Modèles de fondation et IA agentique pour l'oncologie de précision : état des lieux et défis

Utiliser l'IA pour la recherche contre le cancer

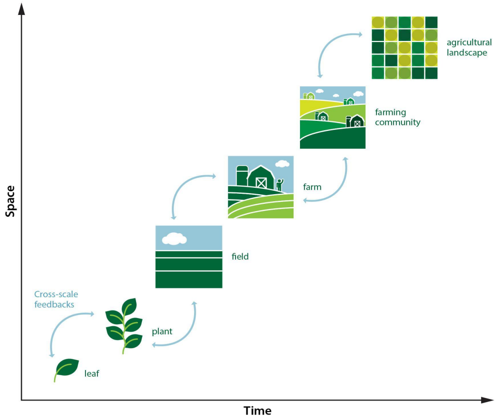
21 Mai 2026

Laboratoire MICS

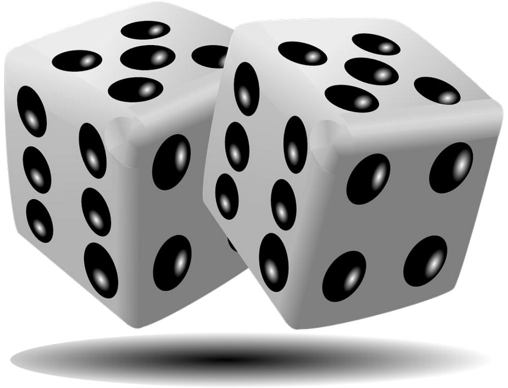
Mathématiques et Informatique pour la Complexité des Systèmes et des Données

Recherche méthodologique et fondamentale en Mathématiques et en Informatique

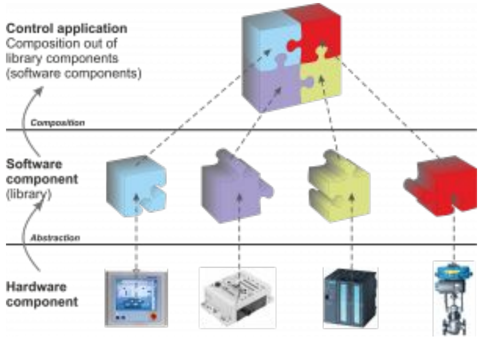
Orientée vers l’étude et la modélisation des systèmes complexes au sens large



Interaction multi-échelle
Ex : vivant



Systèmes stochastiques
Incertitude



Composants hétérogènes
en interaction

Données,
non-structurées,
hétérogènes,
de grande taille

Cancer

20M Cases

10M Deaths

Disease classified by **anatomical locations** but…

in fact driven by **multidimensiona l biological mechanisms**

Vision

Classify cancers at the individual scale based on biological mechanisms

Delivrables

Tools that recapitulate cancer and host biology in each individual or patient

10 Yrs Impact

•New model for drug dvpt
•↓ Mortality (#10%)
•↓ Trt burden (#20%)
• ↓ Healthcare disparities

Plan

To create an **Institute** (PRISM) that supports a scientific strategy to produce multidimensional portraits of cancer & host, guiding **prevention and treatment**

P R I S M

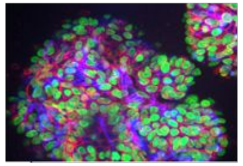
From Unidimensional Analyses to Comprehensive Assessement of Biology in each patient

Uni-dimensional Analyses
using patient samples, molecular profiling, datasciences (Illustration back-up slides)

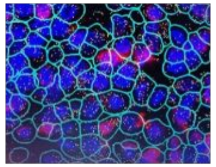
Clonality **Myeloid cells** **Natural Killer** **Microbiome** **Metabolism** **Exposure** **Persistent Tumor cells**

Therapeutic targets + Outcomes predictors for Disease models and Impactful clinical questions

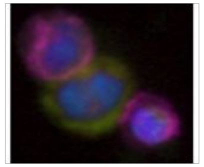
Technologies & Applied mathematics for
comprehensive assessment of biological mechanisms in each patient longitudinally



Organoids:
Multidimensional
Gene edited



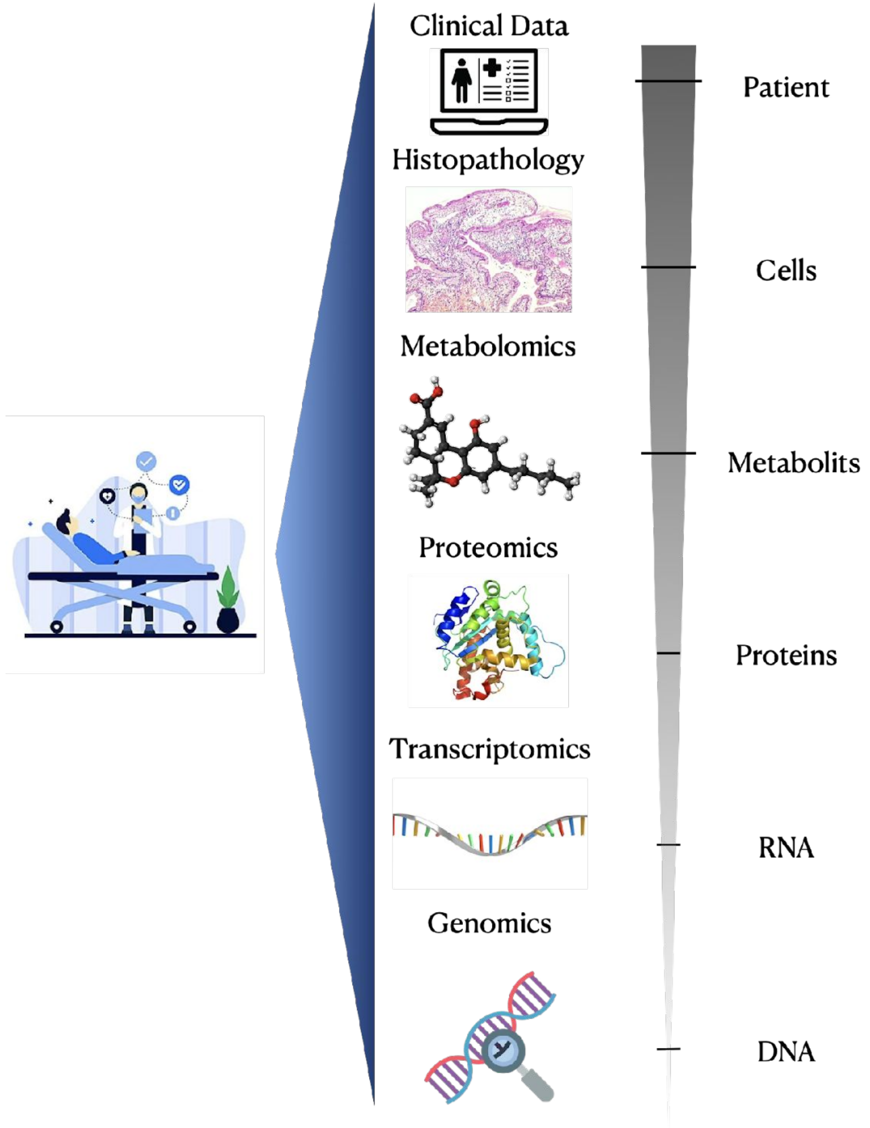
Spatial analyses:
HE n=50 000
Single cell spatial



Circulating markers:
CTCs , ctDNA
Tumor Ecology

Clinical Research (prevention & cancer treatment)

Towards Precision Oncology



Large-Scale Analysis

Leveraging massive cohorts to build robust predictive models with statistical significance.

Artificial Intelligence

Pioneering multidisciplinary AI and machine learning approaches for multi-omics integration.

