COS-D407. Scientific Modeling and Model Validation

Lecturer: Christina Bohk-Ewald

Week 2

University of Helsinki, Finland
26.10.2020–09.12.2020

Second week's class:

Introduction to scientific modeling in general

- Q & A: recap of material of previous lecture session
- Present your findings of previous lab session
- Major ideas behind and steps of the scientific method
- Importance of skepticism and critical thinking
- Start for our application theme in this course with critically analyzing trends of COVID-19

Second week's class in the lab: Scientific sketicism.

- Scientific skepticism. Find alternative explanations for scientific findings.
  - Analyze case fatality rate (CFR; deaths over confirmed cases) of COVID-19 for ten countries with most COVID-19 deaths as of today.
  - Try to find alternative explanations for the large cross-country variation in CFR of COVID-19, also by reading into relevant literature.
  - Extra: do this again with another scientific finding of your choice.

$\longrightarrow$ Present and discuss your findings in class at the beginning of the next session on Monday.

Brief Q&A: recap material of previous lecture session:

- What is (the general purpose of) science?
- What is considered to be a prerequisite for producing valuable scientific outcome?
- How should application, methodology, and validation be interconnected in order to produce scientific outcome?
- What is the idea behind *open science*?
- What is the idea behind *reproducibility* of scientific work?

$\rightarrow$ Open questions?

Present your findings of previous lab session:

- What does science mean to you?
- What could make scientific outcome (in)valuable?

→ Open issues?

About science and creating valuable knowledge

General introduction to the scientific method

About science and creating valuable knowledge

"The method of science,

as stodgy and grumpy as it may seem,

is far more important

than the findings of science"

Carl Sagan (1997, p. 46)

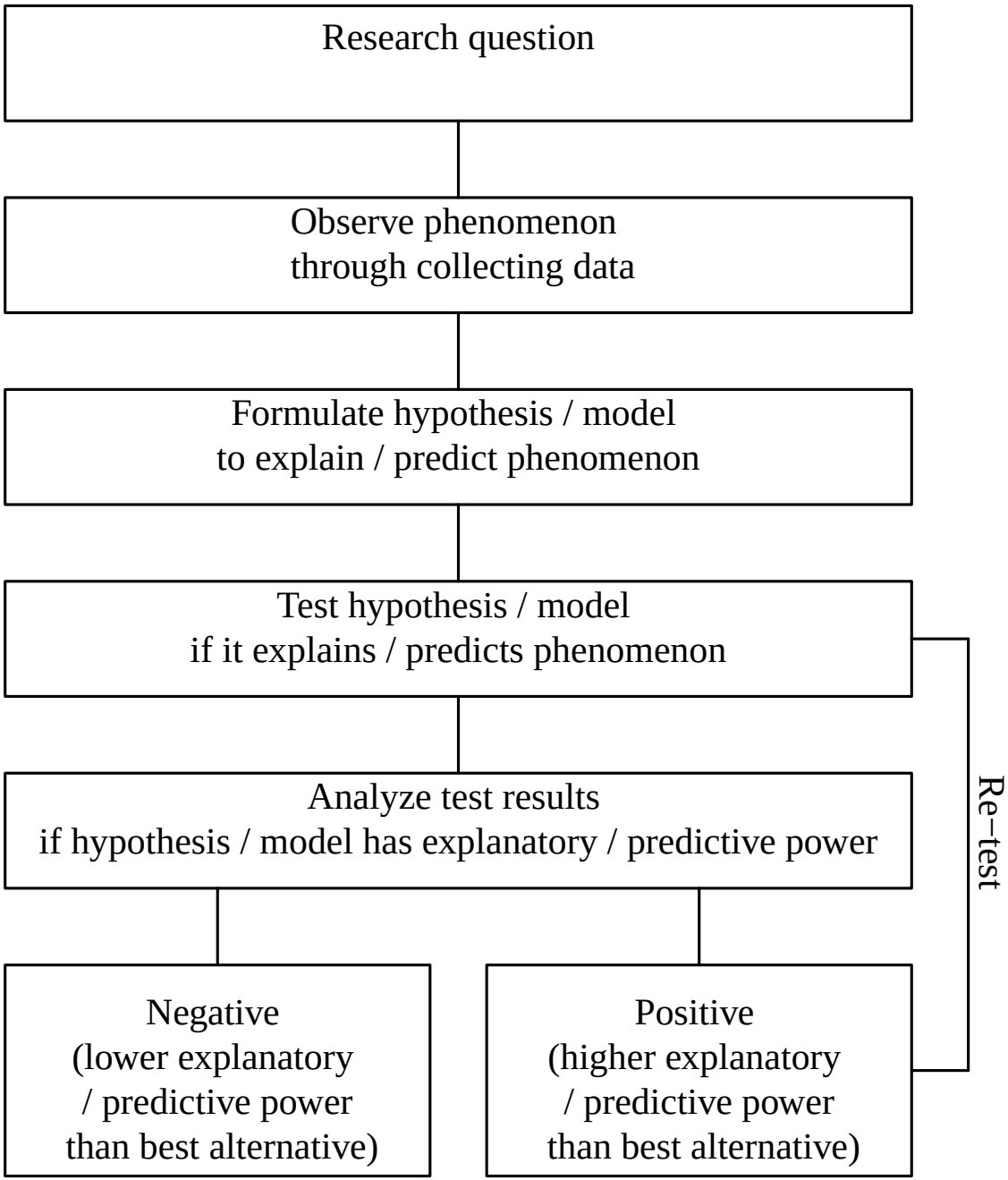
About science and creating valuable knowledge

