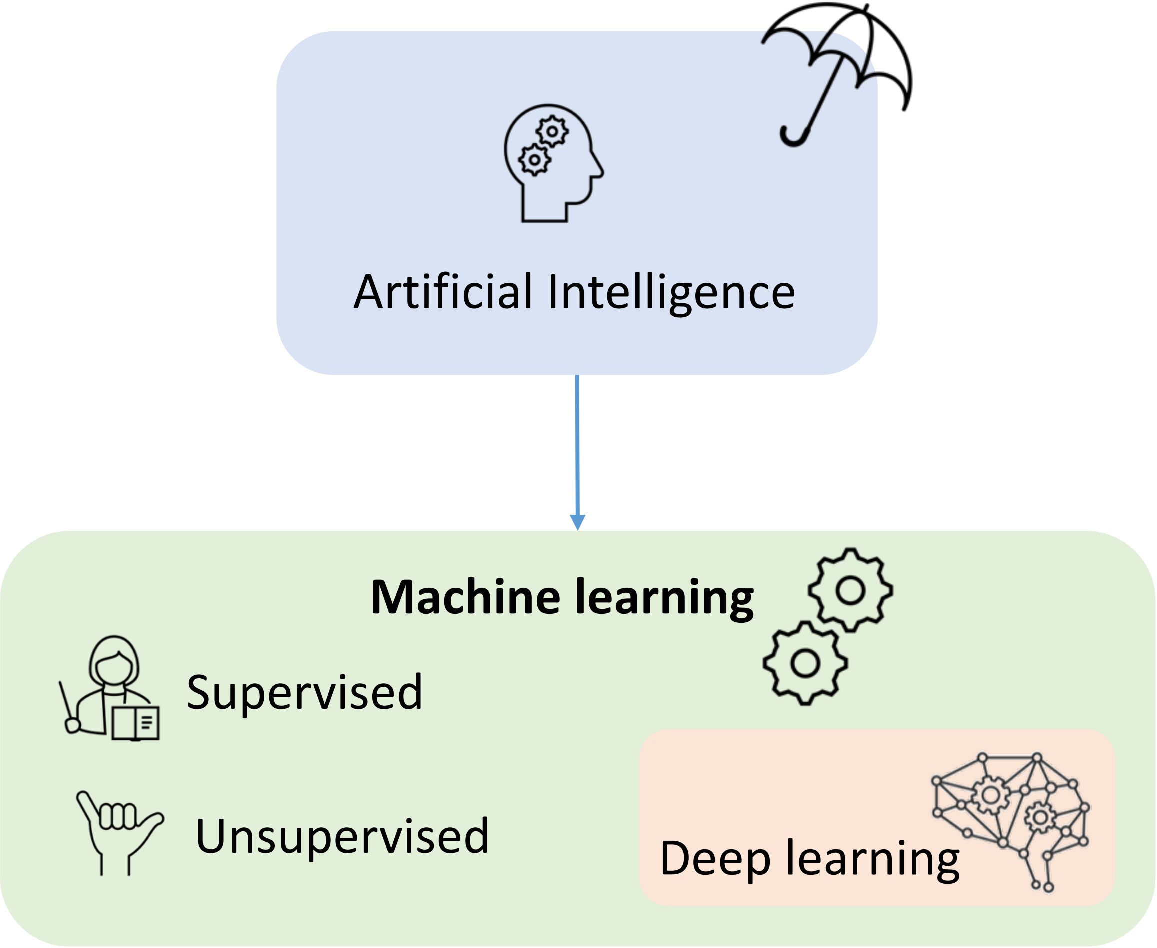
Case study: AI for pneumonia detection in low resource settings

13/09/2022 Biomedical Engineering for sustainable development

Katy Stokes

Part 1: Intro to AI for healthcare

Part 2: Case study


Artificial Intelligence
Machine learning
Supervised
Unsupervised
Deep learning

Machine learning
Deep learning

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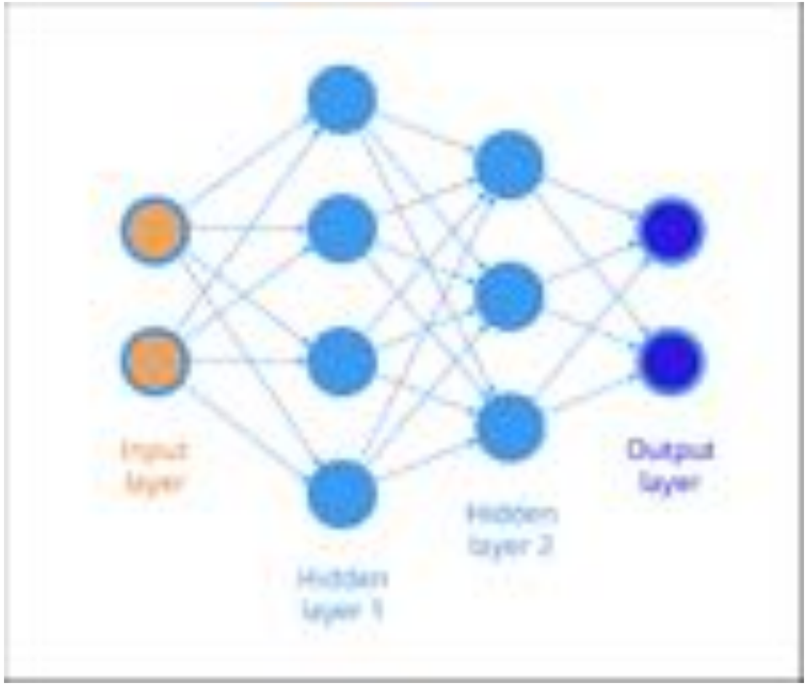
- Based on artificial neural networks
- Processing happens over multiple layers
- Used to extract high level information
- Can be supervised or unsupervised

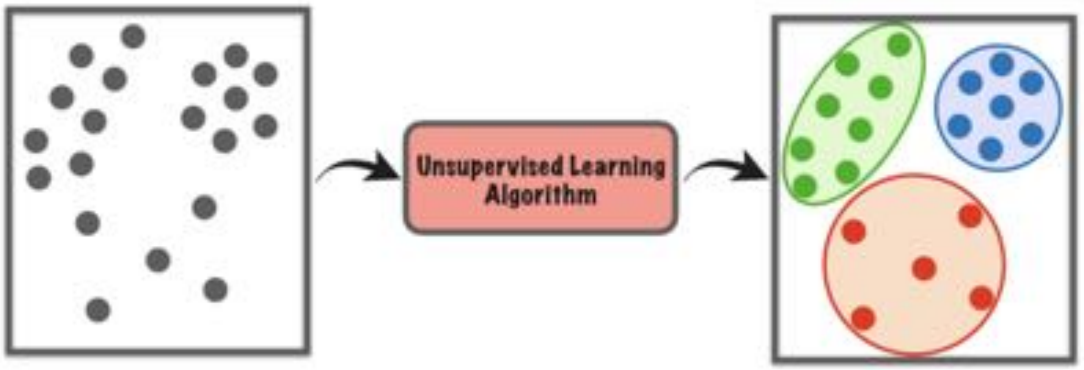


https://machinelearningmastery.com/calculus-in-action-neural-networks/

Machine learning

Unsupervised Learning

- Unlabelled data
- Identify ‘hidden’ unknown patterns in data
- **Example:**
  Are there patterns in the data to indicate whether certain patients respond better to the treatment?