Cross-Cancer Applications

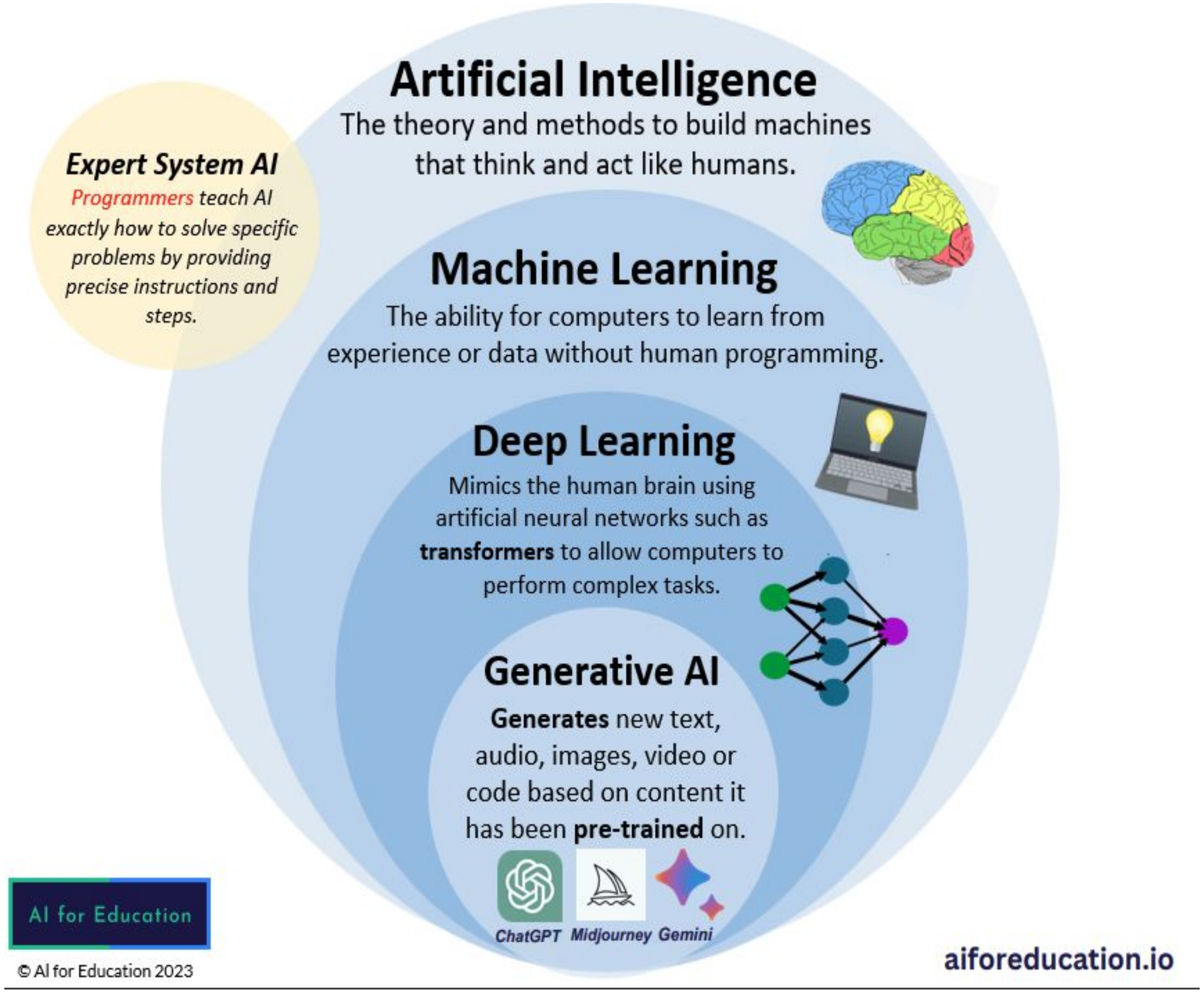
Developing generalizable tools that work across cancer types and research domains.

Clinical Integration

Implementing standardized pipelines from research to patient care.

Artificial Intelligence

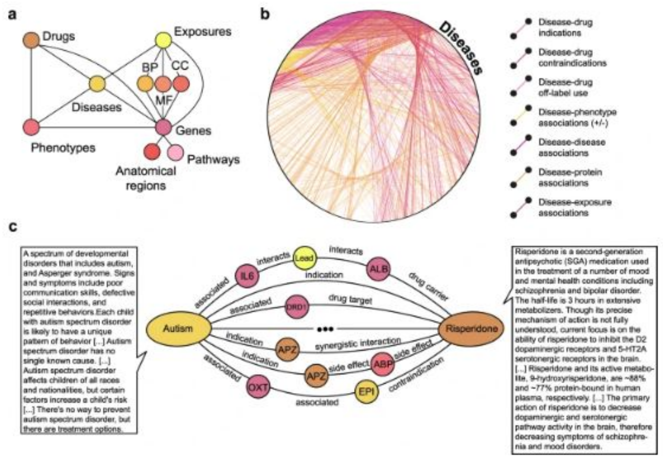
- A long history since the Darmouth conference (1956)
- Different **families of approaches**



Two main approaches : Data-driven vs Symbolic AI

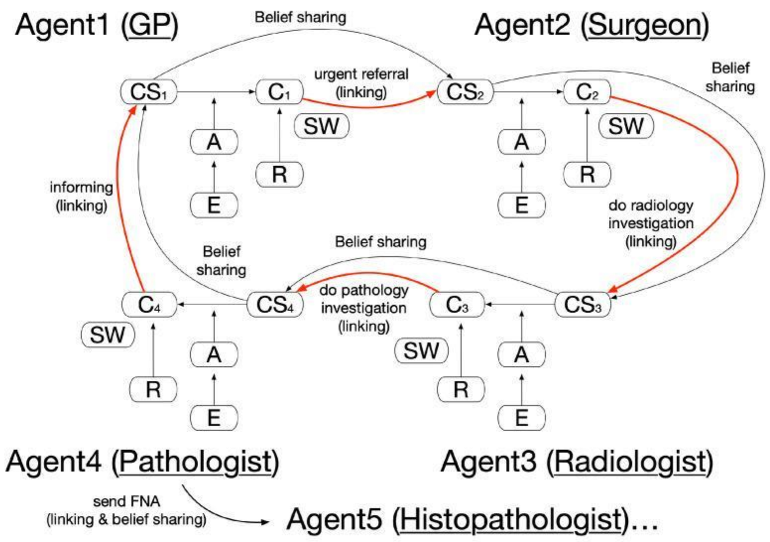
Two different assumptions on the notion of human knowledge and reasoning

- **Symbolic AI** :
  – Human knowlege and reasoning can be captured, even if partially incomplete : **explicit representation** of knowledge (using **symbols** rather than statistics to represent the world)
  – Development of **formalisms for knowledge representation and reasoning**



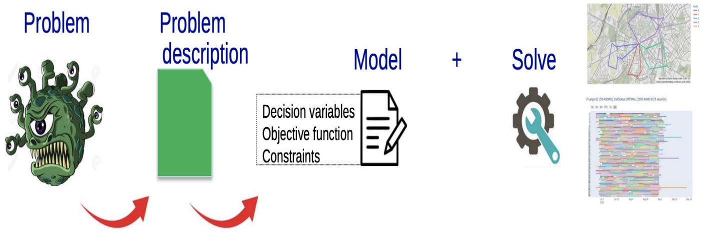
Knowledge graphs, ontologies

Source : [Chandak et al, 23, Nature]



Argumentation, collective decision

Source : [Xiao et al, 23, HeathCare]



AI general problem solvers

CP, LP, SAT, ...

Two main approaches : Data-driven vs Symbolic AI

Two different assumptions on the notion of human knowledge and reasoning

- **Data-driven AI** :
  - Human knowledge and reasoning are complex : knowledge implicitly in data
  - Learning from data : exploitation of the past experience represented by data (preferably annotated data) to build calibrated predictive models from the available data.

Principle

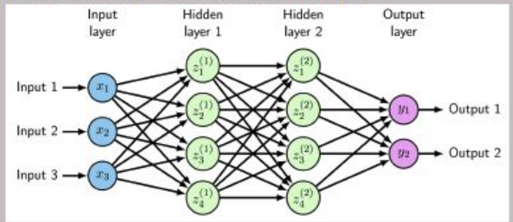
We want to predict Y from X, as for instance :

- X : radiology image, Y : presence of a tumor ?
- X : sensor and monitoring data Y : rule life prediction of the system ?

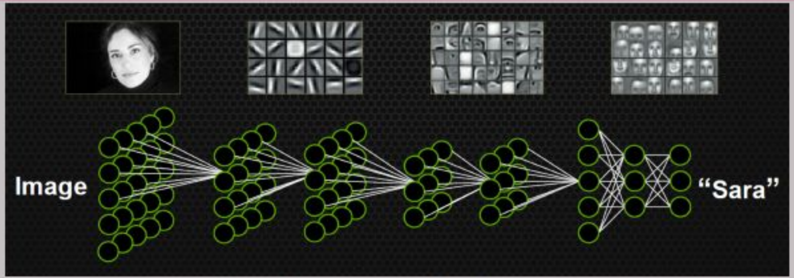
Determination of the fonction ψ (model) such that $Y = \psi(X)$, and ψ is estimated from **labeled data** :
N situations in which one knows at the same time X and Y :
$(X_i, Y_i)_{1 \leq i \leq N}$

Deep neural networks

$Y = \psi(X)$, with $\psi(X) = h_M \circ g_M \circ \ldots \circ h_1 \circ g_1(X)$ where h_i some non-linear transformations and g_i some affine transformations.



