

Integrating complex multimodal health data for clinical prediction with artificial intelligence



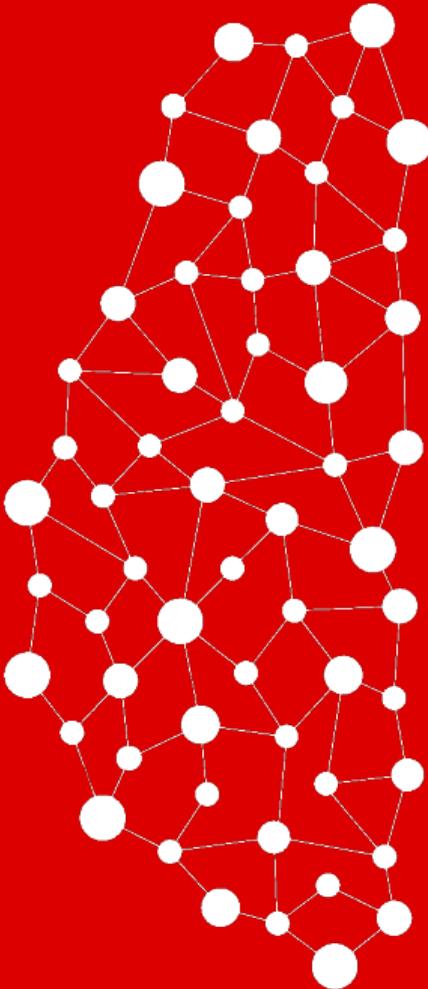
Esten H. Leonardsen

Post-doktor ved Psykologisk institutt,
Universitet i Oslo

Chief Scientific Officer, baba.vision



UNIVERSITETET
I OSLO



What is artificial intelligence?

What is AI?

Artificial Intelligence (AI) is the field of computer science devoted to creating systems that can perform tasks that typically require human intelligence. These tasks include perception (e.g., recognizing images or speech), reasoning (e.g., solving problems, making decisions), learning (e.g., adapting from data and experience), and interaction (e.g., understanding natural language, generating responses, collaborating with humans).

At a high level, AI can be divided into:

- Symbolic AI (knowledge-based, rule-based, expert systems): Uses explicit rules, logic, and symbolic representations to encode reasoning.
- Machine Learning (data-driven): Learns patterns from data, with subfields like deep learning, reinforcement learning, and probabilistic modeling.

AI is not a single method but a spectrum of approaches for replicating or augmenting cognitive functions in machines.

Would you like me to give you a concise working definition (one sentence) or a taxonomy of types of AI (narrow, general, superintelligence, etc.)?



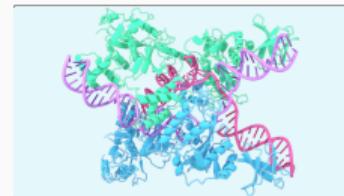
ChatGPT



Spot



Sophia

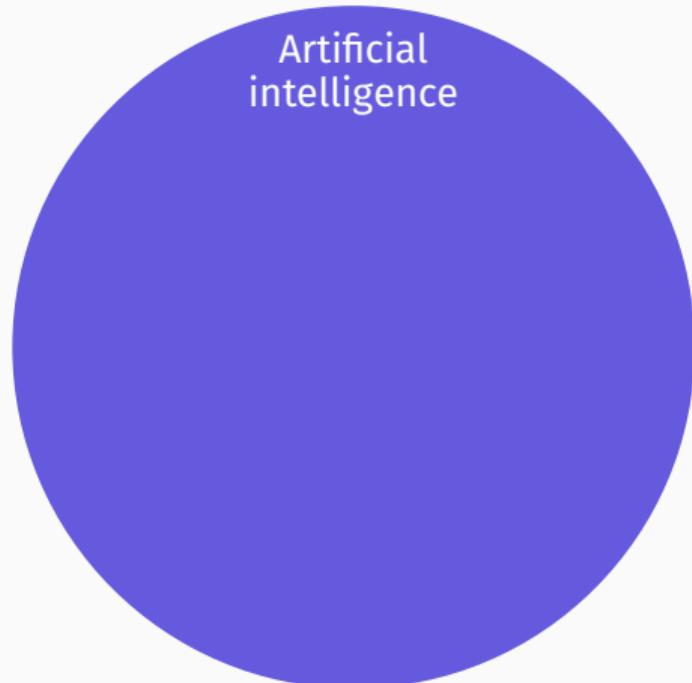


AlphaFold



AlphaZero

What is artificial intelligence?

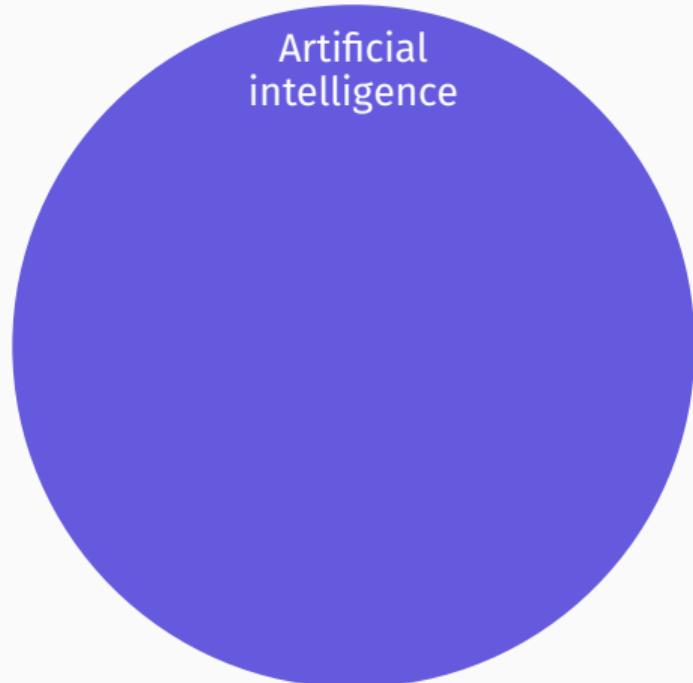


Artificial intelligence

Technology that solves tasks requiring some form of intelligence



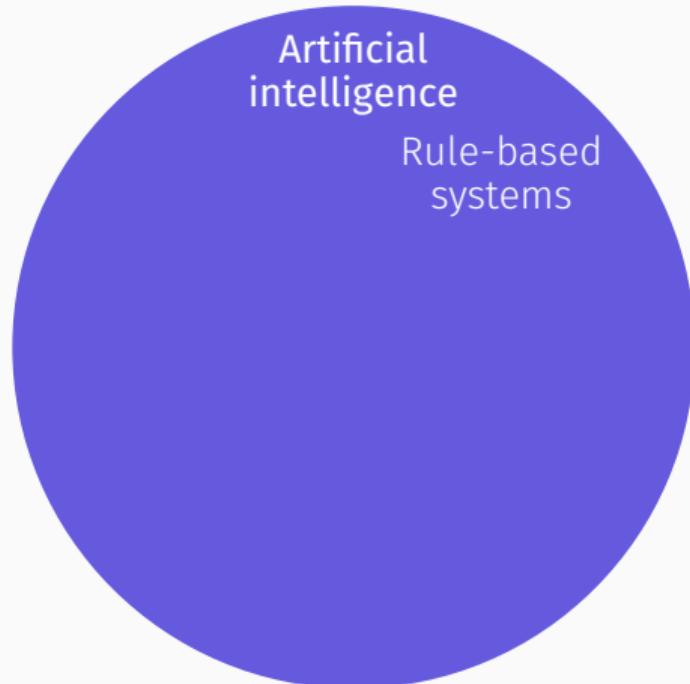
What is artificial intelligence?



Artificial intelligence

The field of study producing technology that solves tasks requiring some form of intelligence

What is artificial intelligence?



Artificial intelligence

The field of study producing technology that solves tasks requiring some form of intelligence

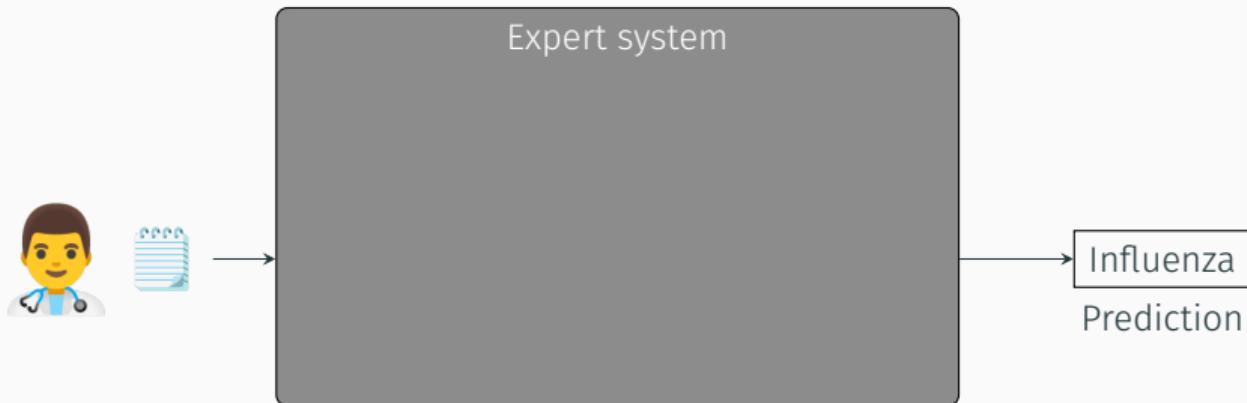


What is artificial intelligence?

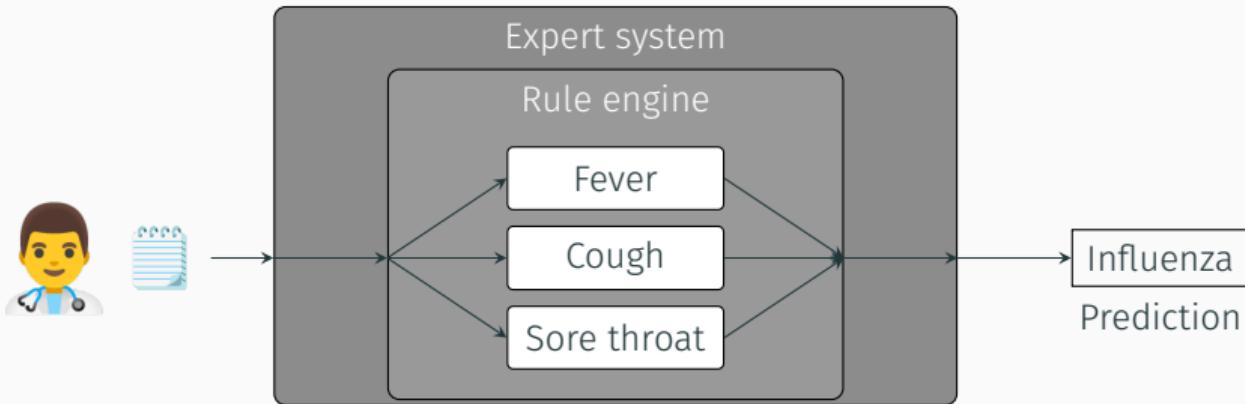
Expert system



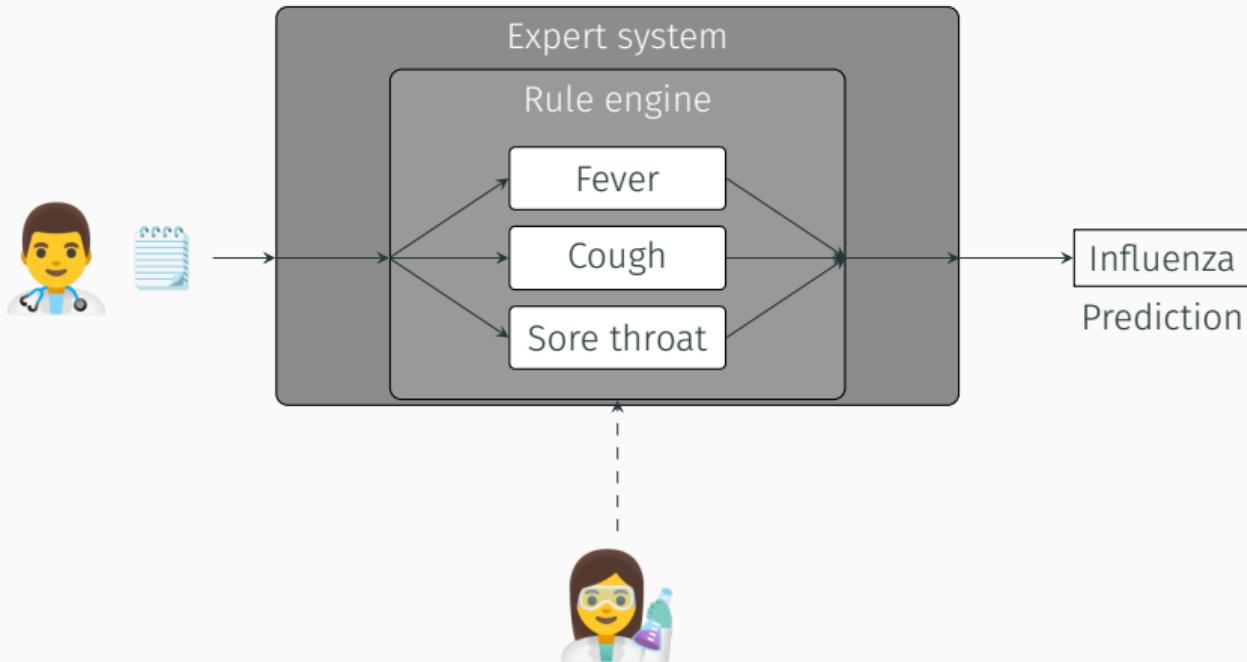
What is artificial intelligence?



