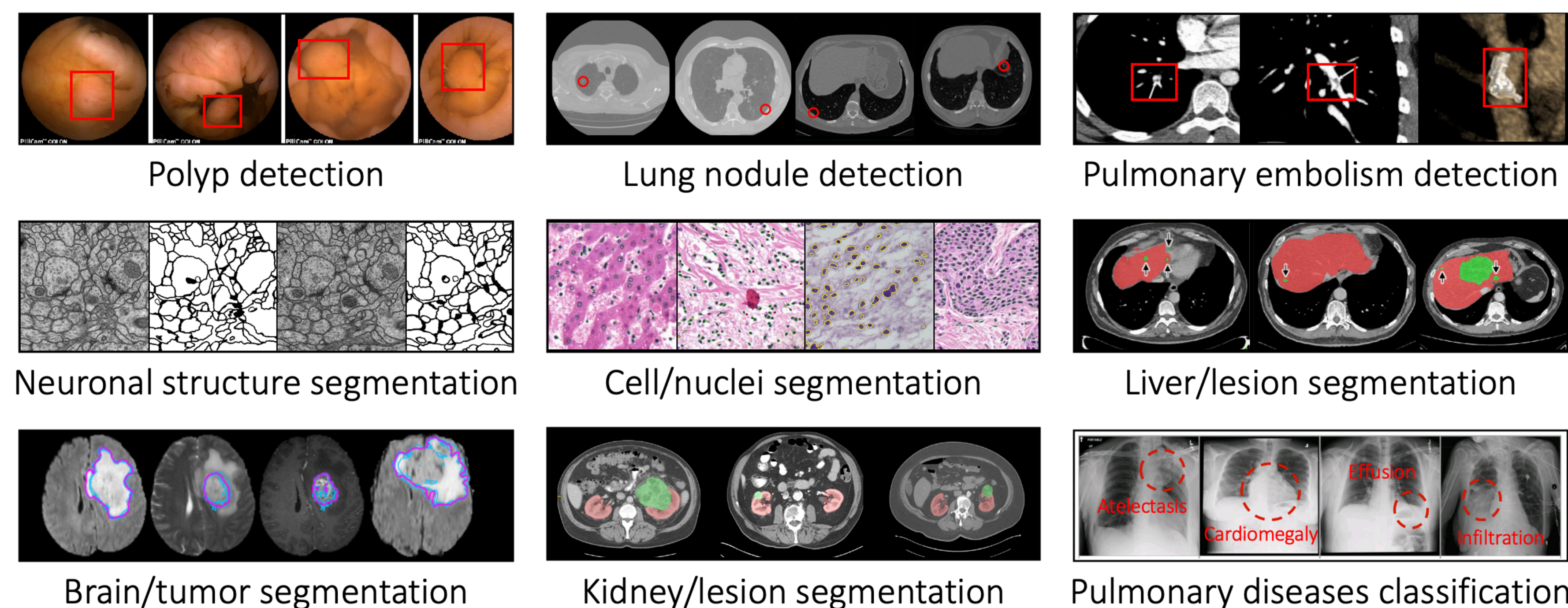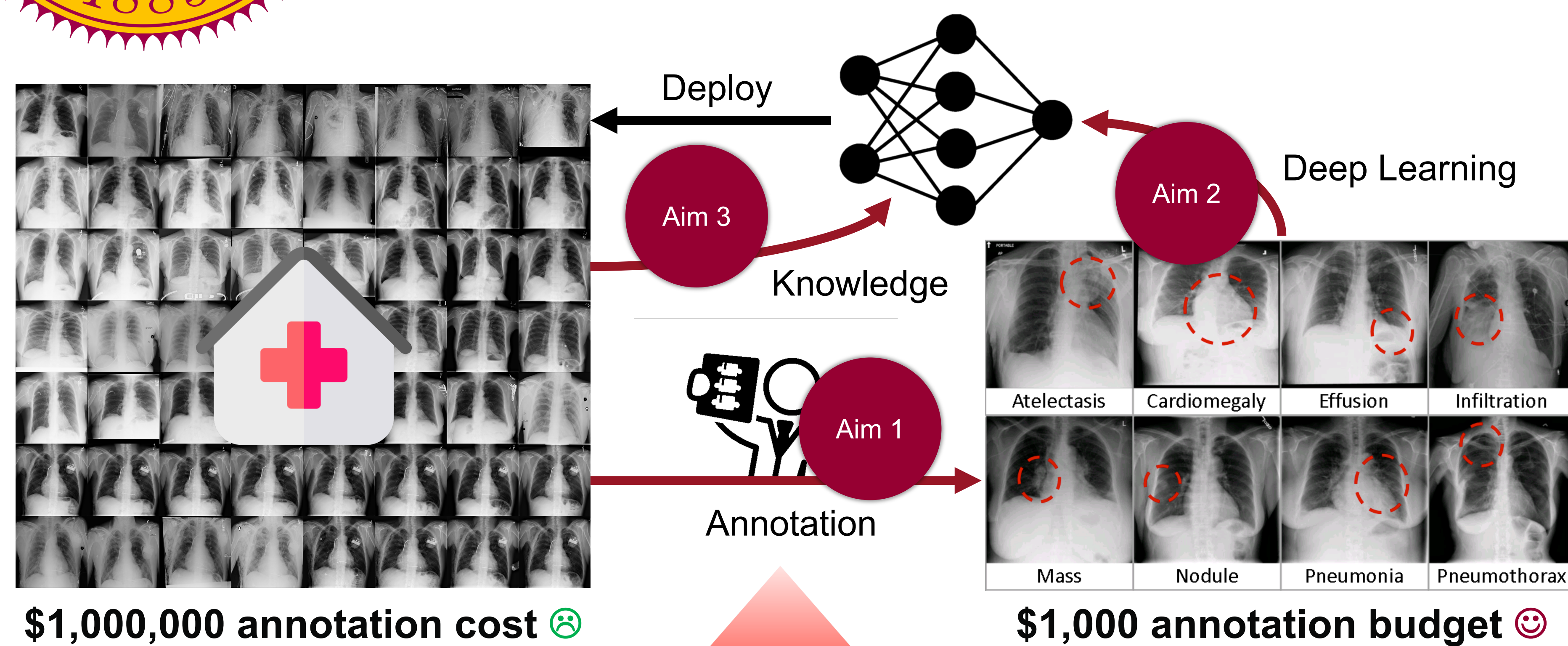# Cost-Effective Deep Learning in Medical Image Analysis