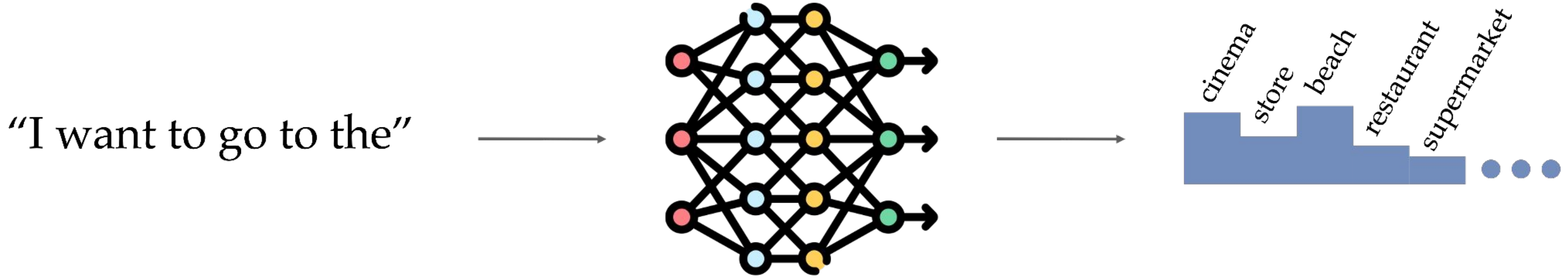
Representation learning



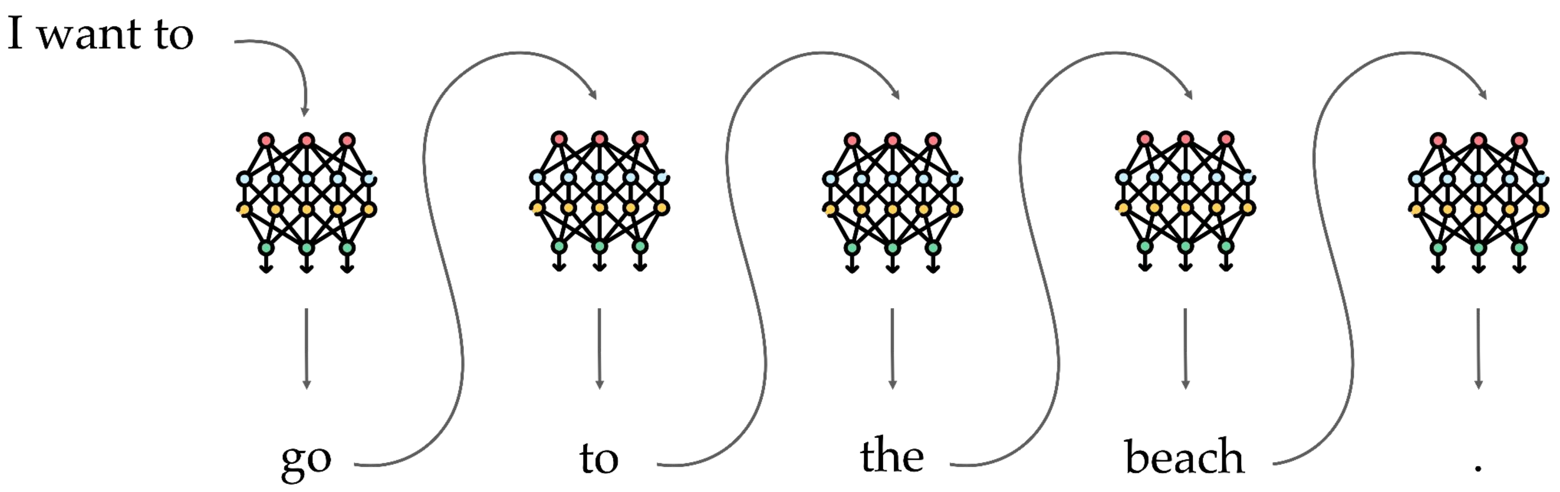
The **Deep** layers capture complex features in the image to extract the most relevant information for the prediction task [Lee et al., 2009].

The rise of generative AI : LLMs

A LLM is a **deep neural network** trained at very **large scale** to generate, given the input, the most probable next words

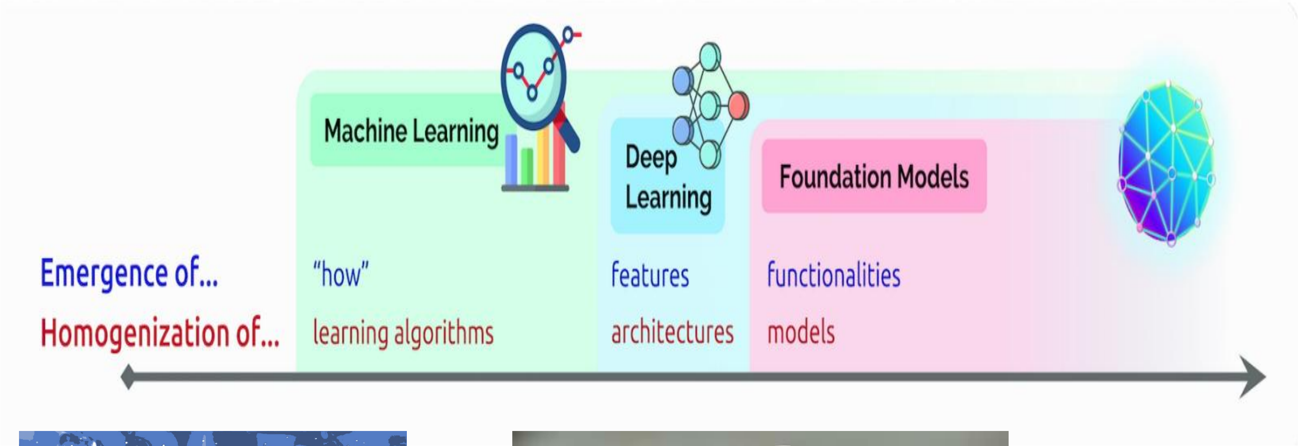


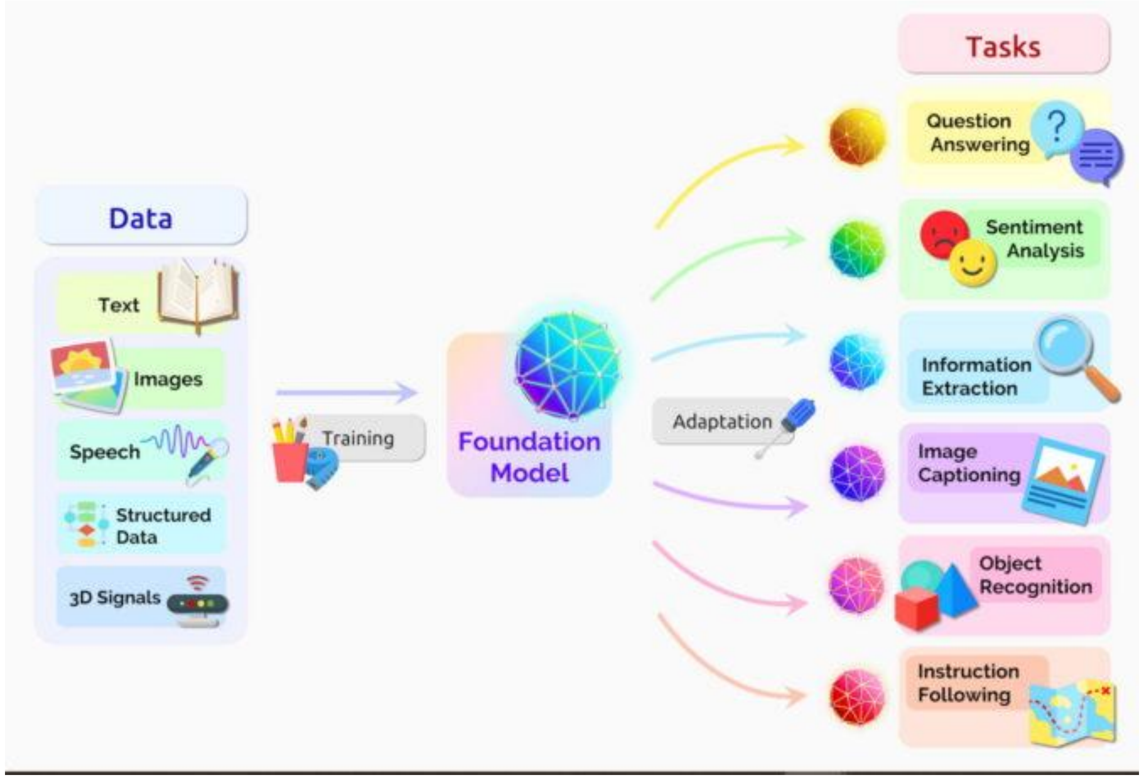
At **inference**, step-by-step approach to generate text by samping in the learned distribution

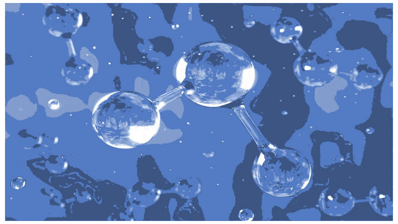


The Era of Foundation Models

A new **major paradigm** for building AI system : train a model on **broad data using pretext tasks** and **adapt** it to a wide range of downstrams tasks.