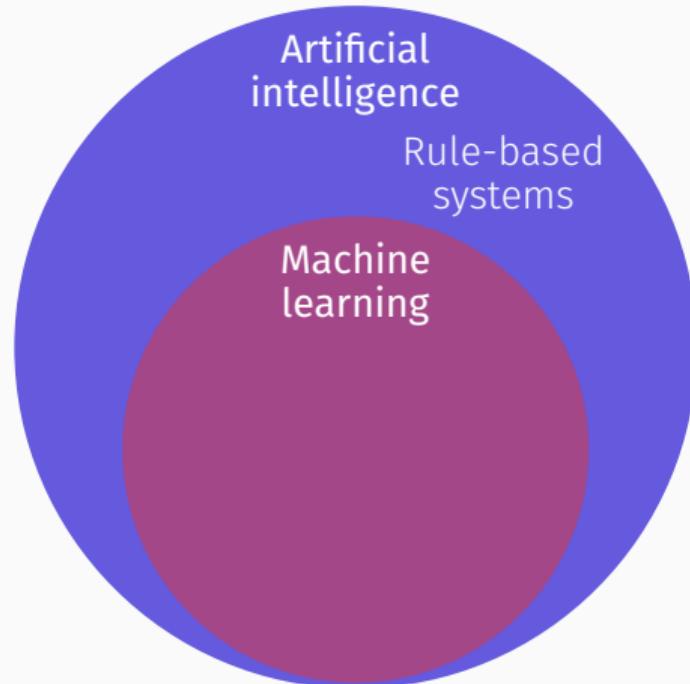
What is artificial intelligence?



What is artificial intelligence?



What is artificial intelligence?

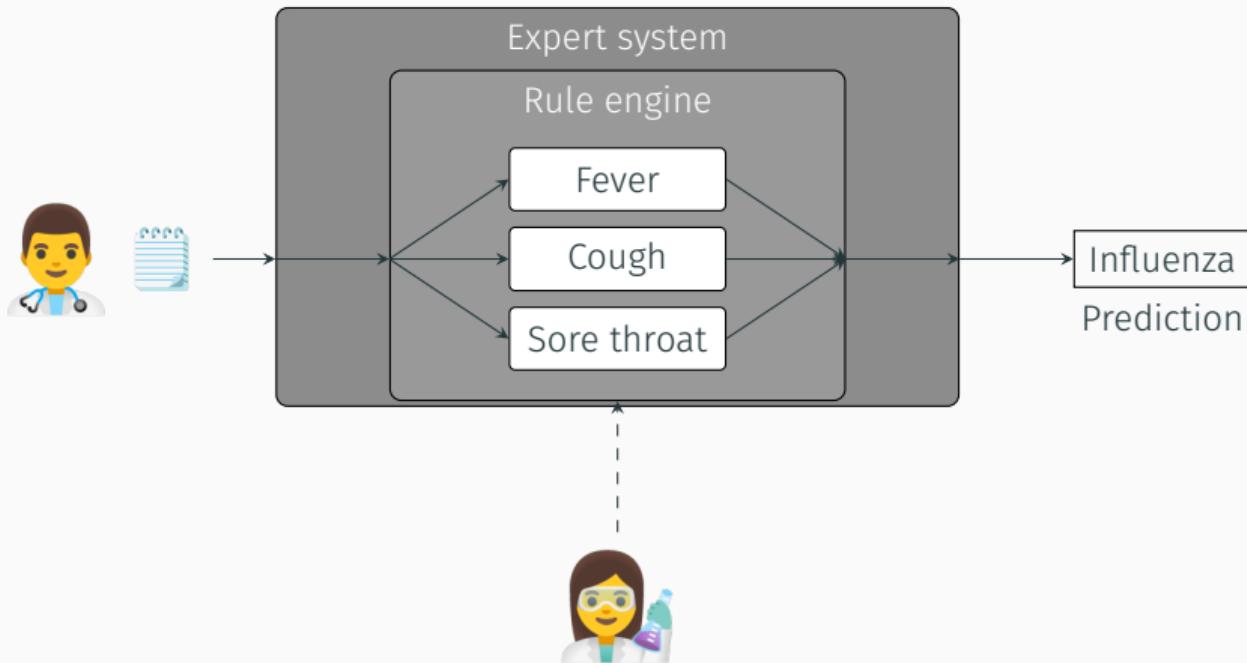


Artificial intelligence

The field of study producing technology that solves tasks requiring some form of intelligence



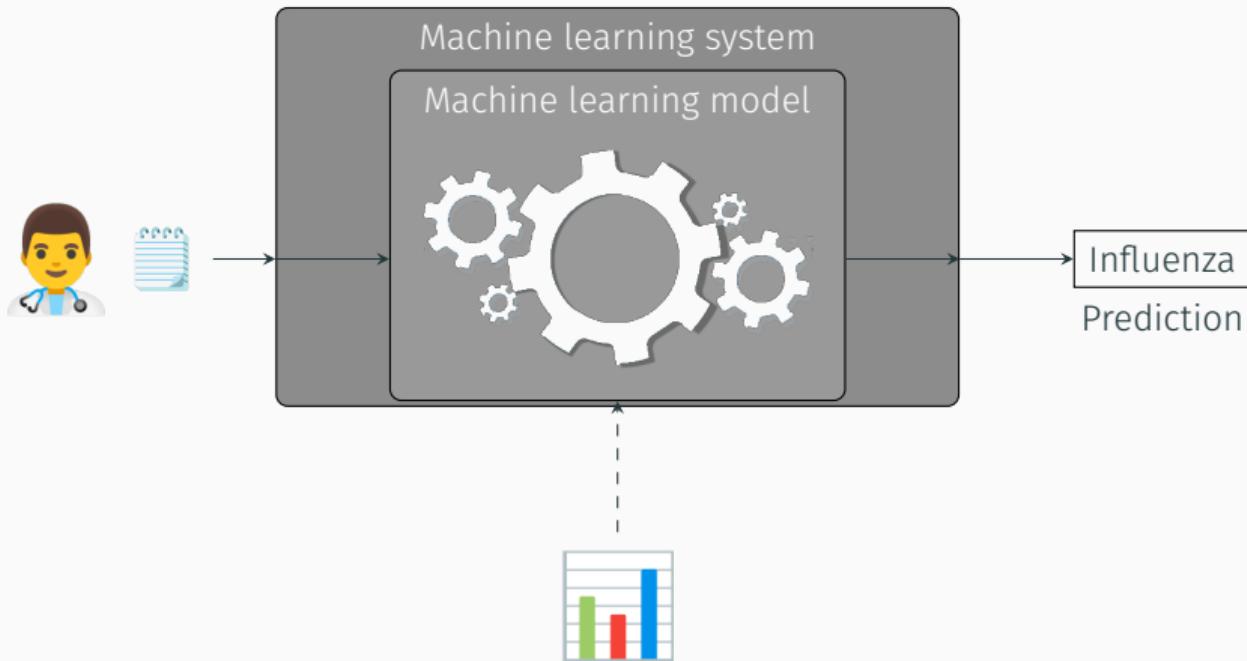
What is artificial intelligence?



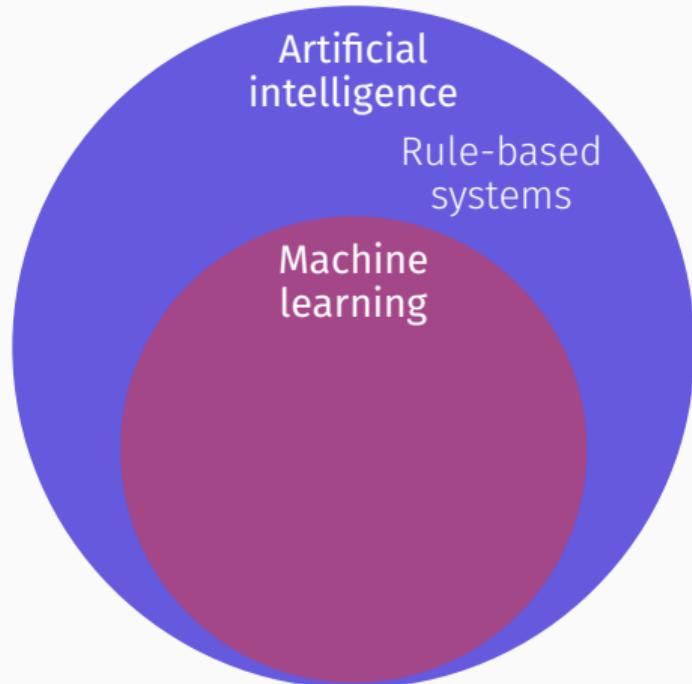
What is artificial intelligence?



What is artificial intelligence?



What is artificial intelligence?



Artificial intelligence

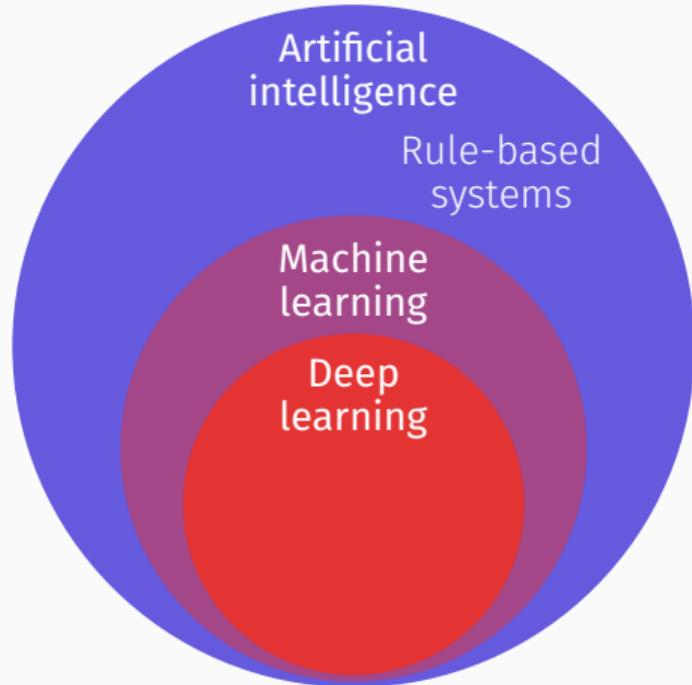
The field of study producing technology that solves tasks requiring some form of intelligence

Machine learning

A set of techniques to solve problems by allowing machines to find patterns in training data



What is artificial intelligence?



Artificial intelligence

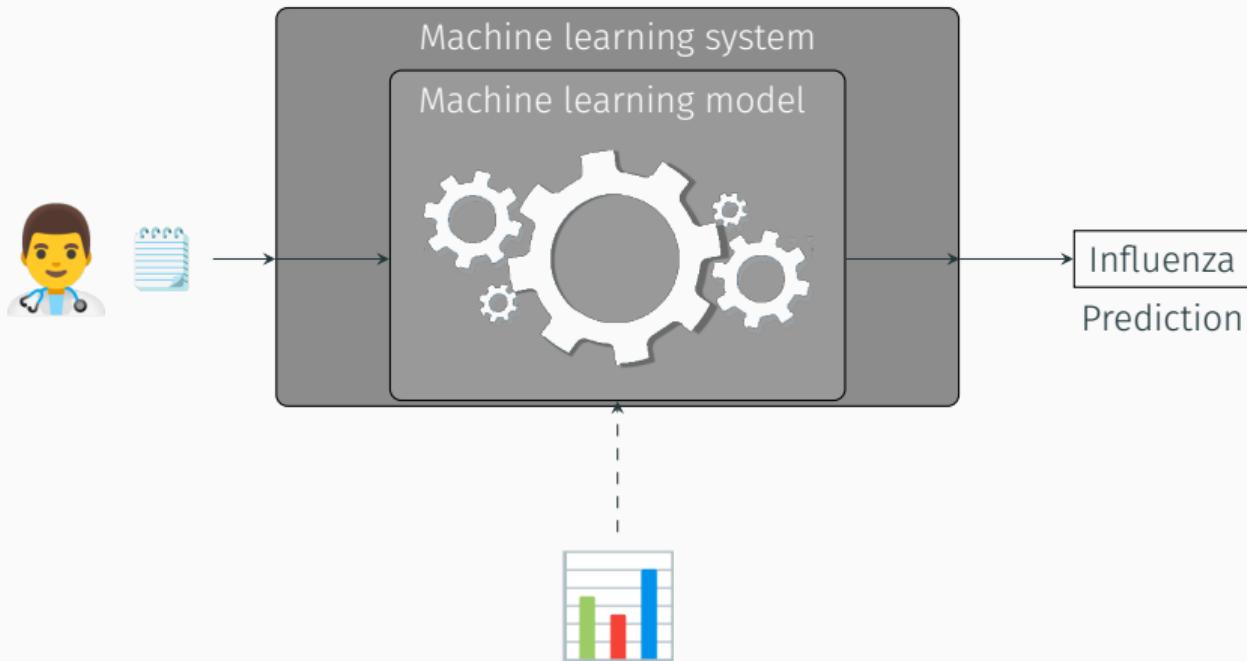
The field of study producing technology that solves tasks requiring some form of intelligence

