AI Transforming Healthcare: The Future of AI in Pathology

By Saeed Pirmoradi (AI PhD)

Winter 2025

KHAYYAM AI Lab

Presenter Profile

- Founder of Khayyam AI Innovation Lab

KHAYYAM
AI Lab

- **10** years of experience in AI developing

- More than 20 projects in AI application in medicine

- Data Scientist in Tabriz Valiasr Hospital
  (Clinical Research Development Unit)

Dr Saeed Primoradi (**AI PhD**)

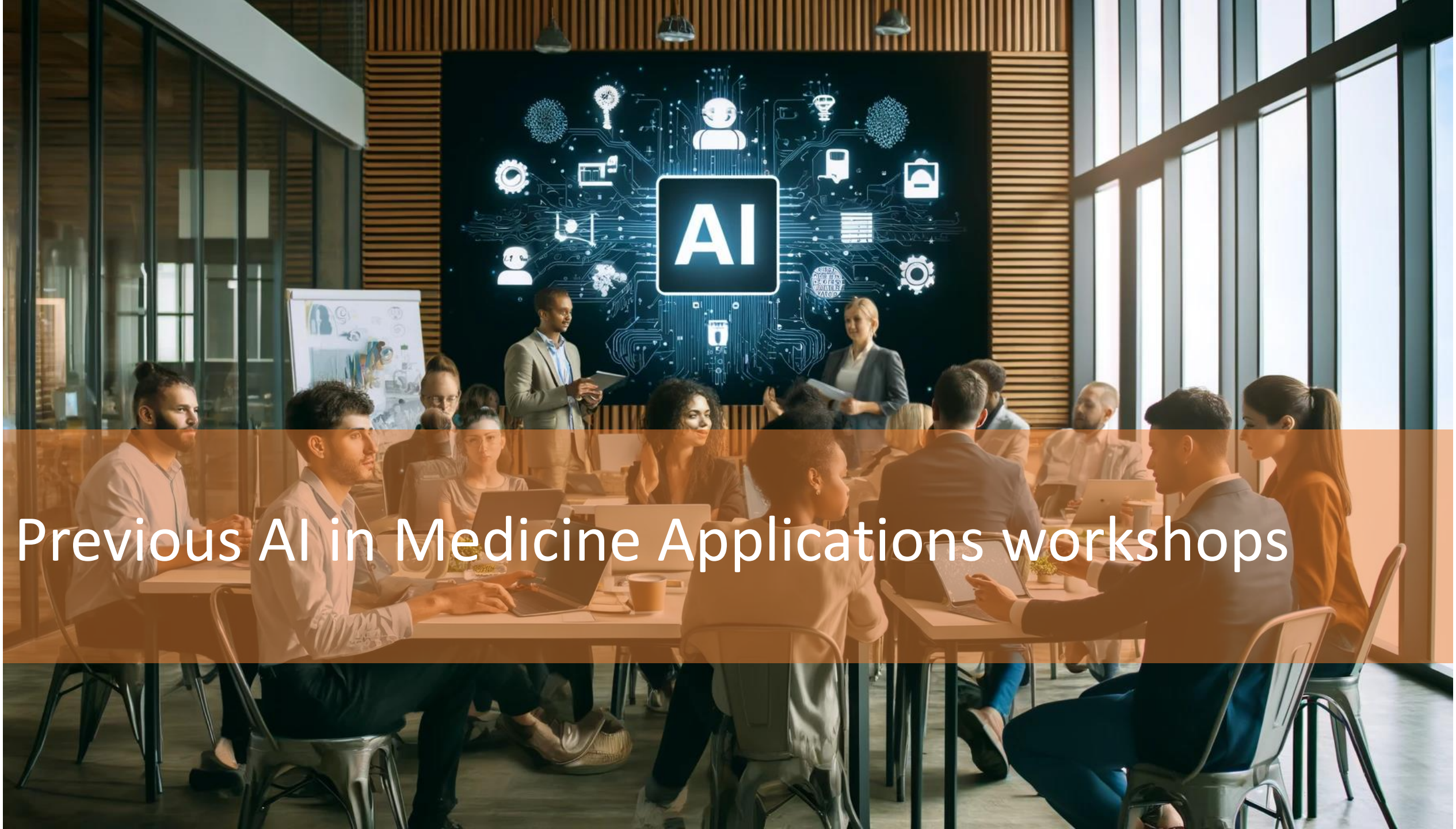
AI Developer

The First (TvAI) Skyroom
International Virtual Congress on the practical Application of Artificial Intelligence in Medical Sciences
Date & Time: 1-5 February 2025 (09:00 Am - 12:00)

تاریخ و زمان برگزاری: ۱۳ تا ۱۷ بهمن ۱۴۰۳ (۹:۰۰ - ۱۲:۰۰ صبح)
اولین کنگره بین المللی مجازی
کاربرد هوش مصنوعی
در علوم پزشکی

بیمارستان لبعیصر تبریز
واحد توسعه تحقیقات بالینی
CLINICAL RESEARCH DEVELOPMENT UNIT

KHAYYAM
AI Lab



Previous AI in Medicine Applications workshops

Facts

Americans experience 12 million diagnostic errors a year.

(Reference link from CBS news)

28 % of diagnostic mistakes are life threatening or result in death or permanent disability.

(Reference link from NCPA)

Breast cancer misdiagnosis costs $4B/year.

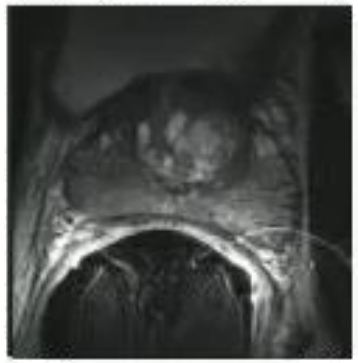
(Reference link from CNBC news)

General Types of **error**:

1) Scanning error
   (we fail to fixate in specific areas)
2) Recognition error
   (we fail to detect abnormality)
3) Decision-making error
   (almost 50% of error by incorrect interpretation of a malignant/benign)

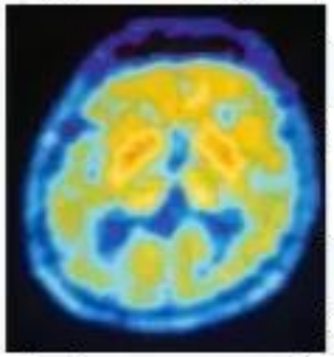
Medical imaging

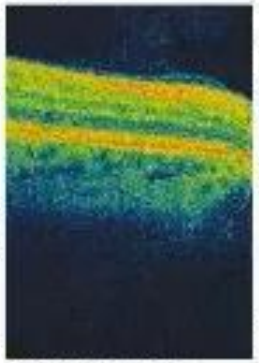
Many modalities/case: 700 Billion images/year in the US alone


Prostate MR


Breast U/S

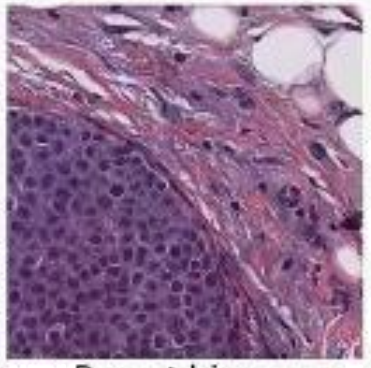

Brain CT


Parkinson PET


OCT retina


Prostate U/S


Lung X-Ray


Breast biopsy

Errors and misdiagnosis

We need to talk: Pathologists, Patients, and Diagnostic errors.

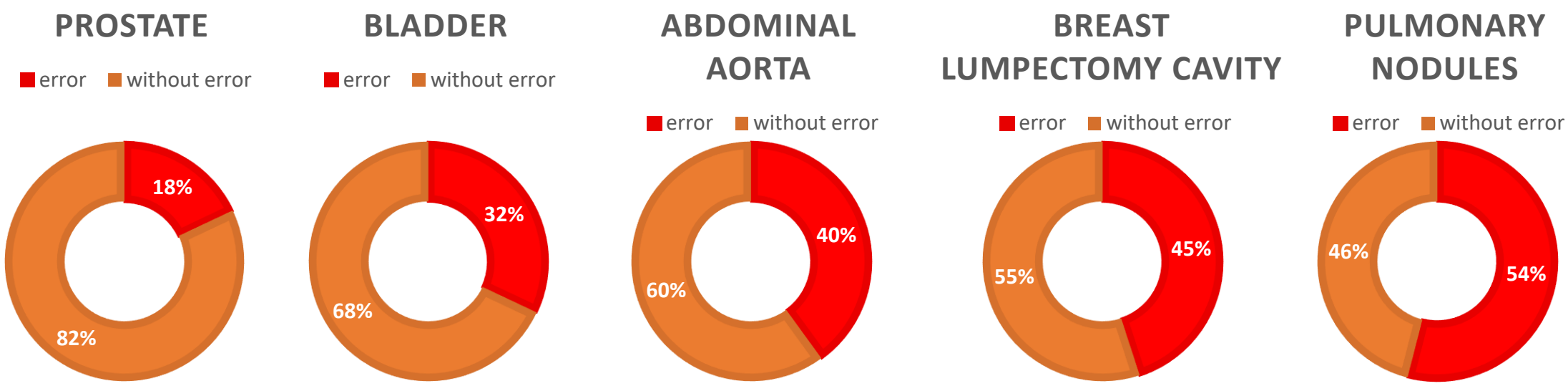
Survey of 260 pathologists and 81 laboratory medical directors with response rate 51%

The pathologist 06/23/2016

(Reference link)

The source of all problems

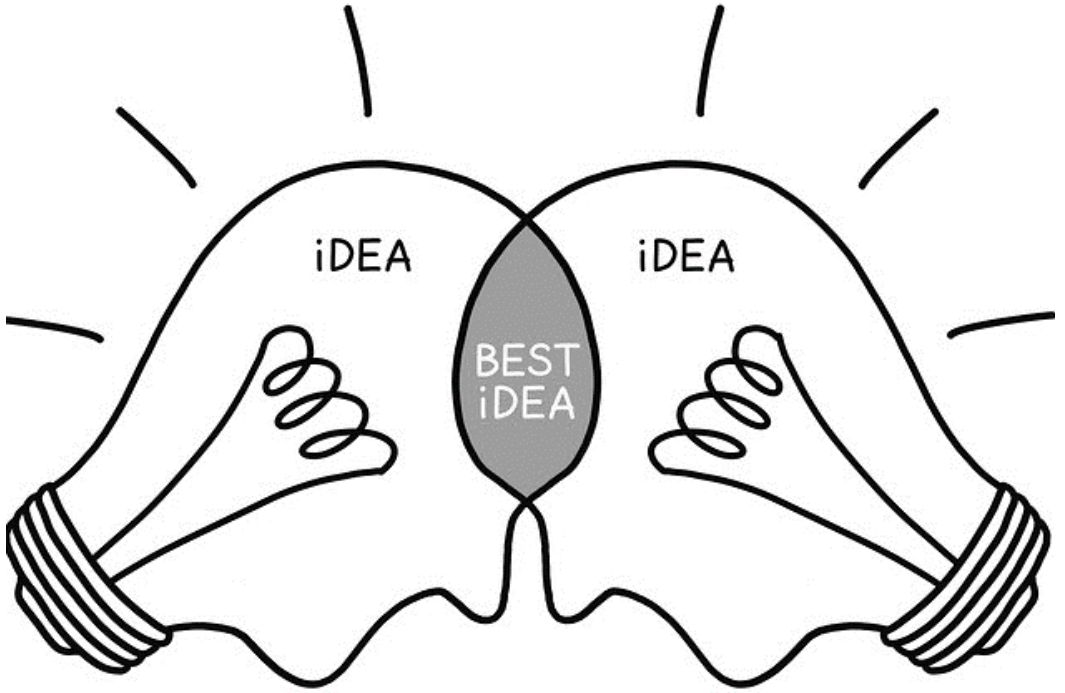
Inter-Observer Variability



Inter-Observer Variability is more scary

Important question

What can Artificial Intelligence do?

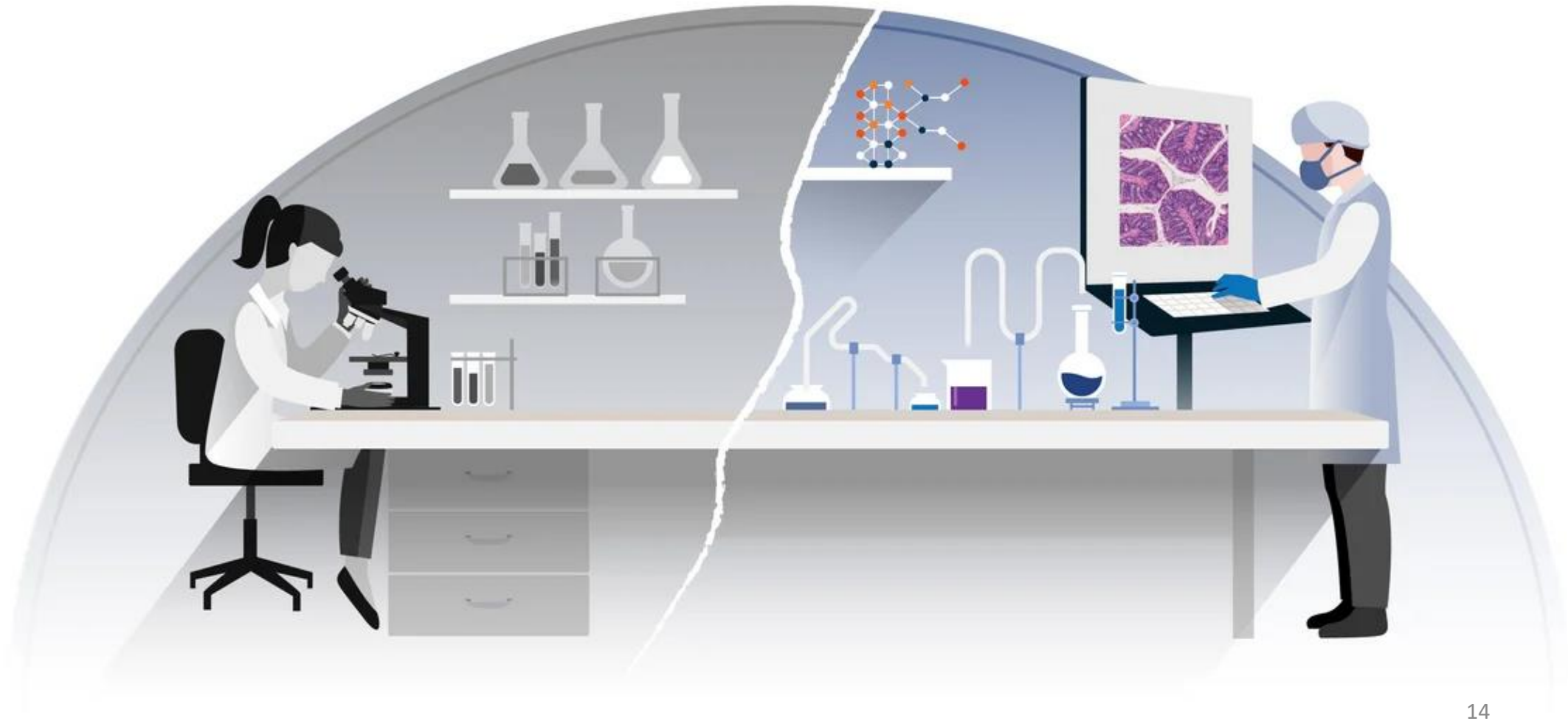


A.I., especially Machine Learning, allows for a computer model to learn and extract meaningful patterns from data in a semi-automatic manner.