MoLFormers, foundation models on chemicals by IBM

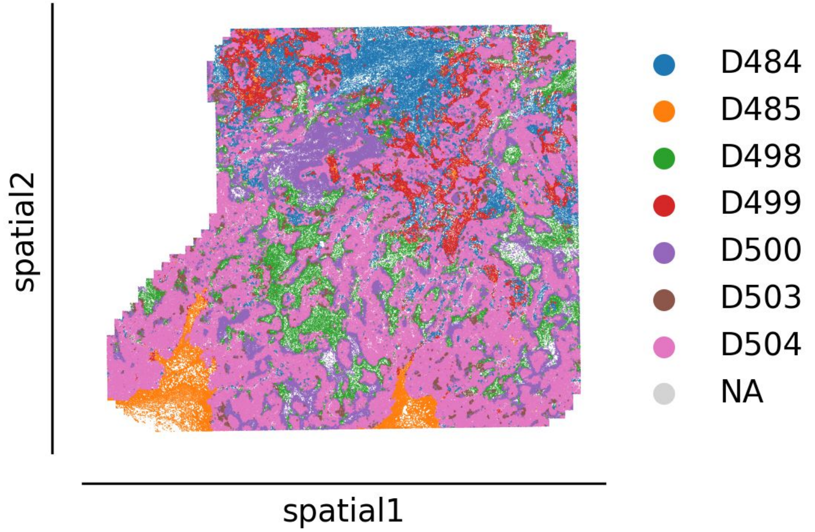
Bommasani et al., "[On the Opportunities and Risks of Foundation Models]"

Fondations models for Precision Oncology
An overview

Foundation Models at Cell Level

A spatial domain (a.k.a. niche) is a localized cellular microenvironment within tissues.

> These domains reflect distinct biological functions and interactions



Which implications for tissue function / disease progression?

nature methods

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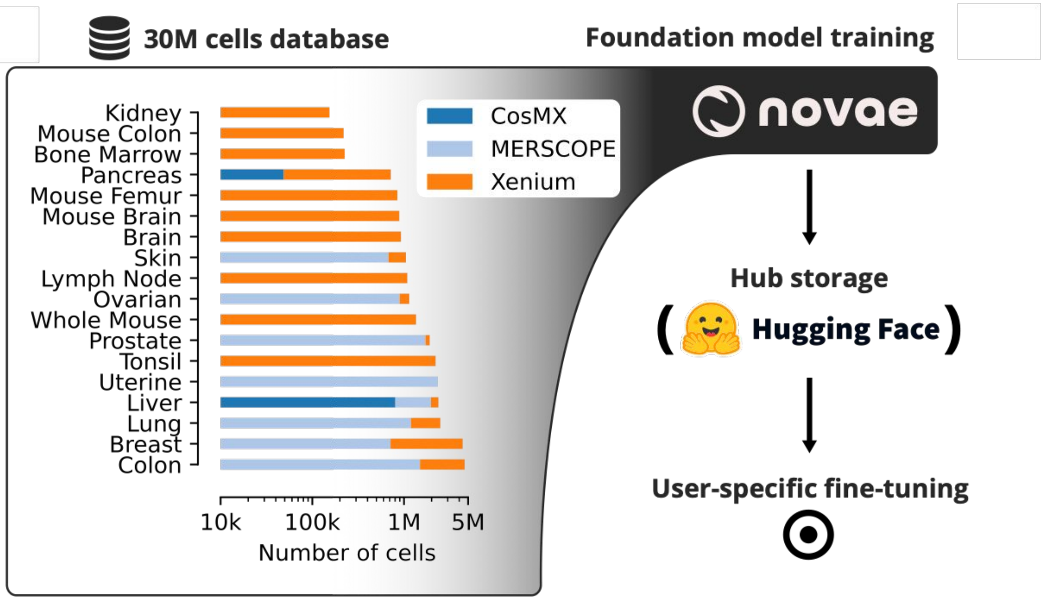
Article | Published: 10 December 2025

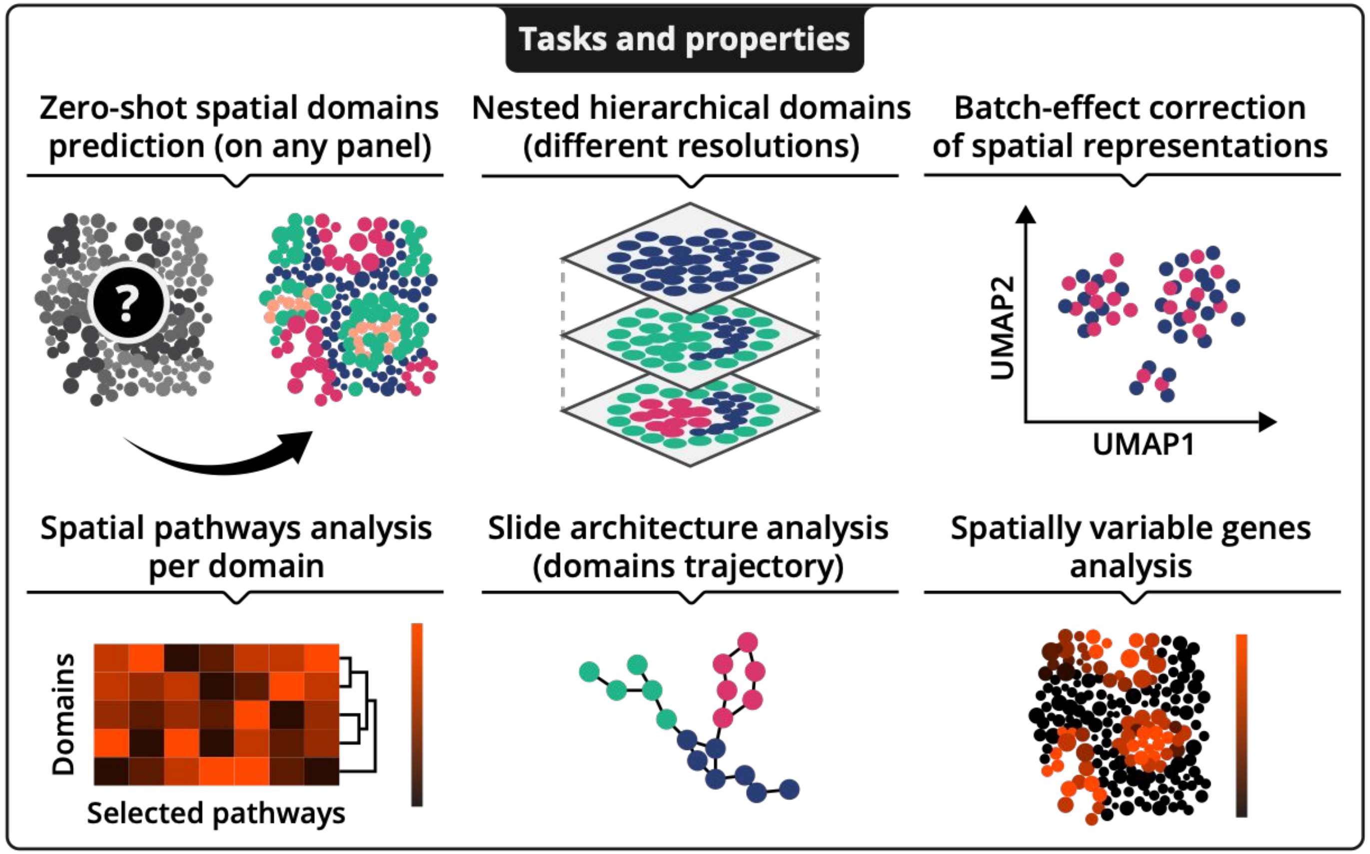
Novae: a graph-based foundation model for spatial transcriptomics data

Quentin Blampey, Hakim Benkirane, Nadège Bercovici, Kevin Mulder, Grégoire Gessain, Florent Ginhoux, Fabrice André & Paul-Henry Cournède