Machine learning

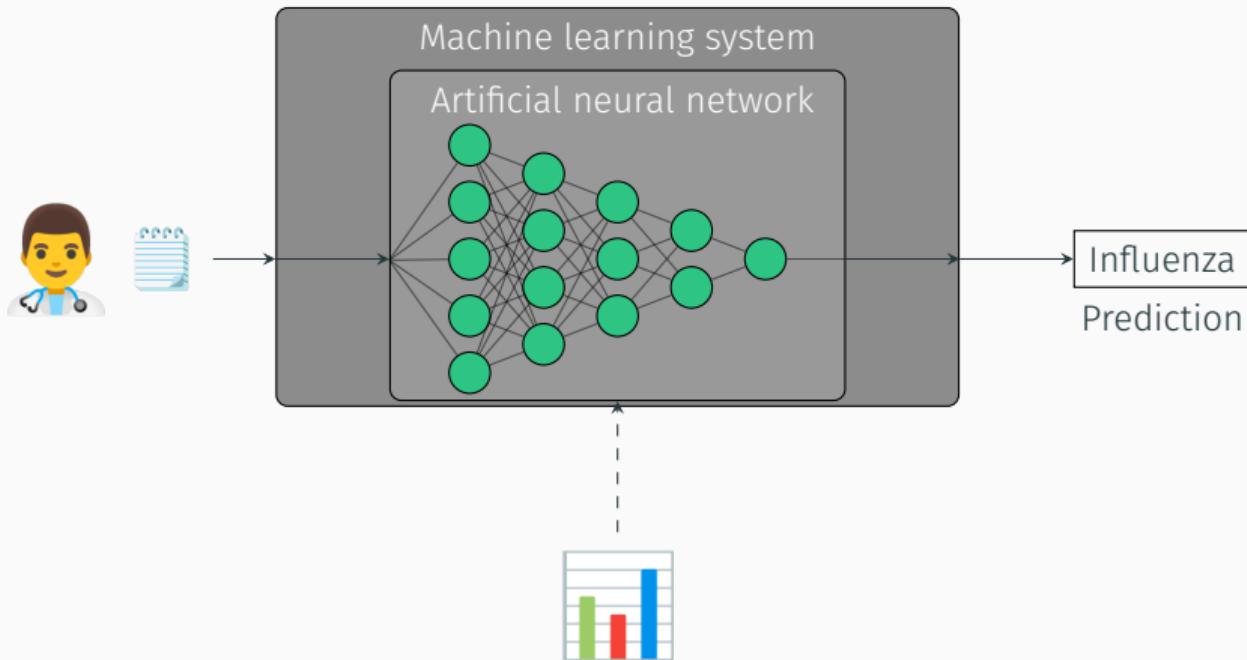
A set of techniques to solve problems by allowing machines to find patterns in training data



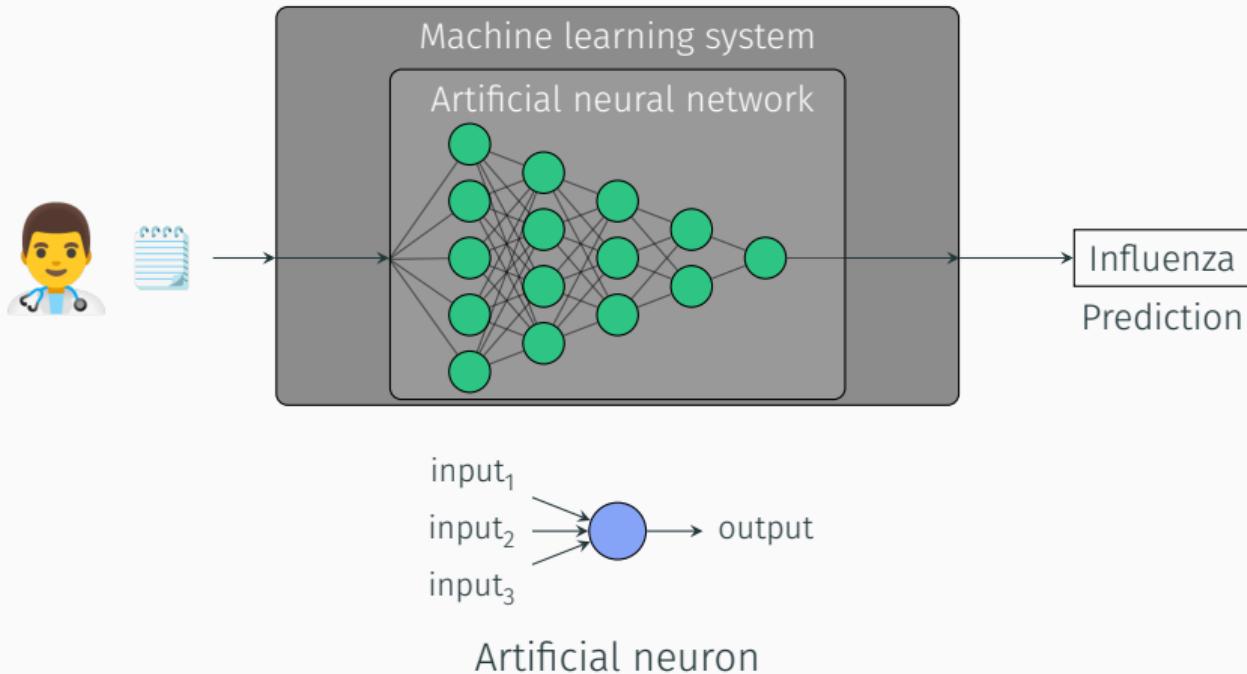
What is artificial intelligence?



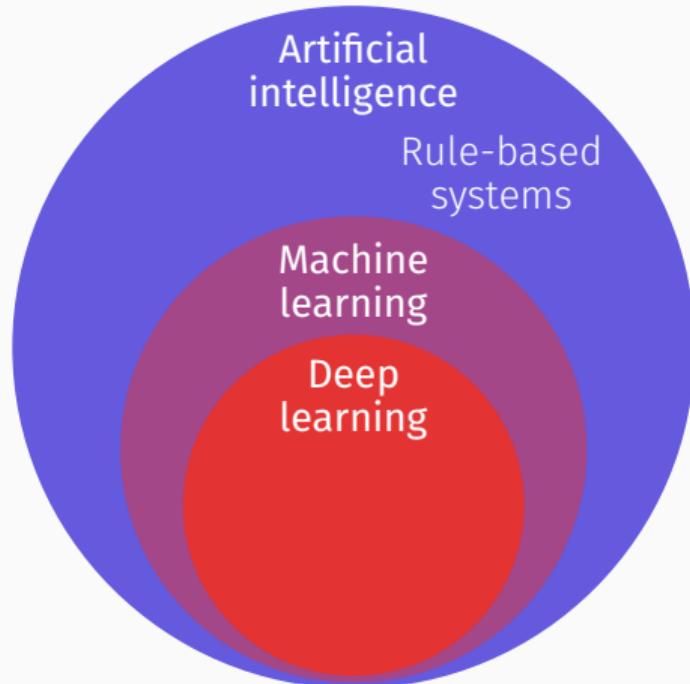
What is artificial intelligence?



What is artificial intelligence?



What is artificial intelligence?



Artificial intelligence

The field of study producing technology that solves tasks requiring some form of intelligence

Machine learning

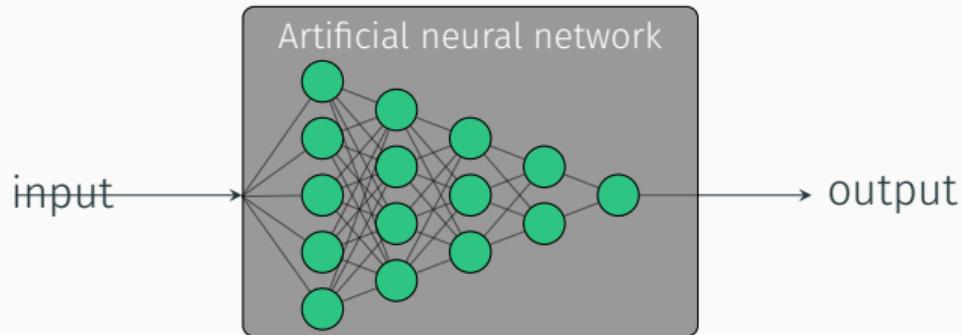
A set of techniques to solve problems by allowing machines to find patterns in training data

Deep learning

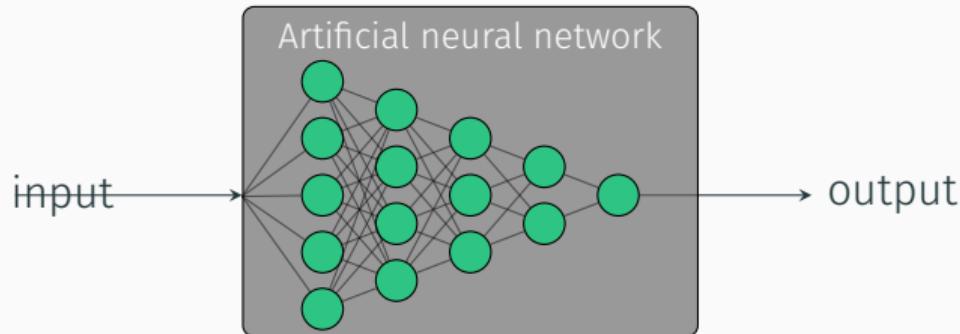
Machine learning approaches that rely on artificial neural networks



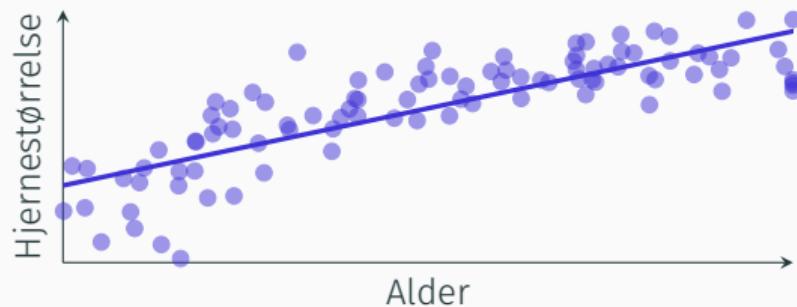
Why do we use artificial neural networks?



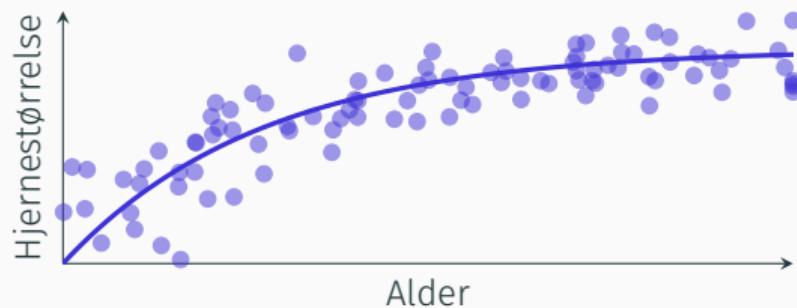
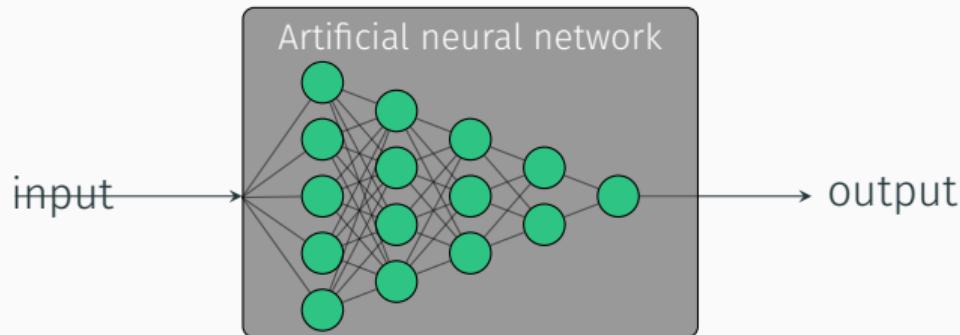
Why do we use artificial neural networks?



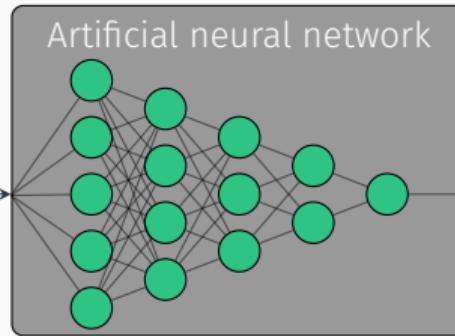
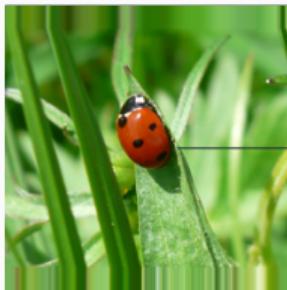
Why do we use artificial neural networks?



Why do we use artificial neural networks?



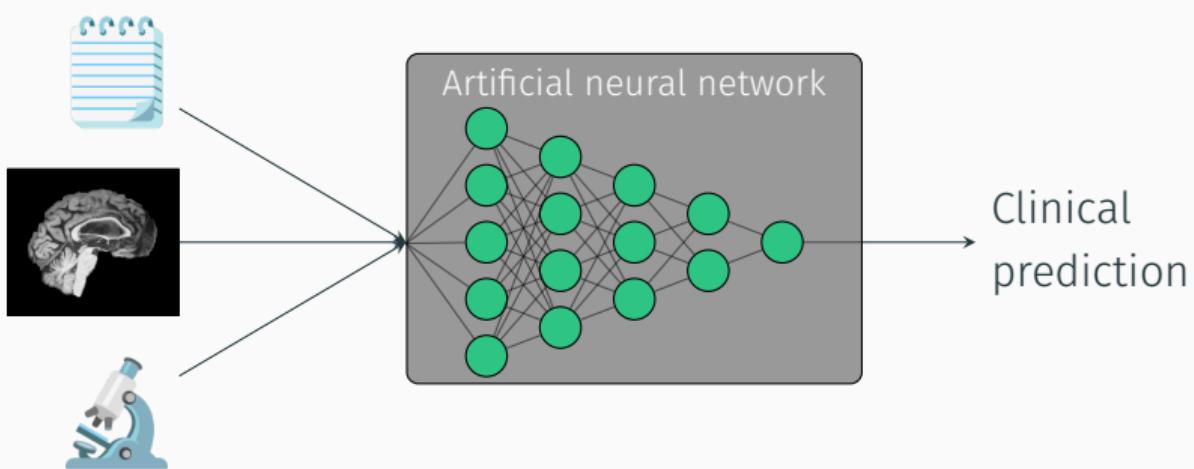
Why do we use artificial neural networks?



ladybug



Why do we use artificial neural networks?