Before we start:

What is your understanding of this matter?

What is the scientific method? And why could it be more important than the scientific finding?

Take a bit of time to think and remember...


Research question
Observe phenomenon
through collecting data
Formulate hypothesis / model
to explain / predict phenomenon
Test hypothesis / model
if it explains / predicts phenomenon
Analyze test results
if hypothesis / model has explanatory / predictive power
Negative
(lower explanatory
/ predictive power
than best alternative)
Positive
(higher explanatory
/ predictive power
than best alternative)
Re−test

About science and creating valuable knowledge

What do you think:

Why to re-test hypothesis / model with high explanatory / predictive power, i.e. after positive evaluation?

About science and creating valuable knowledge

Why to re-test hypothesis / model after positive evaluation?

- Science is like a snapshot of what we know and how we understand reality so far. And it does not stop here.
- Science produces explanations for real-world phenomena that cannot be falsified yet (but that may be falsified later).
- Science continues to test (or simply to reassess) the *best* explanations that we currently have
  - with ever new tools, data, and information.
  - against alternative explanations.
- If there are significant new insights and their evidence is strong, then *old* explanations may need to be either revised or replaced.

About science and creating valuable knowledge

What do you think:

What explanation / model / theory / law do you remember...

that has (not) remained unfalsified for a long time?

About science and creating valuable knowledge

Basic assumption of scientific method:

- Reality is objective and consistent.
- Humans can perceive reality accurately.
- Rational explanations exist for real-world phenomena.

→ These assumptions have been questioned.

→ Philosophy of science.

About science and creating valuable knowledge

- Karl R. Popper (1935; 1959). *The logic of scientific discovery.*
  - Critical rationalism. Empirical falsification.
  - A theory cannot be proven, only falsified (or not falsified) with experiments.
- Thomas S. Kuhn (1962). *The structure of scientific revolutions.*
  - Episodes with conceptual continuity rather than accumulated progress in science; paradigm shifts.
  - Normal science and solving puzzles; paradigm; serious anomalies; crisis; revolution and establishing new paradigm.
- Paul Feyerabend (1975). *Against Method: Outline of an Anarchistic Theory of Knowledge.*
  - Epistemological anarchy.
  - Limitation in coming up with all possible explanations due to, e.g., intuition, cultural background.
- JPA Ioannidis (2005). *Why most published research findings are false.*
  - Conduct and interpretation of scientific findings.
  - Statistical significance and bias. False positive findings.

About science and creating valuable knowledge

Create valuable knowledge

by following the scientific method,

and avoiding common pitfalls.

$\longrightarrow$ Applies to both scientific modeling and model validation.

About science and creating valuable knowledge

"One unerring mark of the love of truth,

is not entertaining any proposition with greater assurance

than the proofs it is built upon will warrant"

John Locke (1690)

About science and creating valuable knowledge

Science requires skepticism, critical thinking regarding its generating process and outcome. Be aware of, e.g.,

- Creating and testing alternative explanations / working hypotheses and systematically eleminating the ones with less explanatory power.
-
-
-
-
- ...

$\longrightarrow$ Credibility of scientific finding is a consequence of the method used to generate it.

About science and creating valuable knowledge

"Whenever a theory appears to you as the only possible one,

take this as a sign

that you have neither understood the theory nor the problem

which it was intended to solve."