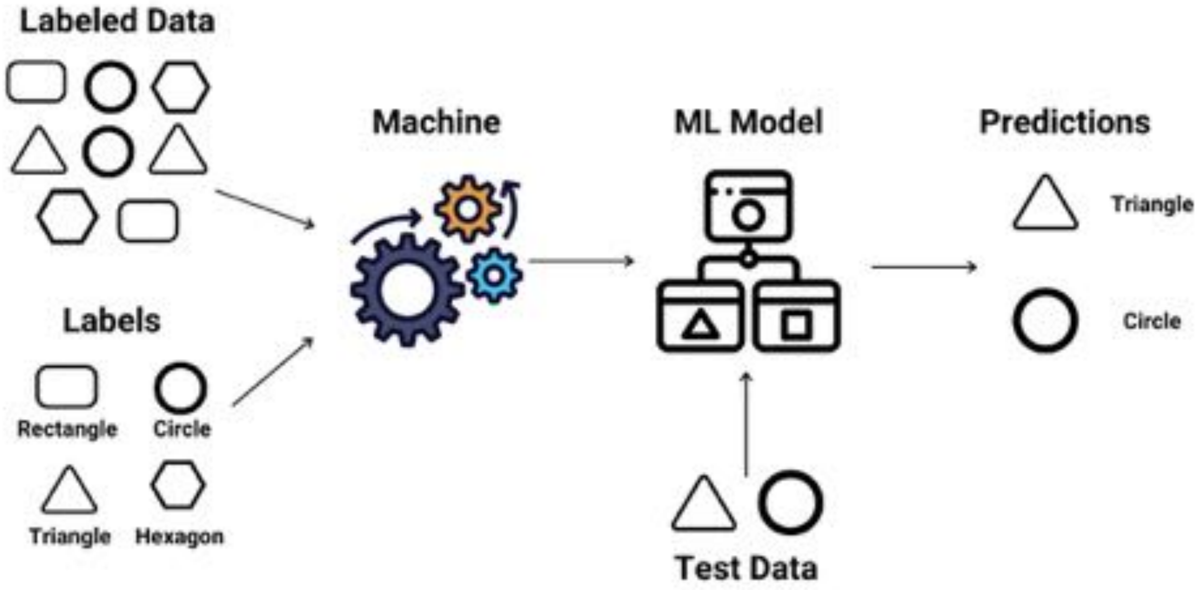


https://towardsdatascience.com/supervised-vs-unsupervised-learning-in-2-minutes-72dad148f242

Machine learning

Supervised Learning

- Labelled data
- Classification/ regression problems
- Algorithms learn based on accuracy of predictions



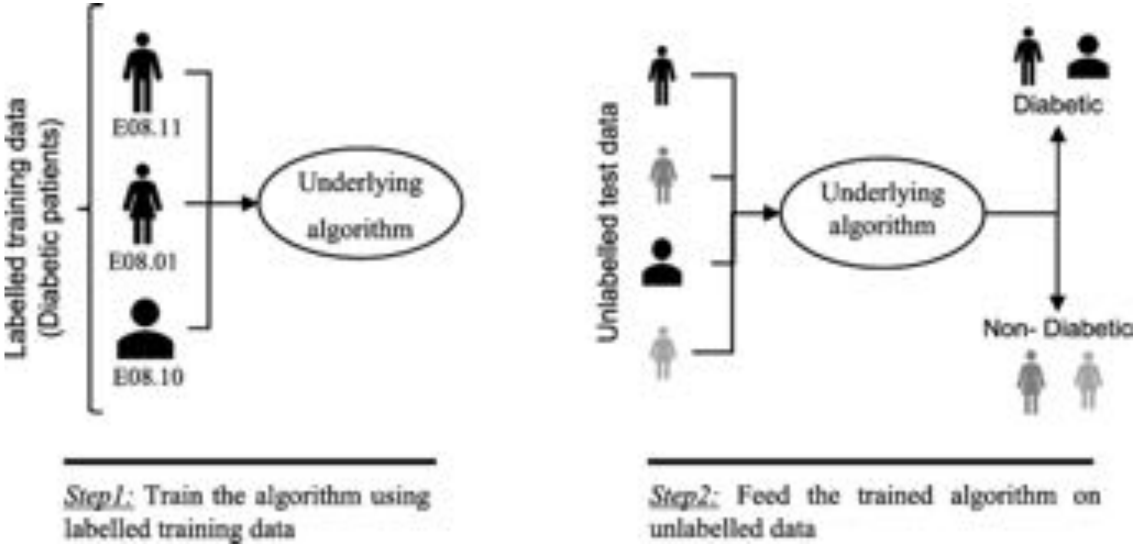
Foster, K.R., R. Koprowski, and J.D. Skufca, *Machine learning, medical diagnosis, and biomedical engineering research - commentary.* Biomedical engineering online, 2014. **13**: p. 94-94.

Machine learning

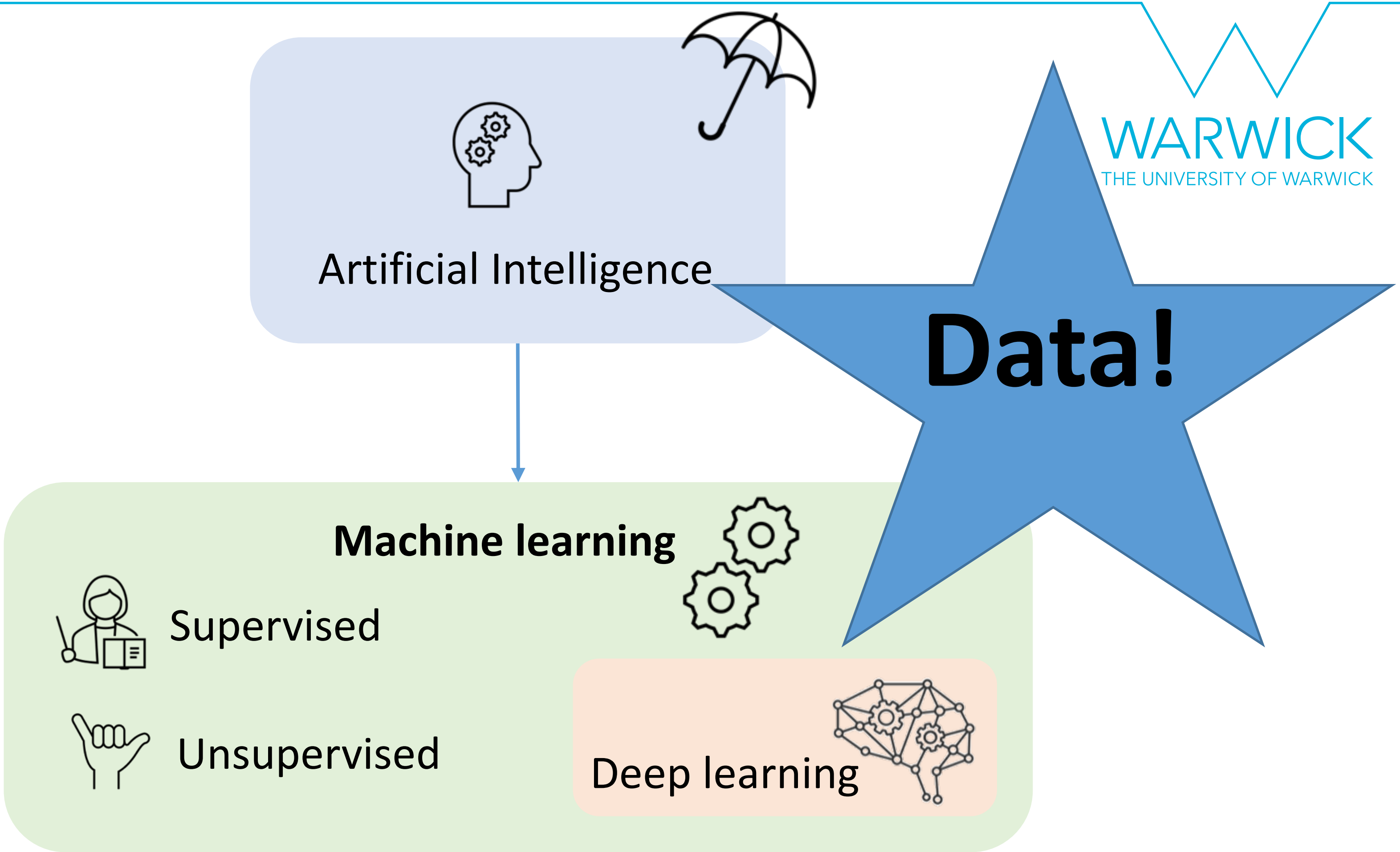
Supervised Learning

- Labelled data
- Classification/regression problems
- Algorithms learn based on accuracy of predictions