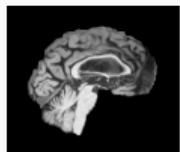


Integrating multimodal health data for clinical predictions

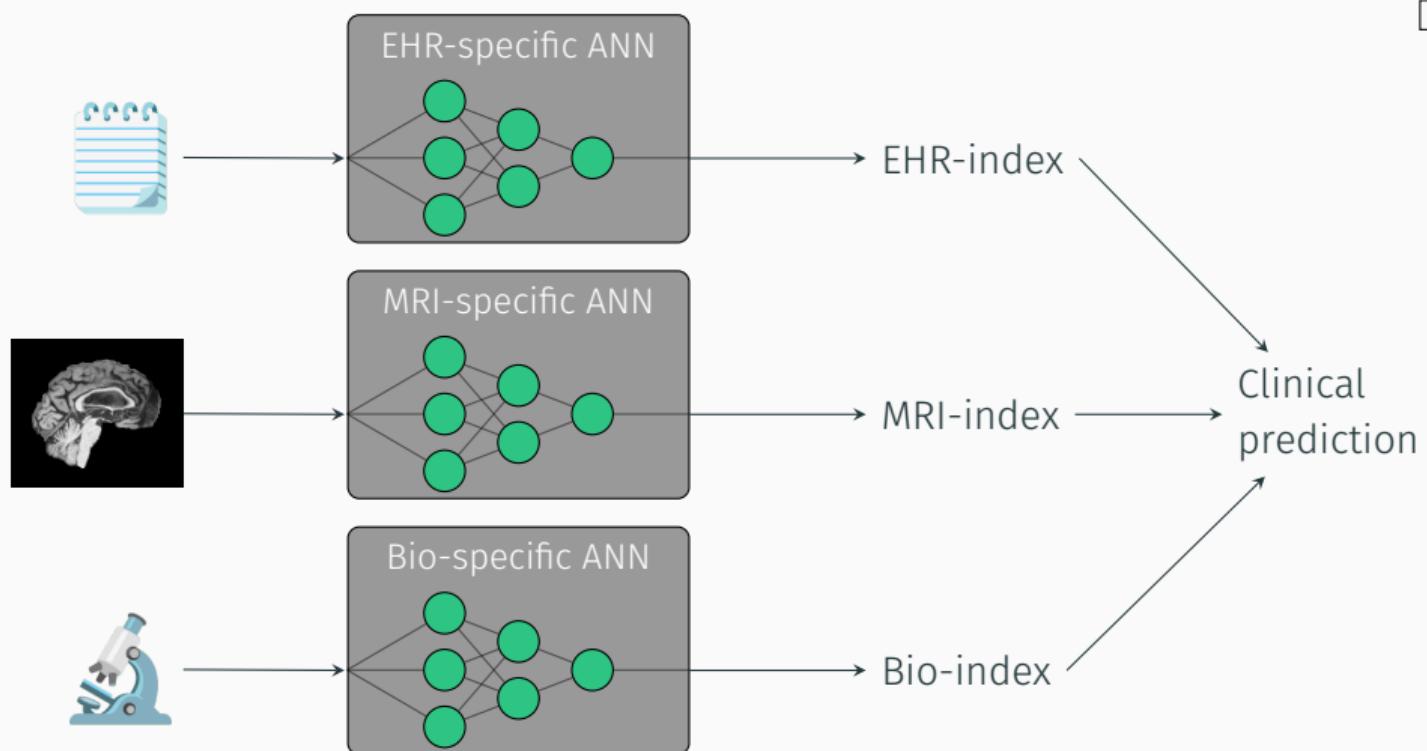


UNIVERSITETET
I OSLO

Late fusion: independent insights, combined decisions



Late fusion: independent insights, combined decisions





Research | [Open access](#) | Published: 27 November 2024

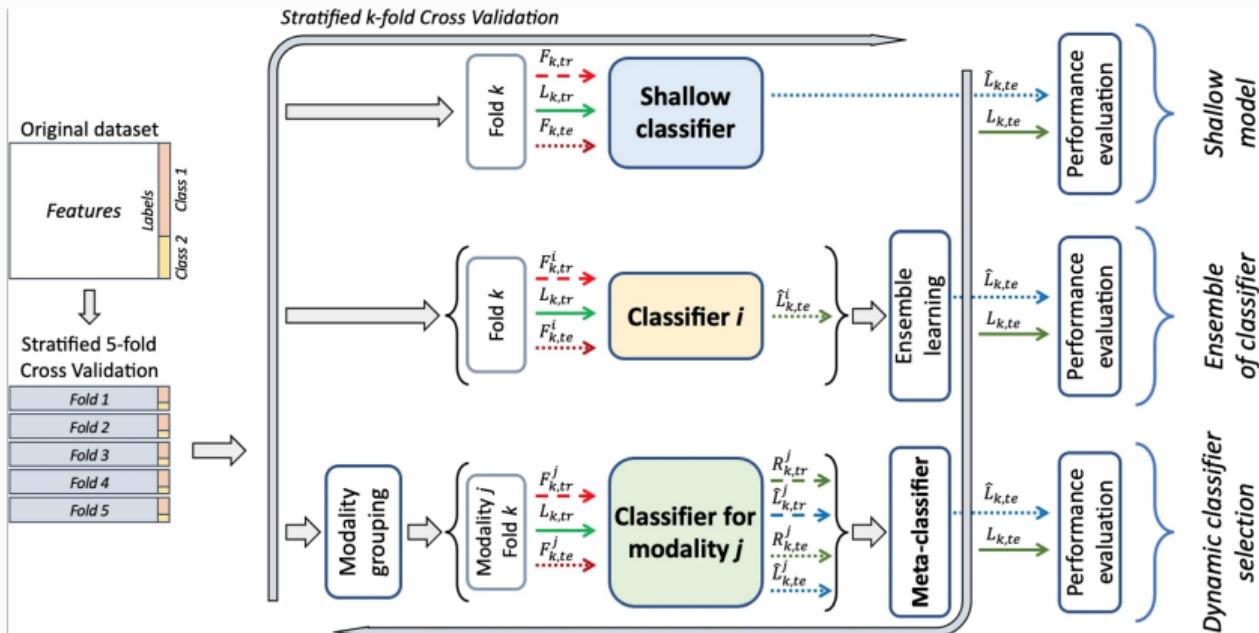
Machine learning predicts pulmonary Long Covid sequelae using clinical data

[Ermanno Cordelli](#), [Paolo Soda](#)✉, [Sara Citter](#), [Elia Schiavon](#), [Christian Salvatore](#), [Deborah Fazzini](#), [Greta Clementi](#), [Michaela Cellina](#), [Andrea Cozzi](#), [Chandra Bortolotto](#), [Lorenzo Preda](#), [Luisa Francini](#), [Matteo Tortora](#), [Isabella Castiglioni](#), [Sergio Papa](#), [Diego Sona](#) & [Marco Ali](#)

[BMC Medical Informatics and Decision Making](#) 24, Article number: 359 (2024) | [Cite this article](#)



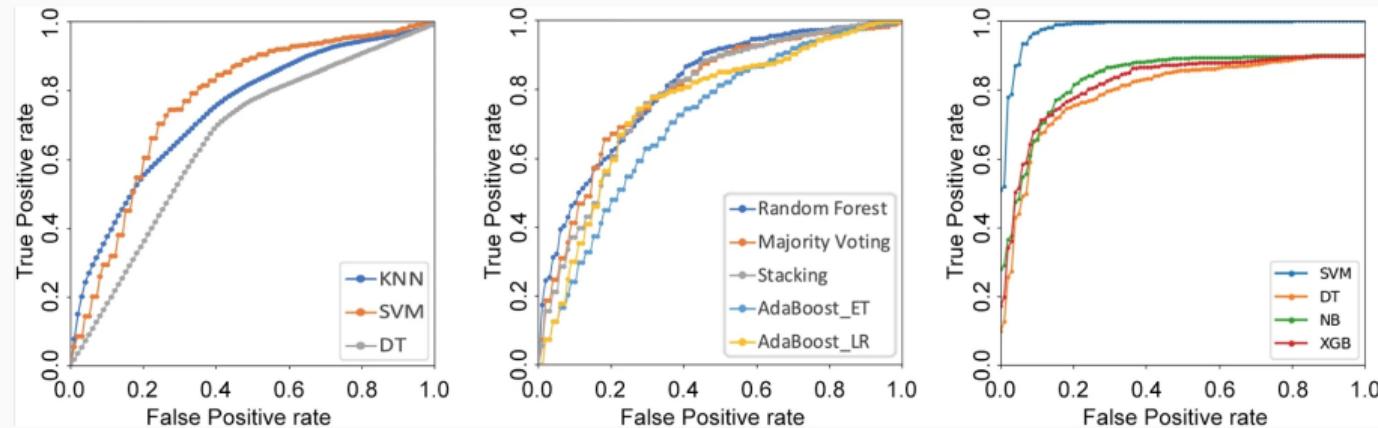
Late fusion: independent insights, combined decisions



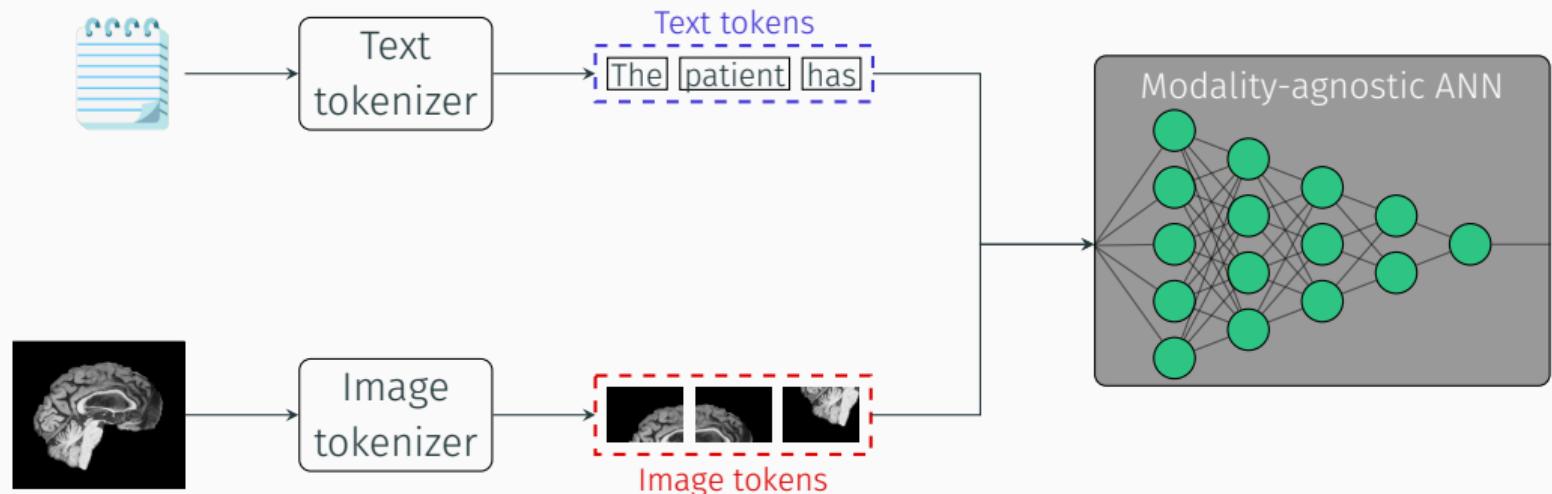
Late fusion: independent insights, combined decisions



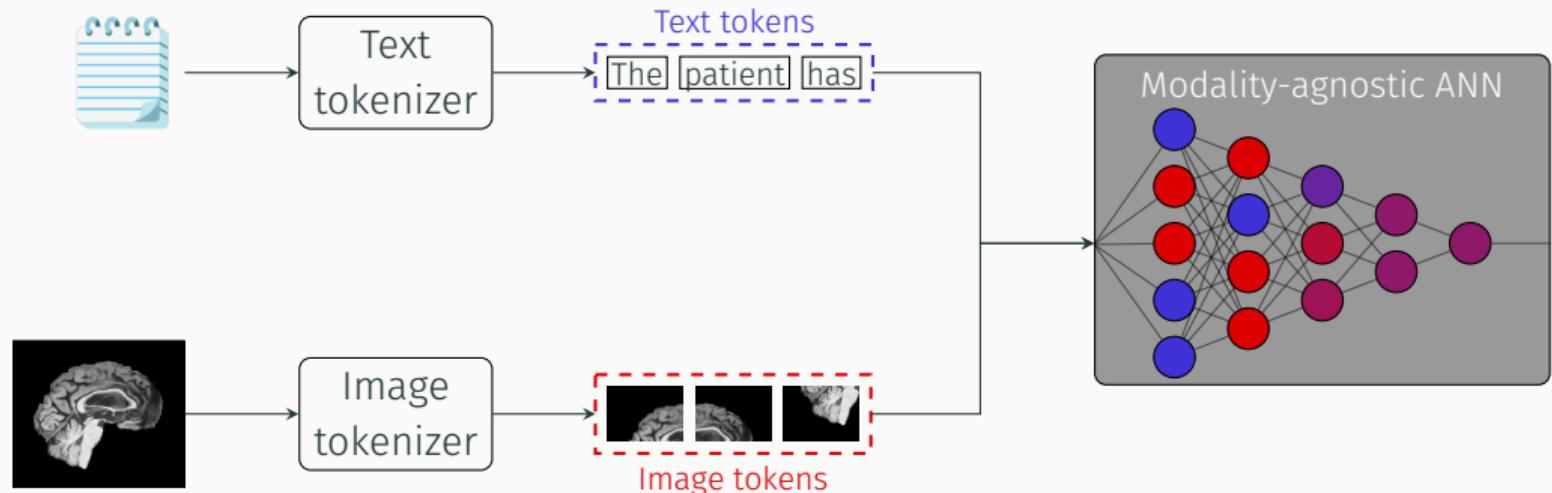
Late fusion: independent insights, combined decisions