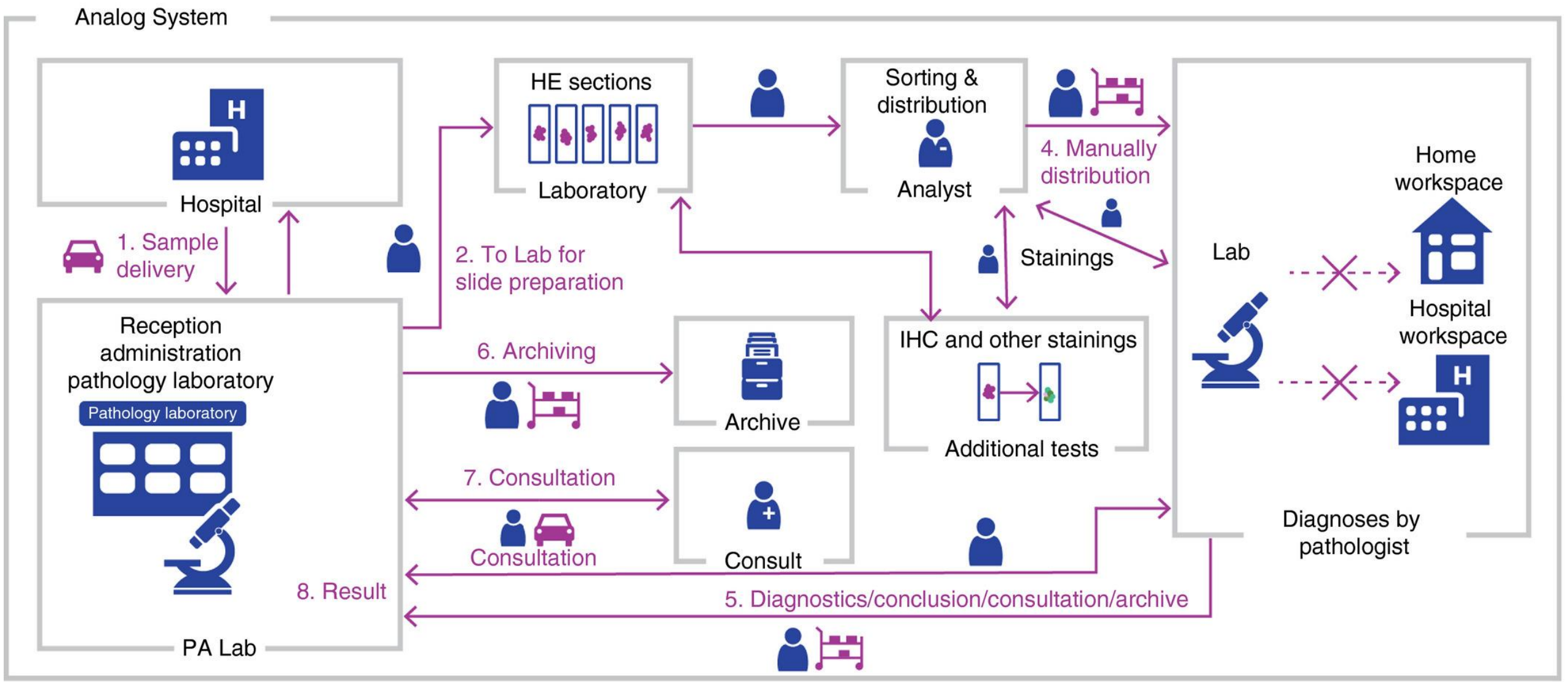
Introduction to Digital Pathology

Pathology Process

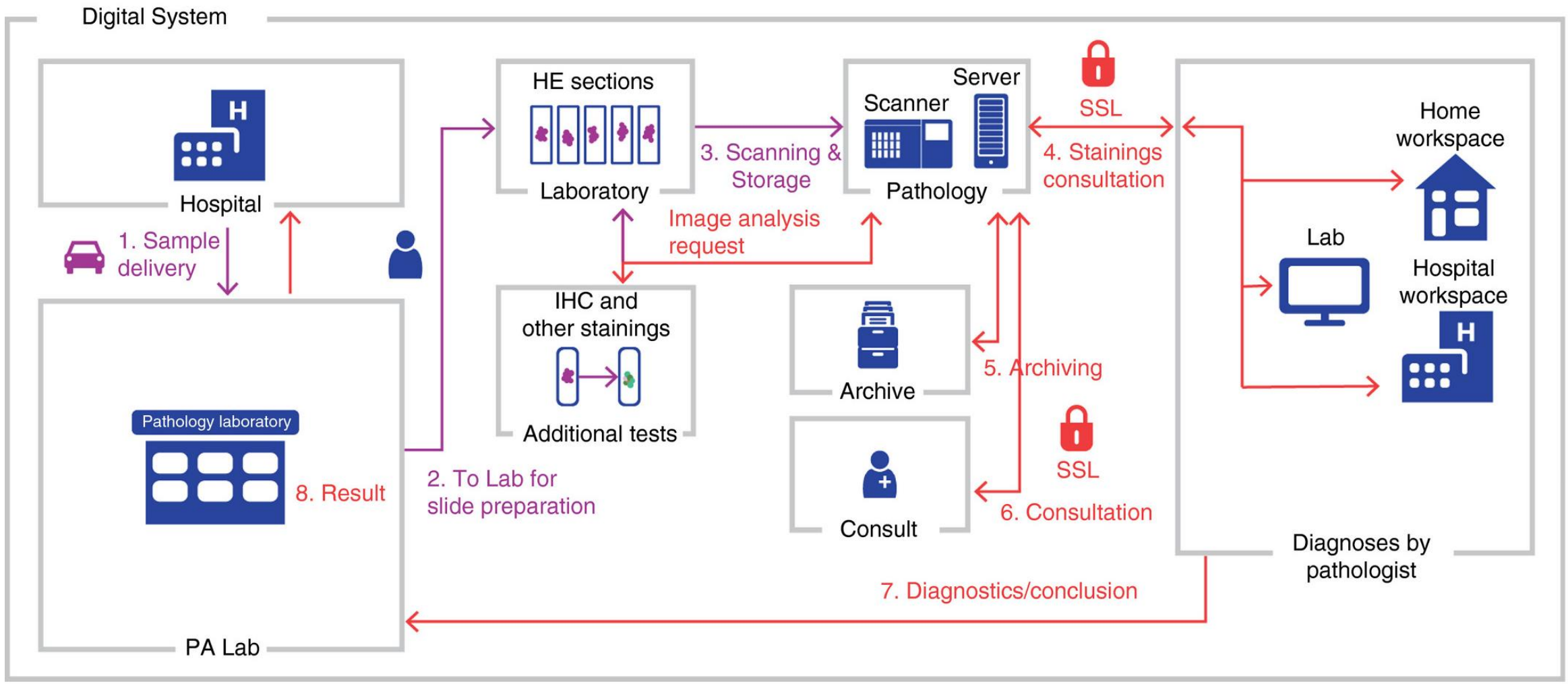
Digital Pathology



Pathology: Conventional Microscopy



Pathology: Virtual Microscopy



the Pathologist® 10 YEARS

Going 100 % Digital

Making the move to 100 Percent Digital:

The **LabPon** is the first laboratory in the world to digitise its histopathology service fully

DP has four key benefits:

- Efficient workflows
- Connected teams
- Increased safety
- New insights from analysing large datasets

The potential operational cost savings for 5 years following the implementation of a digital pathology solution were estimated at around $18 million.

The main contributing factors were gains in pathologist time by higher productivity and better workload distribution ($12.4 million), and reduced costs of incorrect treatment.

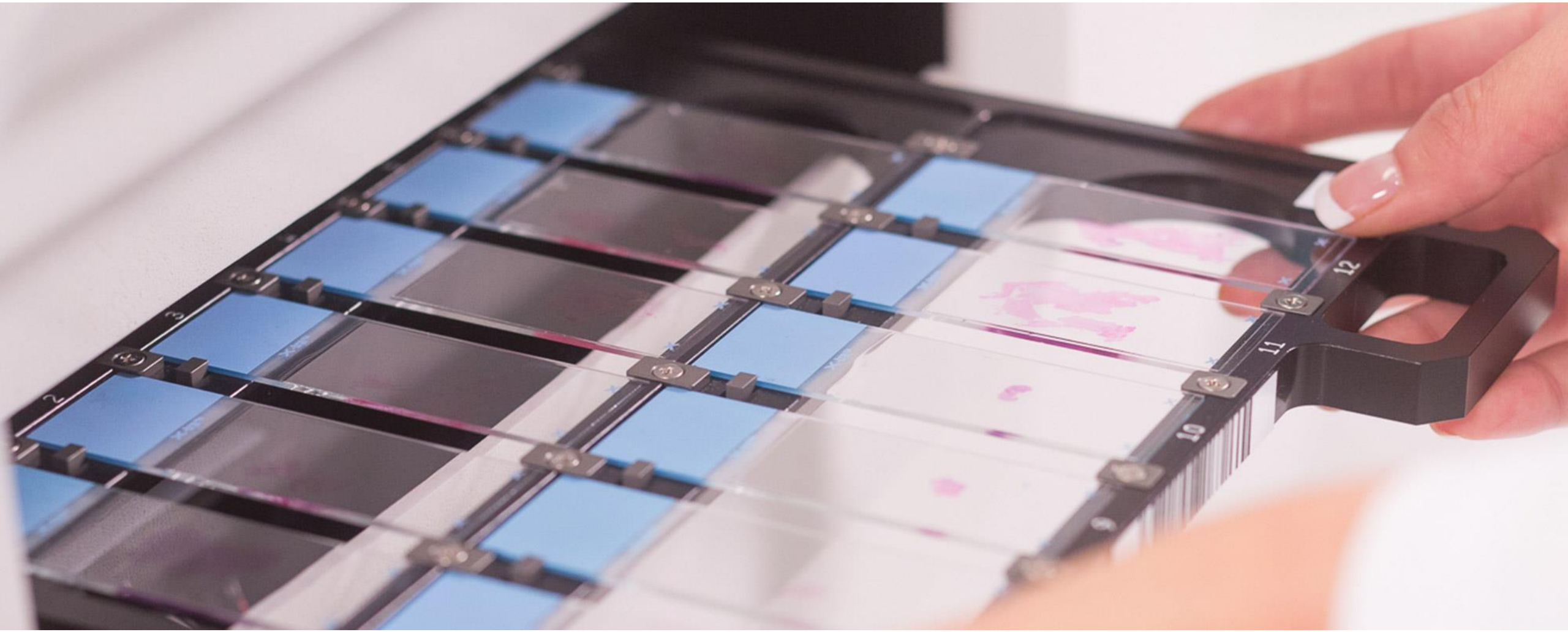
The over- and under-treatment costs in oncology were estimated at $5.4 million.

Digital Pathology: Scanners

HURON Digital Pathology

Grundium

Whole Slide Images (WSI): Setup



Whole Slide Images (WSI): Image View

Magnification

To calculate magnification

Biological / Compound Microscope

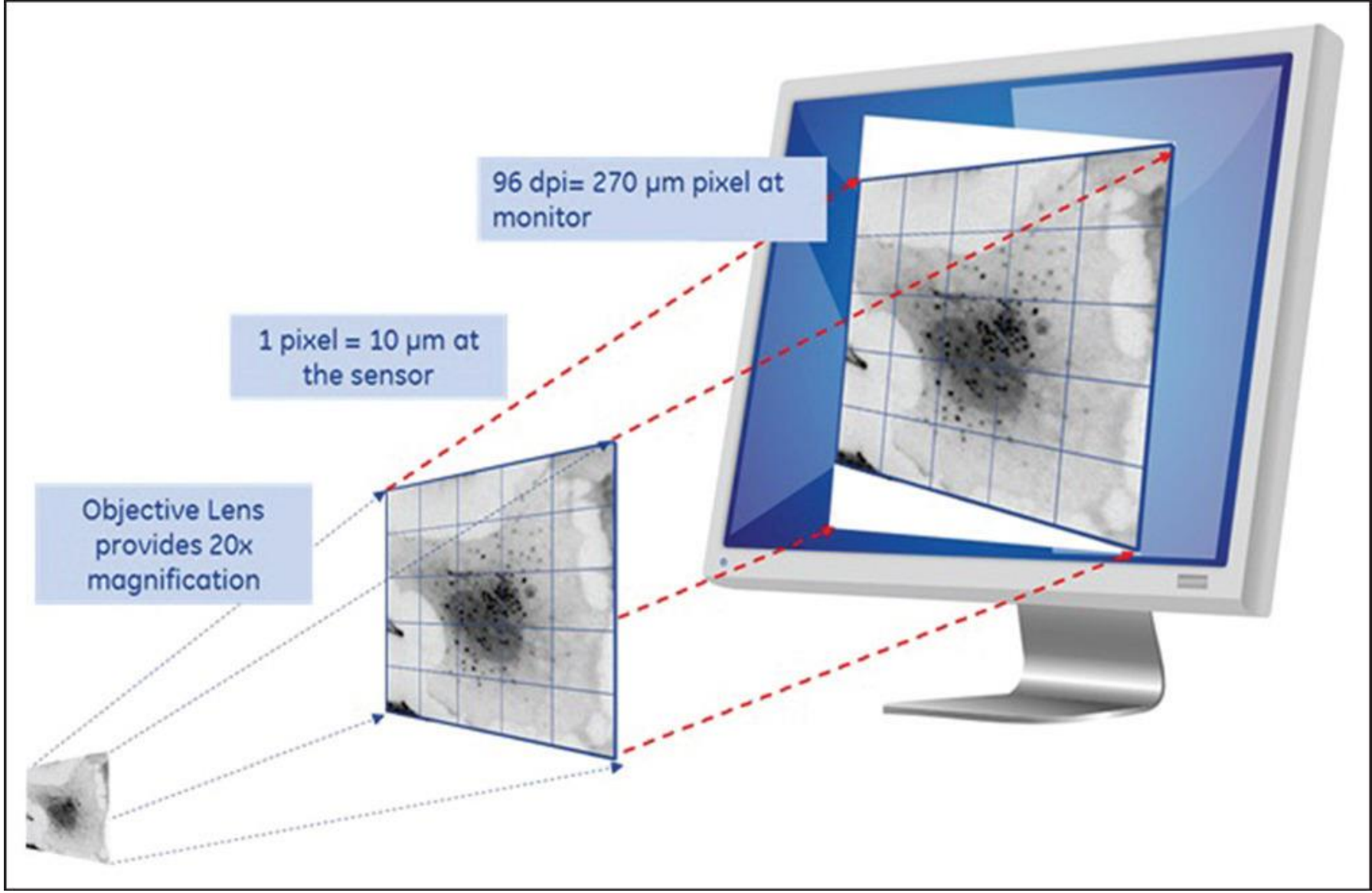
eyepiece x objective lens = magnification