Karl Popper

About science and creating valuable knowledge

Science requires skepticism, critical thinking regarding its generating process and outcome. Be aware of, e.g.,

- Creating and testing alternative explanations / working hypotheses and systematically eleminating the ones with less explanatory power.
- Confirmation bias (e.g., with respect to collecting data and interpreting findings).
-
-
- ...

$\longrightarrow$ Credibility of scientific finding is a consequence of the method used to generate it.

About science and creating valuable knowledge

"It is a capital mistake to theorize

before one has data.

Insensibly one begins to twist facts to suit theories,

instead of theories to suit facts."

Arthur Conan Doyle

About science and creating valuable knowledge

Science requires skepticism, critical thinking regarding its generating process and outcome. Be aware of, e.g.,

- Creating and testing alternative explanations / working hypotheses and systematically eleminating the ones with less explanatory power.
- Confirmation bias (e.g., with respect to collecting data and interpreting findings).
- Rigorous testing, confronting existing explanations repeatedly with new data / information, to get more evidence.
-
- ...

$\longrightarrow$ Credibility of scientific finding is a consequence of the method used to generate it.

About science and creating valuable knowledge

Science requires skepticism, critical thinking regarding its generating process and outcome. Be aware of, e.g.,

- Creating and testing alternative explanations / working hypotheses and systematically eleminating the ones with less explanatory power.
- Confirmation bias (e.g., with respect to collecting data and interpreting findings).
- Rigorous testing; confronting existing explanations repeatedly with new data / information, to get more evidence.
- Testability / falsifiability: can the explanation be falsified? Can the analysis be duplicated?
- ...

$\longrightarrow$ Credibility of scientific finding is a consequence of the method used to generate it.

About science and creating valuable knowledge

Science requires a balance between openness towards new ideas

and skeptically & carefully testing them,

to disprove the ones with less explanatory power

based on evidence.

Creative thinking & critical thinking go hand in hand

in order to produce valid knowledge.

COVID-19: about creating valuable scientific knowledge

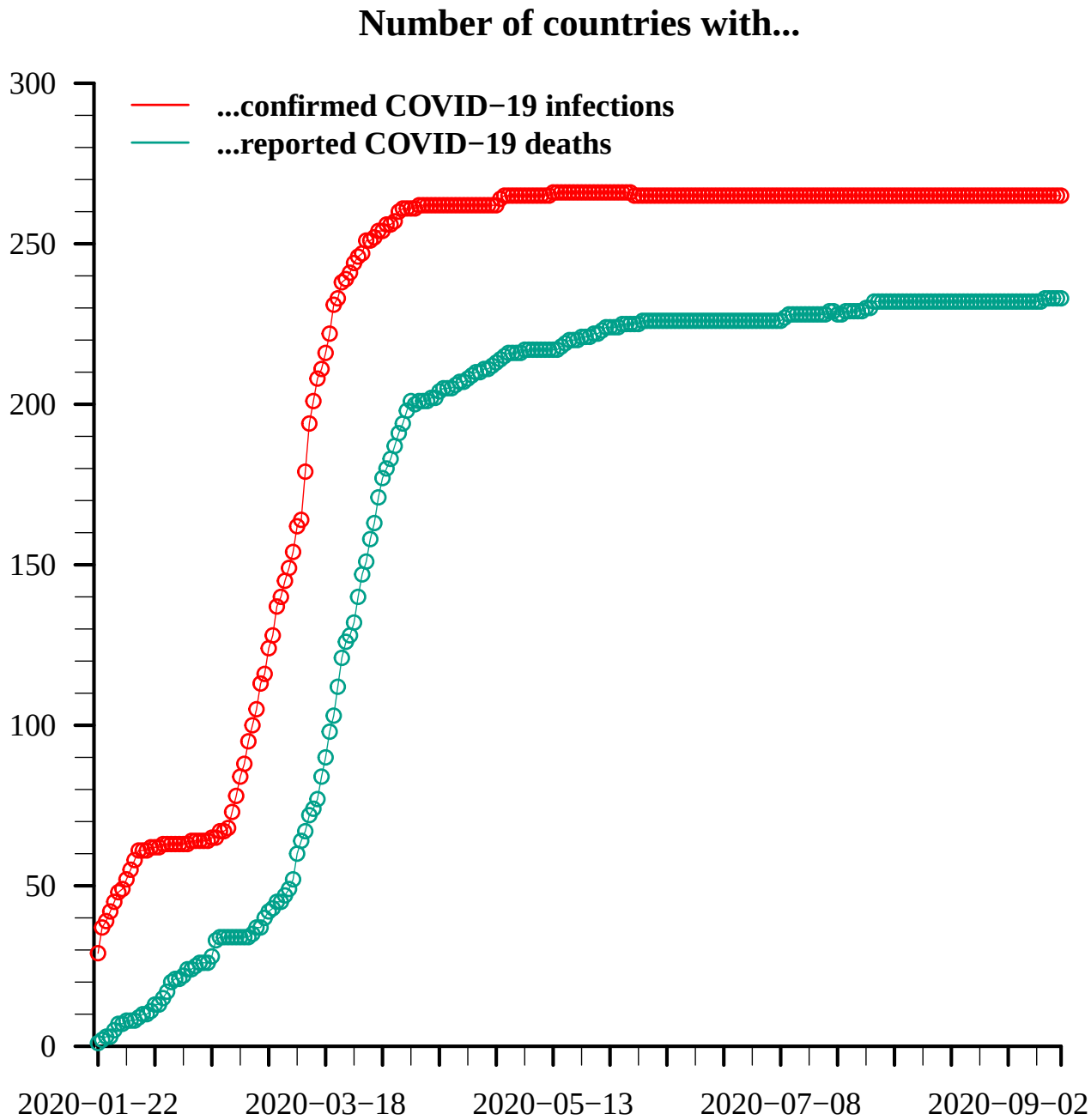
Put creative and critical thinking into practice