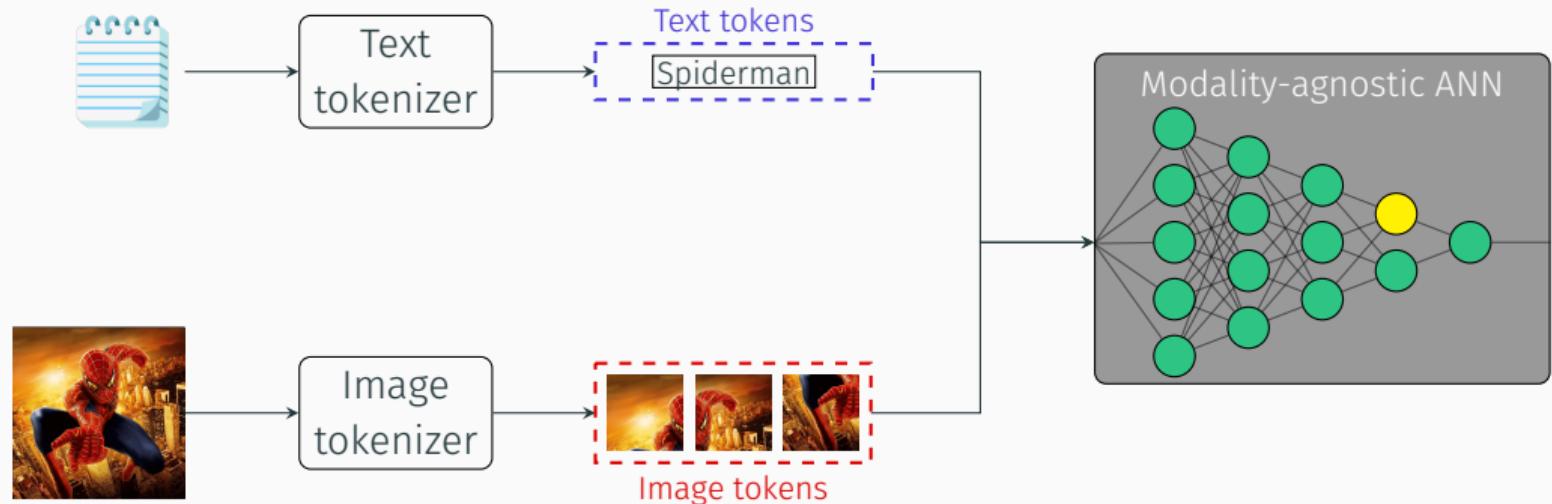
Early fusion: blending information from the start



Early fusion: blending information from the start



Early fusion: blending information from the start





Article | Published: 07 August 2024

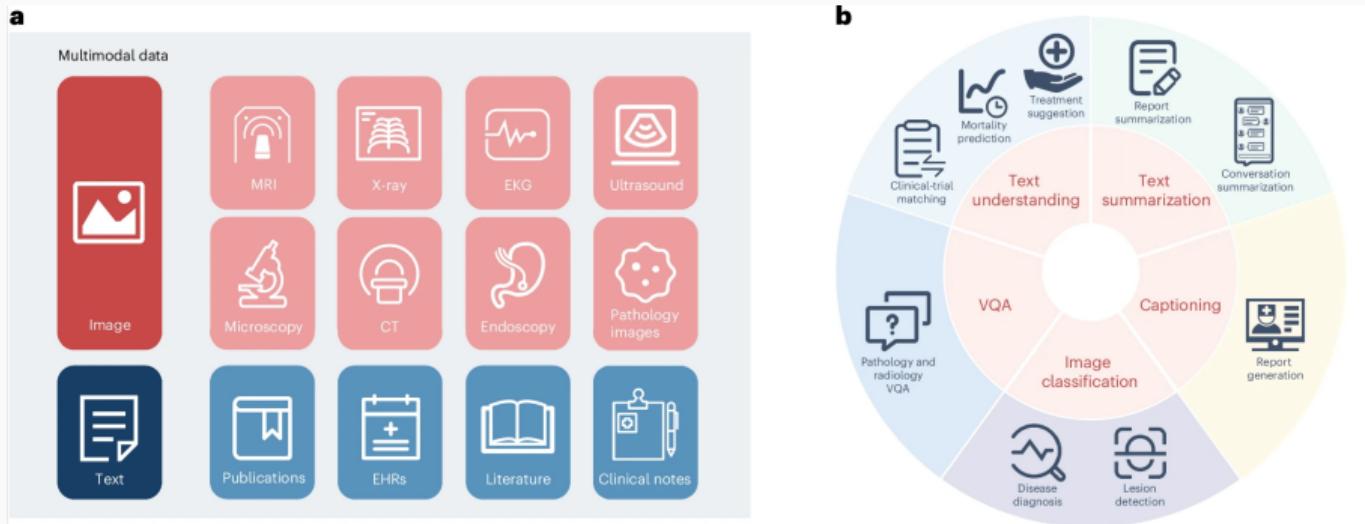
A generalist vision–language foundation model for diverse biomedical tasks

[Kai Zhang](#), [Rong Zhou](#), [Eashan Adhikarla](#), [Zhiling Yan](#), [Yixin Liu](#), [Jun Yu](#), [Zhengliang Liu](#), [Xun Chen](#), [Brian D. Davison](#), [Hui Ren](#), [Jing Huang](#), [Chen Chen](#), [Yuyin Zhou](#), [Sunyang Fu](#), [Wei Liu](#), [Tianming Liu](#), [Xiang Li](#)✉, [Yong Chen](#), [Lifang He](#)✉, [James Zou](#), [Quanzheng Li](#), [Hongfang Liu](#) & [Lichao Sun](#)✉

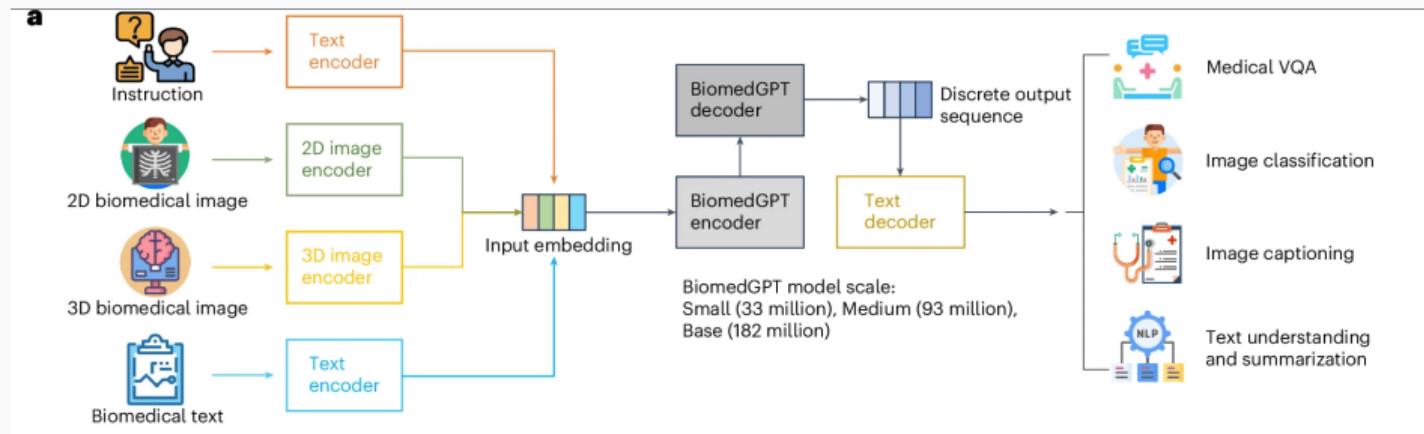
Nature Medicine **30**, 3129–3141 (2024) | [Cite this article](#)



Early fusion: blending information from the start



Early fusion: blending information from the start



Early fusion: blending information from the start



c

Pathology and radiology VQA



Q: What is seen at this stage, associated with regeneration and repair?
A: Numerous reactive type II pneumocytes.

Q: Are bite cells like this one in the smear associated with regeneration and repair at this stage?
A: No.

Report generation



Q: What are the findings based on the image?
A: The nasogastric tube is in adequate position, and there is a resolution of the gastric distention. There is still mild bibasilar atelectasis. There are no pneumothorax no pleural effusion.

Disease diagnosis



Q: What disease does this image depict?
A: Breast cancer.

Lesion detection



Q: What skin lesion does this image depict?
A: Melanoma.



Early fusion: blending information from the start

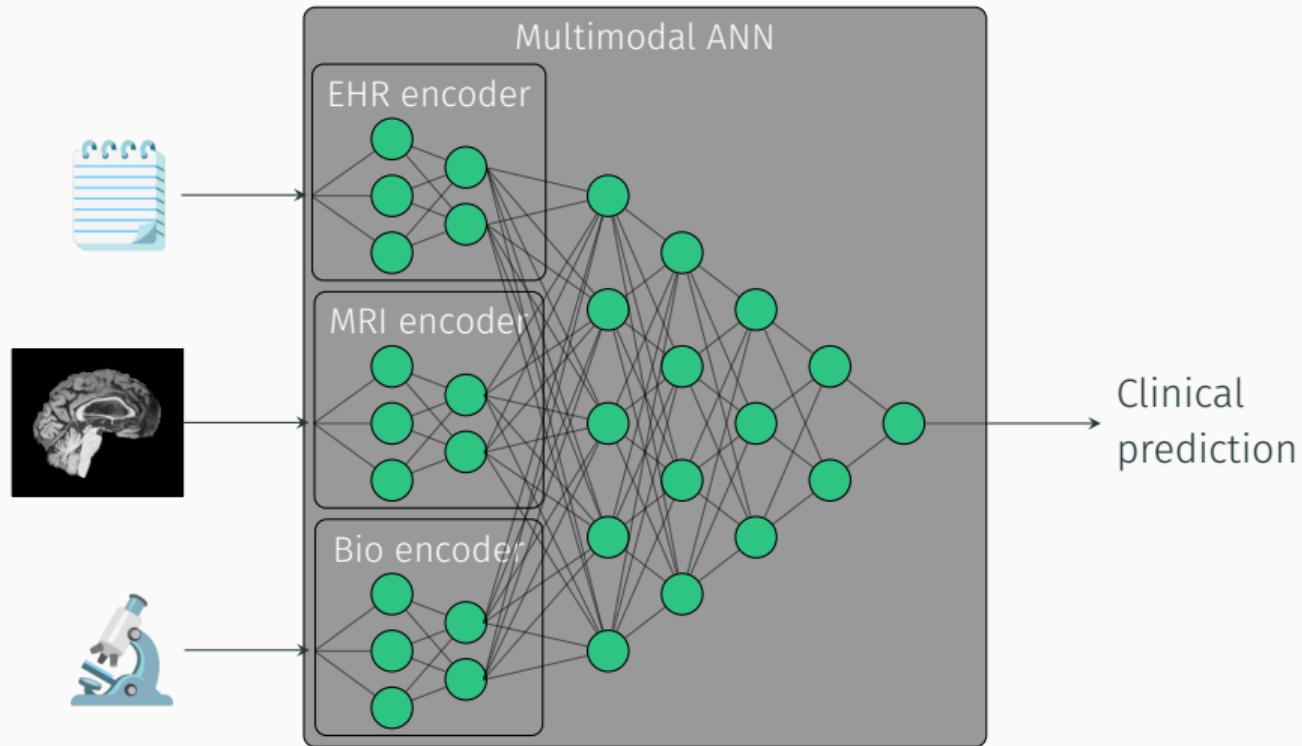


g Average zero-shot accuracy (%) across seven question types

	GPT-4V	BiomedGPT-B	BiomedGPT-M	BiomedGPT-S	OFA-large	Instruct-BiomedGPT-B	Instruct-BiomedGPT-M	Instruct-BiomedGPT-S	LLaVA-med	OFA-huge
Disease diagnosis	50.9	43.5	35.4	45.2	32.8	53.9	52.1	32.6	42.0	34.5
Imaging technical details	73.3	41.0	19.9	19.5	20.9	68.8	68.0	58.1	67.6	20.4
Lesion and abnormality detection	48.6	37.2	38.7	41.2	45.5	49.5	52.9	45.9	40.6	40.6
Modality recognition	77.9	68.7	59.6	42.7	43.4	77.1	69.5	55.5	69.4	55.0
Size assessment	46.6	39.7	59.4	37.8	42.9	44.6	65.3	39.5	68.6	44.6
Spatial relationships	47.7	14.4	21.8	9.5	23.6	44.0	31.8	27.6	35.4	28.2
Structural identification	52.0	41.3	28.8	32.4	30.7	43.1	35.2	37.0	41.0	40.0



Intermediate fusion: integrating insights along the way





Research | [Open access](#) | Published: 09 November 2023

Predicting multiple sclerosis severity with multimodal deep neural networks

[Kai Zhang](#), [John A. Lincoln](#), [Xiaoqian Jiang](#), [Elmer V. Bernstam](#) & [Shayan Shams](#) 

[BMC Medical Informatics and Decision Making](#) 23, Article number: 255 (2023) | [Cite this article](#)



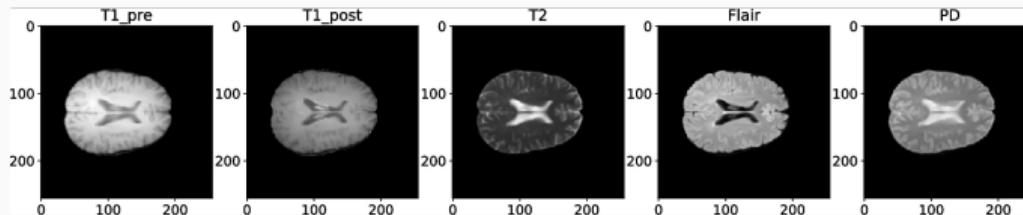
Intermediate fusion: integrating insights along the way



Structured EHR

LABORATORY TEST		VITAL SIGN		MEDICATION
Mean Corpuscular Hemoglobin	Carbon Dioxide	Albumin	Diastolic Blood Pressure	Acetaminophen
Red Cell Distribution Width	Neutrophils	Glucose Level	Systolic Blood Pressure	Gabapentin
Mean Corpuscular Hemoglobin Concentration	White Blood Cell Count	eGFR	Heart Rate	Copaxone
Mean Corpuscular Volume	Hematocrit	Albumin/Globulin Ratio	Weight	Gilenya