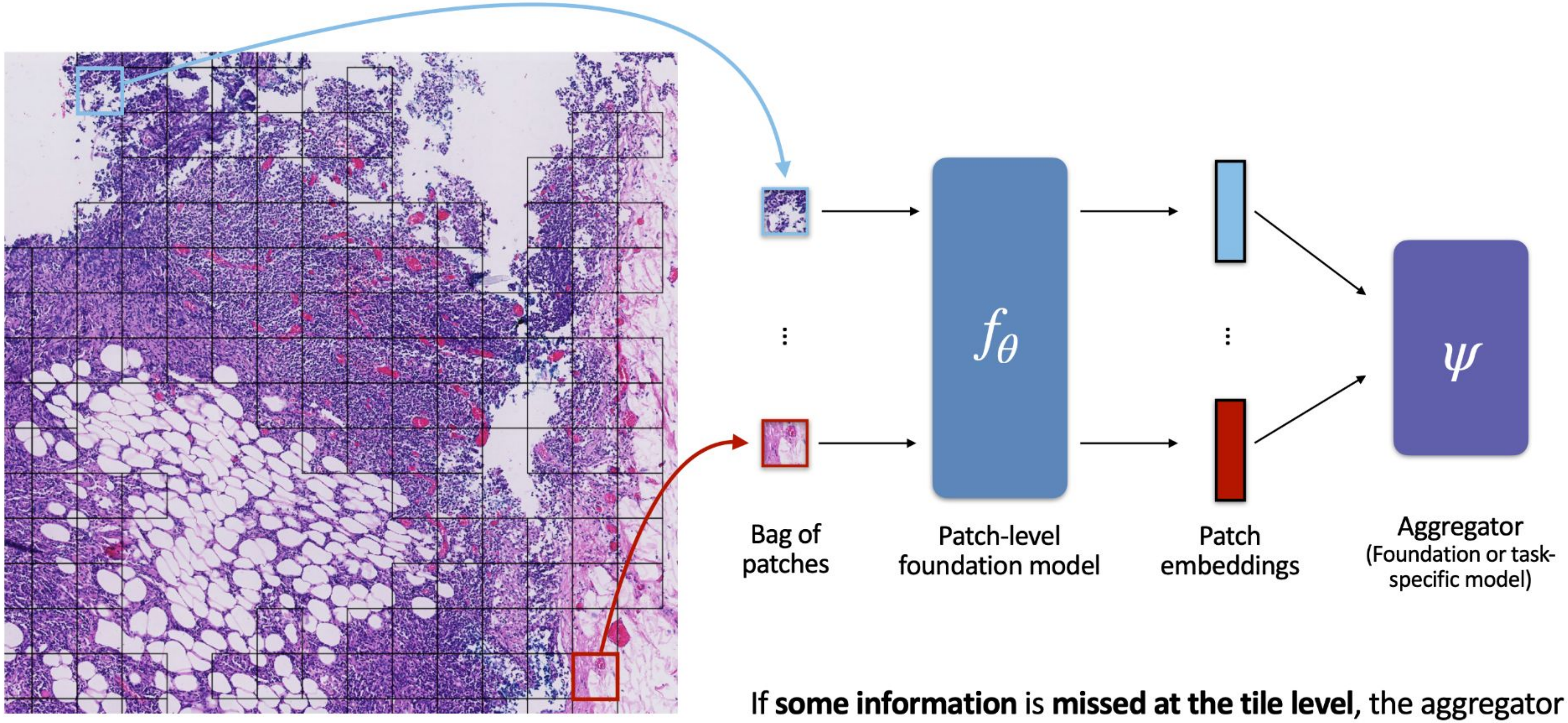
Nature Methods **22**, 2539–2550 (2025) | Cite this article

Foundation Models at Cell Level





Foundation Models at Tissue Level



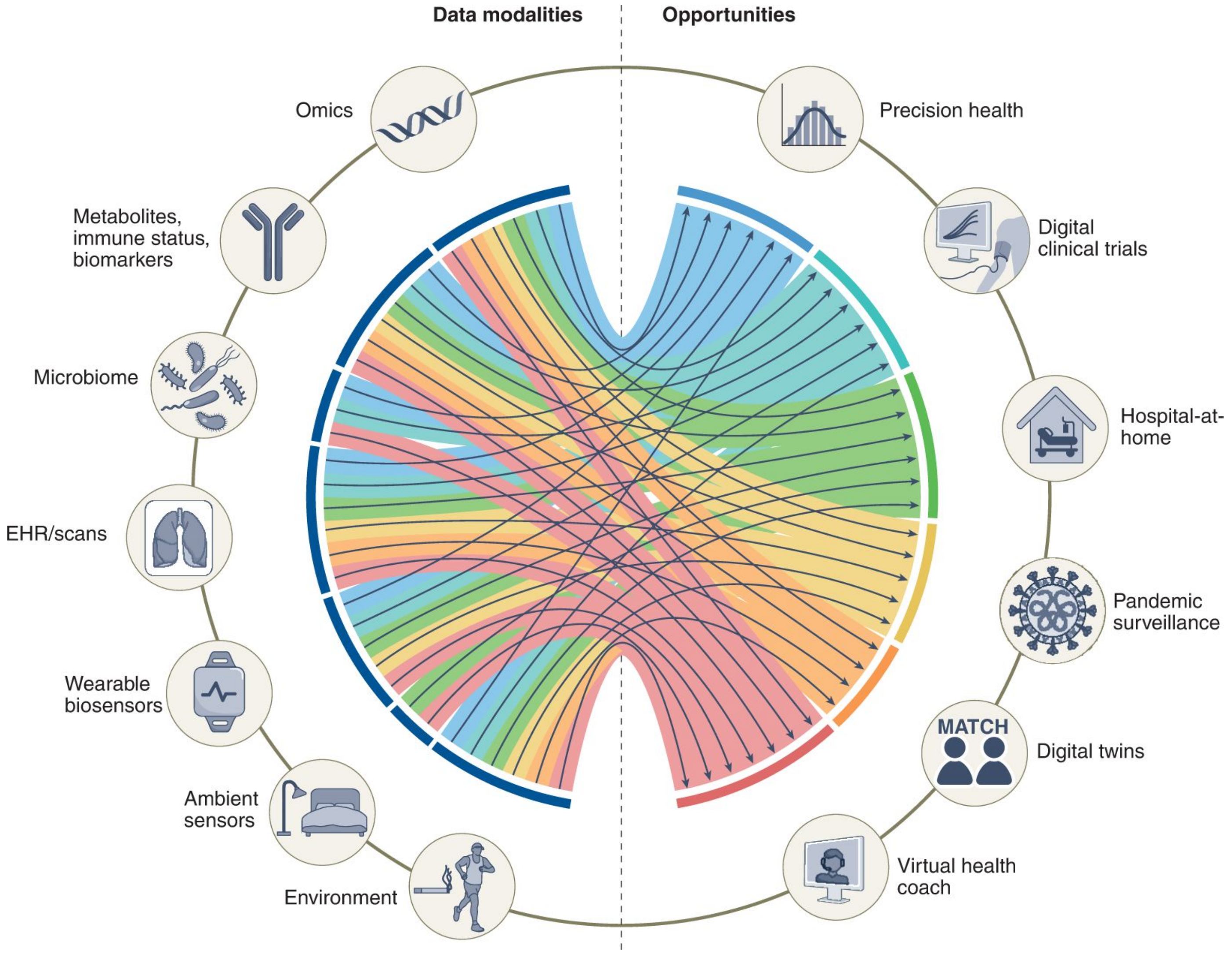
If **some information** is **missed at the tile level**, the aggregator will **lack context** to perform a prediction at the slide level.

Focusing on patches allows to **isolate the impact foundation models** from design choices about aggregators

Foundation Models at Patient Level

Challenge : In Clinical Setting, patient data are everywhere, in a lot of formats and modalities, all at once

> All these data represent one view of the patient, so how to integrate them ?