in the context of the coronavirus pandemic.

COVID-19: about creating valuable scientific knowledge

Coronavirus pandemic — a new phenomenon:

- *Sudden crisis that struck many countries across the globe*
  - **Outbreak.** First confirmed cases of COVID-19 in Wuhan, Hubei Province, Mainland China, since November / December 2019.
  - **Spread.** Rapid increase in the number of countries with infections and deaths related to COVID-19.
  - As of September 15, 2020: **265 countries**, regions, provinces, states have had **non-zero COVID-19 infections**.
  - As of September 15, 2020: **233 countries**, regions, provinces, states have had **non-zero COVID-19 deaths**.
  - Data source: JHU CSSE:
    - ★ Confirmed cases and reported deaths since January 22, 2020.
    - ★ `https://data.humdata.org/dataset/novel-coronavirus-2019-ncov-cases`



Data source: JHU CSSE: `https://data.humdata.org/dataset/novel-coronavirus-2019-ncov-cases`

COVID-19: about science and creating valuable knowledge

Coronavirus pandemic — a new phenomenon:

- Sudden crisis that struck many countries across the globe
- *Unprecedented virus that causes a new disease*

COVID-19 pandemic

- COVID-19: **co**rona**vi**rus **d**isease **2019**
- SARS-CoV-2 is the causative agent of COVID-19
- SARS-CoV-2 belongs to coronavirus family,
  as do e.g. SARS-CoV and MERS-CoV
- COVID-19 is
  a mild to severe respiratory illness that is caused by a coronavirus (Severe acute respiratory syndrome coronavirus 2 of the genus Betacoronavirus), is transmitted chiefly by contact with infectious material (such as respiratory droplets), and is characterized especially by fever, cough, and shortness of breath and may progress to pneumonia and respiratory failure

Source of information is the Merriam Webster Dictionary:

`https://www.merriam-webster.com/words-at-play/new-dictionary-words-coronavirus-covid-19`

`https://www.merriam-webster.com/dictionary/COVID-19`

COVID-19 pandemic

- COVID-19 is
  a mild to severe respiratory illness that is caused by a coronavirus (Severe acute respiratory syndrome coronavirus 2 of the genus Betacoronavirus), is transmitted chiefly by contact with infectious material (such as respiratory droplets), and is characterized especially by fever, cough, and shortness of breath and may progress to pneumonia and respiratory failure