Multimodal MRI

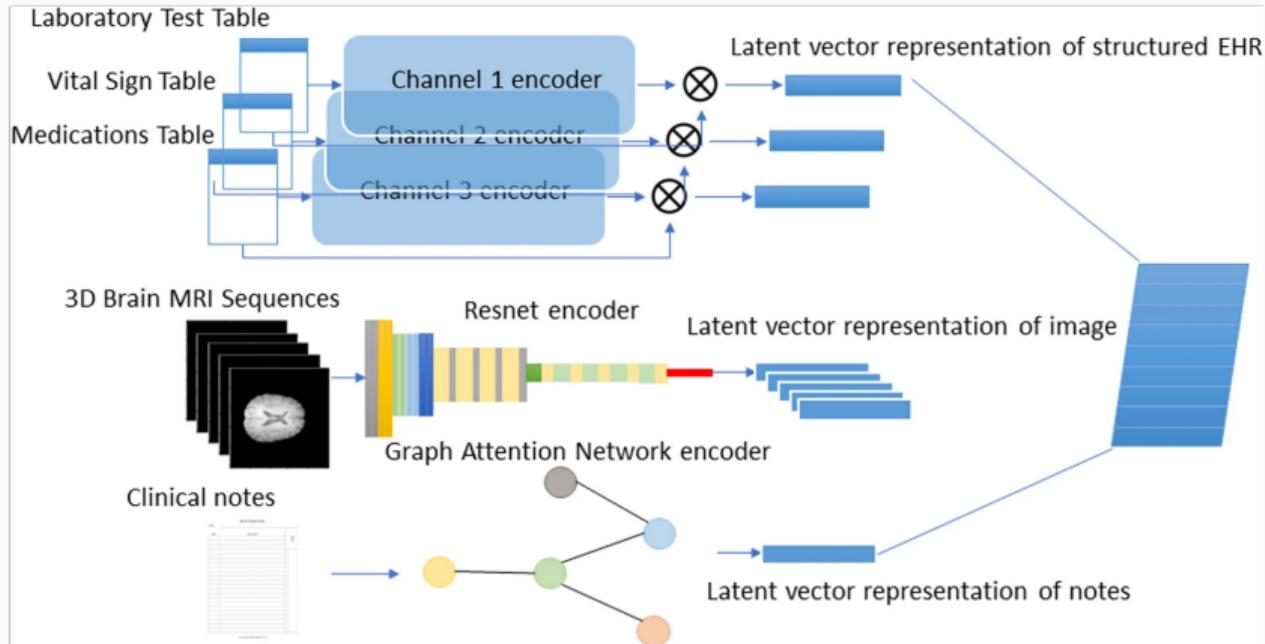


Clinical notes

The patient's clinical notes are documented in unstructured free-text format and provide a comprehensive account of the patient's health status. These notes encompass a range of vital



Intermediate fusion: integrating insights along the way



Intermediate fusion: integrating insights along the way



	AUROC	AUPRC	Sensitivity	Specificity	Accuracy
MRI T1-pre	0.6462 ± 0.0352	0.2074 ± 0.0145	0.5089 ± 0.0397	0.7679 ± 0.0209	0.6567 ± 0.0300
MRI T1-post	0.6437 ± 0.0389	0.2027 ± 0.0180	0.5501 ± 0.0390	0.6536 ± 0.0252	0.6697 ± 0.0199
MRI T2	0.7736 ± 0.0268	0.2245 ± 0.0198	0.6834 ± 0.0223	0.7409 ± 0.0398	0.7467 ± 0.0390
MRI FLAIR	0.7945 ± 0.2798	0.3306 ± 0.0309	0.7689 ± 0.0261	0.7423 ± 0.0265	0.7423 ± 0.0399
MRI PD	0.5430 ± 0.0401	0.0998 ± 0.0321	0.7536 ± 0.0218	0.4862 ± 0.0300	0.5046 ± 0.0399
Clinical Notes	0.7048 ± 0.0365	0.5201 ± 0.0293	0.4632 ± 0.0320	0.8956 ± 0.0235	0.4958 ± 0.0301
Structured EHR	0.6589 ± 0.0193	0.3651 ± 0.0265	0.7015 ± 0.0263	0.6587 ± 0.0366	0.6984 ± 0.0265
MRIs & Notes	0.7988 ± 0.0465	0.6321 ± 0.0299	0.7024 ± 0.0536	0.7792 ± 0.0563	0.7963 ± 0.0422
MRIs & EHR	0.7836 ± 0.0531	0.4265 ± 0.0323	0.6789 ± 0.0411	0.6875 ± 0.0333	0.6841 ± 0.0523
EHR & Notes	0.8078 ± 0.0232	0.7978 ± 0.0453	0.7268 ± 0.0435	0.7643 ± 0.0255	0.8125 ± 0.0353
MS-BERT([11])	0.6010 ± 0.0222	0.2064 ± 0.0356	0.3090 ± 0.0265	0.7936 ± 0.0512	0.7788 ± 0.0398
MRI & Notes & EHR	0.8380 ± 0.0438	0.7963 ± 0.0520	0.7489 ± 0.0502	0.7936 ± 0.0488	0.7960 ± 0.0312

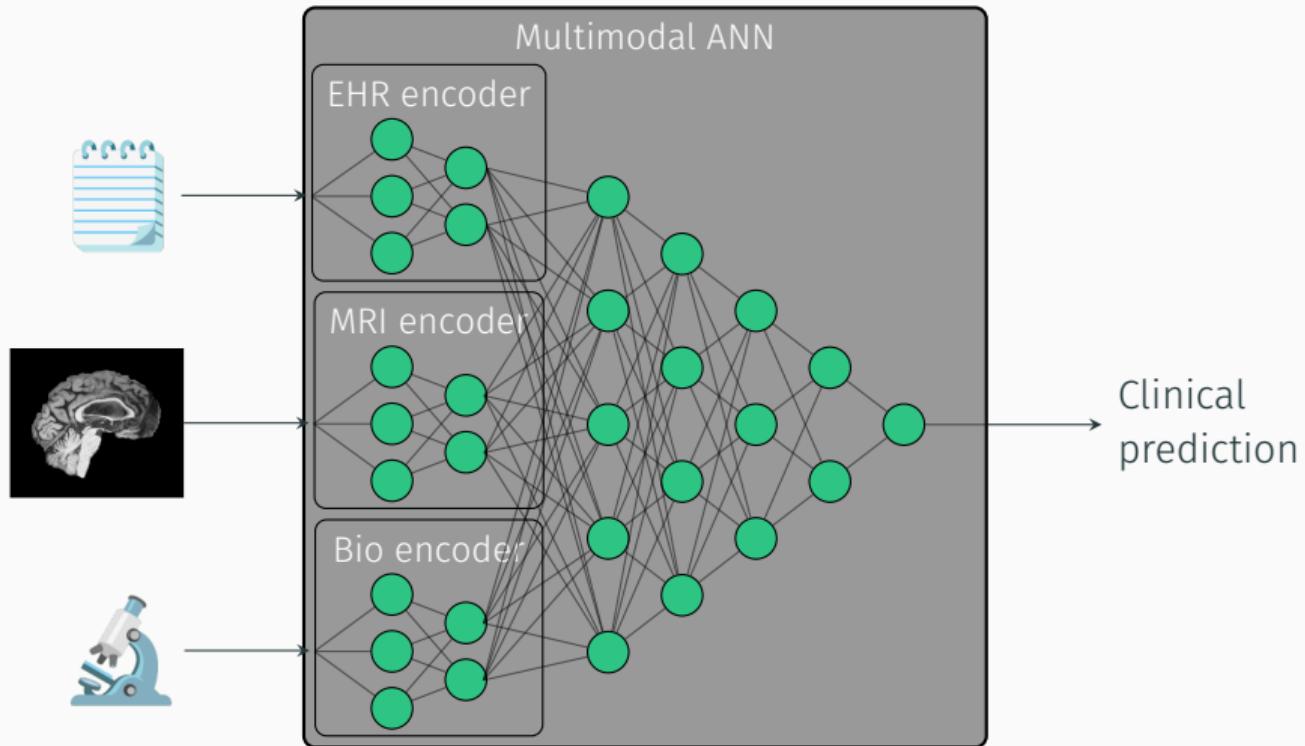


The black-box problem of modern AI systems

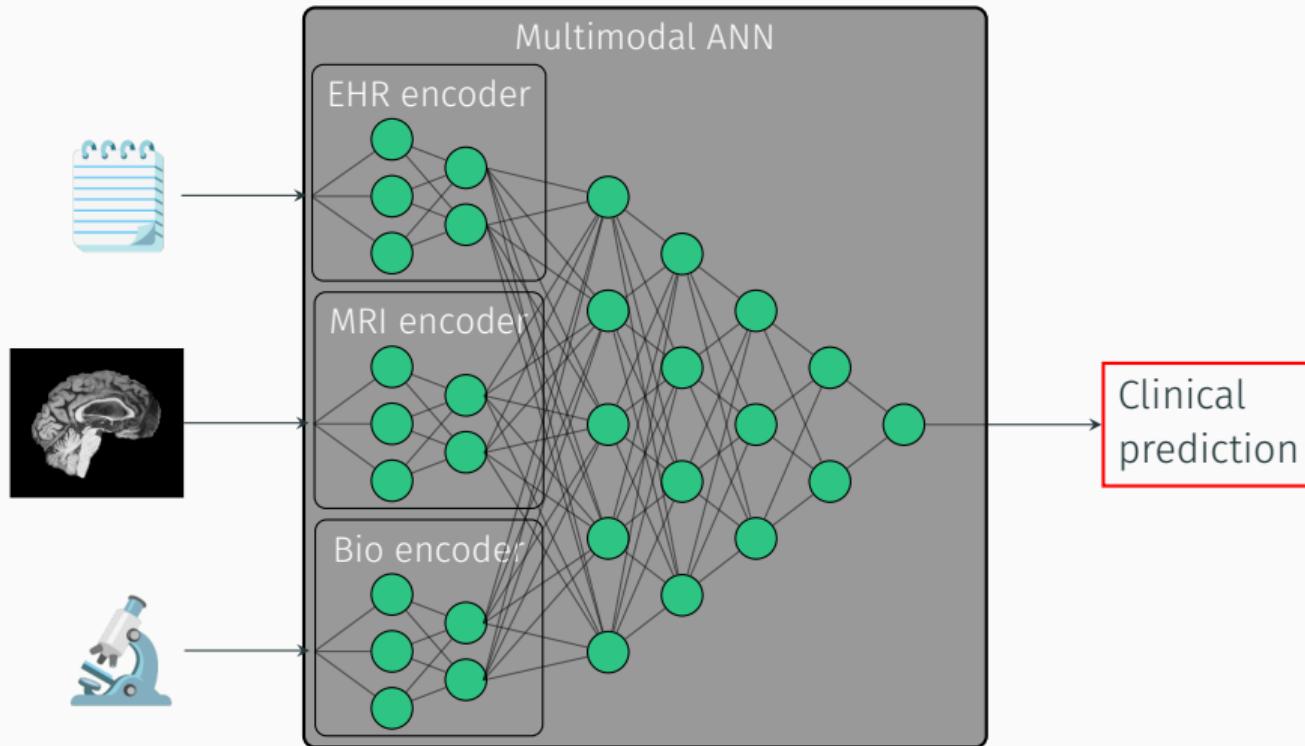


UNIVERSITETET
I OSLO

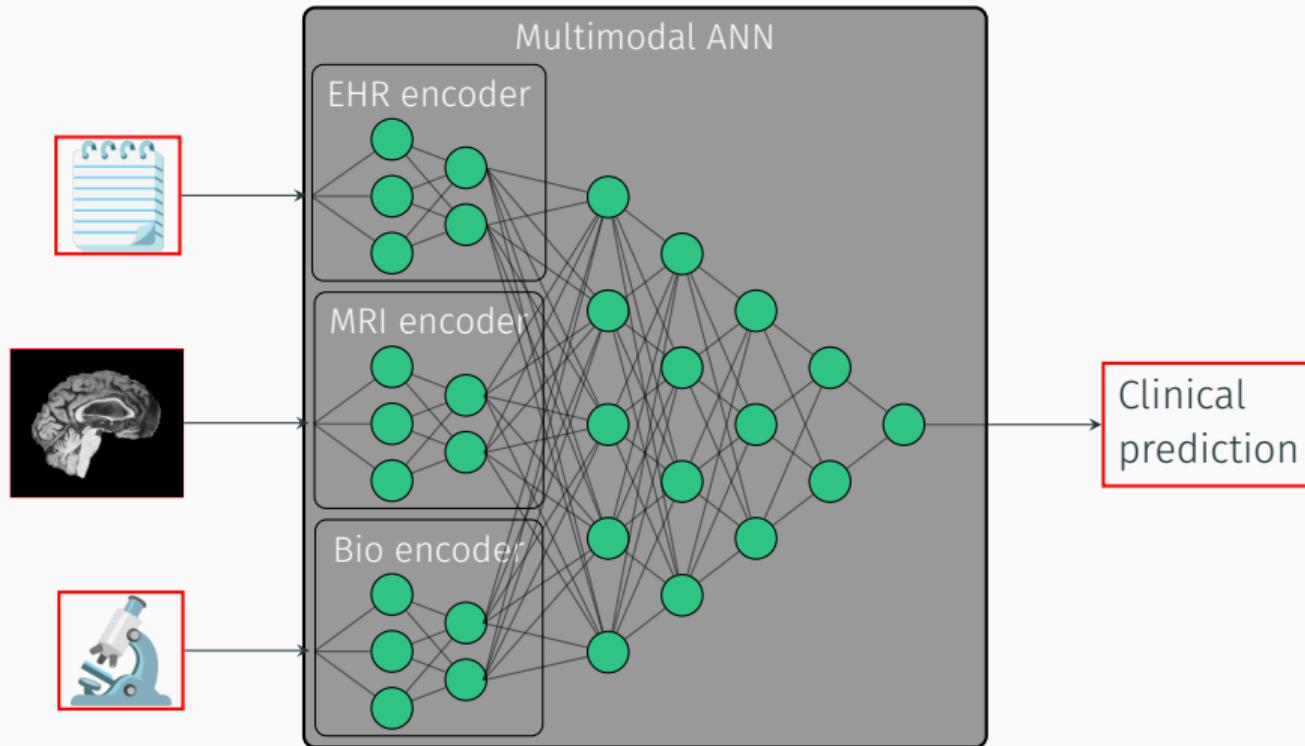
The black-box problem of modern AI systems