(10x) x (4x) = 40x

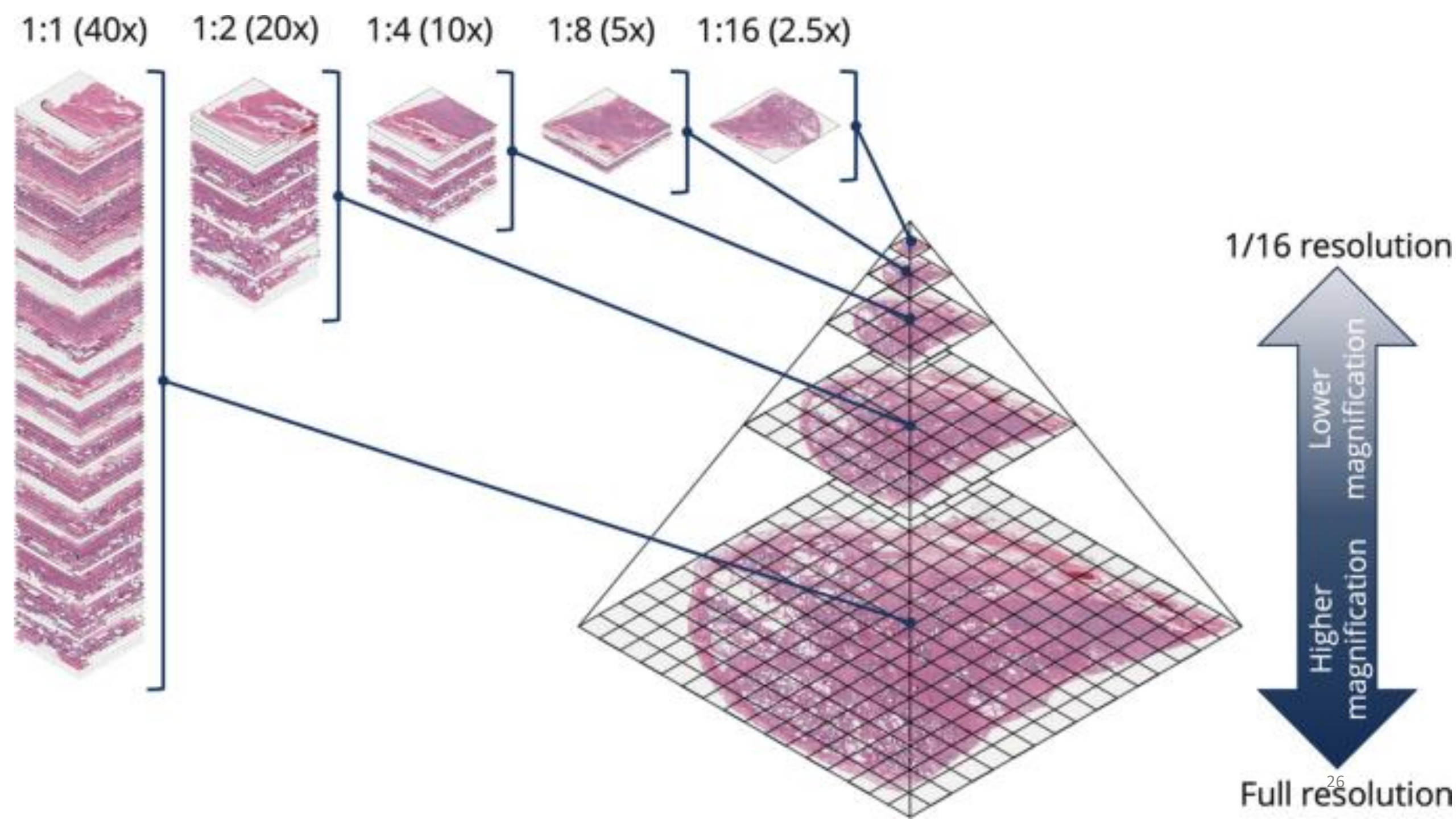
Magnification ≠ Resolution

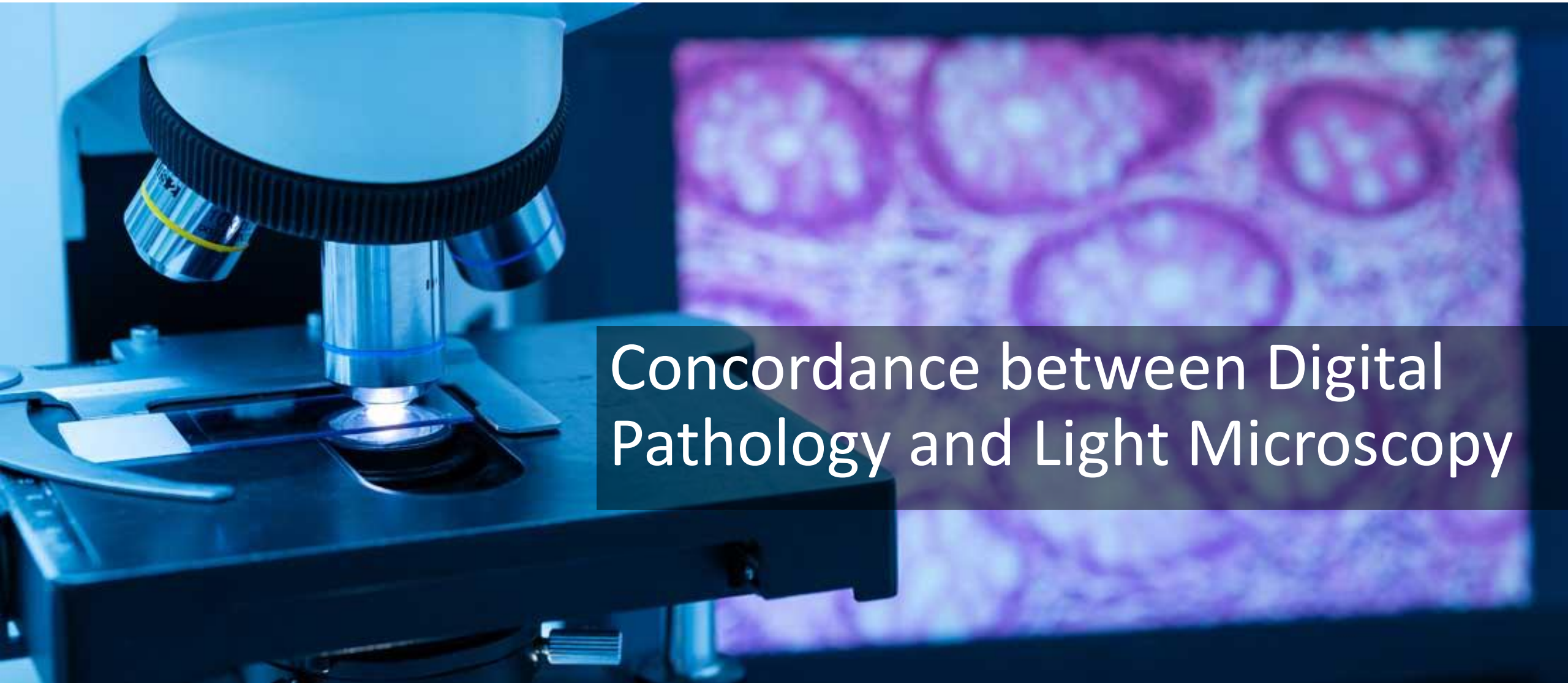
Optical Resolution = f(Objective Lenses)

The added boost at magnification comes from the monitor's workstation.



Digital Resolution = f(Objective Lens, Digital Camera Sensor, Monitor)


1:1 (40x)
1:2 (20x)
1:4 (10x)
1:8 (5x)
1:16 (2.5x)
1/16 resolution
Lower magnification
Higher magnification
Full resolution



Concordance between Digital Pathology and Light Microscopy

2014

Journal of Clinical Pathology

Concordance between digital pathology and light microscopy in general surgical pathology: a pilot study of 100 cases

Joseph P Houghton,[1] Aaron J Ervine,[2] Sarah L Kenny,[2] Paul J Kelly,[2]
Seamus S Napier,[2] W Glenn McCluggage,[2] Maureen Y Walsh,[2] Peter W Hamilton[3]

There was concordance between the original light microscopy diagnosis and digital pathology-based diagnosis in 95 of the 100 cases while the remaining 5 cases showed only slight discordance (with no clinical consequence). None of the cases were categorised as discordant. Participants had mixed experiences using digital pathology technology.

2017

ARCHIVES
of Pathology & Laboratory Medicine

The Diagnostic Concordance of Whole Slide Imaging and Light Microscopy

A Systematic Review

Edward Goacher, BSc; Rebecca Randell, PhD; Bethany Williams, MBBS; Darren Treanor, MB, BSc, PhD, FRCPath

Thirty-eight studies were included in the review. The mean diagnostic concordance of WSI and LM, weighted by the number of cases per study, was 92.4%. The weighted mean κ coefficient between WSI and LM was 0.75, signifying substantial agreement. Of the 30 studies quoting percentage concordance, 18 (60%) showed a concordance of 90% or greater, of which 10 (33%) showed a concordance of 95% or greater. This review found evidence to support a high level of diagnostic concordance. However, there were few studies, many were small, and they varied in quality, suggesting that further validation studies are still needed.

2018

Digital pathology for the primary diagnosis of breast histopathological specimens: an innovative validation and concordance study on digital pathology validation and training

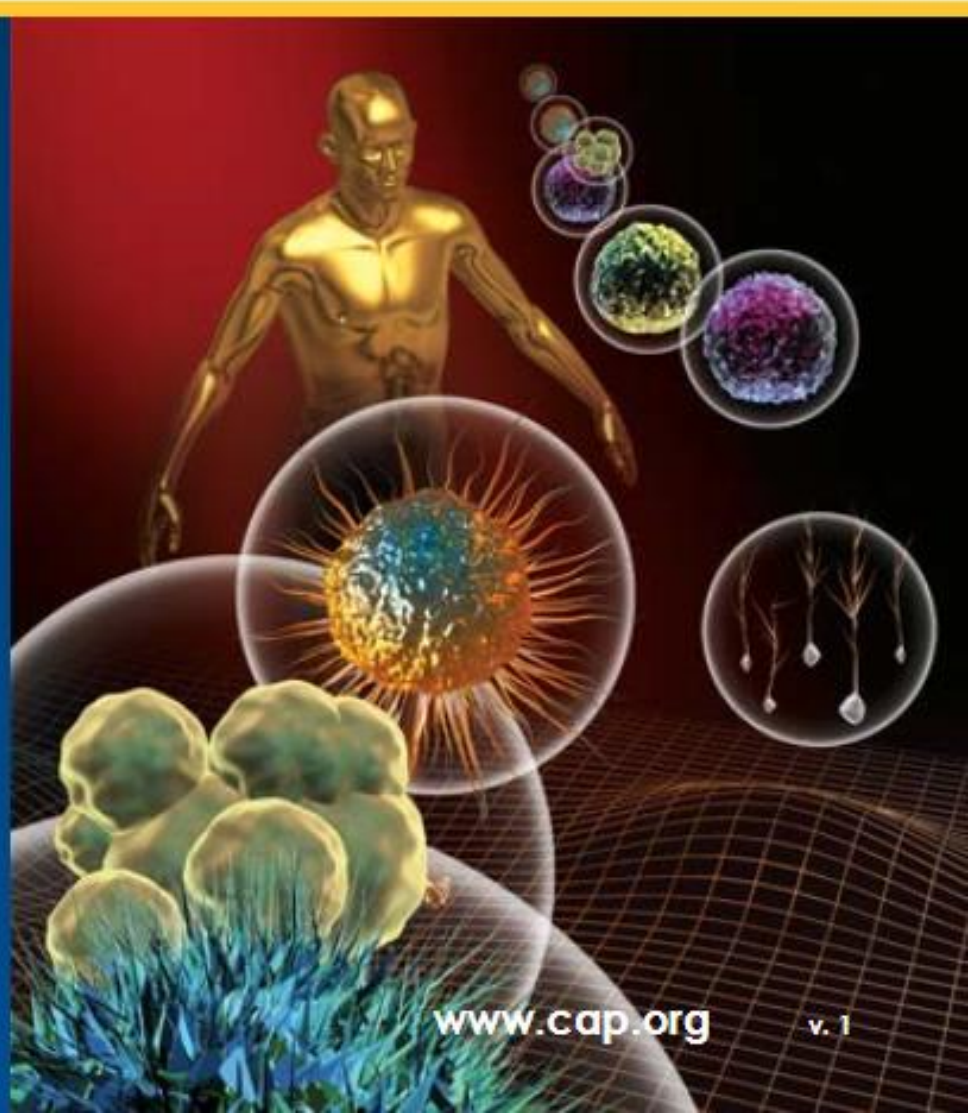
Bethany Jill Williams ✉, Andrew Hanby, Rebecca Millican-Slater, Anju Nijhawan, Eldo Verghese, Darren Treanor

Three specialty breast pathologists completed training in using a digital microscopy system. They were exposed to a training set of 20 challenging cases, designed to help them identify personal digital diagnostic pitfalls. Following this, the three pathologists viewed a total of 694 live, entire breast cases. All primary diagnoses were made on digital slides, with immediate glass slide review and reconciliation before the final case sign-out. There was complete clinical concordance between the glass and digital impression of the case in 98.8% of cases.

Pathology and Laboratory Quality Center

Recommendations for Validating Whole Slide Imaging Systems for Diagnostic Purposes in Pathology

Anil V Parwani, MD, PhD
On behalf of the CAP WSI Validation Expert Panel



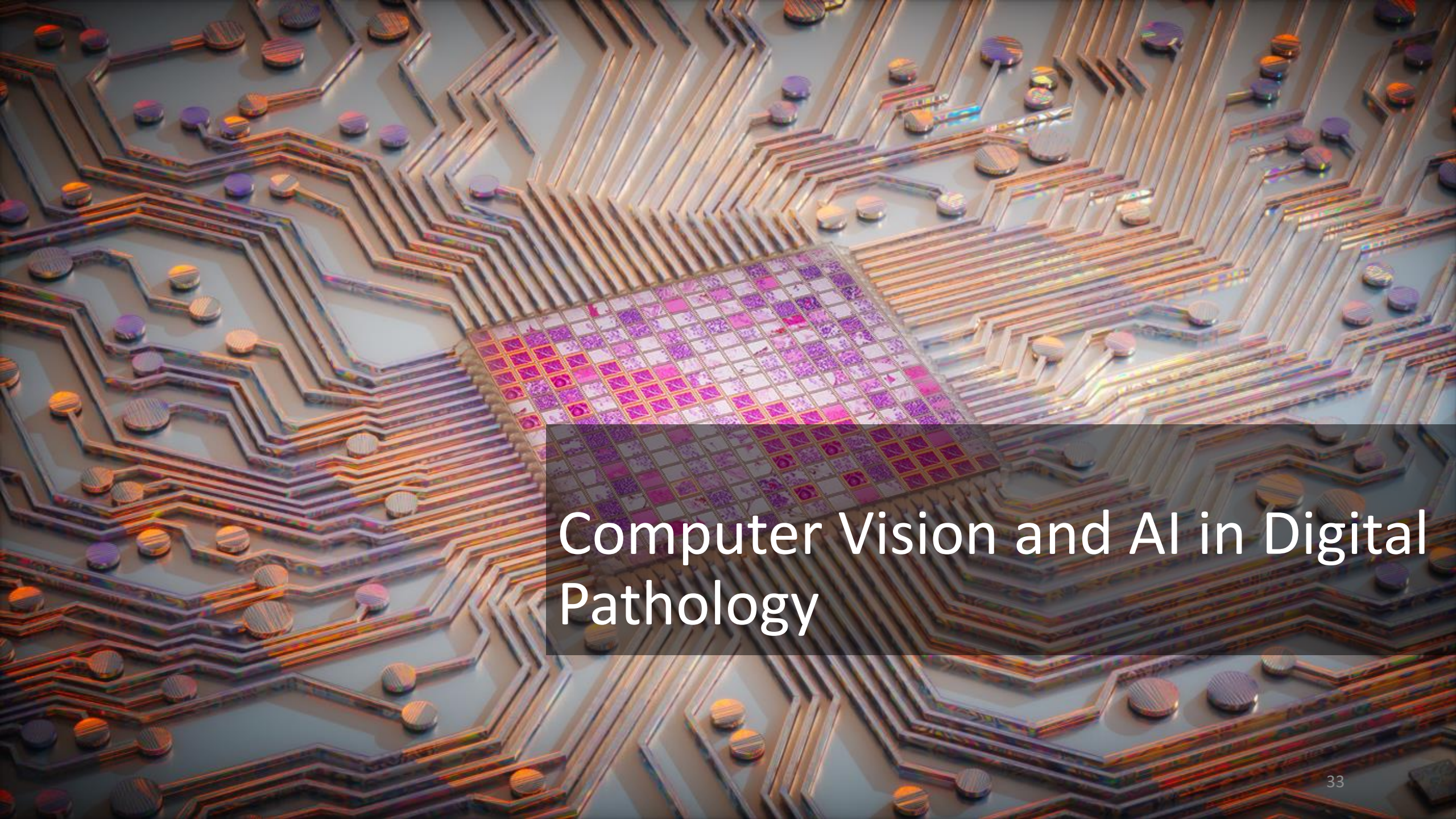
CAP Recommendations

The validation study should encompass the entire WSI system

-The validation process should include at least 60 cases for one application… reflecting the spectrum and complexity of specimen types and diagnoses likely to be encountered during routine practice.

-The validation study should establish a diagnostic concordance between digital and glass slides for the same observer (i.e., intraobserver variability).

-The washout period of at least 2 weeks should occur between viewing digital and glass slides.