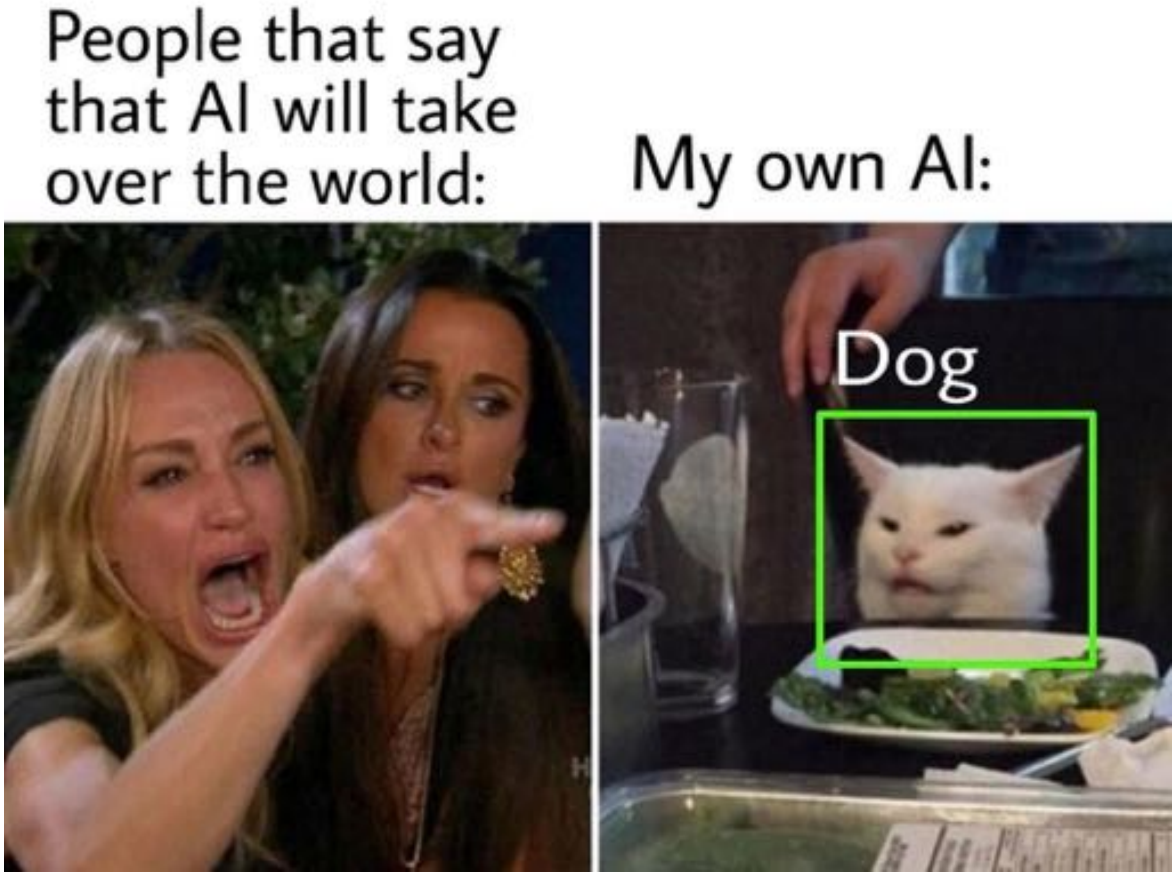
Example: Diagnose diseases using a trained ML algorithm



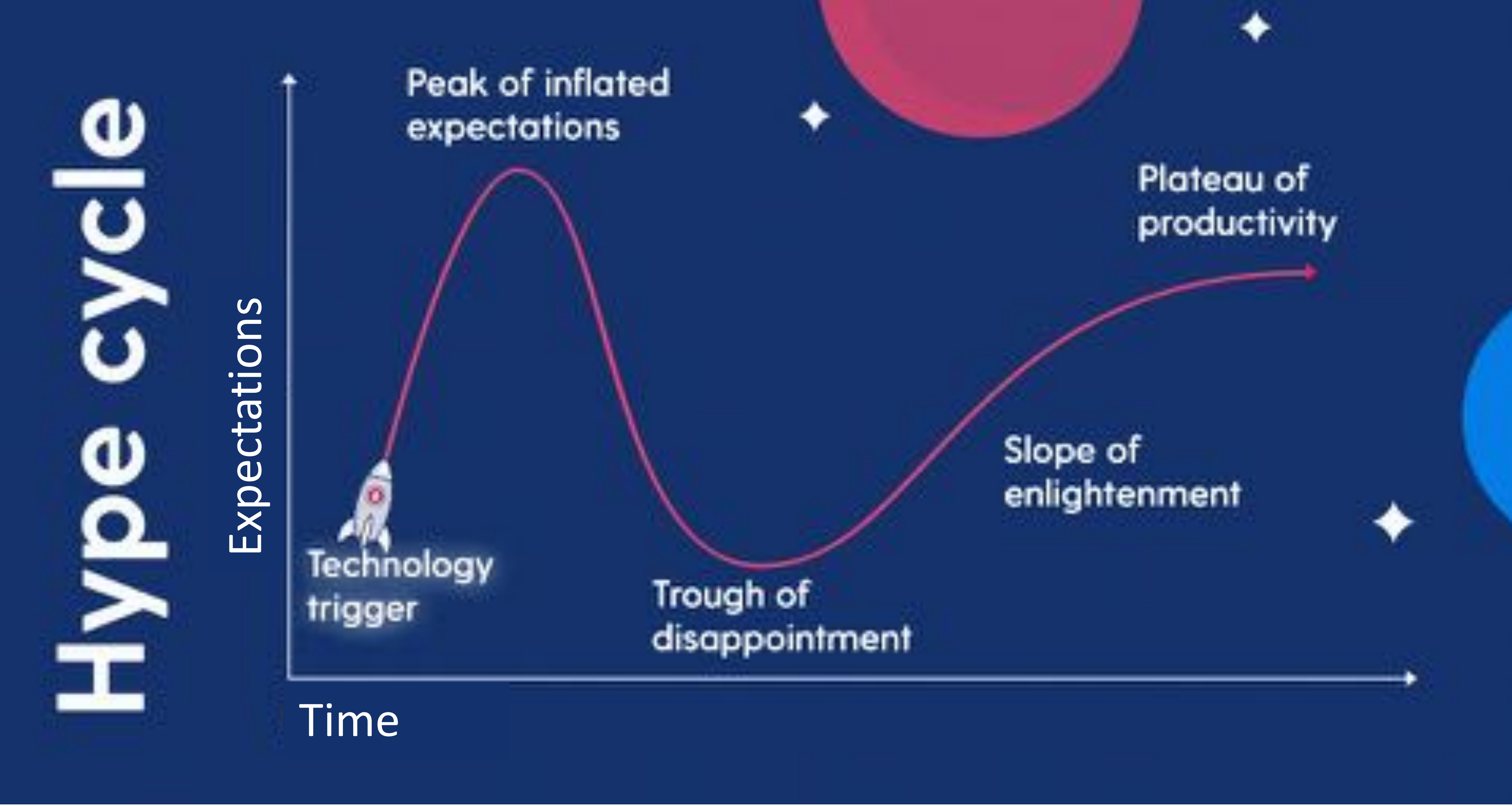
Uddin, S., Khan, A., Hossain, M. *et al.* Comparing different supervised machine learning algorithms for disease prediction. *BMC Med Inform Decis Mak* **19**, 281 (2019). https://doi.org/10.1186/s12911-019-1004-8



Artificial Intelligence
Data!
Machine learning
Supervised
Unsupervised
Deep learning