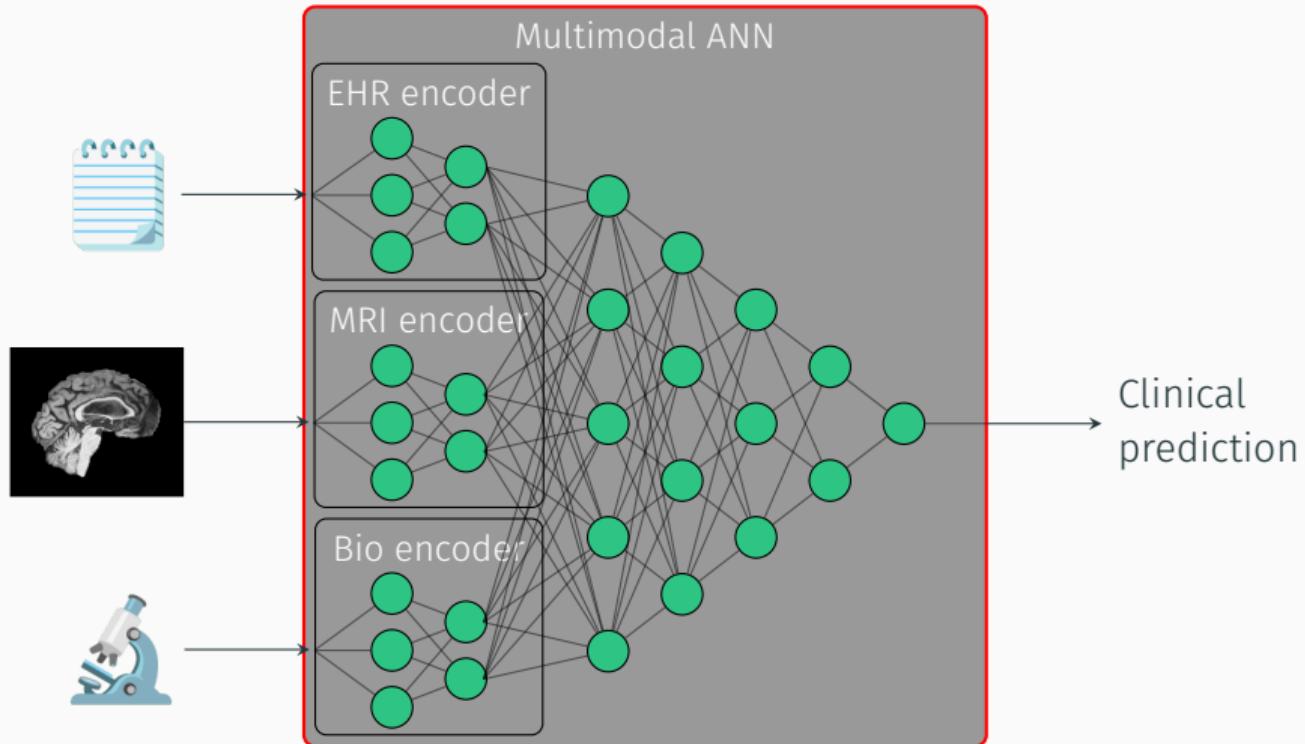
The black-box problem of modern AI systems



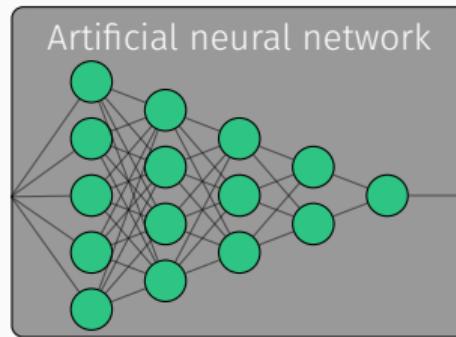
The black-box problem of modern AI systems



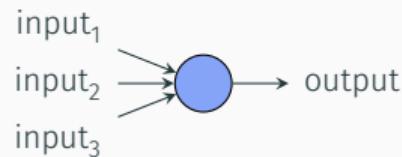
The black-box problem of modern AI systems



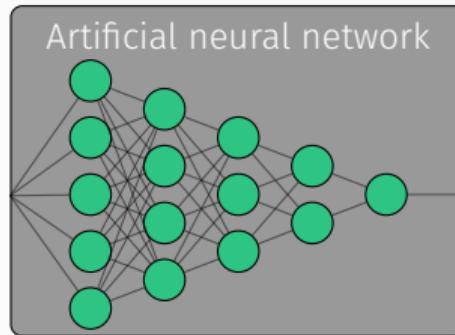
The black-box problem of modern AI systems



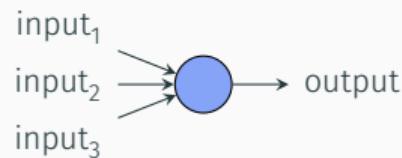
Artificial neuron



The black-box problem of modern AI systems



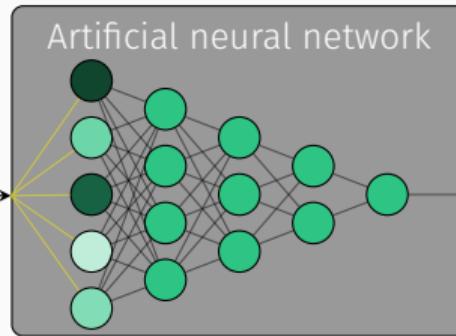
Artificial neuron



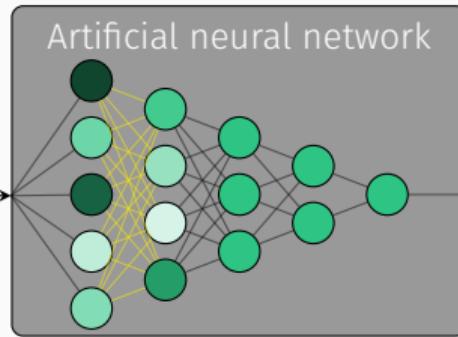
$$\text{output} = \max(0, \text{input}_1 * w_1 + \text{input}_2 * w_2 + \text{input}_3 * w_3)$$



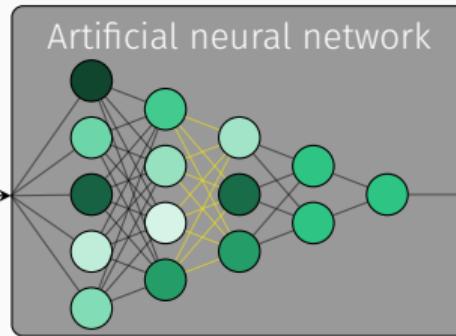
The black-box problem of modern AI systems



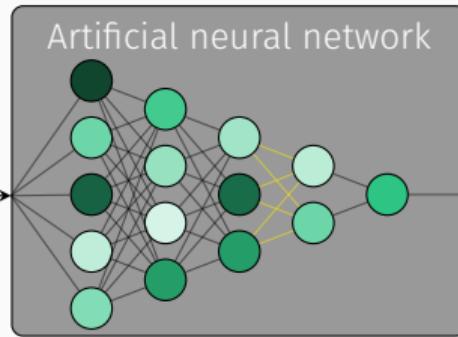
The black-box problem of modern AI systems



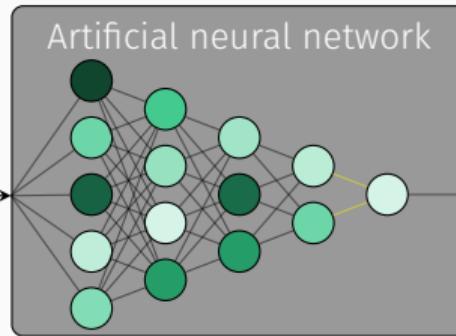
The black-box problem of modern AI systems



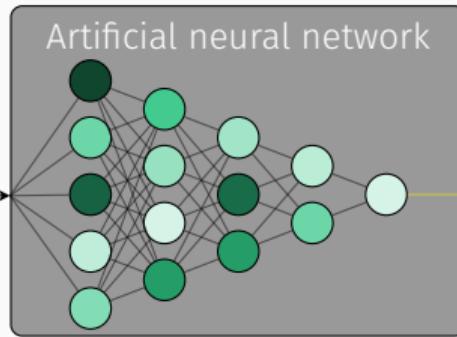
The black-box problem of modern AI systems



The black-box problem of modern AI systems



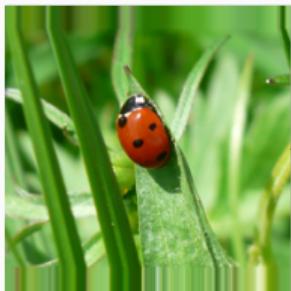
The black-box problem of modern AI systems



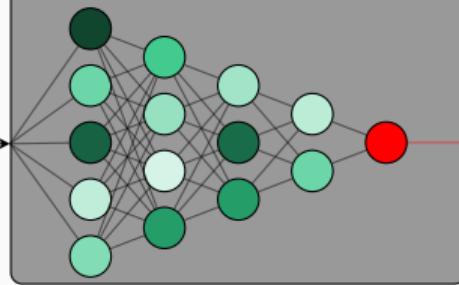
ladybug



The black-box problem of modern AI systems



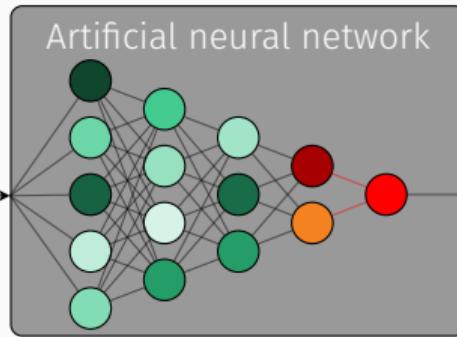
Artificial neural network



ladybug



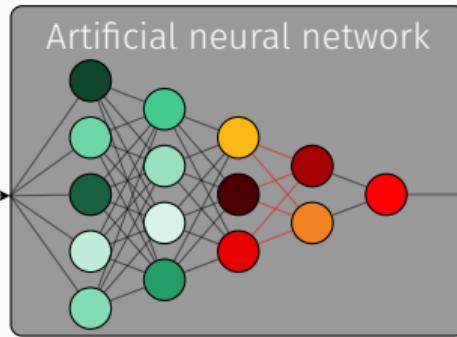
The black-box problem of modern AI systems



ladybug



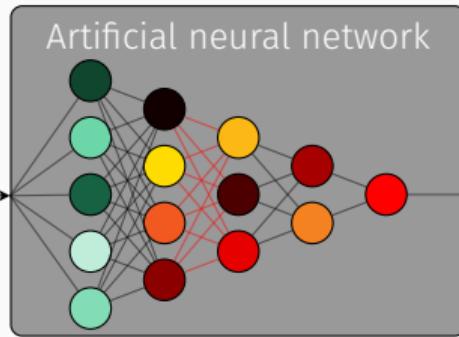
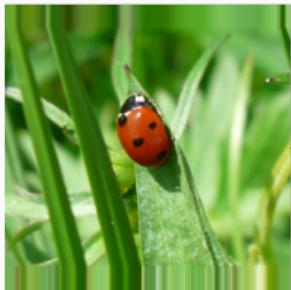
The black-box problem of modern AI systems



ladybug



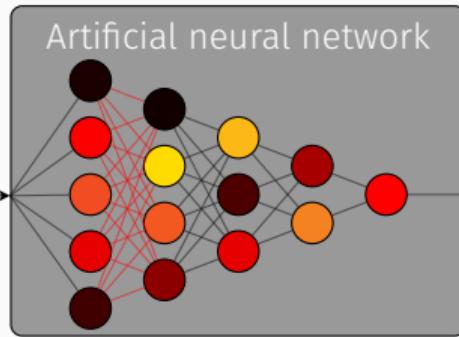
The black-box problem of modern AI systems



ladybug



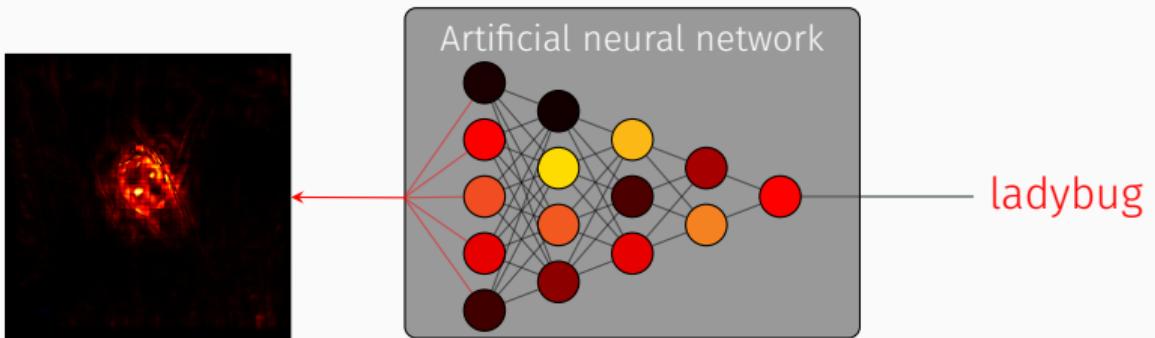
The black-box problem of modern AI systems