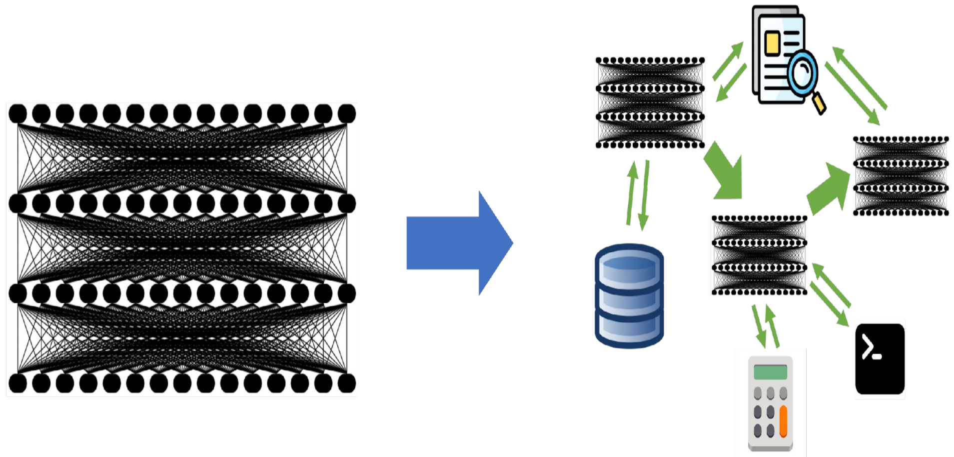
Acosta et al. , Nat. Med 2025

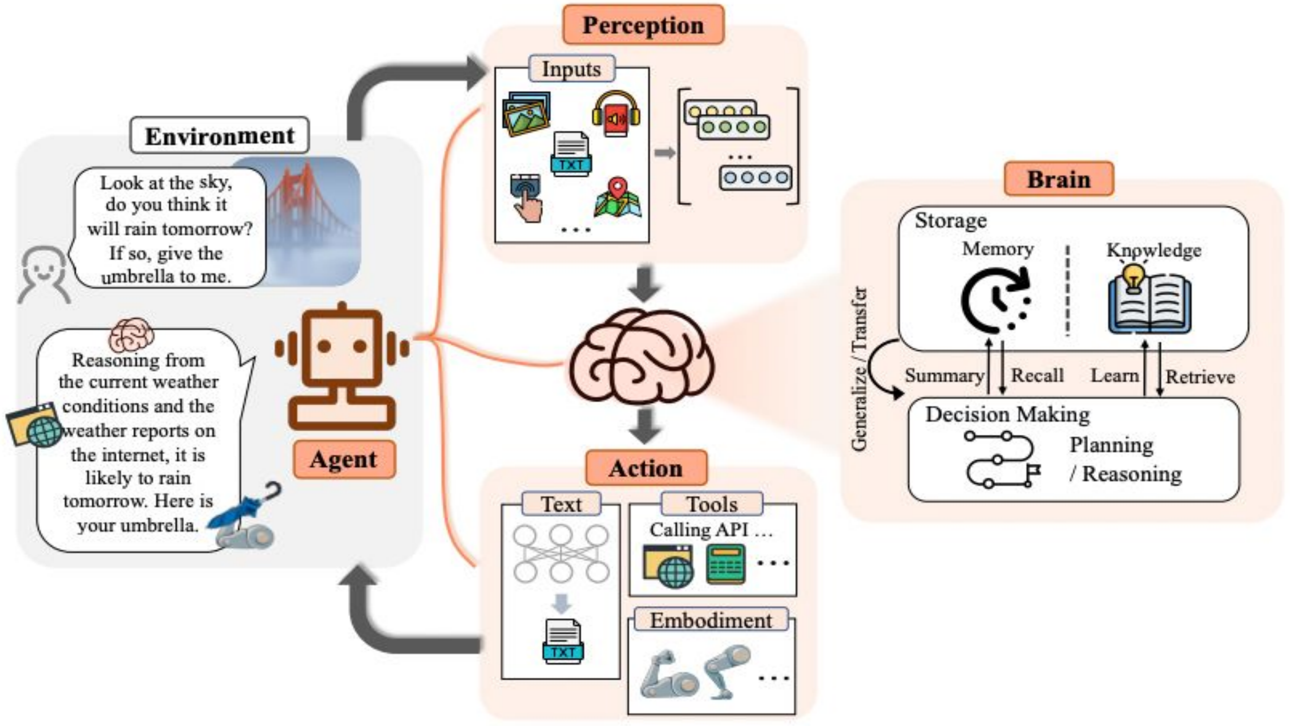
Challenges

Going Multimodal with agentic AI

AI agent : can gather useful sensory information and interact with their environments in meaningful ways

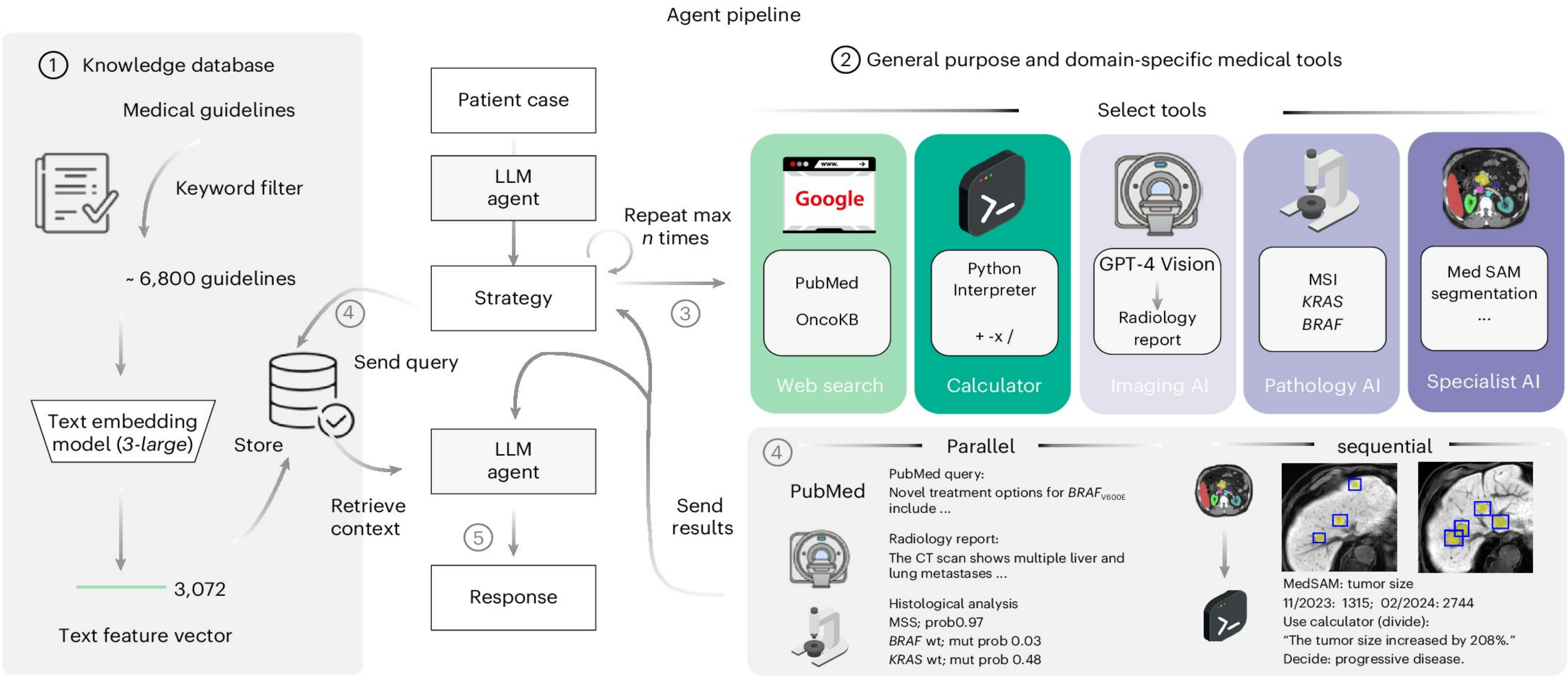
Enable the orchestration of complex pipelines with LLMs and foundations models applications executing complex tasks through the use of an architecture combining them with key modules like planning and memory.





Xi et al., "The Rise and Potential of Large Language Model Based Agents: A Survey"