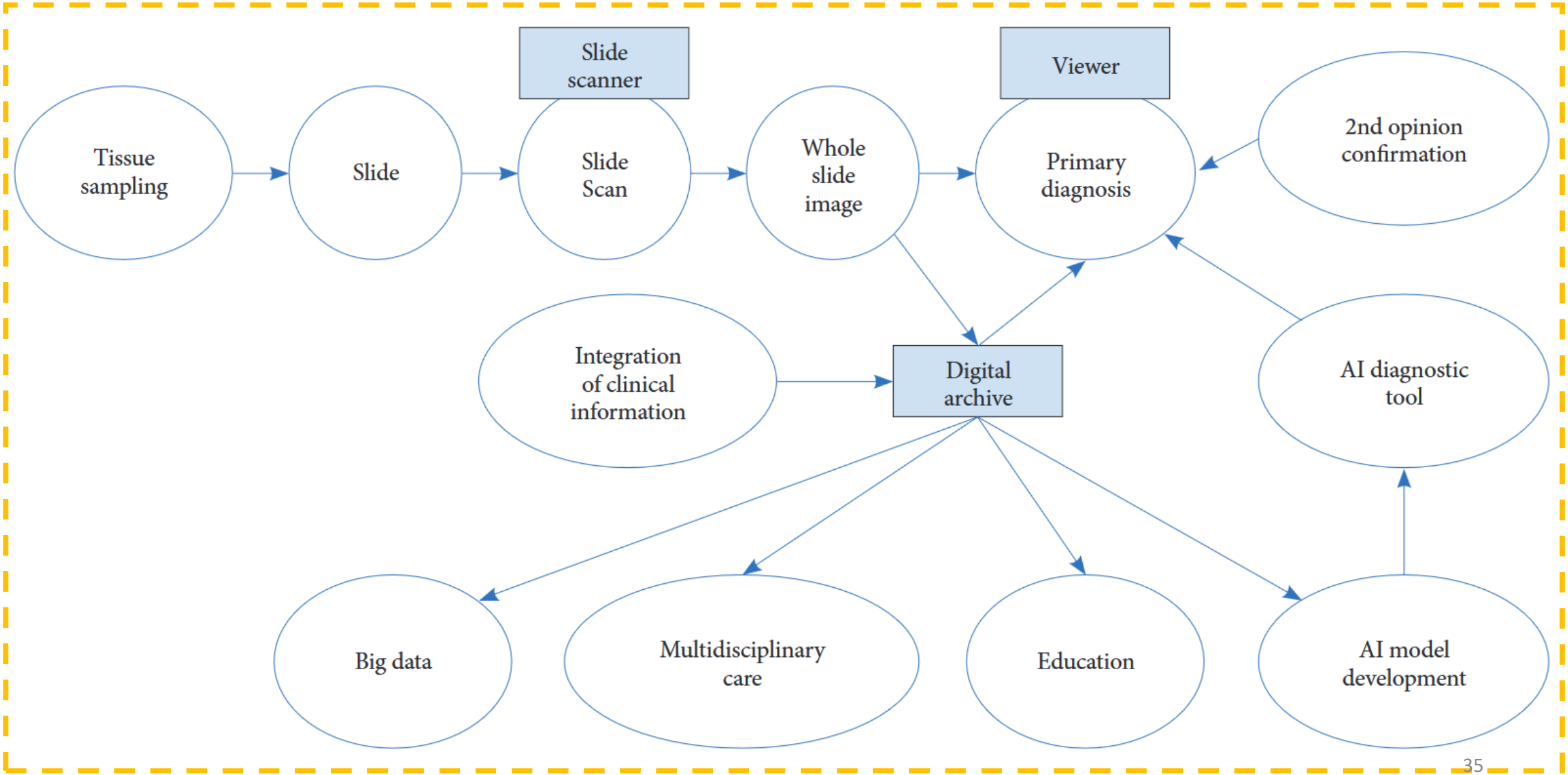


Computer Vision and AI in Digital Pathology

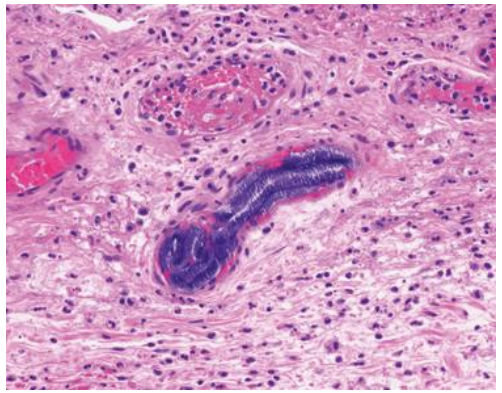
Clinical Pathology Challenges:

- Inter-observer variance
- Intra-observer variance
- Lack of quantitative, objective, and reproducible measures to assess patient biopsies
- The human brain can keep track of only a few variables

Workflow of digital pathology

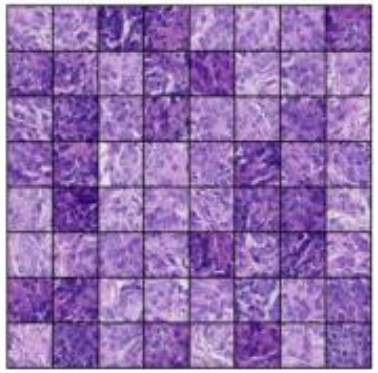


What can AI do with images?

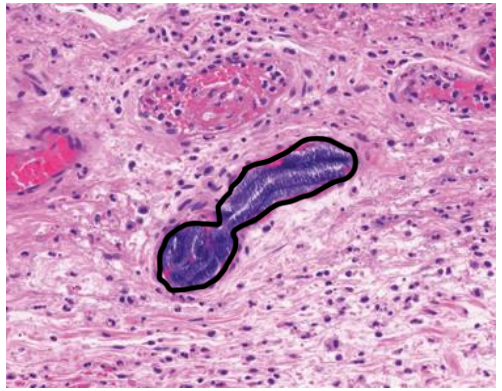


Classify
Yes / No

Generate



Segmentation



Search

Pathology report generator

NATIONAL CANCER INSTITUTE
Center for Cancer Genomics

TCGA

Genomic Data Commons
Data Portal

Harmonized Cancer Datasets

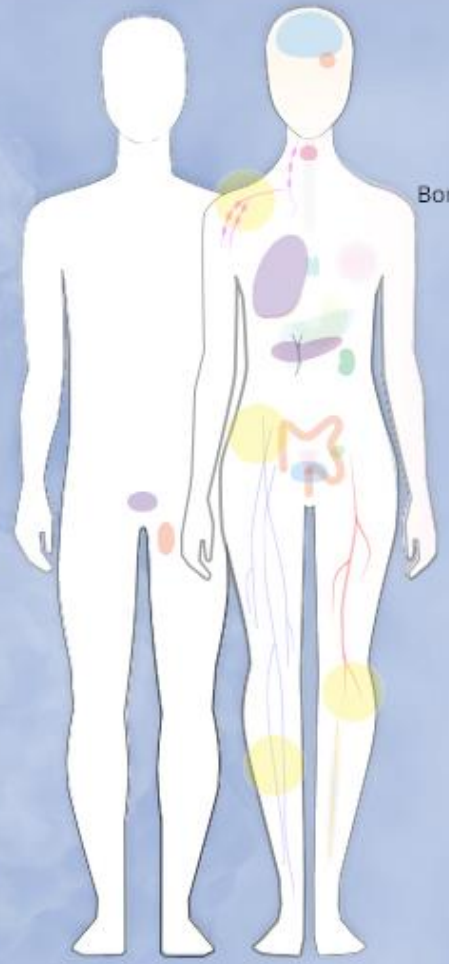
A repository and computational platform for cancer researchers who need to understand cancer, its clinical progression, and response to therapy.

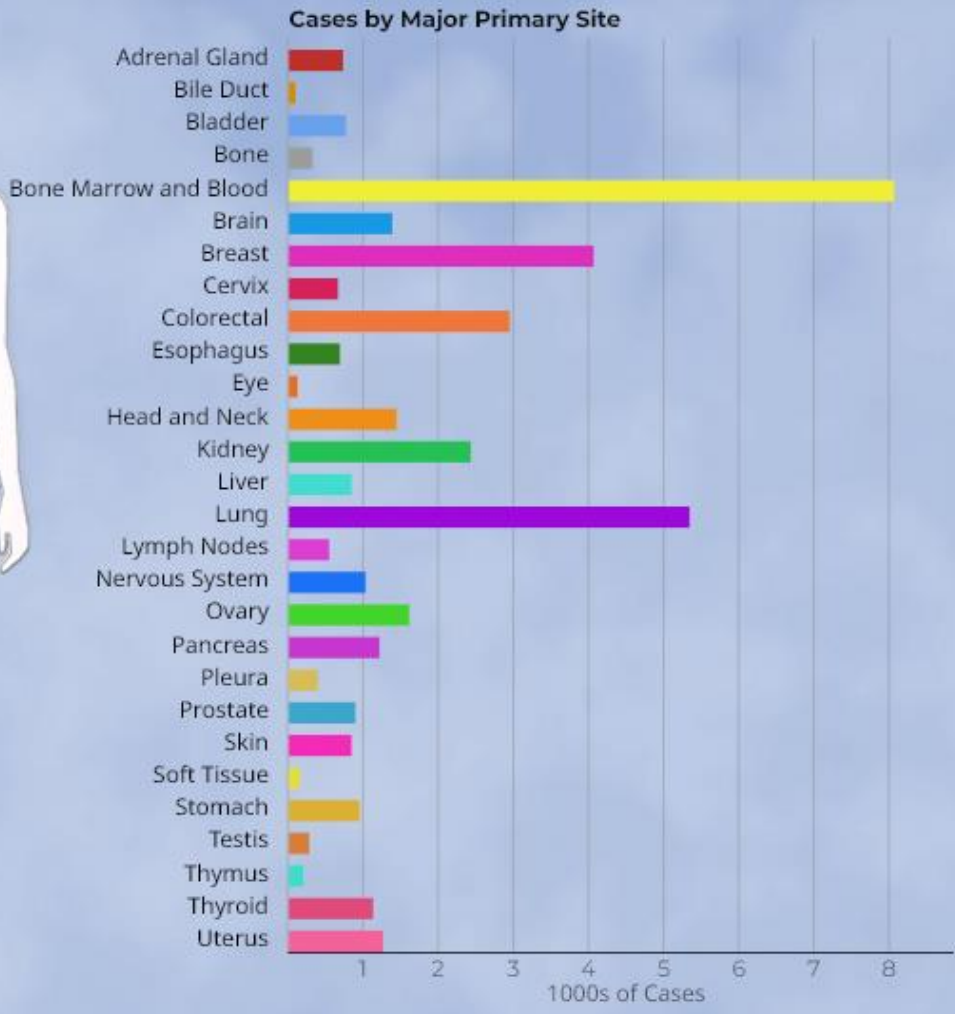
Explore Our Cancer Datasets

Data Portal Summary

Data Release 41.0 - August 28, 2024

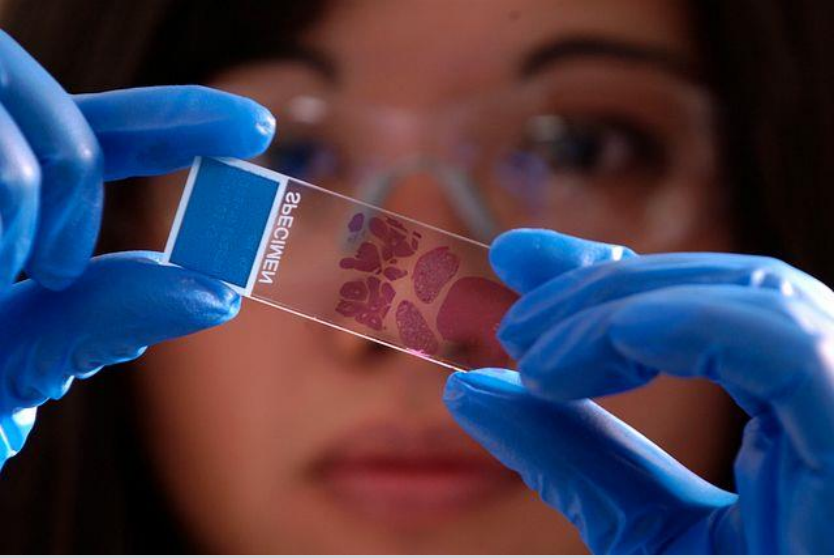
86	69	44,736	1,027,517	22,534	2,940,240
Projects	Primary Sites	Cases	Files	Genes	Mutations





The data in this challenge contains whole-slide images (WSI) of hematoxylin and eosin (H&E) stained lymph node sections.
Depending on the particular data set (see below), ground truth is provided:

- On a **lesion-level:** with detailed annotations of metastases in WSI.
- On a **patient-level:** with a pN-stage label per patient.

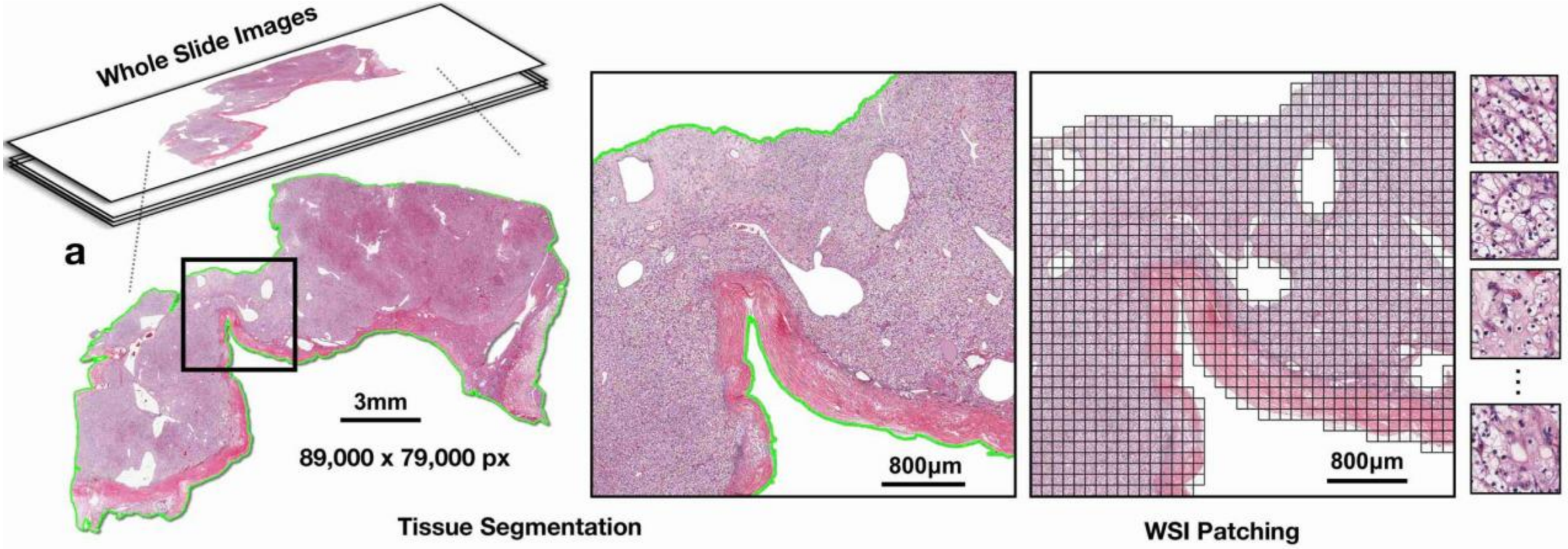


Datasets

The TCGA has many cancers, with over 1.2 petabytes of data, including pathology slides.