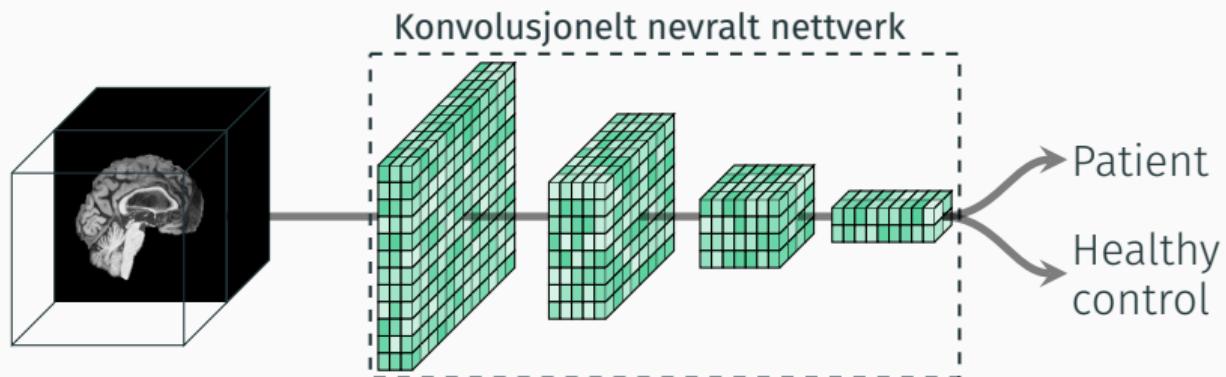
ladybug



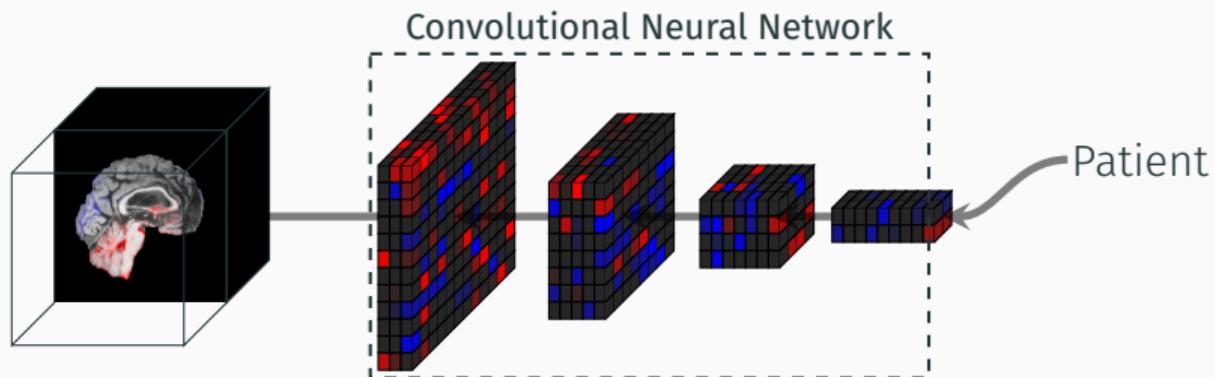
The black-box problem of modern AI systems



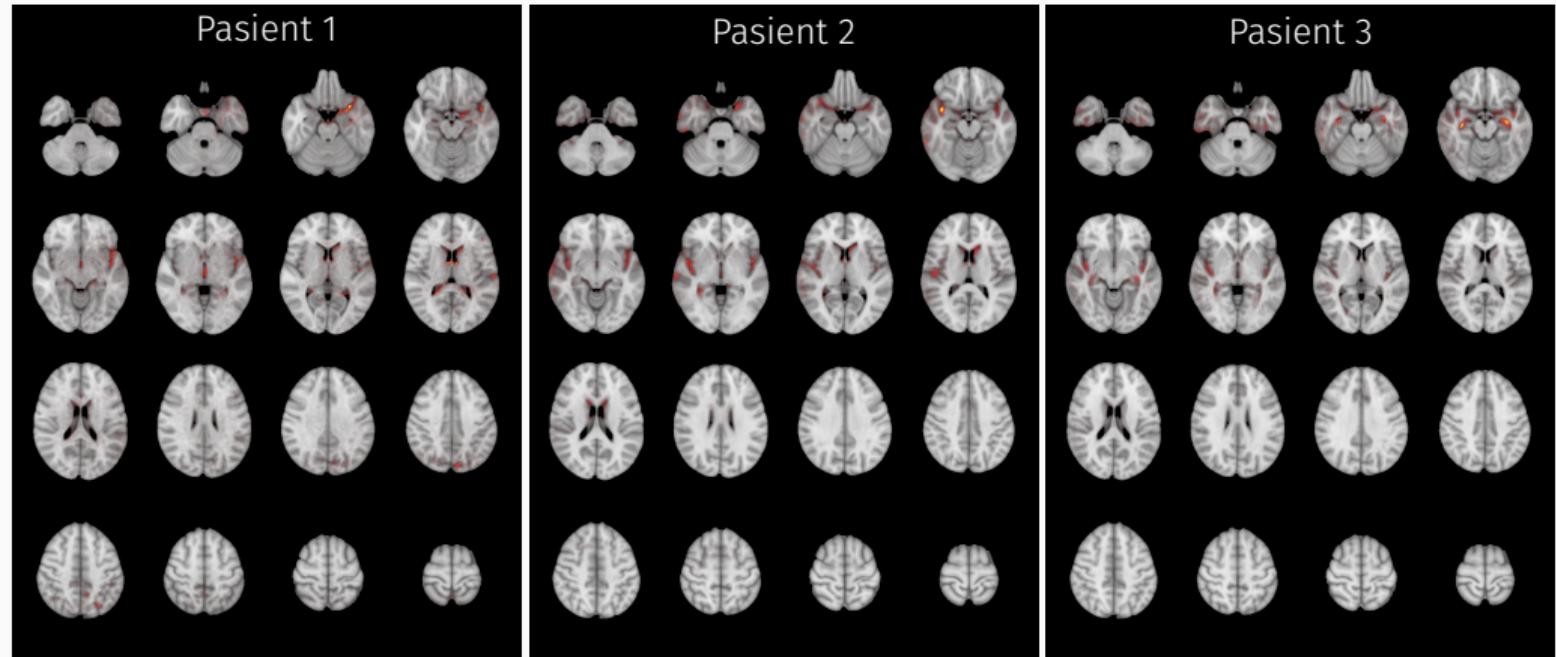
The black-box problem of modern AI systems



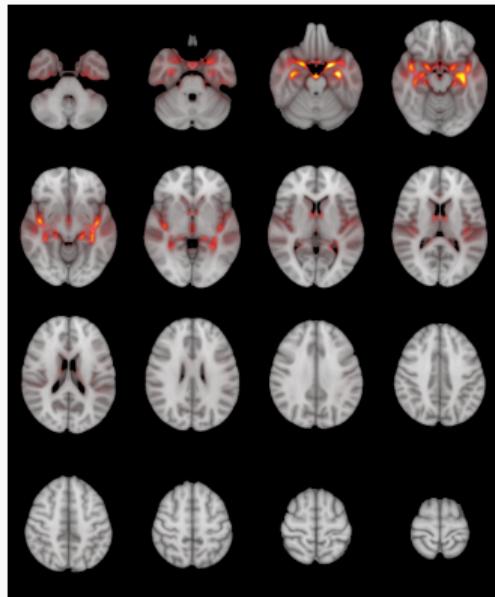
The black-box problem of modern AI systems



Explainable AI and dementia

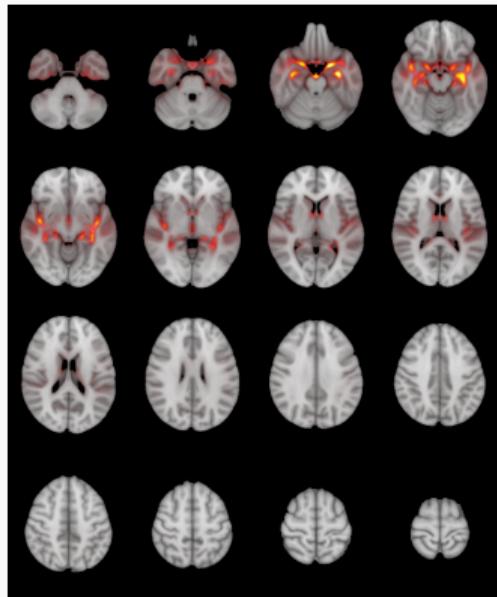


Forklarbar KI

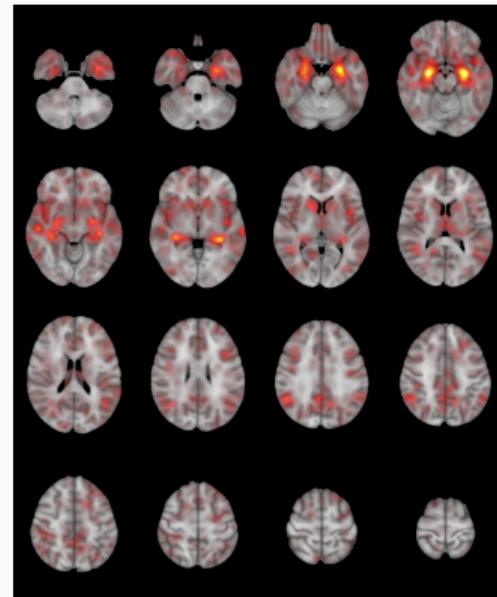


Explainable AI and dementia

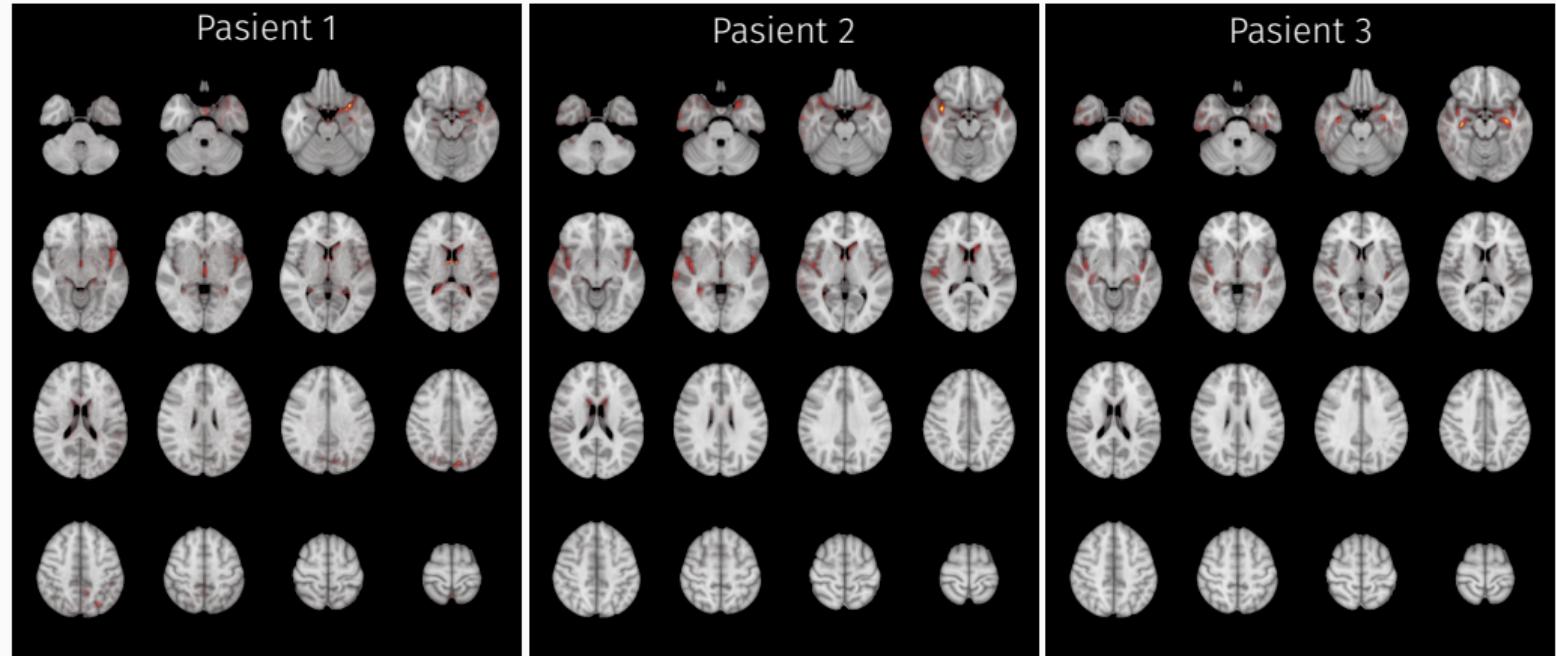
Forklarbar KI



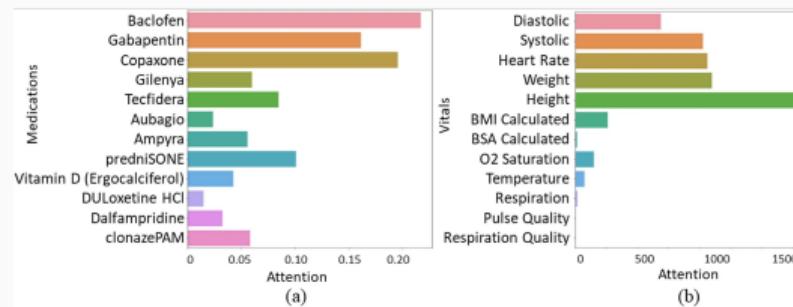
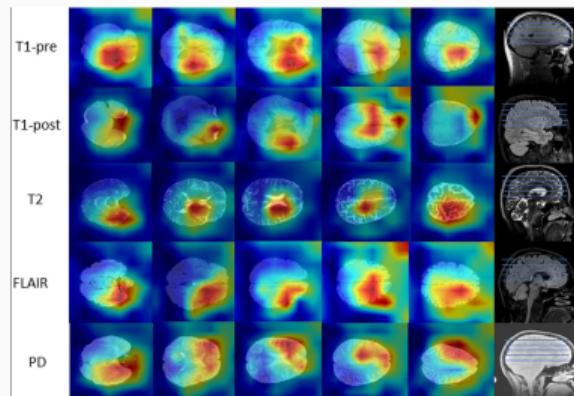
Mennesker



Explainable AI and dementia



Explainable AI and multimodality



Explainable AI and multimodality



Summary

- Deep learning is transforming many fields, enabling complex modelling of diverse, unstructured data.
- Multimodal AI requires decisions about how and when to combine information.
 - Late fusion: Information is merged after the most complex modelling
 - Early fusion: Information is merged before the most complex modelling
 - Intermediate fusion: Information is merged as a part of the most complex modelling
- Multimodal AI systems may enable clinical predictions with an accuracy surpassing what is currently possible, but explainability remains a challenge
 - Methods are emerging to alleviate these problems, at least partially



Takk for oppmerksomheten!
estenhl@uios.no



UNIVERSITETET
I OSLO