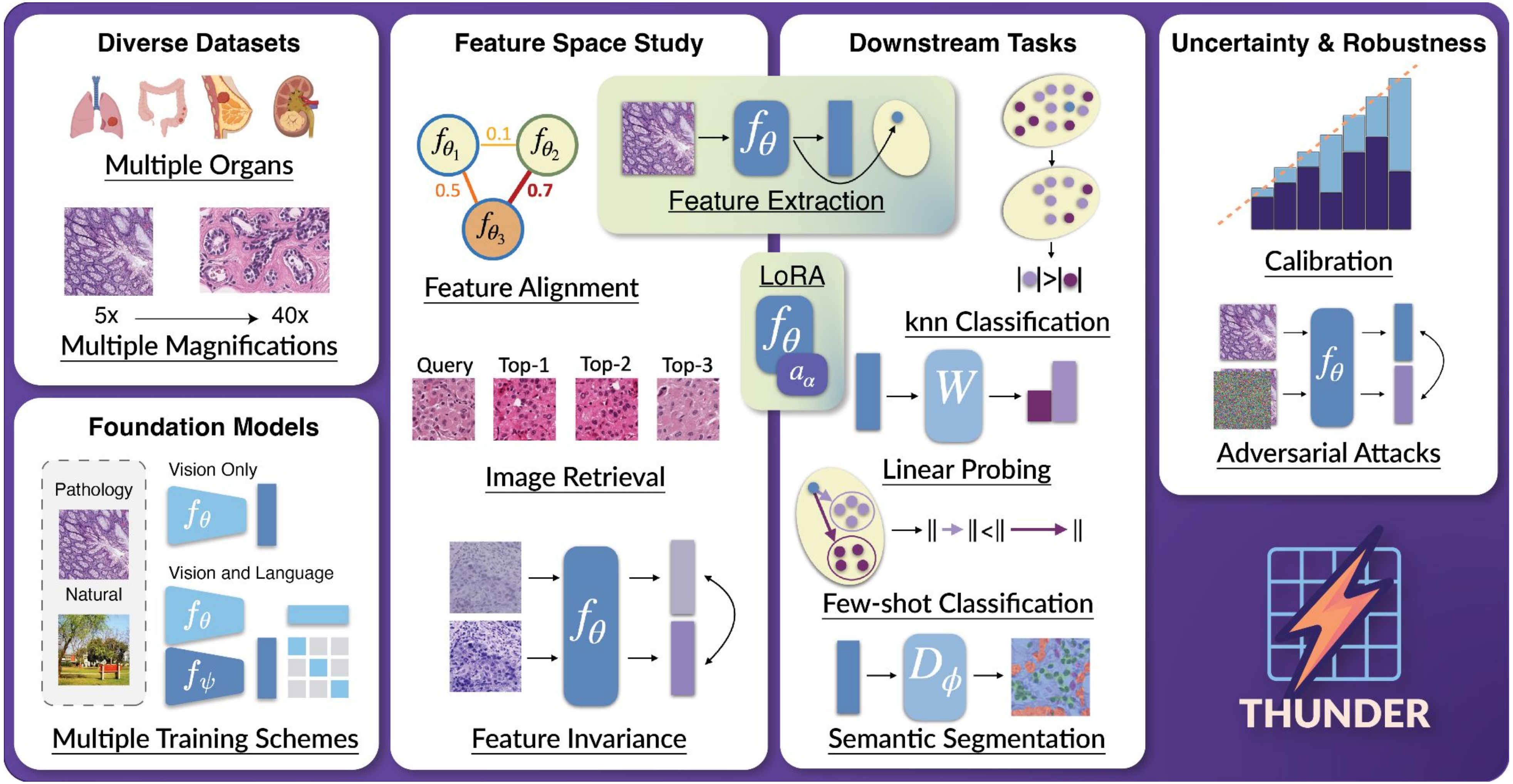
Going Multimodal with agentic AI



Kather Lab, Ferber el al, [Nature Cancer 2025]

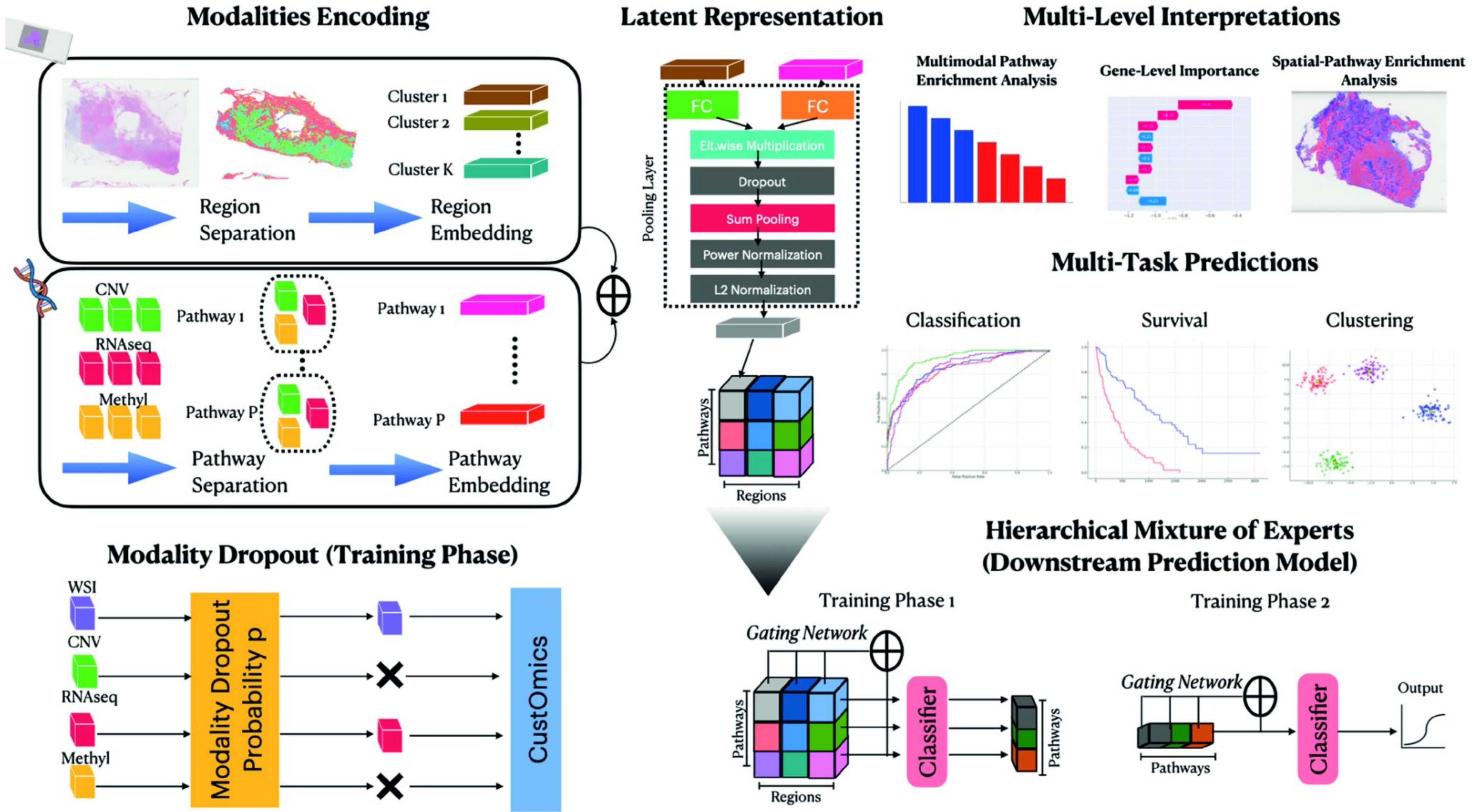
Fair and robust evaluation

Tile-level Histopathology image Understanding benchmark ([Marza et al.](#))



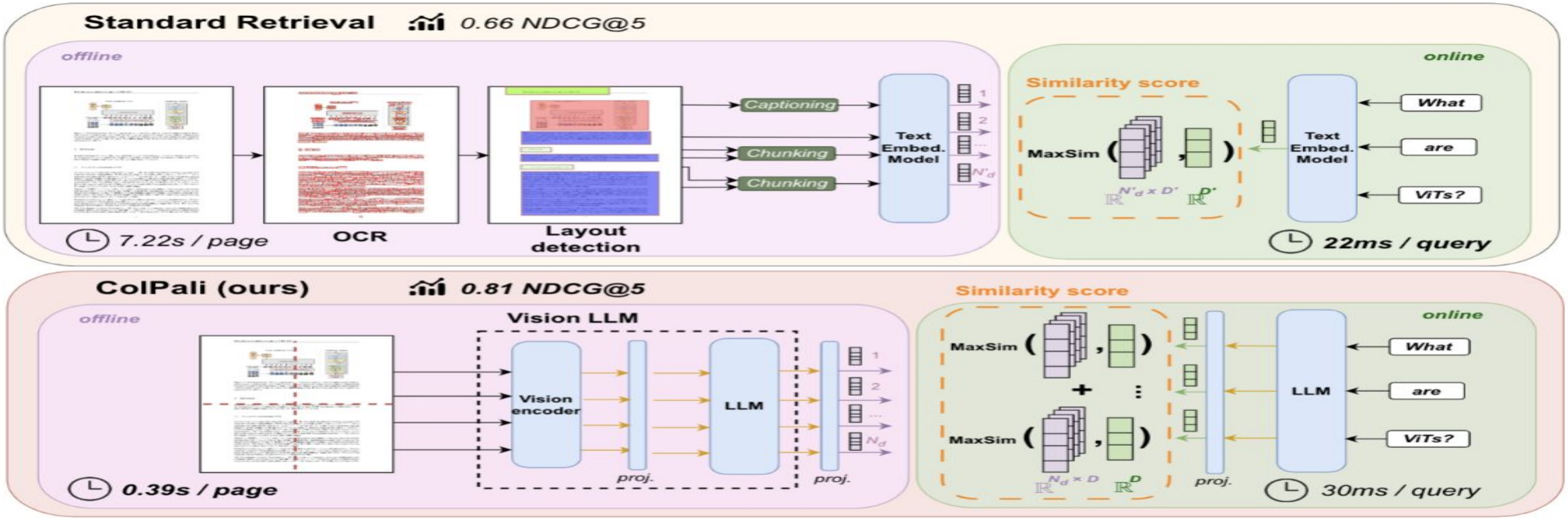
Handling Multimodality

Multimodal CustOmics (Benkirane et al.)



