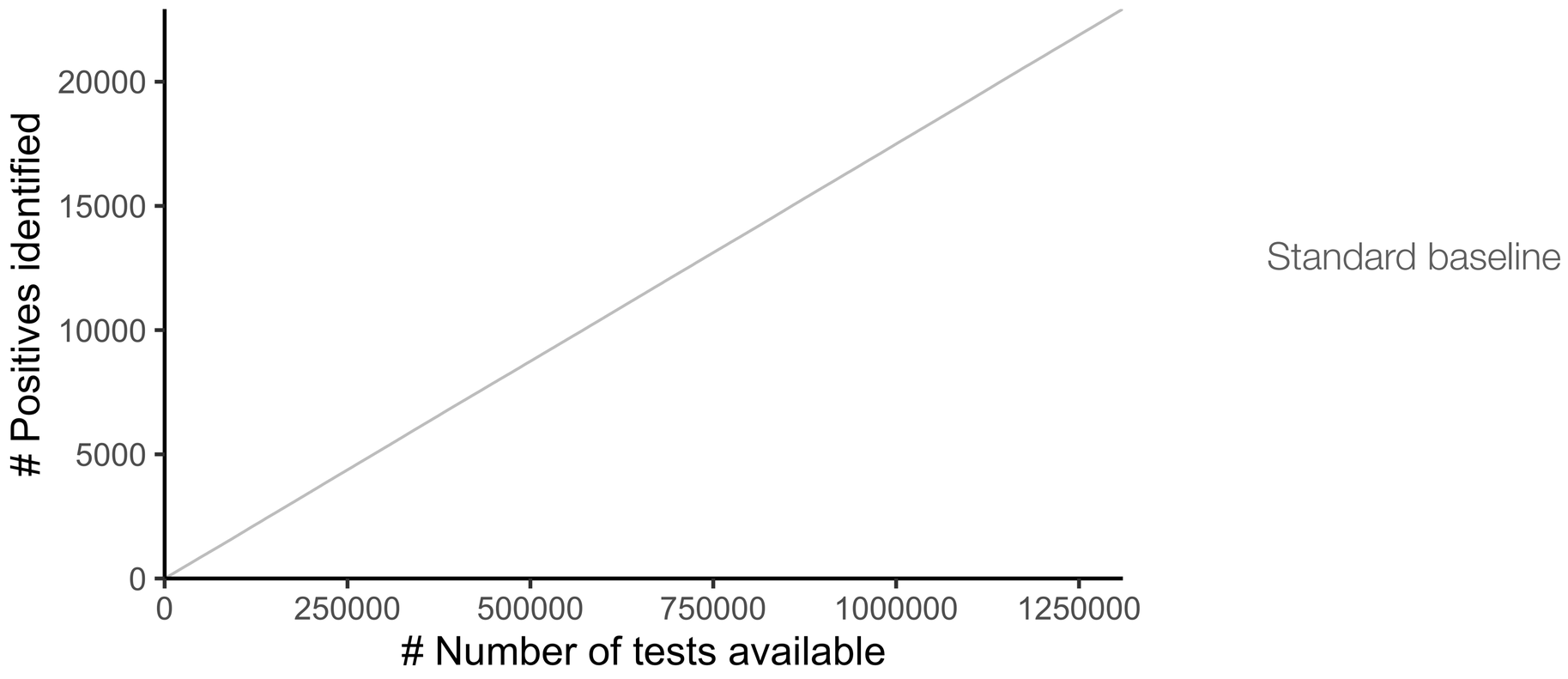
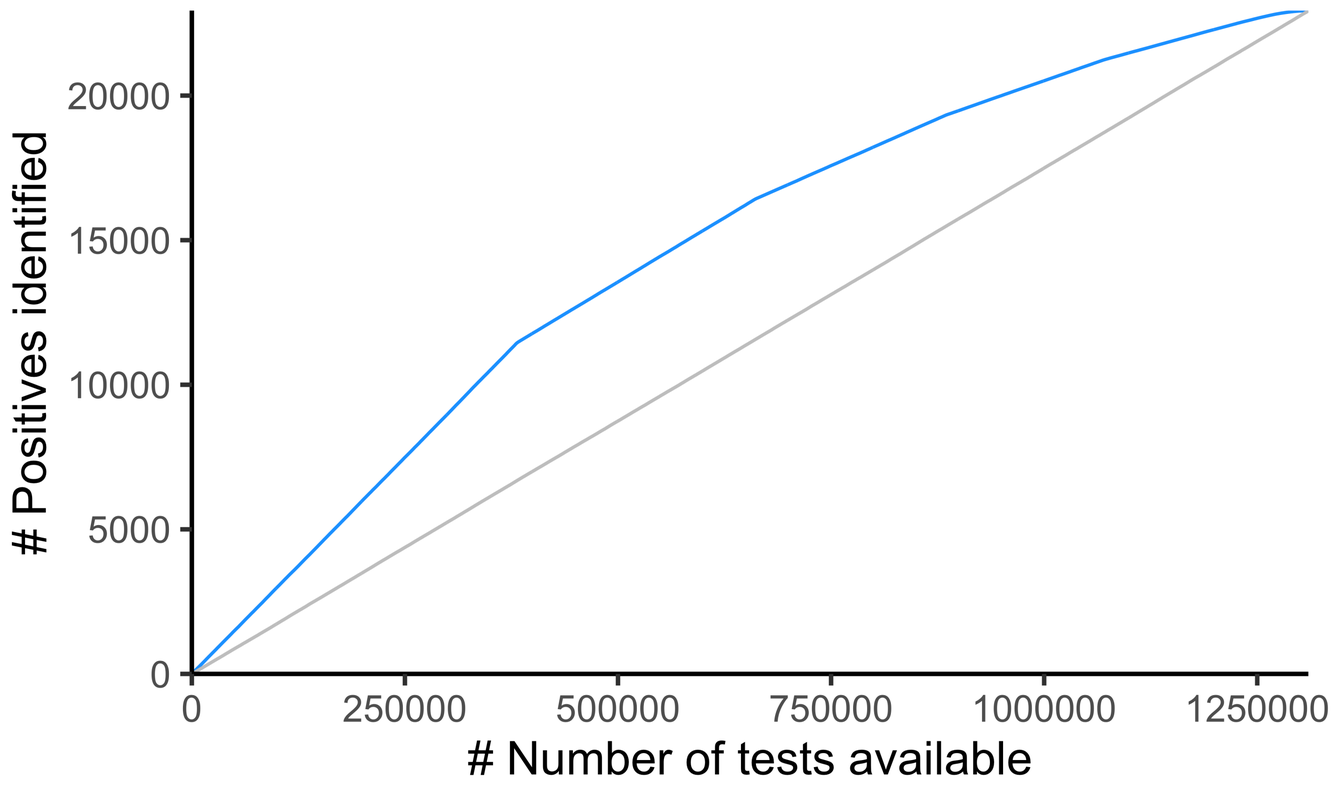