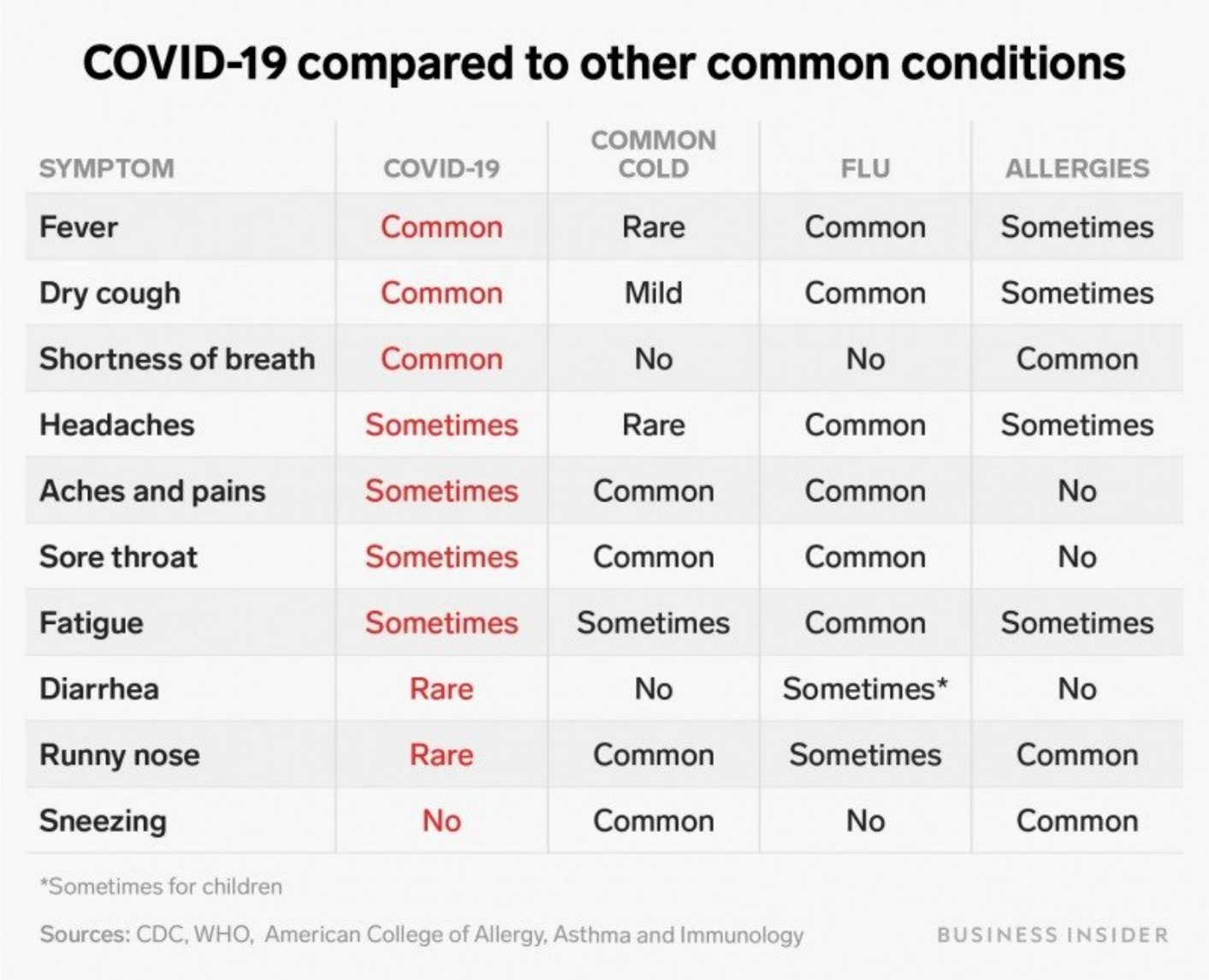
- NOTE: While fever, cough, and shortness of breath are common symptoms of COVID-19, other symptoms may include fatigue, chills, body aches, headache, loss of taste or smell, sore throat, runny nose, nausea, vomiting, or diarrhea. COVID-19 was first identified in Wuhan, China in December 2019.

Source of information is the Merriam Webster Dictionary:

`https://www.merriam-webster.com/words-at-play/new-dictionary-words-coronavirus-covid-19`

`https://www.merriam-webster.com/dictionary/COVID-19`

COVID-19 pandemic



COVID-19 compared to other common conditions

SYMPTOM	COVID-19	COMMON COLD	FLU	ALLERGIES
Fever	Common	Rare	Common	Sometimes
Dry cough	Common	Mild	Common	Sometimes
Shortness of breath	Common	No	No	Common
Headaches	Sometimes	Rare	Common	Sometimes
Aches and pains	Sometimes	Common	Common	No
Sore throat	Sometimes	Common	Common	No
Fatigue	Sometimes	Sometimes	Common	Sometimes
Diarrhea	Rare	No	Sometimes*	No
Runny nose	Rare	Common	Sometimes	Common
Sneezing	No	Common	No	Common

*Sometimes for children

Sources: CDC, WHO, American College of Allergy, Asthma and Immunology

BUSINESS INSIDER

https://www.businessinsider.com/coronavirus-symptoms-compared-to-flu-common-cold-and-allergies-2020-3

COVID-19: about science and creating valuable knowledge

Coronavirus pandemic — a new phenomenon:

- Sudden crisis that struck many countries across the globe
- Unprecedented virus that causes a new disease
- *Leads to many unknowns in all areas of life.* For example:
  -
  -
  -
  -
  -
  - ...
- ...