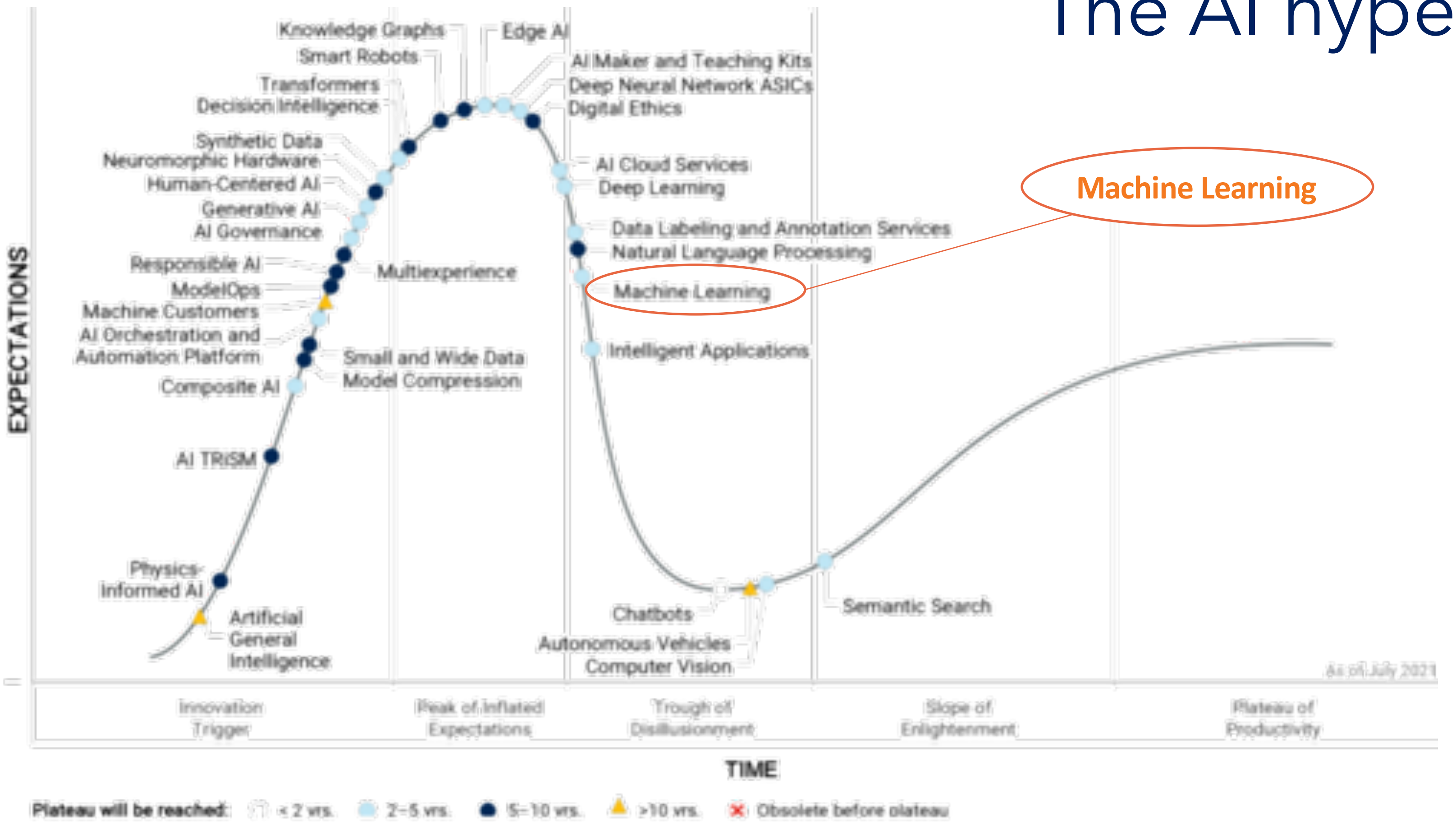


https://aihubprojects.com/is-ai-overhyped-reality-vs-expectation/



https://discover.luno.com/from-hype-to-legitimacy/, https://www.gartner.com/en/research/methodologies/gartner-hype-cycle

The AI hype cycle



Source: Gartner (September 2021), https://www.gartner.com/en/documents/3887767

Sector(s) targeted	Australia	Czech Rep.	Denmark	France	Finland	Hungary	Japan	Korea	Latvia	Netherlands	Norway	Poland	Turkey	U.K.	U.S.	China	India	Singapore	Malta	Saudi Arabia	U.A.E.
Agriculture and food																					
Cybersecurity																					
Defence/ Security																					
Education																					
Energy																					
Environment																					
Finance																					
Health care																					
Manufacturing																					
Mobility and transportation																					
Productivity																					
Public administration																					
Seas and oceans/Marine																					
Smart cities/ Construction																					
Aerospace/ Space																					
Telecomms and IT																					

Priorities of national AI strategies and policies

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Which sectors do most countries target with AI policies?
Why?

OECD.AI (2021), powered by EC/OECD (2021), database of national AI policies, accessed on 2/08/2022, https://oecd.ai

Sector(s) targeted	Australia	Czech Rep.	Denmark	France	Finland	Hungary	Japan	Korea	Latvia	Netherlands	Norway	Poland	Turkey	U.K.	U.S.	China	India	Singapore	Malta	Saudi Arabia	U.A.E.
Agriculture and food	✓		✓			✓	✓	✓	✓	✓		✓	✓		✓	✓	✓				
Cybersecurity							✓					✓	✓					✓			
Defence/ Security				✓				✓	✓				✓		✓	✓		✓			✓
Education		✓				✓	✓	✓					✓		✓		✓	✓	✓		
Energy			✓		✓	✓			✓	✓	✓	✓		✓	✓	✓			✓	✓	✓
Environment	✓			✓		✓				✓				✓	✓					✓	
Finance								✓	✓									✓			
Health care	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Manufacturing						✓	✓	✓					✓	✓	✓					✓	
Mobility and transportation		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Productivity					✓		✓					✓	✓								
Public administration				✓	✓	✓	✓	✓	✓		✓	✓	✓						✓		
Seas and oceans/Marine								✓	✓		✓										
Smart cities/ Construction	✓								✓			✓	✓				✓			✓	✓
Aerospace/ Space		✓						✓							✓						
Telecomms and IT							✓	✓	✓				✓		✓				✓		

OECD.AI (2021), powered by EC/OECD (2021), database of national AI policies, accessed on 2/08/2022, https://oecd.ai

AI for healthcare

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Think of some different ways AI can be applied to healthcare

Some ideas:

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Mobile health

Health informatics

Decision support systems

Diagnostics

Healthcare management

The role of AI:

Learning from data, prediction vs detection

Predict event/condition -> prevent

Detect event/condition -> mitigate

The role of AI:

Learning from data, prediction vs detection

Predict event/condition -> prevent

Detect event/condition -> mitigate

Example:
Fall detection algorithms

AI and the clinical workflow

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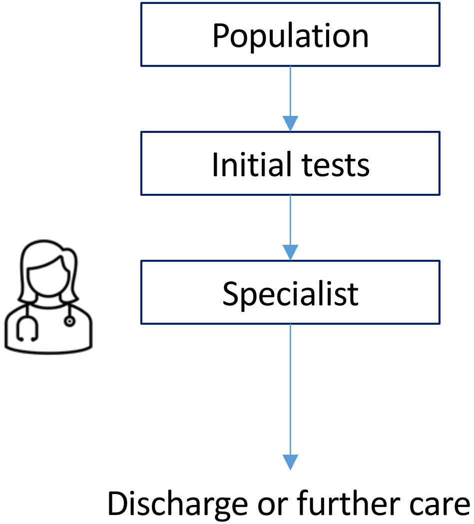
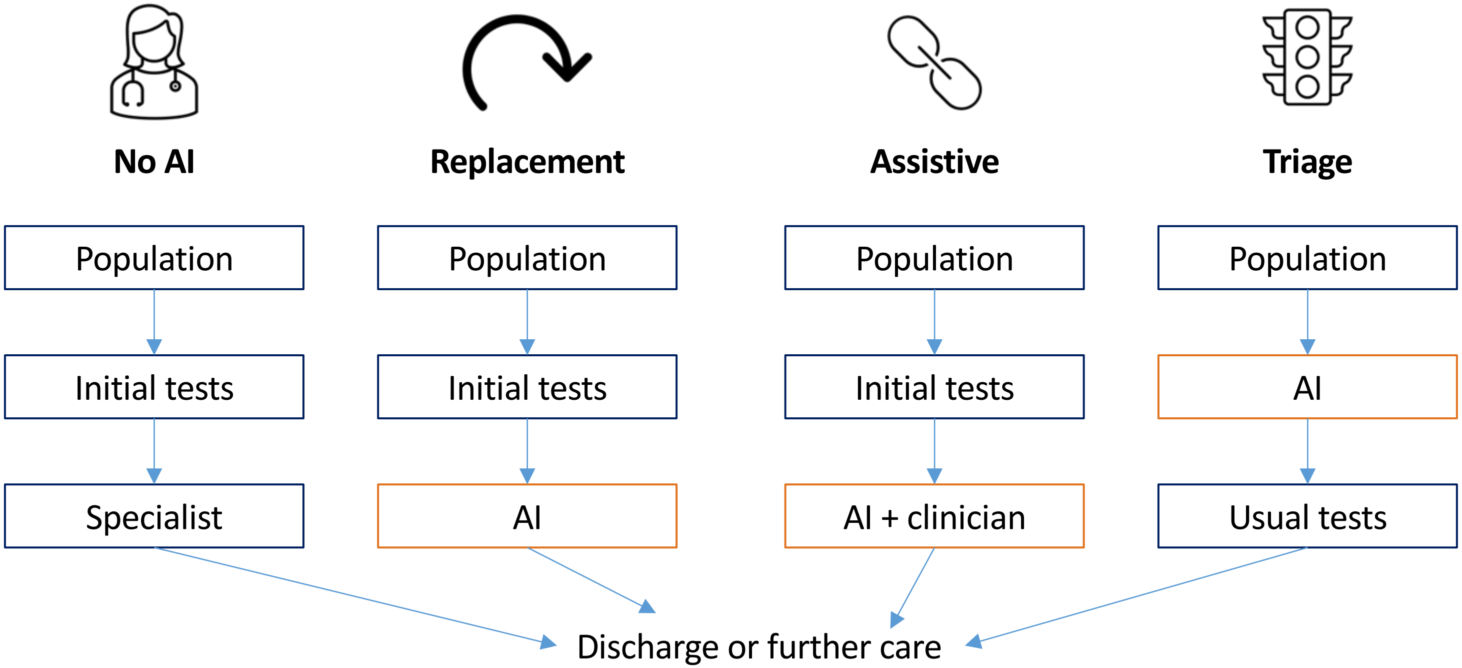
Example care pathway



AI and the clinical workflow



Breakout discussion

What are the different factors that you would need to consider for the different approaches?

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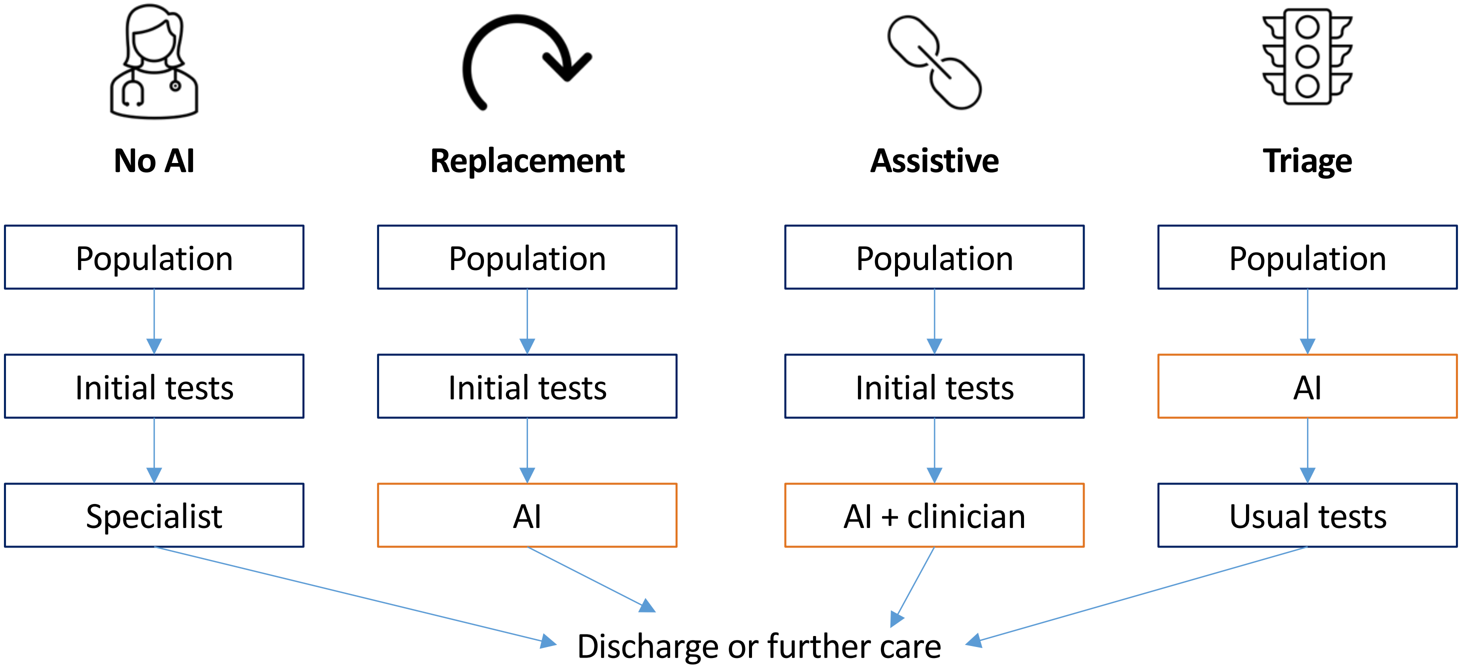

A few ideas…

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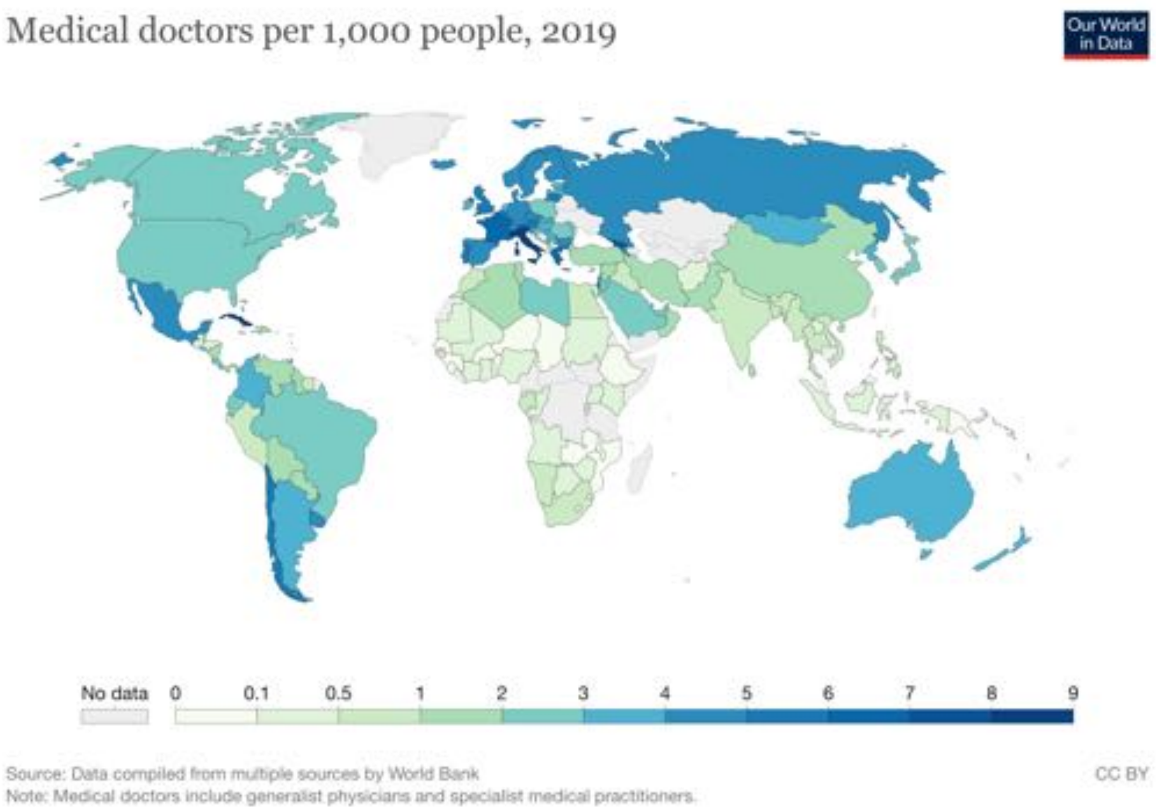
- **Replacement**: how can you ensure that previous standards will be met? Will the validation process be the same?
- **Assistive**: How interpretable do the results need to be?
    - Can the system direct a healthcare workers attention to particular factors?
- **Triage**: will data be consistent across individuals?
    - Can you build flexibility into the system?