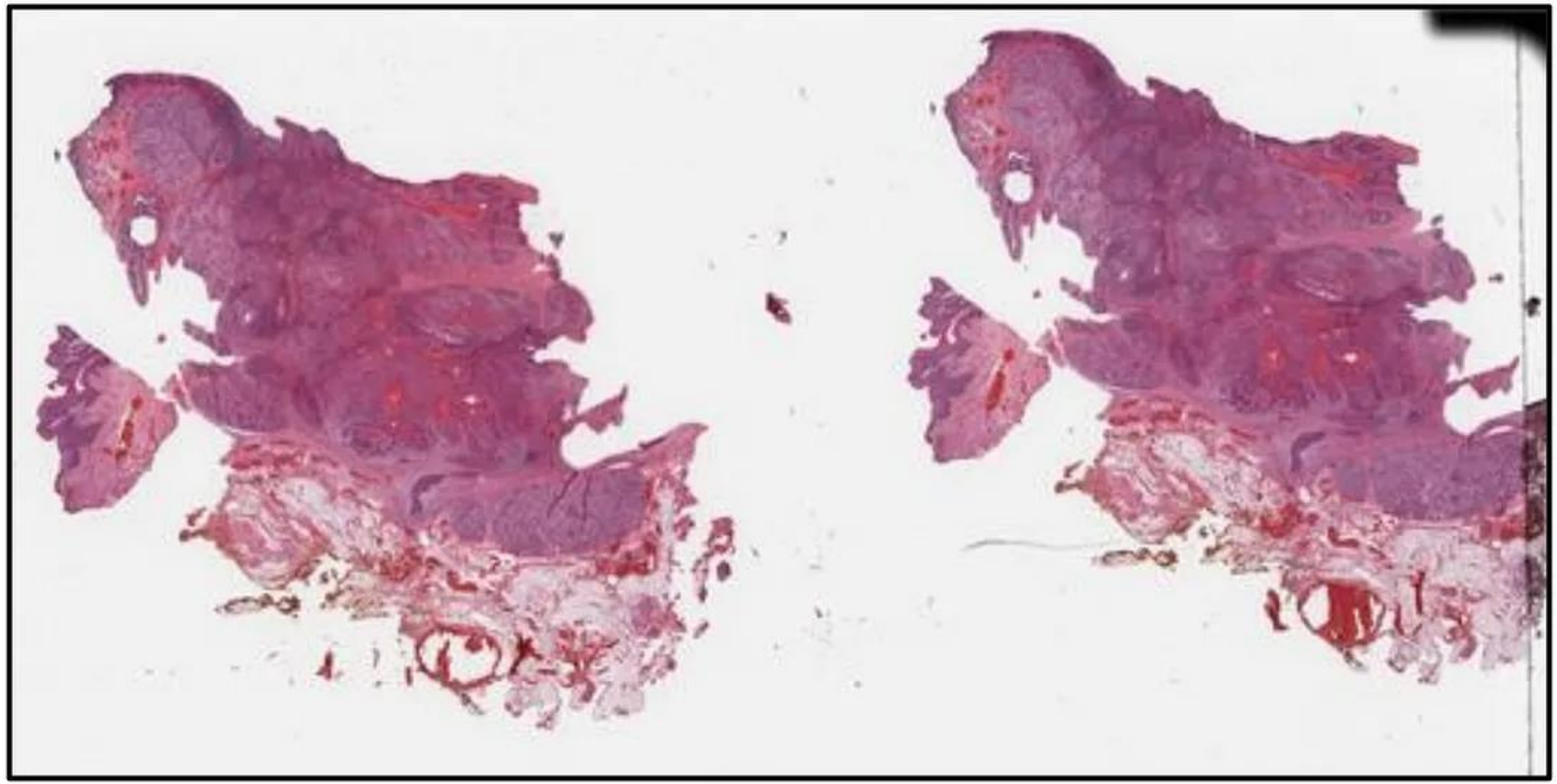
The Camelyon has 1399 WSIs with tumor marking in metastasis, without subtyping, not configuring a diagnosis.

However, most public datasets are not in WSIs or do not have pathologists' pixel-level annotations.



Images that can have more than 10 billion pixels, cannot be used fully as an input of a neural network without overflowing memory.

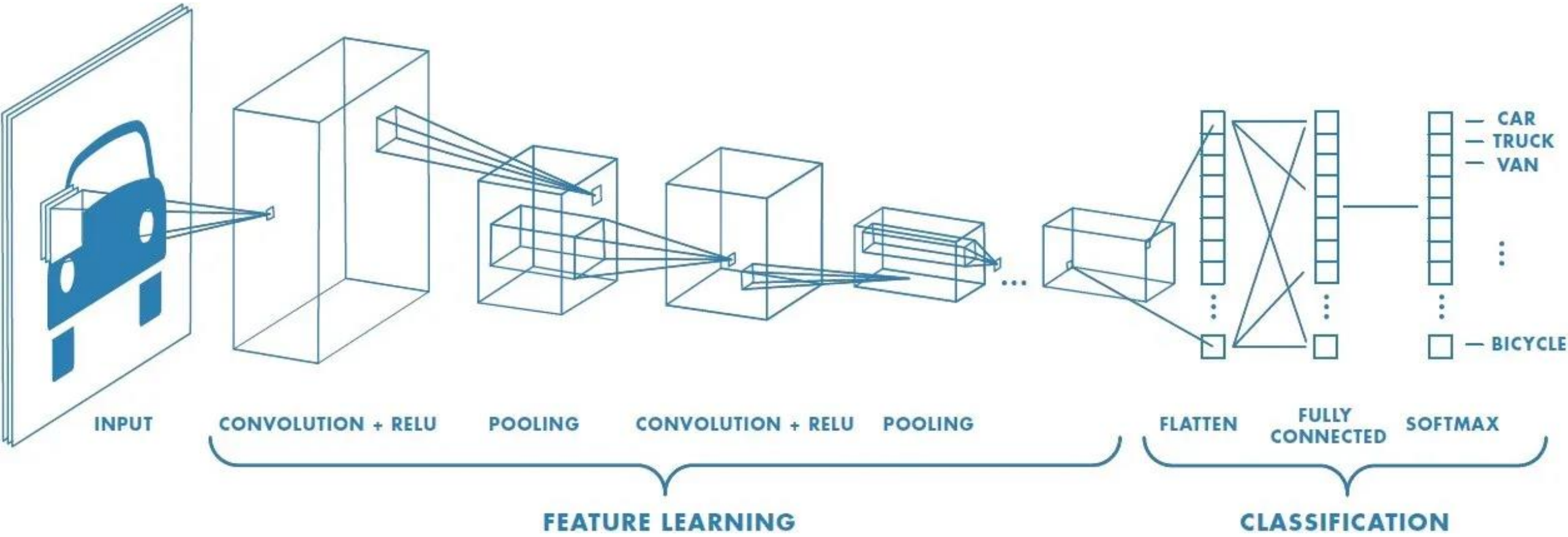
Therefore, all studies divided the WSIs into smaller patches (such as 256x256 pixels), using overlap or not as data augmentation, to feed their models.



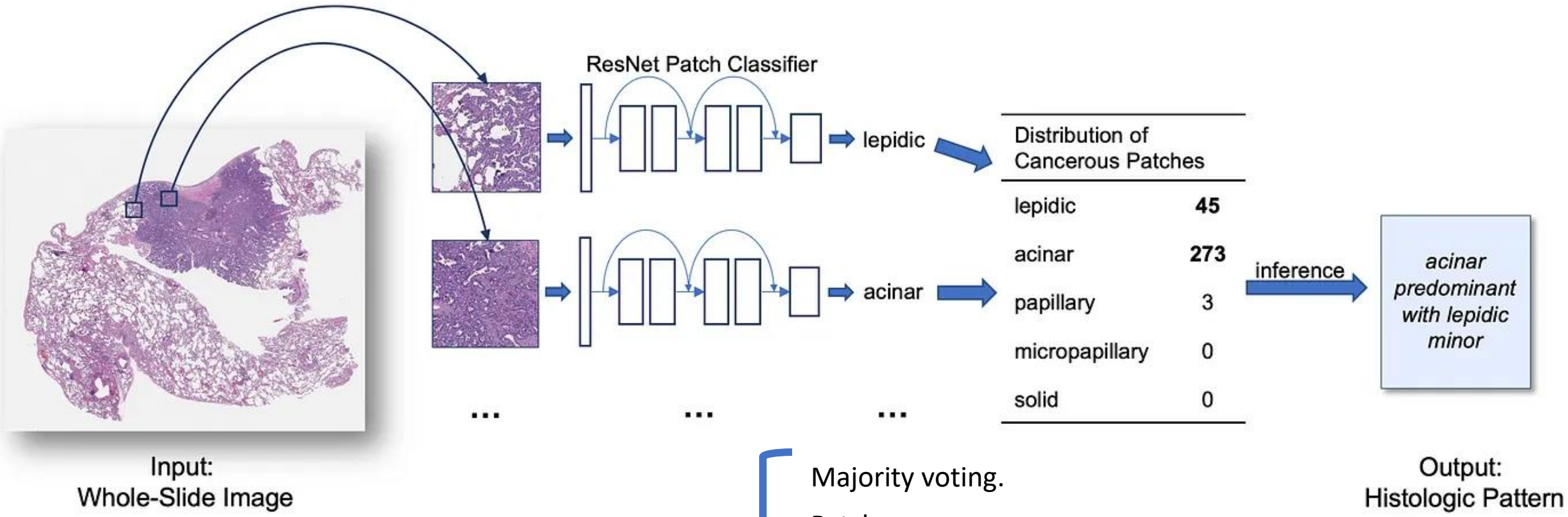
77781 pixels

158002 pixels

Deep Learning & Convolutional Neural Nets

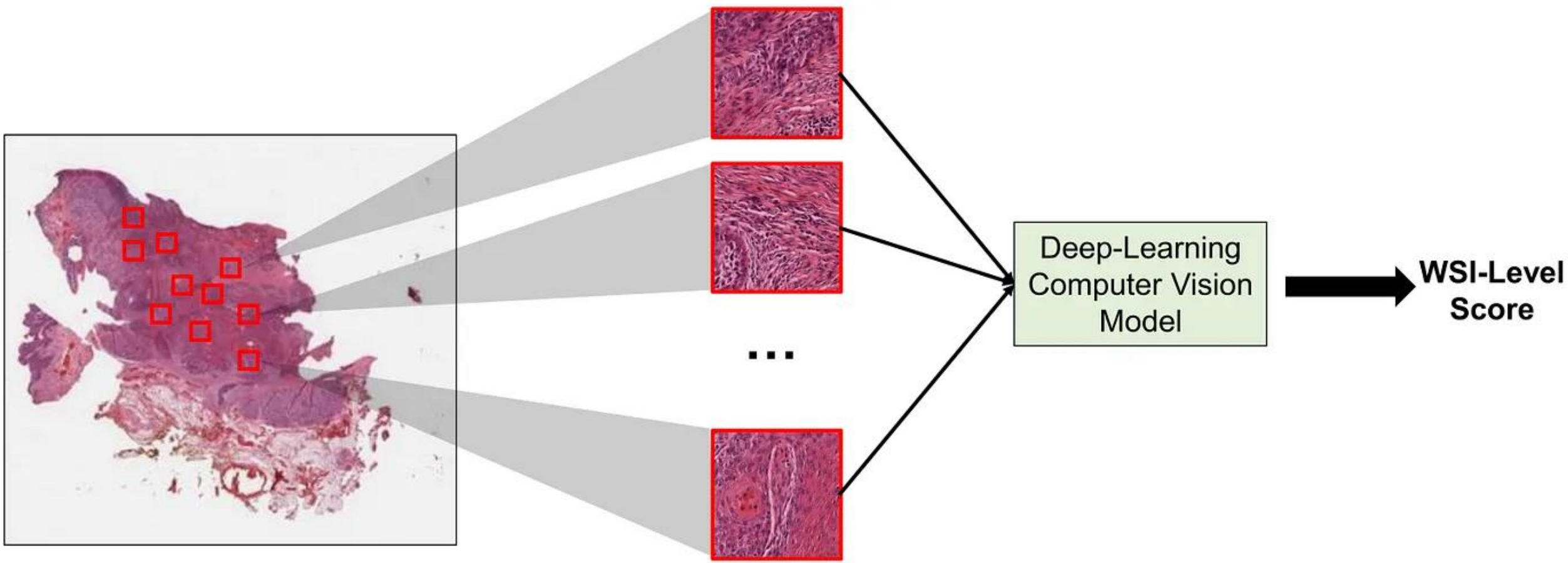


Whole-Slide Inference

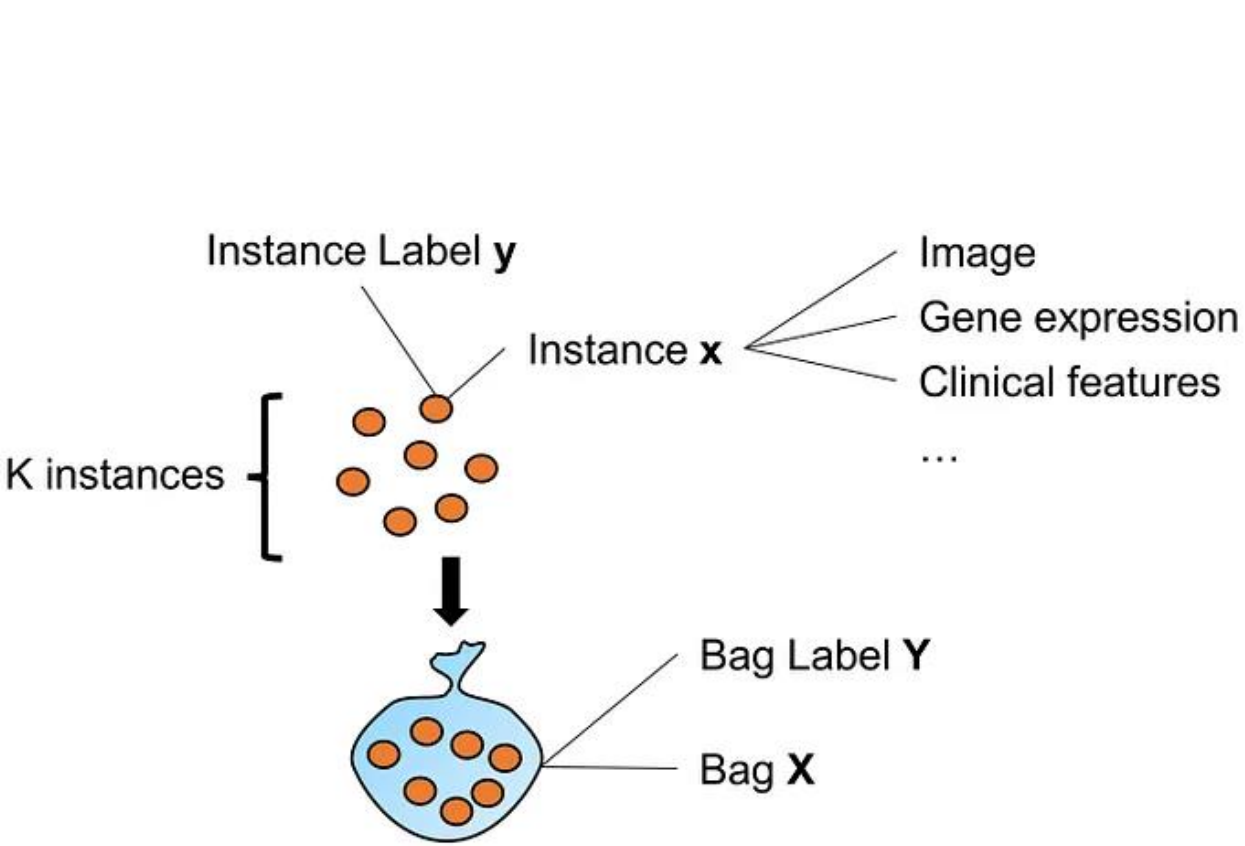


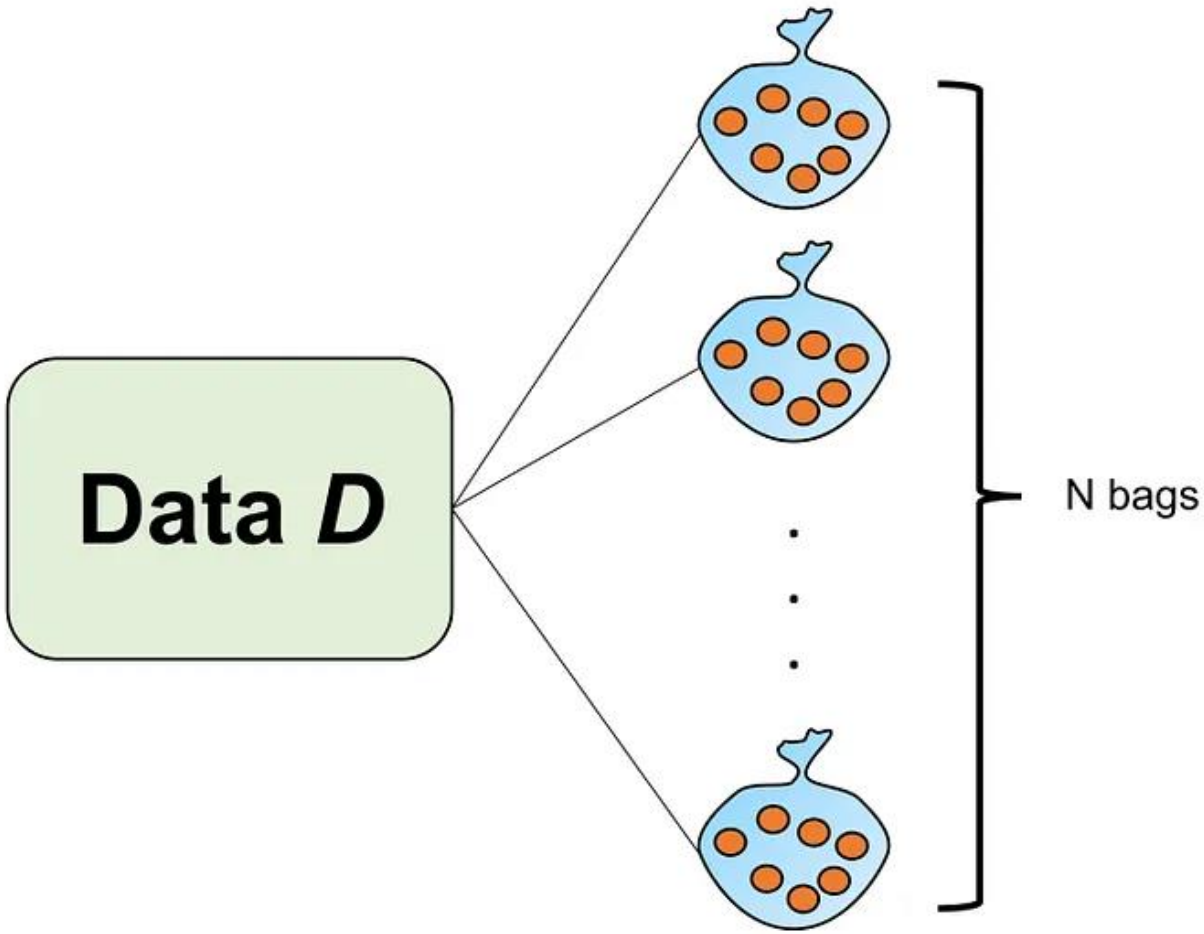
- Majority voting.
- Patch averages.
- Thresholding.
- Machine learning.