# Pakistan


20000
15000
10000
5000
0
# Positives identified
0
250000
500000
750000
1000000
1250000
# Number of tests available
Standard baseline

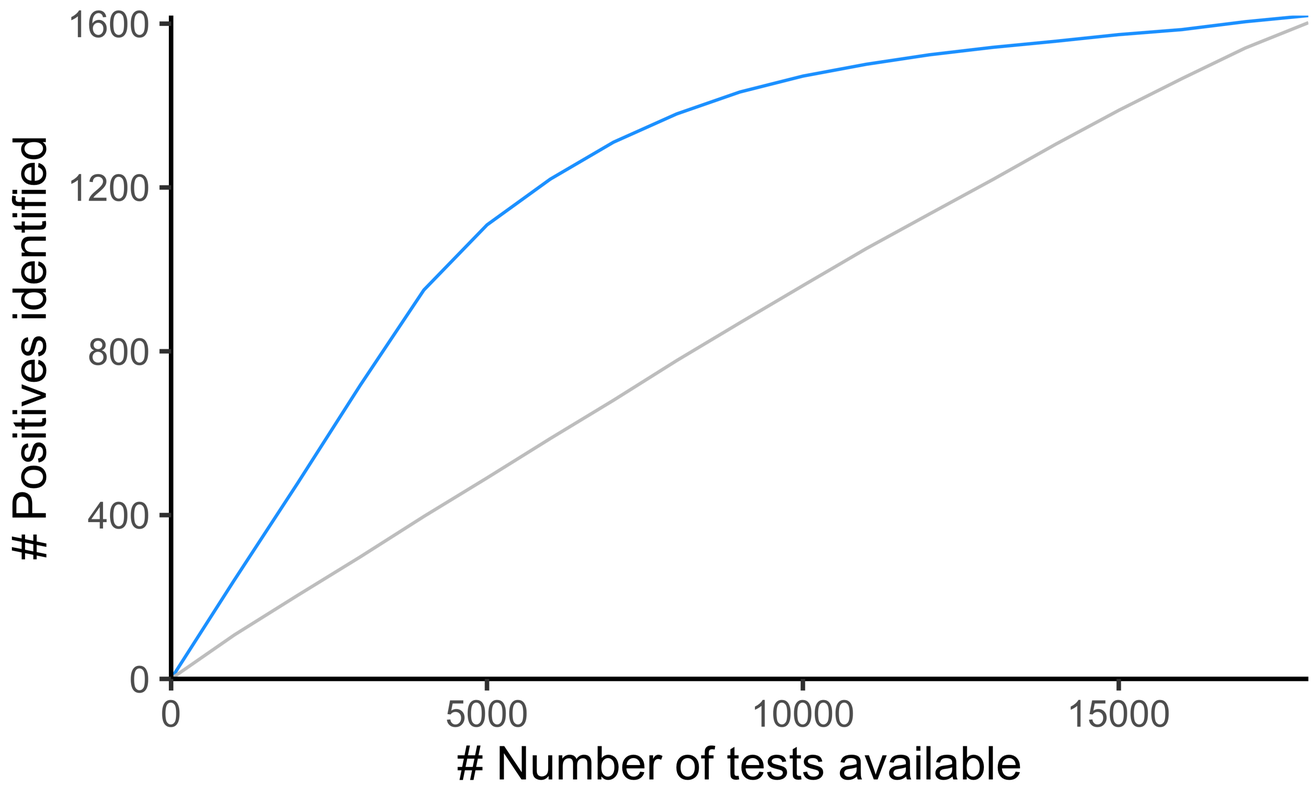
# Pakistan




Standard baseline

Mortal multi-armed bandit ($n = 4$, $k = 1$)

# Punjab




Standard baseline

Mortal multi-armed bandit ($n = 3$, $k = 1$)

# Conclusion

Formulated contact tracing as a multi-armed bandit problem.

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Captured heterogeneity in infectivity.