AI for healthcare: low-resource settings



Motivations:

- Shortage of healthcare personnel, resources and tests
- Healthcare cost
- Disease burden

AI for healthcare: low-resource settings

Challenges to AI implementation

- Availability of high quality training data
- Infrastructure
  - Power
  - Network
- Digital literacy
- Regulatory and policy frameworks

Owoyemi A, Owoyemi J, Osiyemi A, *et al*, Artificial intelligence for healthcare in Africa. Front Digit Health 2020;**2**:6. doi:10.3389/fdgth.2020.00006

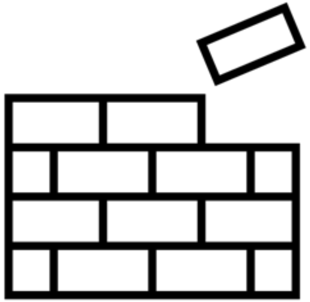
AI for healthcare in low-resource settings, where are we?

- **Research**: little evidence in academic literature
- **Industry**: over half of the global medical device market held by the US and Europe.
- **Policy**: relatively few policy initiatives

More policy initiatives for AI and health in the UK than across Africa.

OECD.AI (2021), powered by EC/OECD (2021), database of national AI policies, accessed on 2/08/2022, https://oecd.ai

AI for healthcare in low-resource settings; important considerations



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- Clear definition of the healthcare problem to be addressed
- Inclusivity for local populations
- Sustainability for development and maintenance of medical technologies
- Regulatory and legal strategies for reliability

Case study:
ML for pneumonia detection

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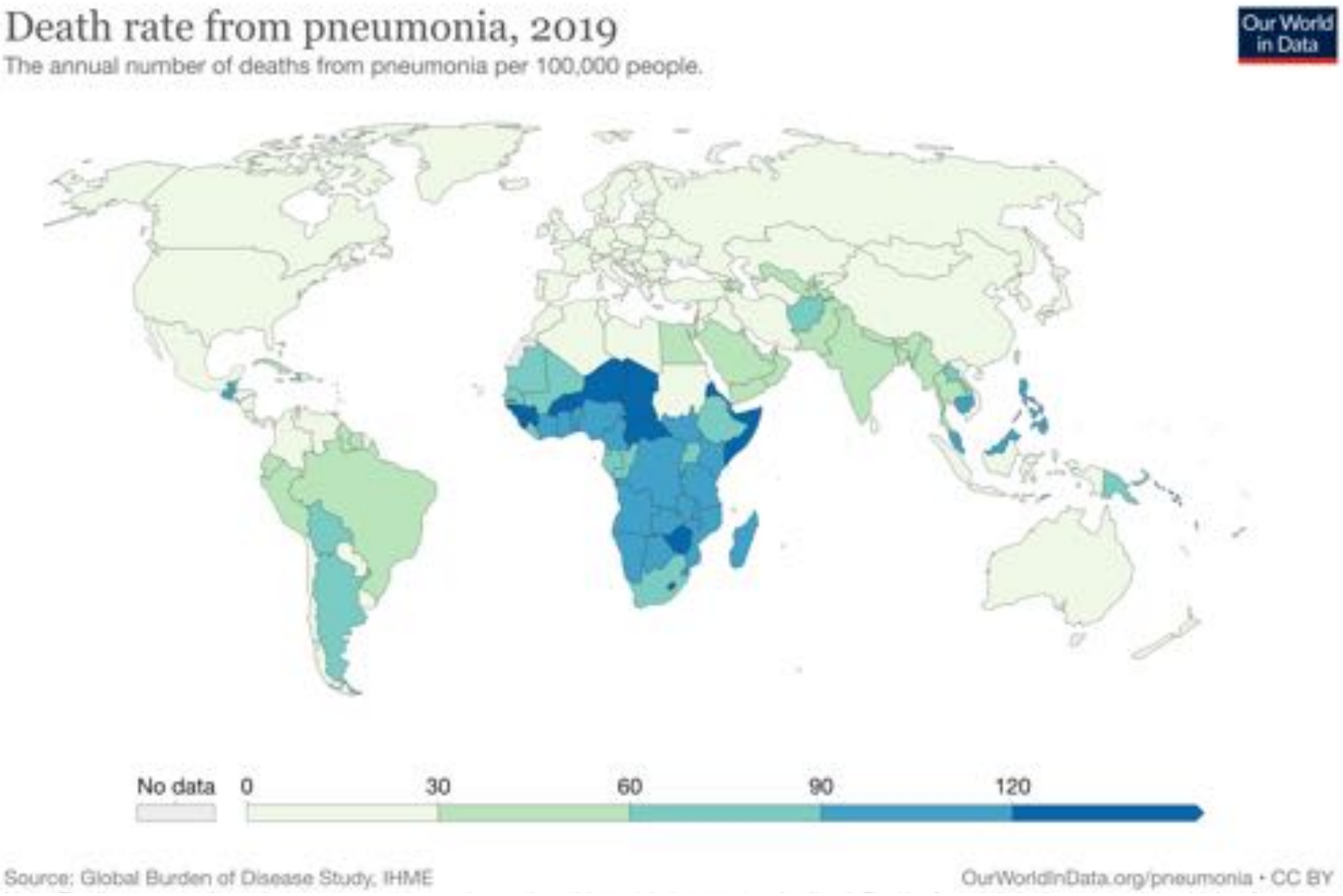
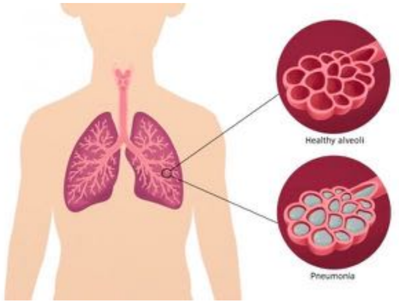
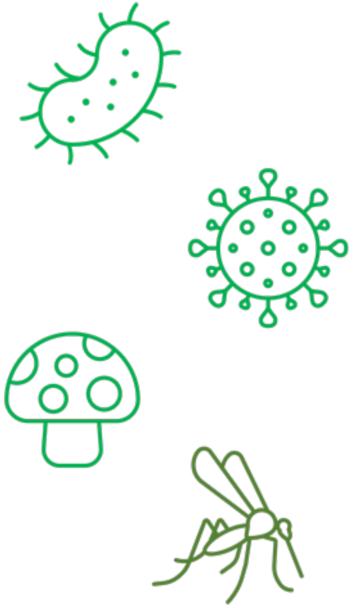
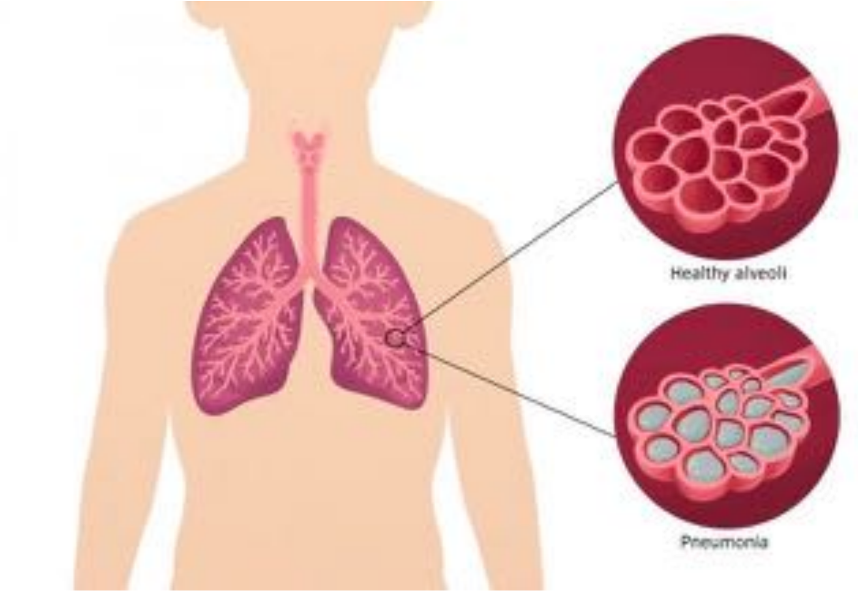