→ Scientific research is needed to solve unknowns in order to effectively manage and overcome this crisis.

COVID-19: about science and creating valuable knowledge

What do you think:

What are good examples for the many unknowns

related to the coronavirus pandemic

in all areas of life?

COVID-19: about science and creating valuable knowledge

Coronavirus pandemic — a new phenomenon:

- Sudden crisis that struck many countries across the globe
- Unprecedented virus that causes a new disease
- *Many unknowns in all areas of life.* For example:
  - How many people get infected with COVID-19?
  - How many people die from COVID-19?
  - What control measures are suitable to contain further spread?
  - What are the long-term consequences of a COVID-19 infection?
  - What are effective vaccines against COVID-19 and when will they become available?
  - ...
- ...

→ Scientific research is needed to solve unknowns in order to effectively manage and overcome this crisis.

COVID-19: about science and creating valuable knowledge

Coronavirus pandemic — a new phenomenon

Possible implications of the unknowns:

- Numbers of infections, severe patients, and deaths indicate demand for hospital beds in intensive care unit?
- Differing case fatality rates (deaths over confirmed cases) between countries indicate ...?
- Increasing unemployment indicates ...?
- Missing vaccines indicate ...?
- Social distancing indicates ...?
- ...

$\rightarrow$ Scientific research is needed to solve unknowns in order to effectively manage and overcome this crisis.

COVID-19: about science and creating valuable knowledge

Coronavirus pandemic — a new phenomenon

Science is reacting: Flood of preprints and articles on COVID-19. For example, as of September 16, 2020:

- 6 879 preprints on medRxiv (not peer-reviewed)
- 1 867 preprints on bioRxiv (not peer-reviewed)
- 2 265 preprints on arXiv (not peer-reviewed)
- 1 453 articles in the COVID-19 Resource Centre of The Lancet
- Google scholar: 1 310 000 results for "COVID-19"

→ Jeffrey Brainard (2020). Scientists are drowning in COVID-19 papers. Can new tools keep them afloat? Science. https://www.sciencemag.org/news/2020/05/scientists-are-drowning-covid-19-papers-can-new-tools-keep-them-afloat

→ **Valid and reliable** scientific research is needed to solve the many unknowns in order to effectively manage and overcome this crisis.

In the lab this week

"You learn something by doing it yourself,

by asking questions,

by thinking,

and by experimenting"