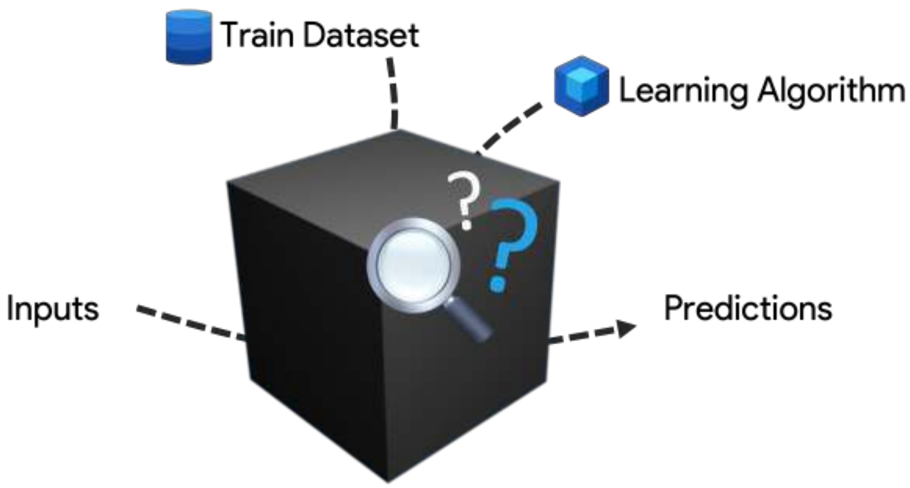
Efficient extraction

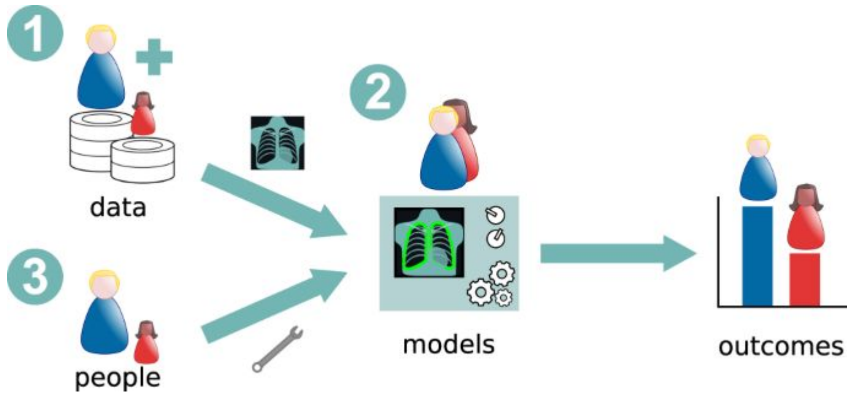
ColPali: Efficient Document Retrieval with Vision Language Models
[(Faysse et al.)]



The need of explainability

The era of black box models

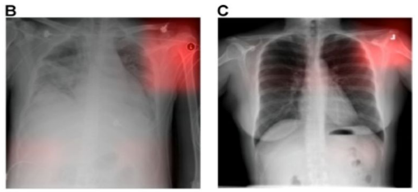




Fairness and robustness

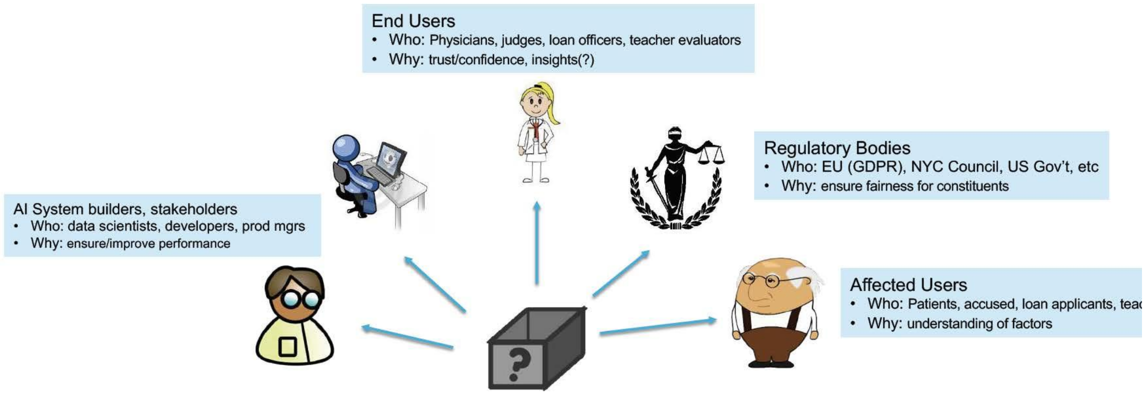
CNNs learn to predict pneumonia by detecting hospital which took the image

- Study on detecting pneumonia using 158,323 chest radiographs
- CNNs robustly identified hospital system and department within a hospital
- CNN has learned to detect a metal token that radiology technicians place on the patient in the corner of the image



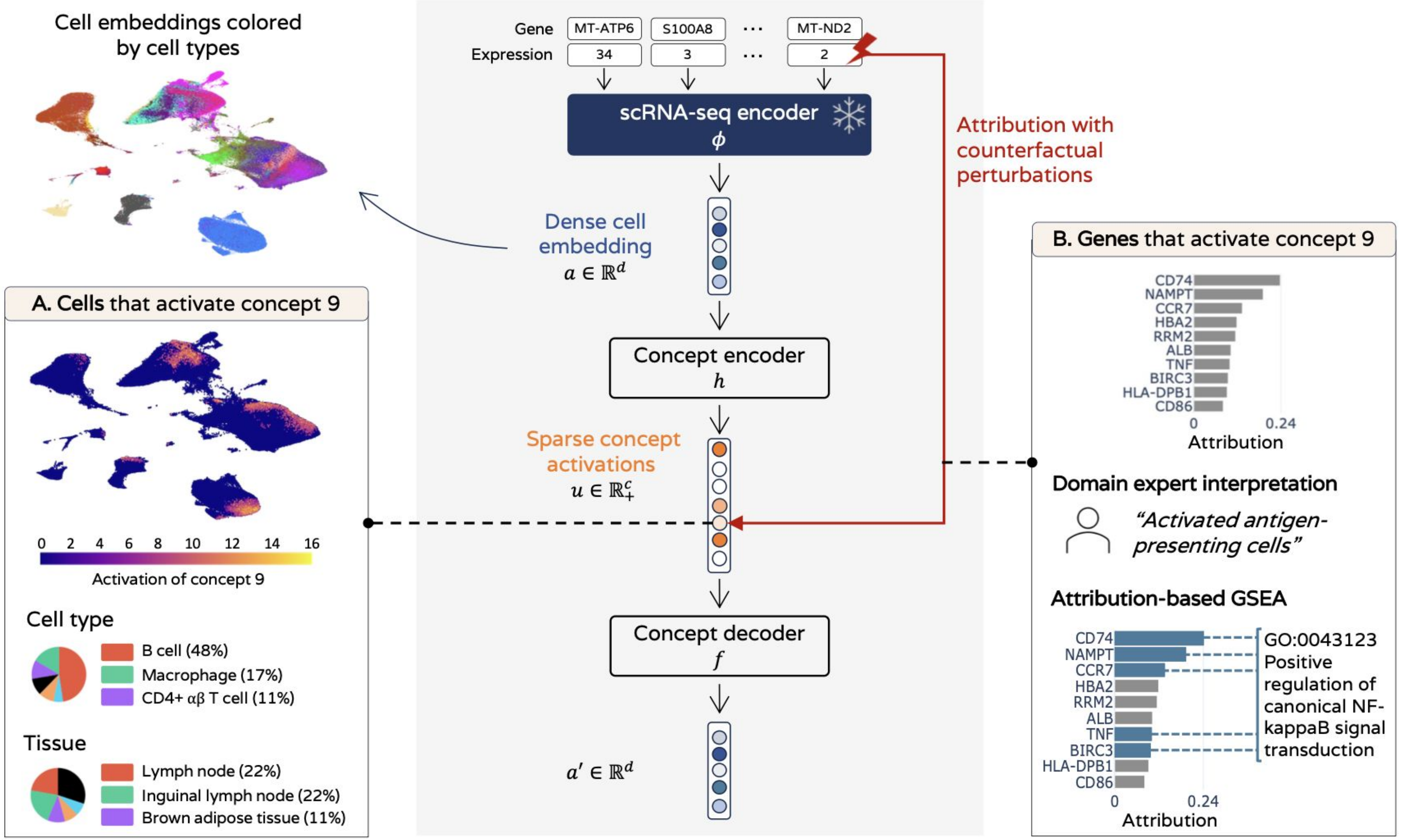
Variable generalization performance of a deep learning model to detect pneumonia in chest radiographs: A cross-sectional study.
Zech JR1, Badgeley MA2, Liu M2, Costa AB3, Titano JJ4, Oermann EK3. https://www.ncbi.nlm.nih.gov/pubmed/30399157

Trust in model decision aided



Must match the complexity capability of the consumer
Must match the domain knowledge of the consumer

Explainability for scientific discovery



Concept-based and counterfactual XAI for discovering interpretable biological concepts in RNA-seq Foundations models
[(Claye et al.,)]

Acknowledgments

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