The idea of Multiple Instance Learning (MIL) in WSI analyses



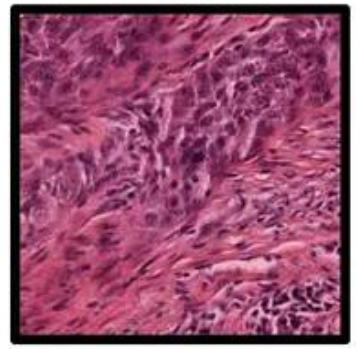
Problem Statement of general MIL (MIL-G)





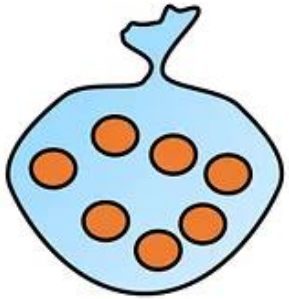
Instance **x**

Patch **x**

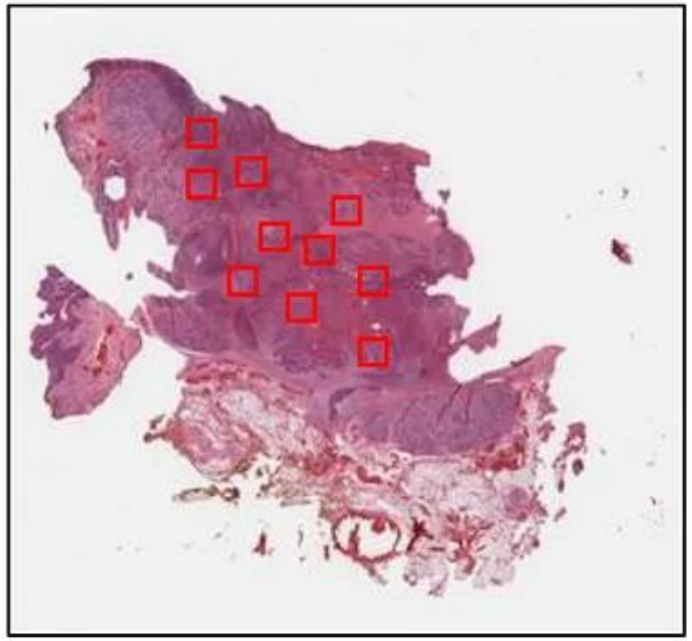


Refined Problem Statement of MIL-WSI

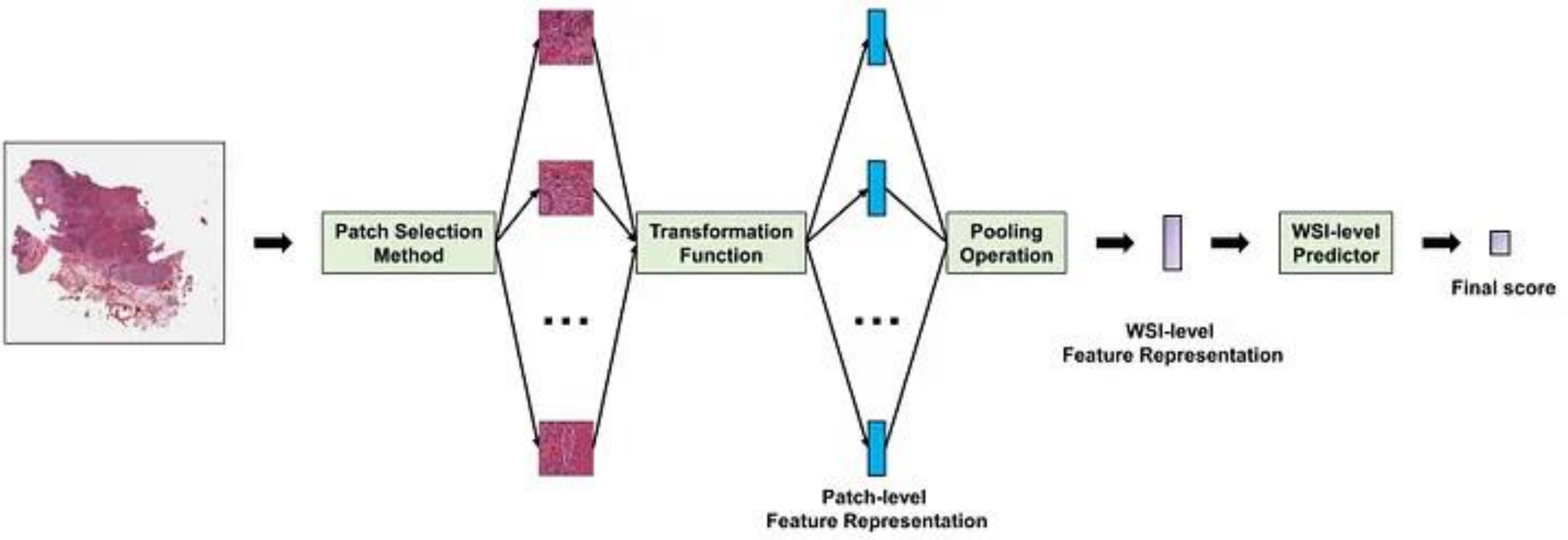
Bag **X**



WSI **X**



Main Components of MIL-WSI Framework



Categories of Patch Selection Methods

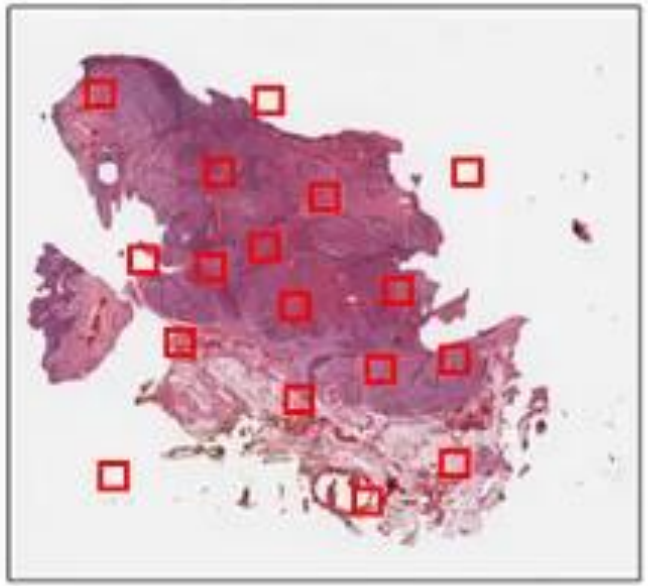
(i) Completely random selection

(ii) Random selection with the region of interest (ROI).

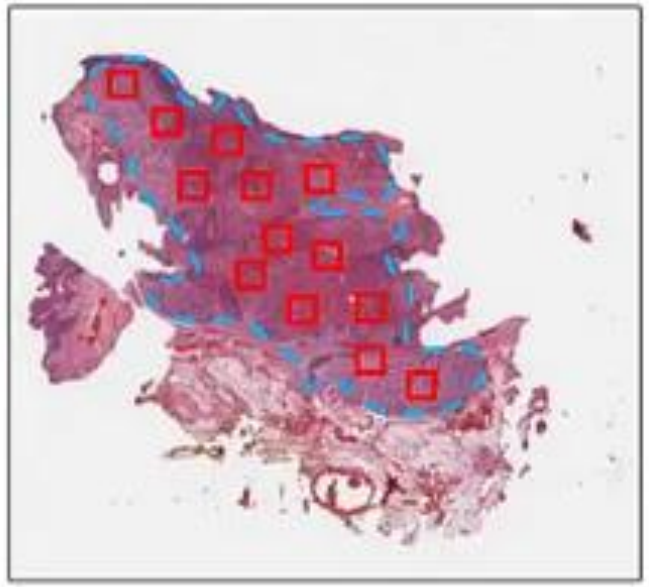
(iii) Feature-based selection.

(iv) Hierarchical selection.