Pneumonia etiology





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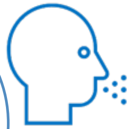
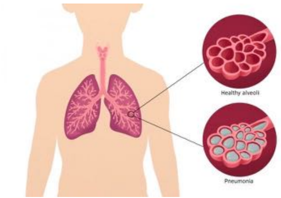
- Strong overlap with other commonly presenting respi[...] diseases





Diagnosis

Symptoms and signs

Radiograph[1,2]

- Lack of standardized interpretation
- Low sensitivity for early stages
- Specialist staff and facilities

Laboratory tests[3]

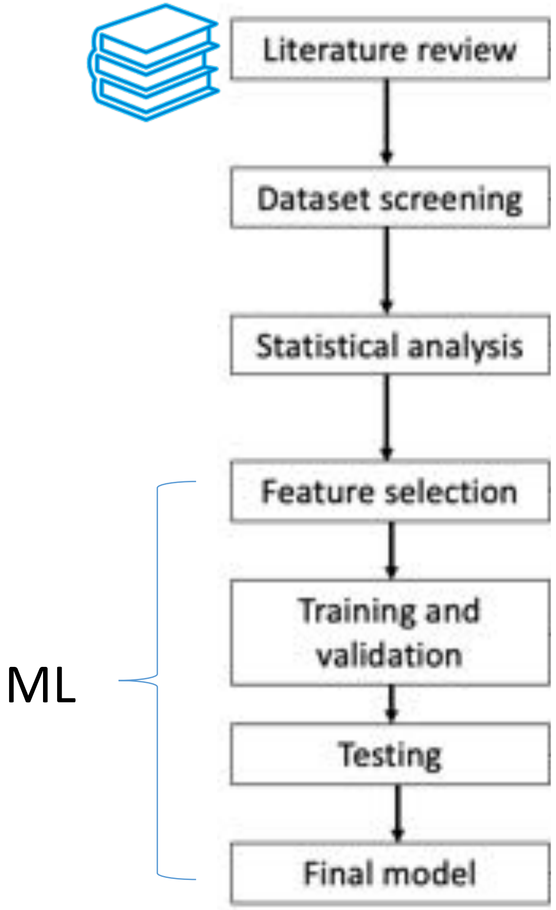
- Specialist staff and facilities
- Time
- Inconclusive

1. World Health Organization. Pneumonia Vaccine Trial Investigators, G. and O. World Health, *Standardization of interpretation of chest radiographs for the diagnosis of pneumonia in children / World Health Organization Pneumonia Vaccine Trial Investigators' Group*. 2001, World Health Organization: Geneva.
2. Garber, M.D. and R.A. Quinonez, *Chest Radiograph for Childhood Pneumonia: Good, but Not Good Enough.* Pediatrics, 2018. **142**(3): p. e20182025.
3. Principi, N. and S. Esposito, *Biomarkers in Pediatric Community-Acquired Pneumonia.* International journal of molecular sciences, 2017. **18**(2): p. 447.

Methods

- Finding the evidence: Systematic literature review
  - Type of pneumonia
  - Study design and subject population

- Machine Learning (ML) methods and performance



Review: Finding the evidence and informing ML methods

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Identify most used symptomatic predictors

Identify models frequently used

-

Lack of clarity in type and diagnosis of pneumonia

Unclear reporting of methods and performance

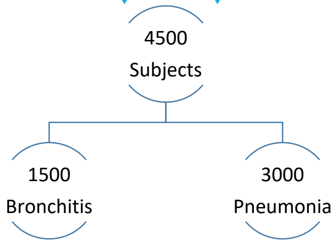
Lack of studies distinguishing pneumonia from other respiratory diseases

Commonly used symptomatic predictors:

- Fever/temperature
- abnormal breathing
- cough
- productive cough
- dyspnoea
- absence of runny nose
- chest in drawing

The dataset

- Bosnia and Herzegovina, low-middle-income country



Population descriptive

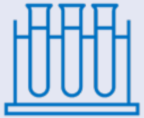
- Age
- Sex
- Exposure to air pollution
- Malnutrition
- Immunosuppression
- Allergy
- Associated diseases

Symptomatic

- Cough
- Expectoration
- Dyspnoea
- Pleura pain
- Temperature
- Fever
- Sweating
- Muscle pain
- Headache
- Loss of appetite
- Sputum
- Auscultation

Laboratory tests

- Sedimentation
- Fibrinogen
- CRP
- Leukocytes
- Neutrophils
- Lymphocytes
- Monocytes
- Basophils
- Eosinophils
- Spirometry