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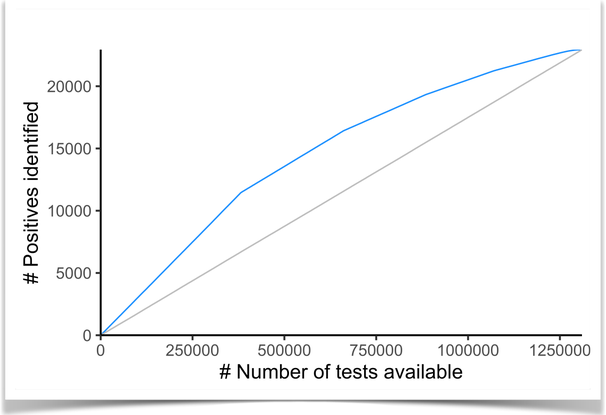
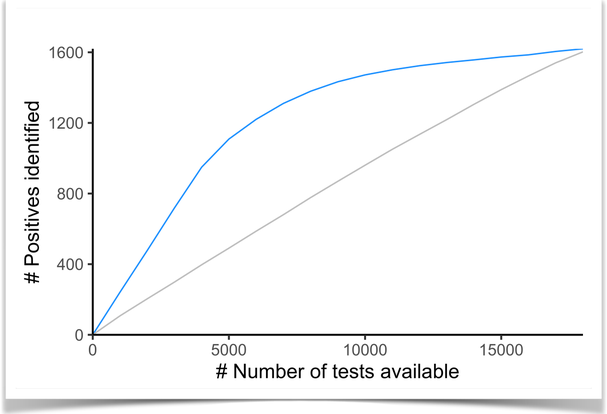



Punjab



# Conclusion

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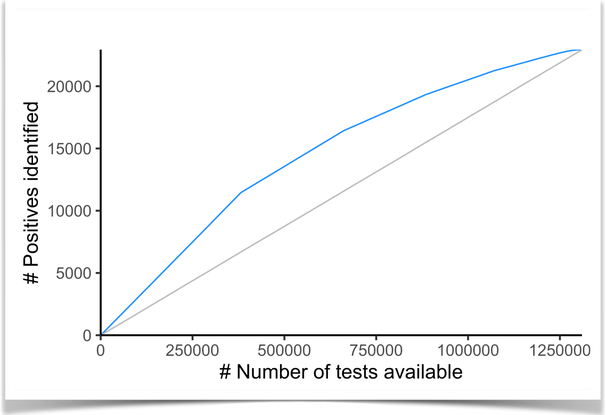
Even just a small increase in number of infections we identify can help us to better control the spread of the disease, especially in the early stages.

Pakistan

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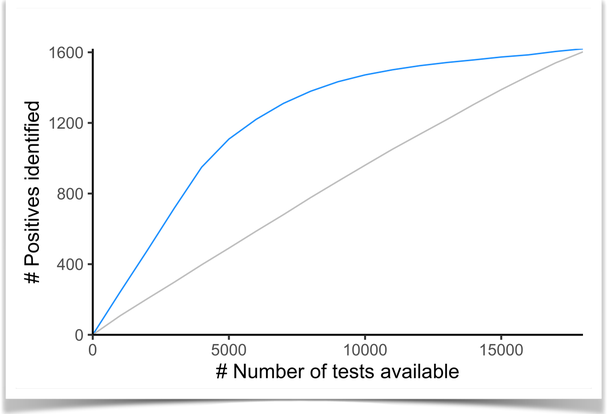

# Acknowledgements

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