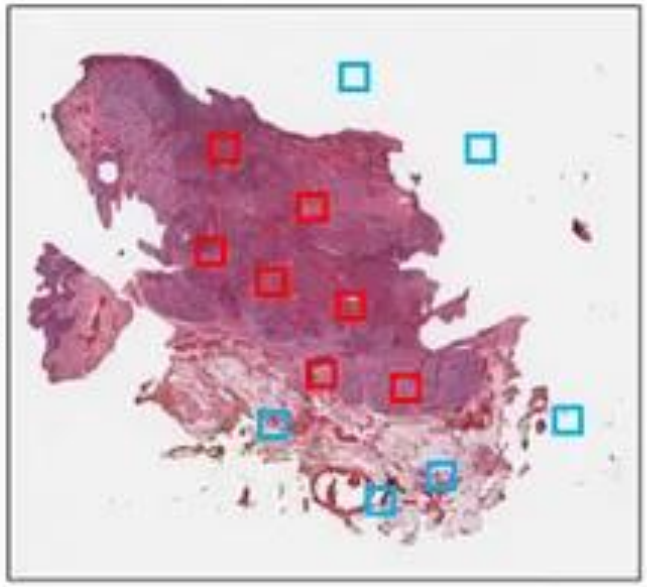
Completely Random Selection



Random Selection with ROI



Feature-based Selection



Hierarchical Selection

Source: https://github.com/mahmoodlab/HIPT

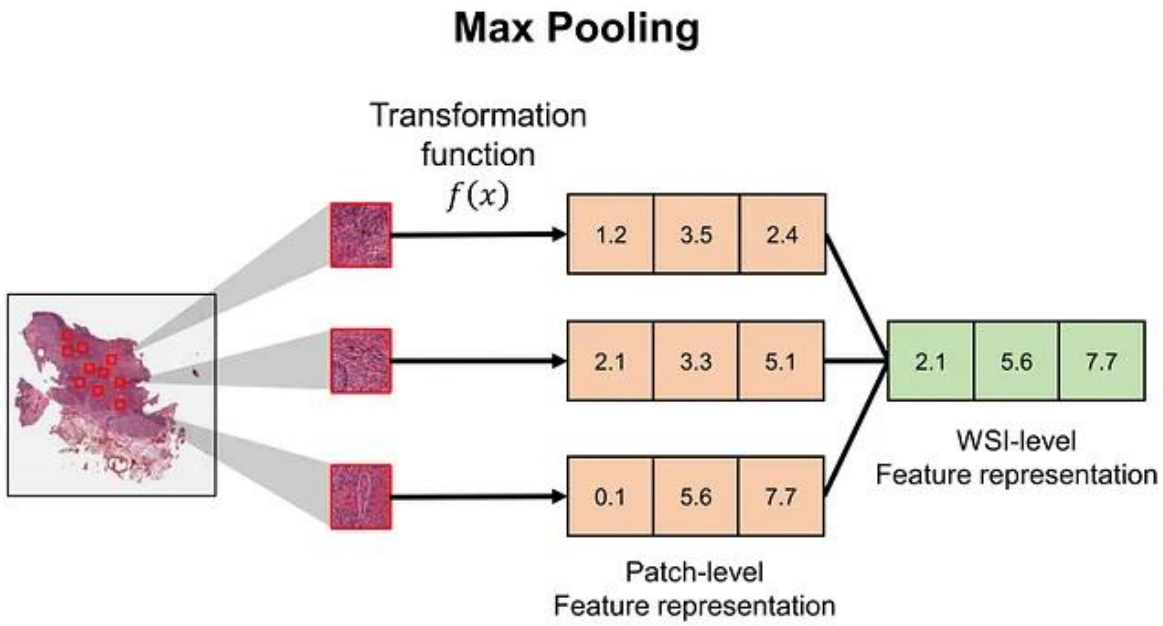
Categories of Pooling Operations

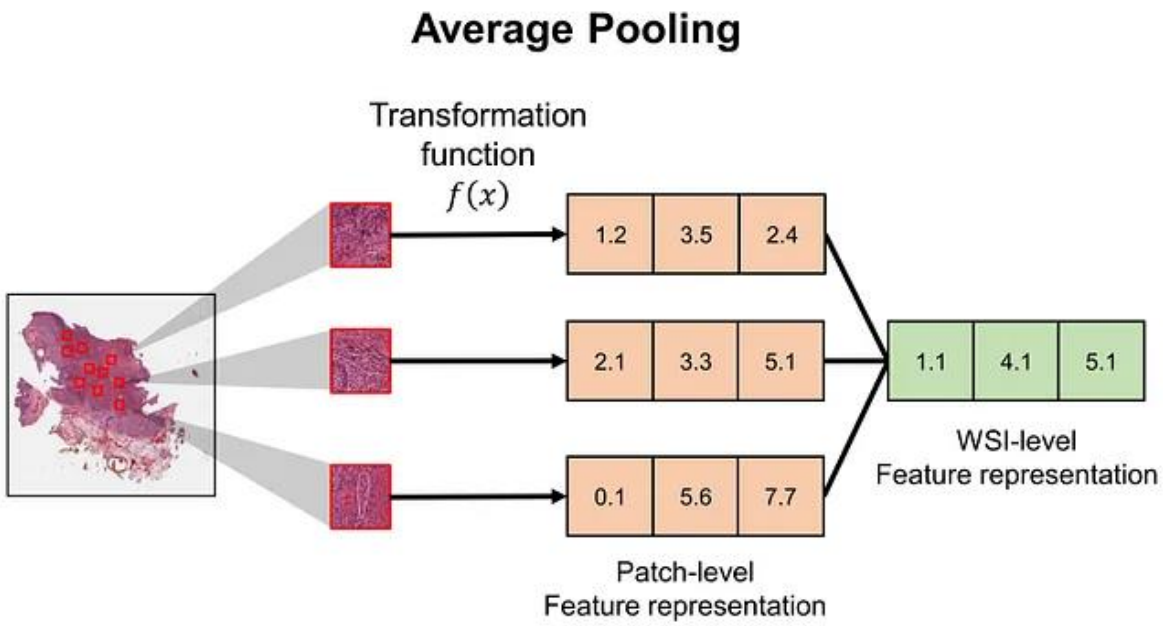
1- Static Pooling

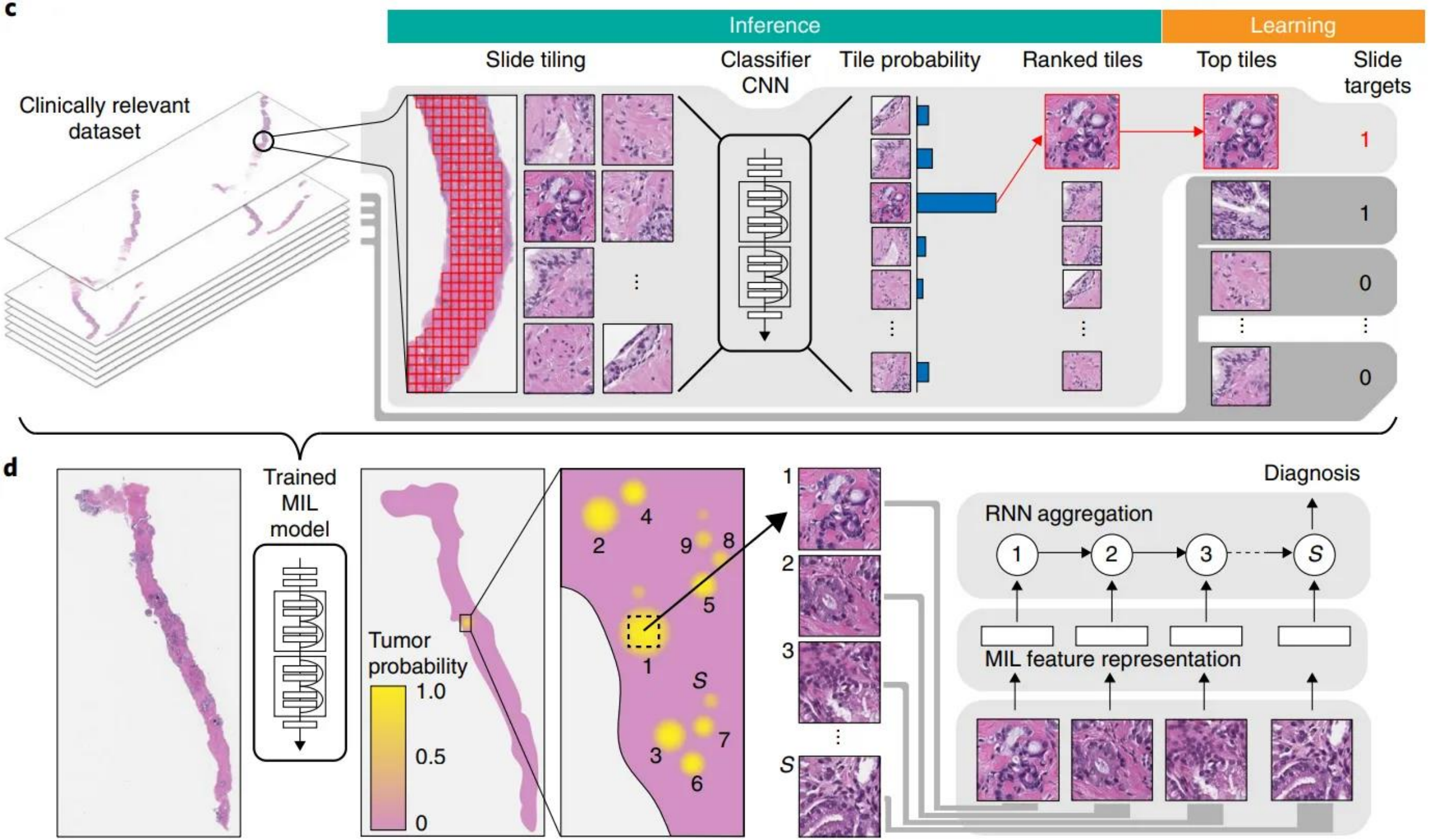
2- Adaptive Pooling

These methods adaptively update the patch contribution to its WSI. This category contains trainable pooling, dynamic pooling, differential evolutionary pooling, and so on. Generally, the adaptive pooling operation is changed iteration by iteration as we train the MIL-WSI framework. Interesting examples of this category are Attention-based pooling and Hopfield pooling, both of which belong to trainable pooling.

Static Pooling





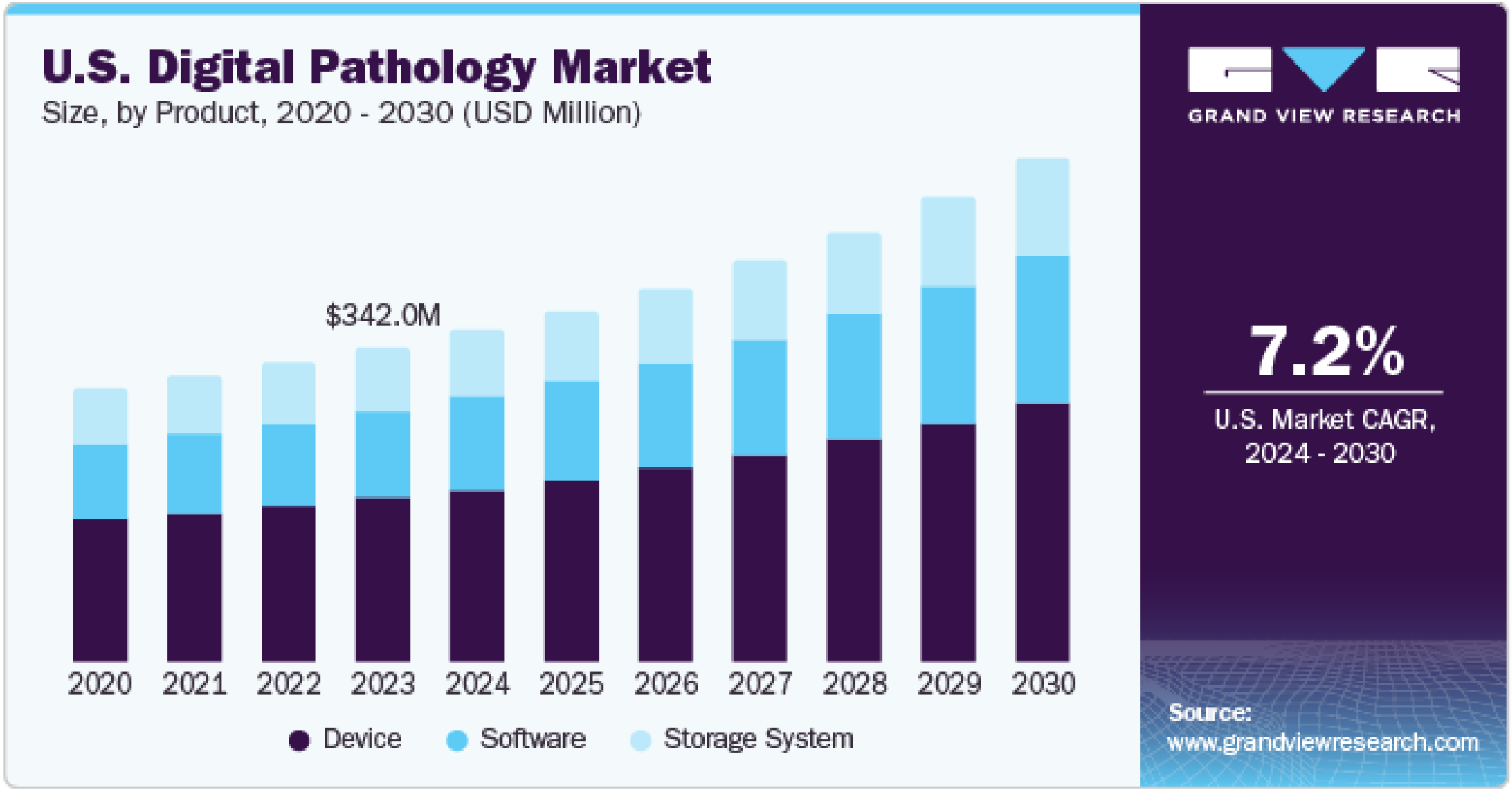

c
Inference
Learning
Slide tiling
Classifier CNN
Tile probability
Ranked tiles
Top tiles
Slide targets
Clinically relevant dataset
1
1
0
0
d
Trained MIL model
Tumor probability
1.0
0.5
0
Diagnosis
RNN aggregation
MIL feature representation
1
2
3
S

Education

Traditional Pathology

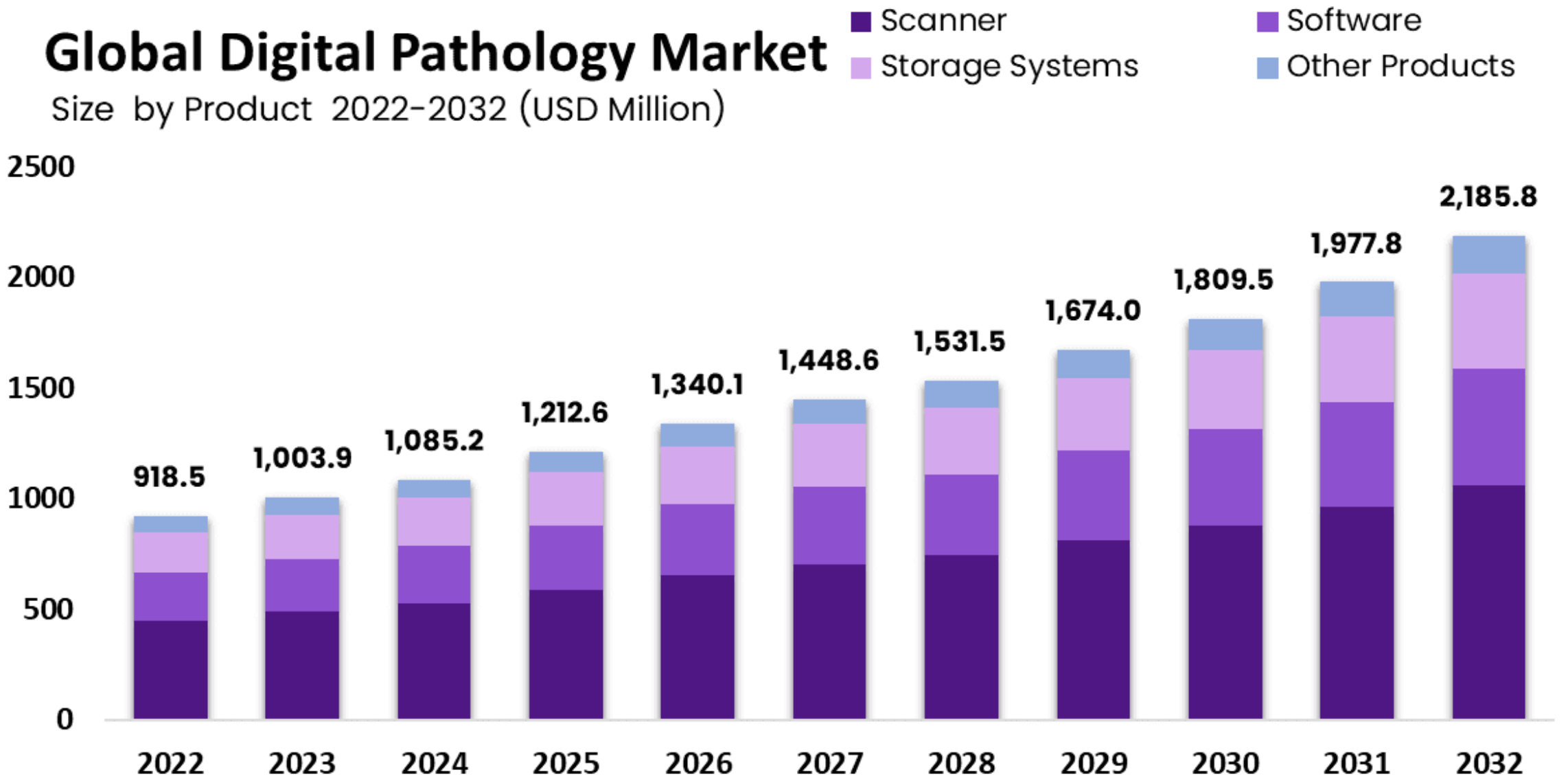
Digital Pathology


Global
DIGITAL PATHOLOGY
Market
Opportunities and Forecasts,
2021-2030
Global Digital Pathology Market is expected to reach $1791.3 Million by 2030
Growing at a
CAGR of 9.3% (2021-2030)


U.S. Digital Pathology Market
Size, by Product, 2020 - 2030 (USD Million)
$342.0M
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Device
Software
Storage System
GRAND VIEW RESEARCH
7.2%
U.S. Market CAGR, 2024 - 2030
Source: www.grandviewresearch.com

Global Digital Pathology Market

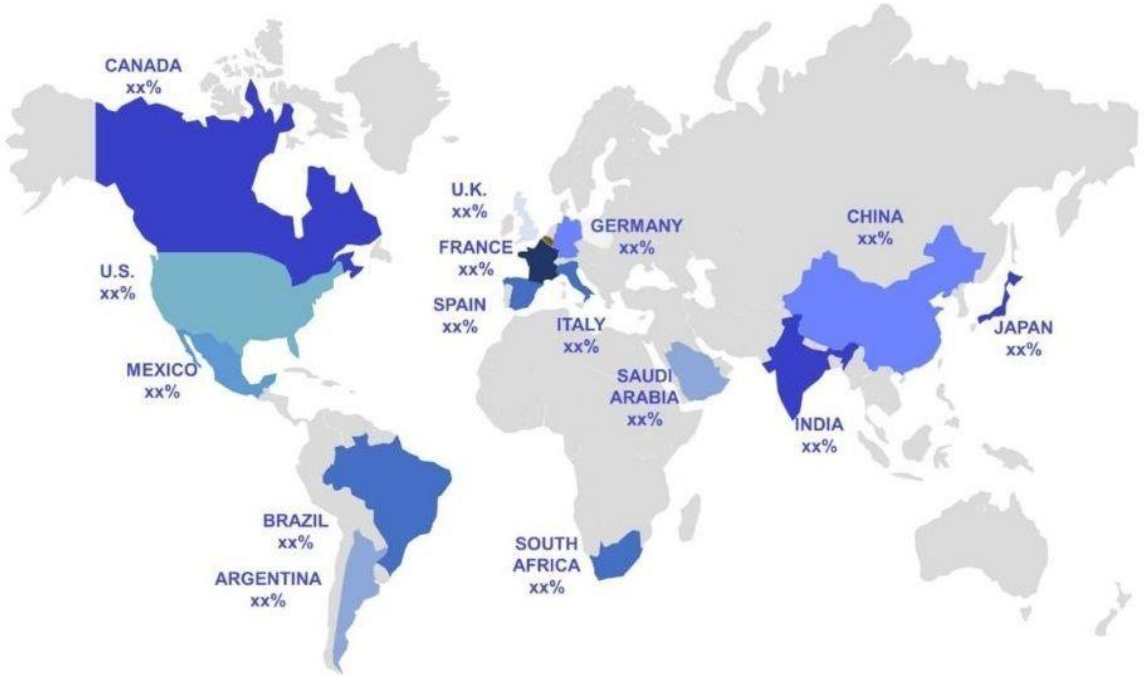
Size by Product 2022-2032 (USD Million)

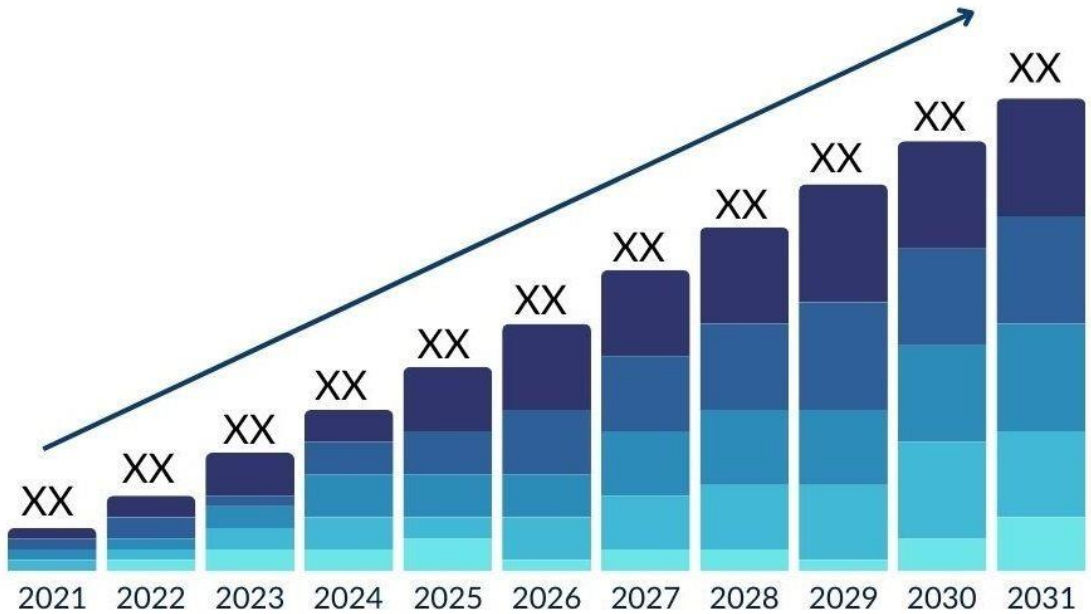


The Market will Grow At the CAGR of 9.3% The forecasted market size for 2032 in USD $2,185.8M