Machine Learning methods

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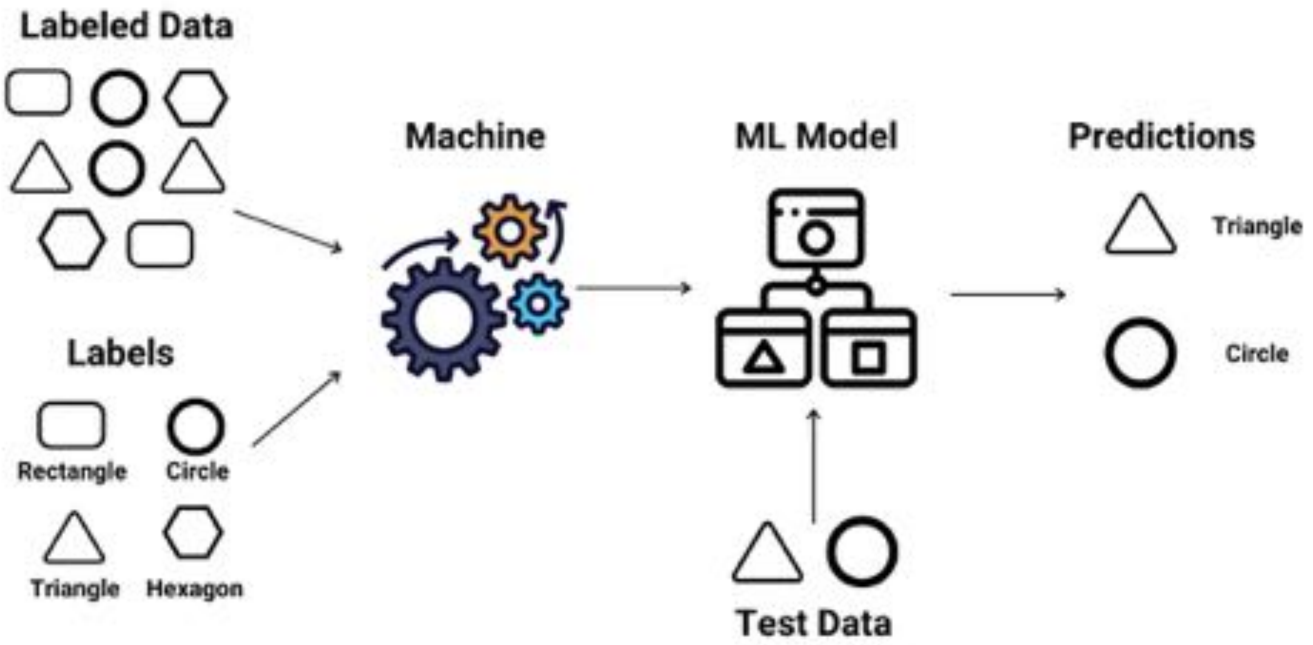
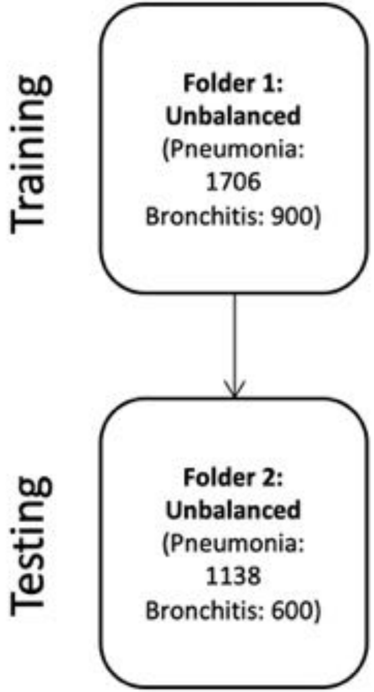
- Using symptoms/signs as predictors

- Decision tree: Set of 'if-else' conditions to predict class of a given case
    - Simple, interpretable
- Logistic regression: Simple – finds equation with coefficients for predictors and an intercept
    - Simple, interpretable
- Linear Support Vector Machine (SVM): Seeks to find optimum hyperplane giving best separation of variables
    - 'Black-box'

Foster, K.R., R. Koprowski, and J.D. Skufca, *Machine learning, medical diagnosis, and biomedical engineering research - commentary.* Biomedical engineering online, 2014. **13**: p. 94-94.

Building a Machine Learning model: Training and testing





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Machine Learning model: best predictors

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- Manual approach
  - Only considering variables measurable in low resource setting
- Several symptoms excluded as they were not reported for bronchitis patients
- Addition of population descriptive variables did not improve performance

- Cough
- Expectoration (coughing up substances)
- Dyspnoea (difficulty breathing)
- Pleura pain (chest pain)
- Temperature
- Fever
- Sweating
- Muscle pain
- Headache
- Loss of appetite
- Sputum (lung mucus inspection)
- Auscultation

Evaluating performance

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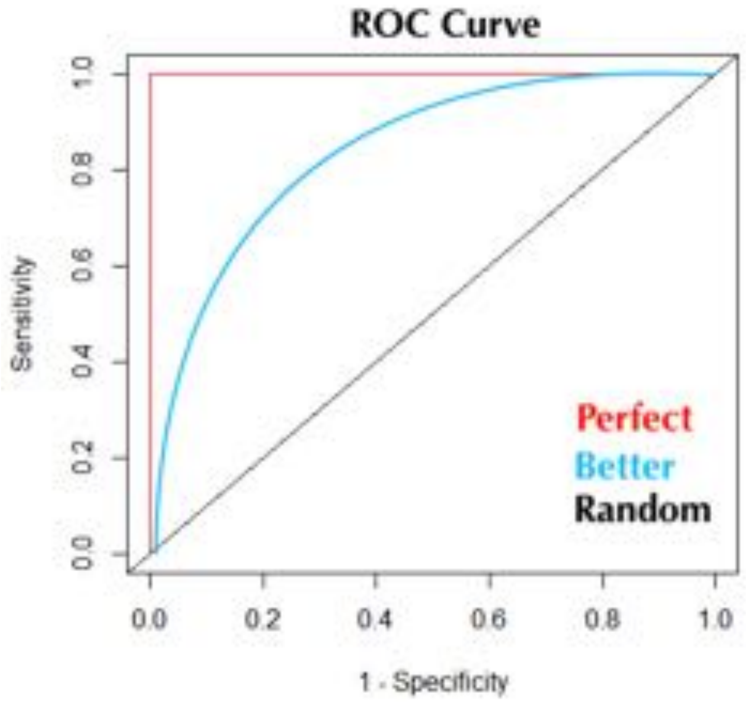
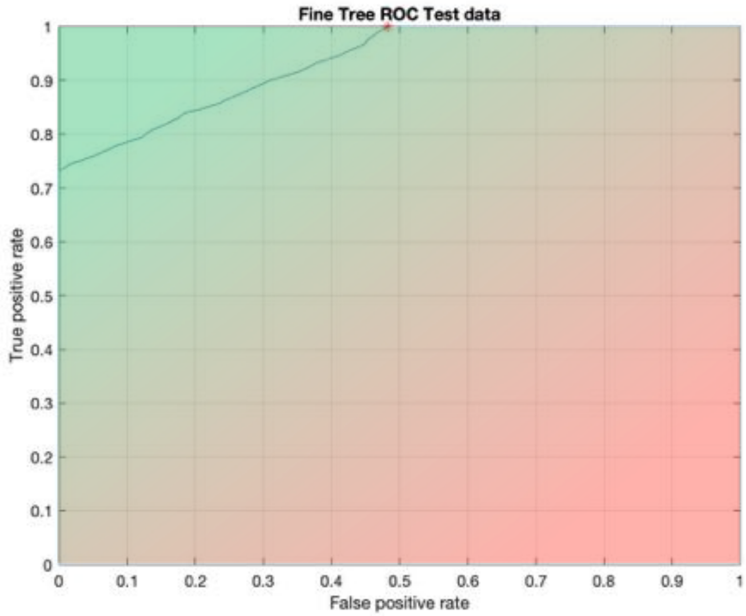
Method	AUC	Sensitivity	Specificity
Decision Tree	93%	81%	84%
SVM	93%	78%	86%
LR	93%	73%	88%

- Comparable with results of literature review
- Good interpretability of final model

Evaluating performance





Conclusion

- Future work:
  - Verify/validate model using data form low-income countries/populations with high pneumonia burden
  - Inclusion of additional commonly co-presenting respiratory diseases
  - Explore improvements in performance
    - Incorporation of sensor readings: e.g., cough sounds, temperature reading
- Limitations:
  - Only distinguishing 2 respiratory diseases
  - No information on type of pneumonia or diagnosis criteria
  - Some symptoms not measurable by all healthcare workers – such as auscultation

Acknowledgements/ publications

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- Rosanna Castaldo and Leandro Pecchia (supervision)
- Lejla Gurbeta Pokvic, Almir Badnjevic (data)

- Stokes K, Castaldo R, Federici C, et al. The use of artificial intelligence systems in diagnosis of pneumonia via signs and symptoms: A systematic review. *Biomedical Signal Processing and Control* 2022;72:103325. doi: https://doi.org/10.1016/j.bspc.2021.103325
- Stokes K, Castaldo R, Franzese M, et al. A machine learning model for supporting symptom-based referral and diagnosis of bronchitis and pneumonia in limited resource settings. *Biocybernetics and Biomedical Engineering* 2021;41(4):1288-302. doi: https://doi.org/10.1016/j.bbe.2021.09.002

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Questions/discussion

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