Richard P Feynman

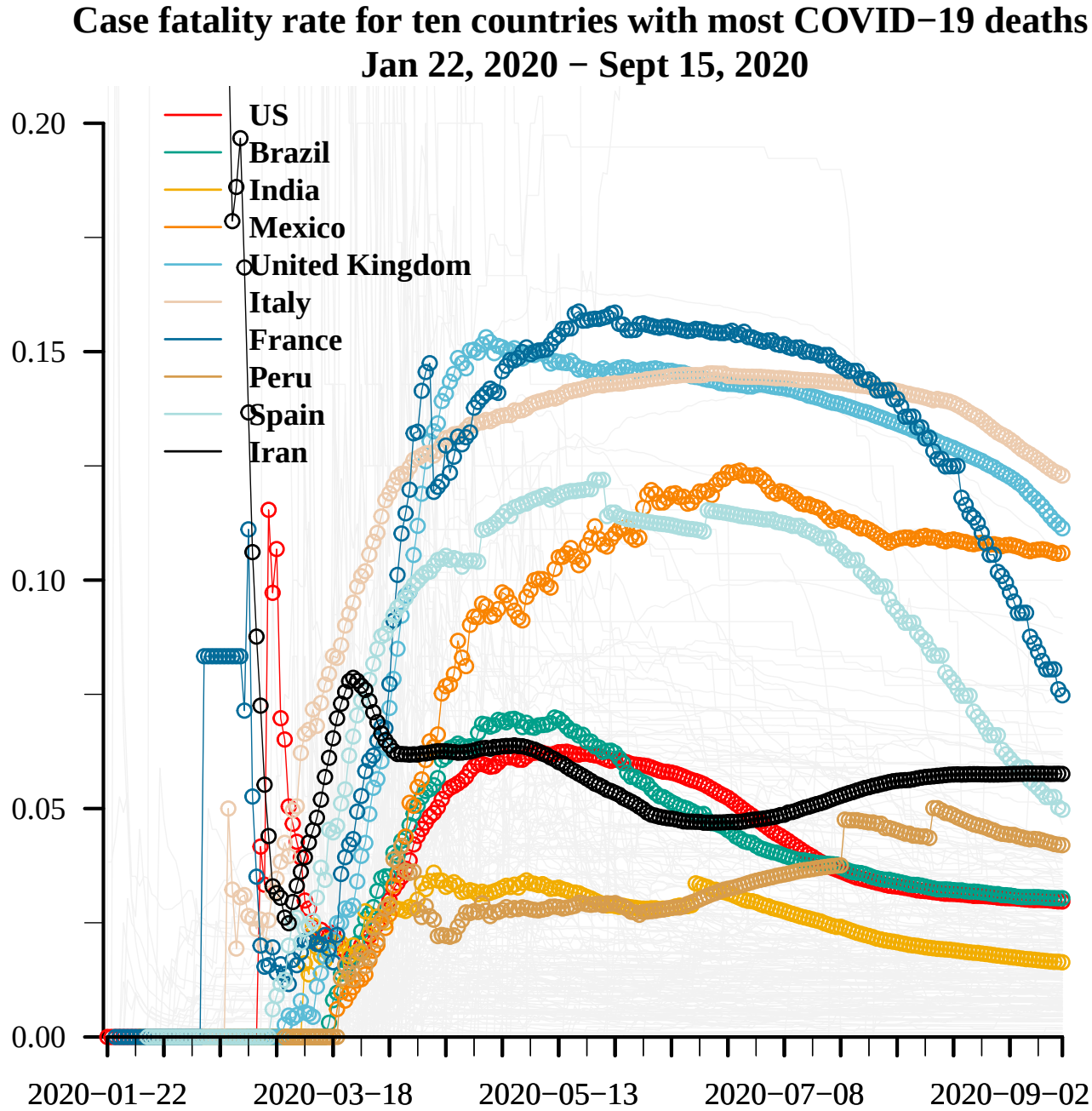
COVID-19: about science and creating valuable knowledge

Coronavirus pandemic — a new phenomenon

Hands-on exercise: Explain cross-country differences in case fatality rate!

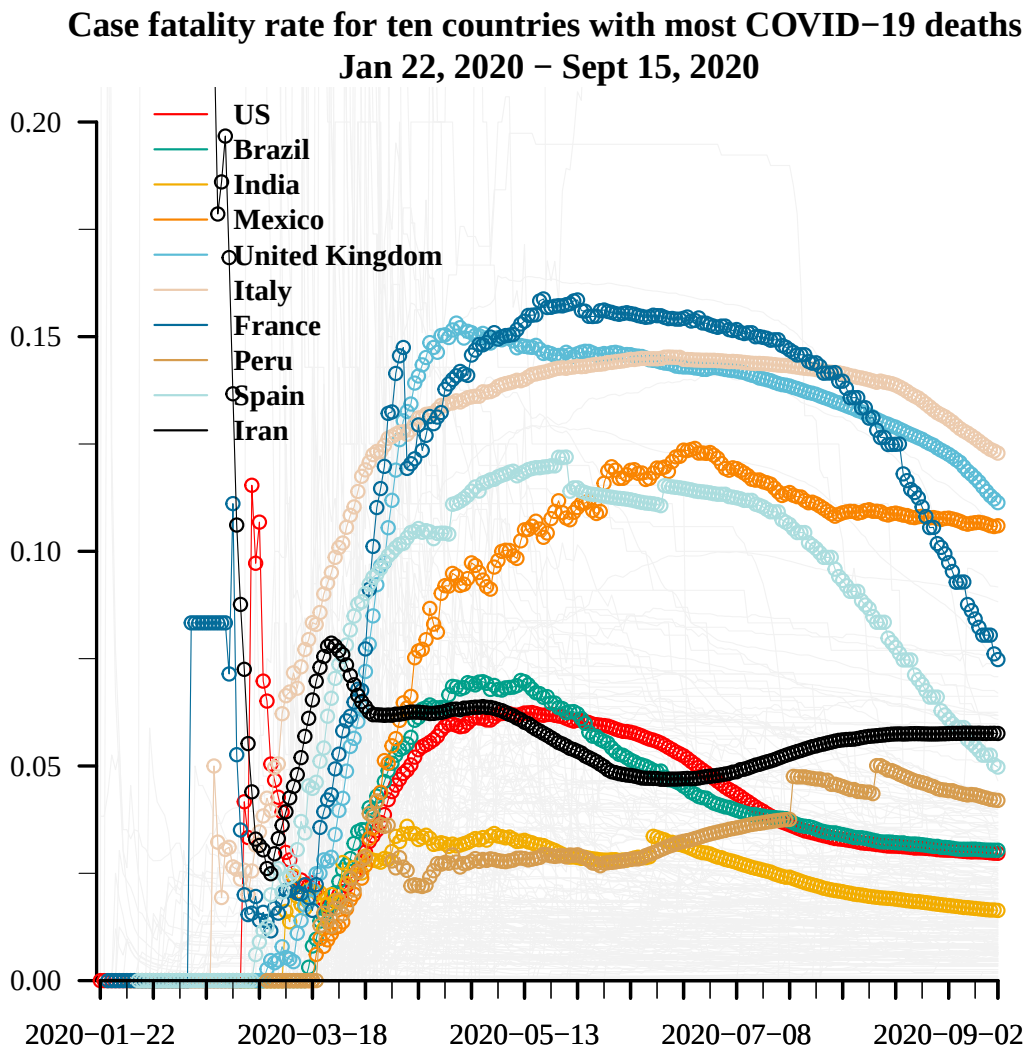
- Case fatality rate (CFR; reported deaths over confirmed cases)
- Infection fatality rate (IFR; reported deaths over confirmed and undiagnosed cases)
- Source of data: JHU CSSE
- Supporting literature, e.g., Dowd et al. (2020) and Dudel et al. (2020)