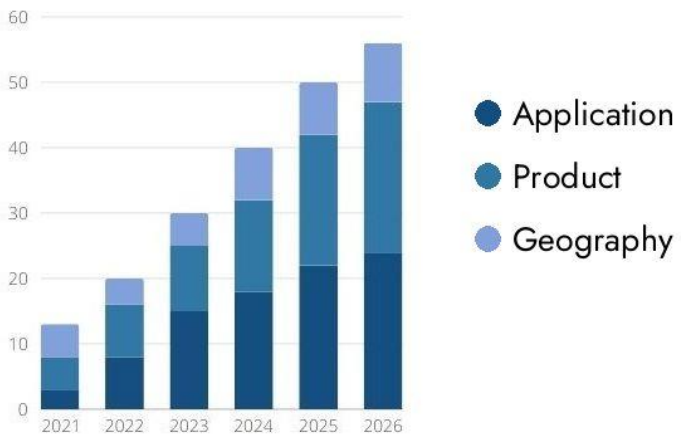
market.us
ONE STOP SHOP FOR THE REPORTS

Global Digital Pathology Market Size and Scope

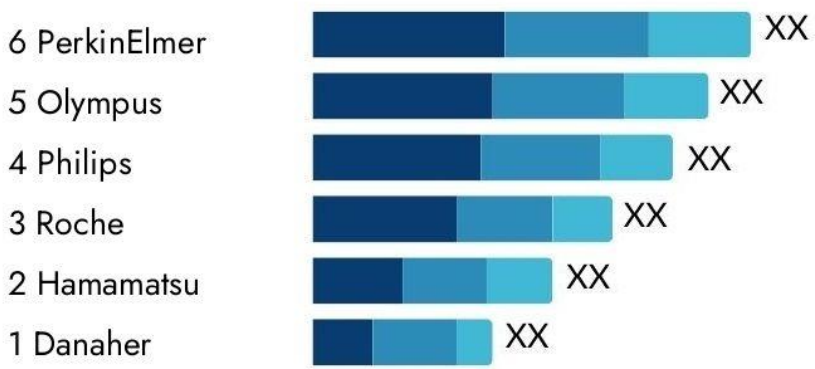




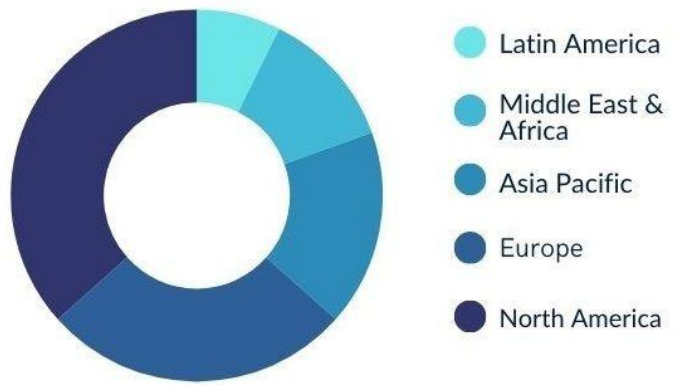
Market Segmentation



Top Key Players

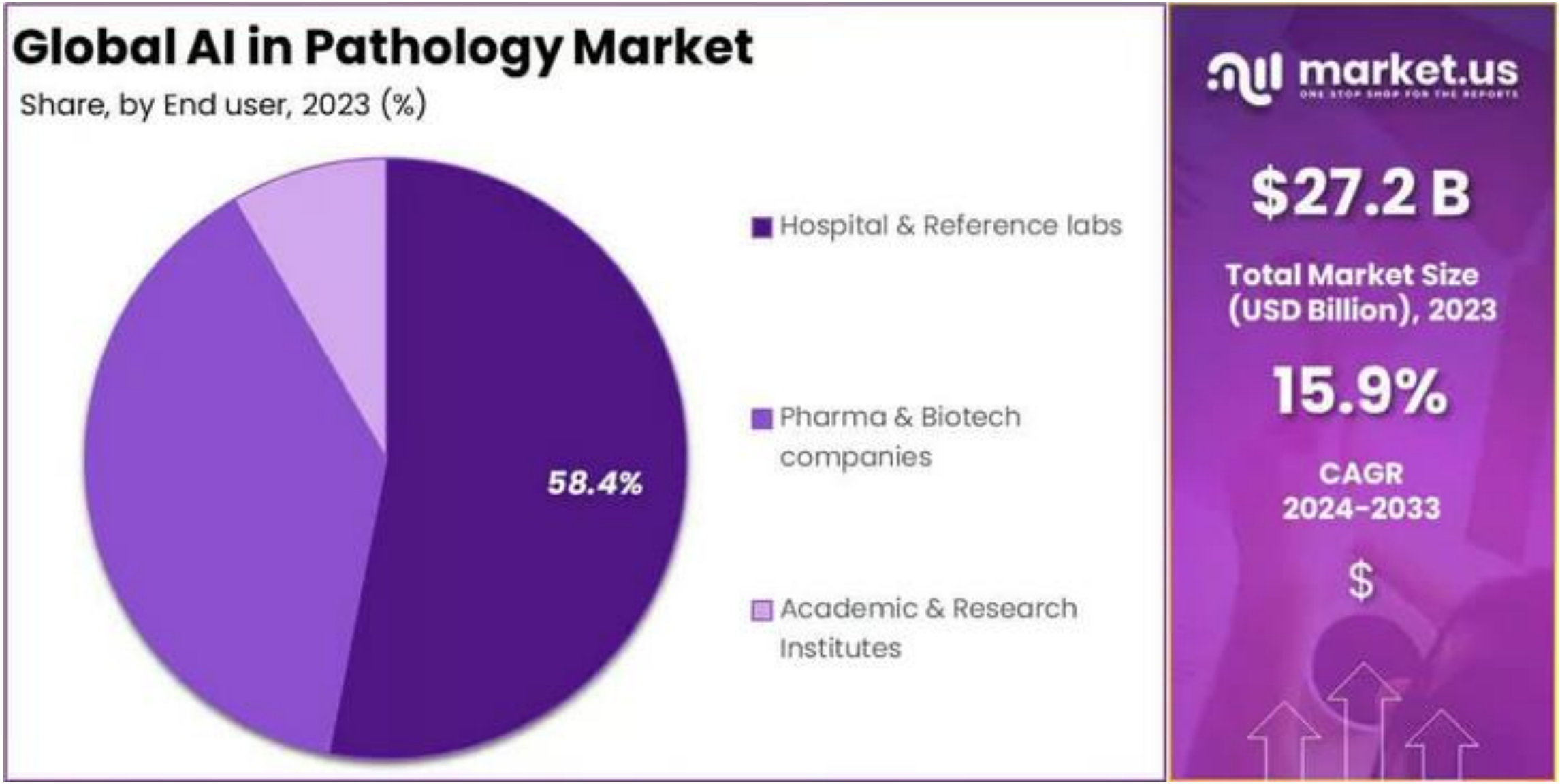


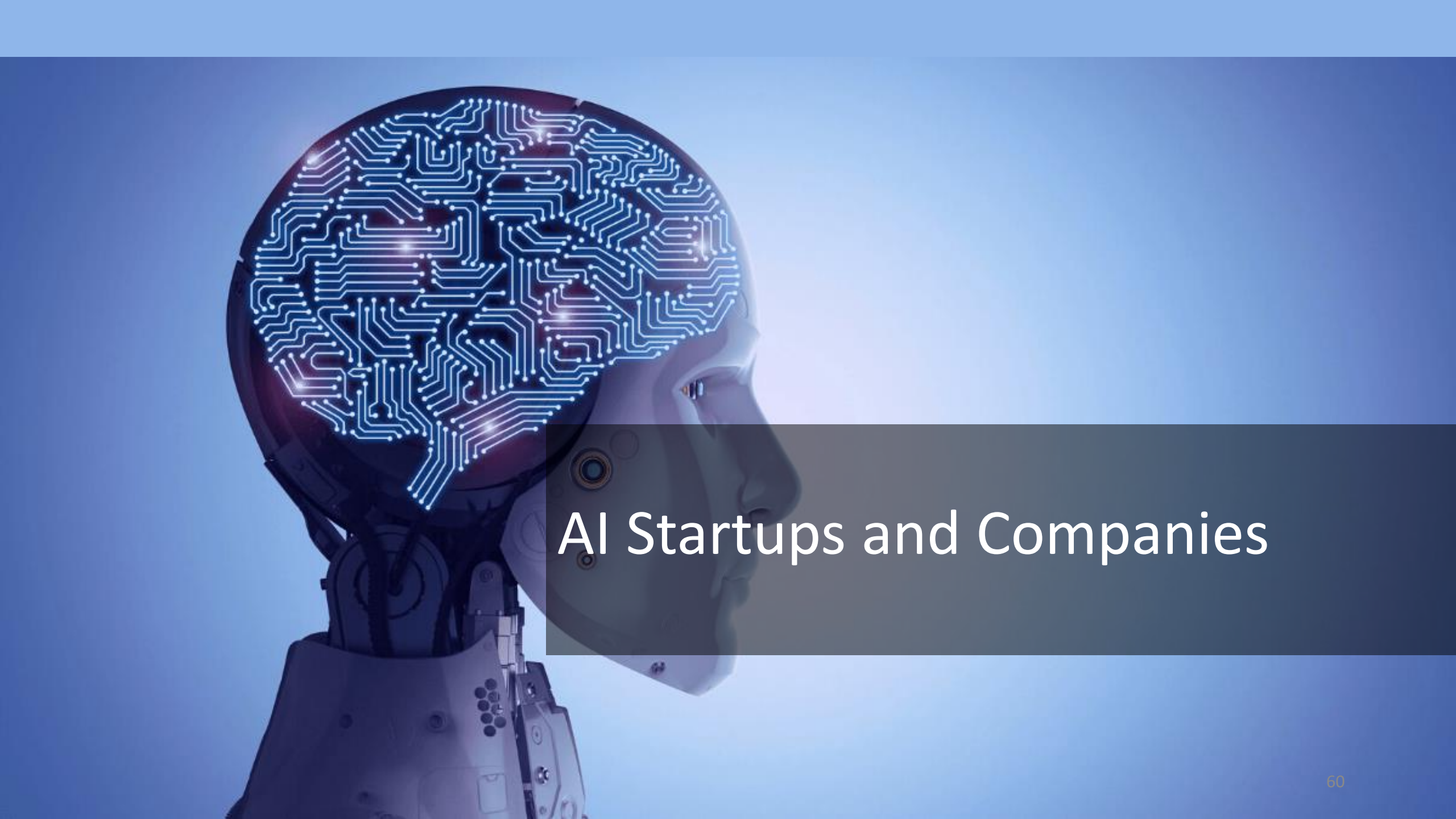
Regional Analysis



Source : www.marketresearchintellect.com


Global AI in Pathology Market
Size, by Component, 2023-2033 (USD Billion)
Software
Scanners
140
120
100
80
60
40
20
0
27.2
31.5
36.5
42.3
49.1
56.9
65.9
76.4
88.6
102.6
119.0
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
The Market will Grow At the CAGR of:
15.9%
The Forecasted Market Size for 2033 in USD:
$119.0 Bn
market.us


Global AI in Pathology Market
Share, by End user, 2023 (%)
58.4%
Hospital & Reference labs
Pharma & Biotech companies
Academic & Research Institutes
market.us
$27.2 B
Total Market Size (USD Billion), 2023
15.9%
CAGR 2024-2033

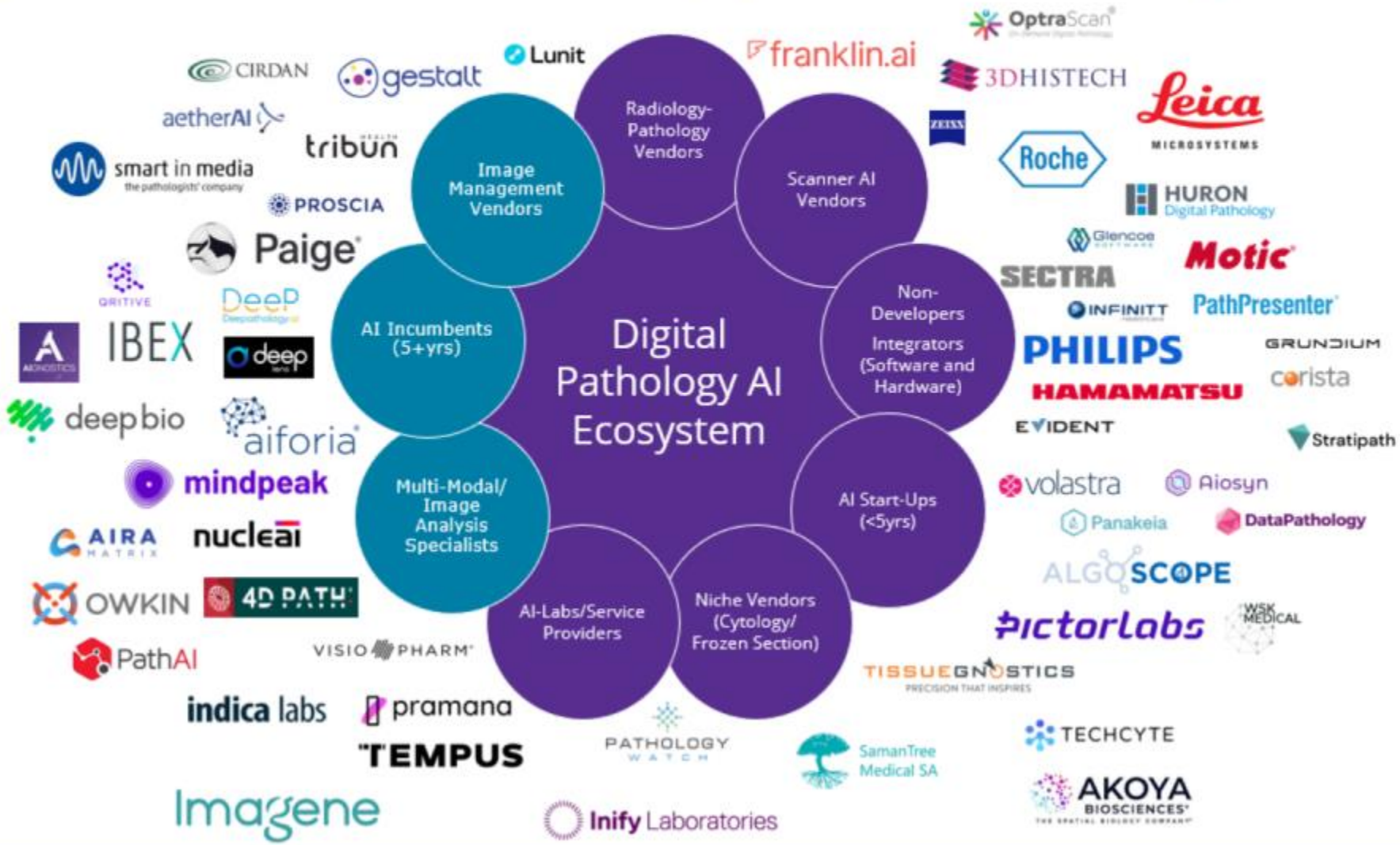


AI Startups and Companies

Companies


IBEX
Paige
nucleai
Primaa
DoMore
DIAGNOSTICS
aetherAI
CLARAPATH
AIRA
MATRIX
aiforia
deepbio
Lunit
aignostics
Fraunhofer
IIS
bioview
OptraScan®
On-Demand Digital Pathology
3DHISTECH
katanalabs
KFBIO
technology for health.
indica labs
Stratipath
KMLVISION
mindpeak
bioview
OWKIN
techcyte
VISIOPHARM®
Aiosyn
PROSCIA
PathAI
VMSCOPE

Digital Pathology AI Ecosystem



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Thank you

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