→ Creative and critical thinking: what could be possible explanations for cross-country differences in CFRs?



Data source: JHU CSSE: https://data.humdata.org/dataset/novel-coronavirus-2019-ncov-cases

COVID-19: about science and creating valuable knowledge



Data source: JHU CSSE:

https://data.humdata.org/dataset/novel-coronavirus-2019-ncov-cases

- Are these cross-country differences in CFR solely due to different mortality from COVID-19?
- Or what else could be driving them?

⇒ Time for you to think creatively & critically

What you have learned today about the scientific method in general

- Describe main ideas behind and steps of the scientific method.
- Explain why the undertaken steps of the scientific method can be at least as important as the research findings.
- Explain the requirement for a scientific outcome to be testable / falsifiable.
- Explain the need for skeptism and critical thinking in order to create valid knowledge and relate it to common pitfalls of scientific work.
- Describe recent trends in the case fatality rate of COVID-19.

Course learning materials

Course learning materials on GitHub:

`https://github.com/christina-bohk-ewald/2020-COS-D407-scientific-modeling-and-model-validation`

Recommended learning material for today's class

- **Karl Popper (1959; 2002)**
  The logic of scientific discovery.
  Abingdon-on-Thames: Routledge
- **Thomas S. Kuhn (1962; 2012)**
  The structure of scientific revolutions.
  University of Chicago Press
- **Paul Feyerabend (1975; 2010)**
  Against Method: Outline of an Anarchistic Theory of Knowledge.
  NY: Verso Books
- **John PA Ioannidis (2005)**
  Why most published research findings are false.
  PLoS Medicine 2(8): e124

Recommended learning material for today's class

- **Richard P Feynman (1974)**
  Cargo Cult Science. Some remarks on science, pseudoscience, and learning how to not fool yourself.
  Caltech's 1974 commencement address.
  `http://calteches.library.caltech.edu/51/2/CargoCult.htm`
- **Carl Sagan (1997)**
  The Demon-Haunted World: Science as a Candle in the Dark.
  Ballantine Books.
- **Dowd et al. (2020)**
  Demographic science aids in understanding the spread and fatality rates of COVID-19. PNAS 117 (18) 9696-9698
  `https://doi.org/10.1073/pnas.2004911117`
- **Dudel et al. (2020)**
  Monitoring trends and differences in COVID-19 case-fatality rates using decomposition methods: Contributions of age structure and age-specific fatality. PLOSone.

Thank you for your attention!

christina.bohk-ewald@helsinki.fi

Second week's class in the lab: Scientific sketicism.

- Scientific skepticism. Find alternative explanations for scientific findings.
  - Analyze case fatality rate (CFR; deaths over confirmed cases) of COVID-19 for ten countries with most COVID-19 deaths as of today.
  - Try to find alternative explanations for the large cross-country variation in CFR of COVID-19, also by reading into relevant literature.
  - Extra: do this again with another scientific finding of your choice.

$\longrightarrow$ Present and discuss your findings in class at the beginning of the next session on Monday.