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Deploy — Deep Learning — Aim 2 — Aim 3 — Knowledge — Aim 1 — Annotation

Atelectasis — Cardiomegaly — Effusion — Infiltration — Mass — Nodule — Pneumonia — Pneumothorax

$1,000,000 annotation cost ☹

$1,000 annotation budget ☺

Polyp detection — Lung nodule detection — Pulmonary embolism detection — Neuronal structure segmentation — Cell/nuclei segmentation — Liver/lesion segmentation — Brain/tumor segmentation — Kidney/lesion segmentation — Pulmonary diseases classification

Introduction: Success of deep learning relies heavily on large annotated datasets. Without such large annotated datasets, deep learning often results in algorithms that perform poorly and lack generalizability.

- 42,290 CT images needed for lung cancer diagnosis
- 129,450 images needed for skin cancer classification
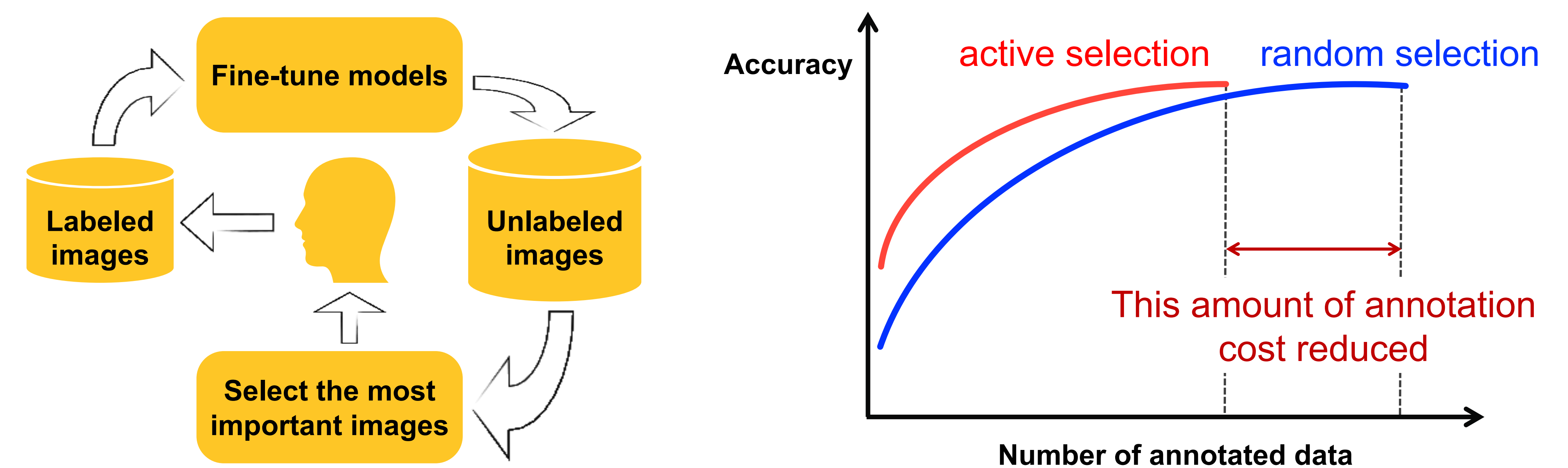- 128,175 retinal images needed for diabetic retinopathy detection

Research goal: Promote **rapid**, **precise** computer-aided diagnosis systems by minimizing the manual labeling efforts

**Aim 1:** Acquire necessary annotation efficiently from human experts

Aim 2: Utilize existing annotation effectively from advanced architecture

Aim 3: Extract generic knowledge directly from unannotated images

Method & Result 1: We present active learning procedure, cutting annotation cost by >60% compared with random selection

Fine-tune models — Labeled images — Unlabeled images — Select the most important images

Accuracy — active selection — random selection — This amount of annotation cost reduced — Number of annotated data

Method & Result 2: We devised advanced architecture that significantly improves disease/organ segmentation

Intersection over Union — U-Net — UNet++ — EM — Cell — Nuclei — Brain tumor — Liver — Lung nodule
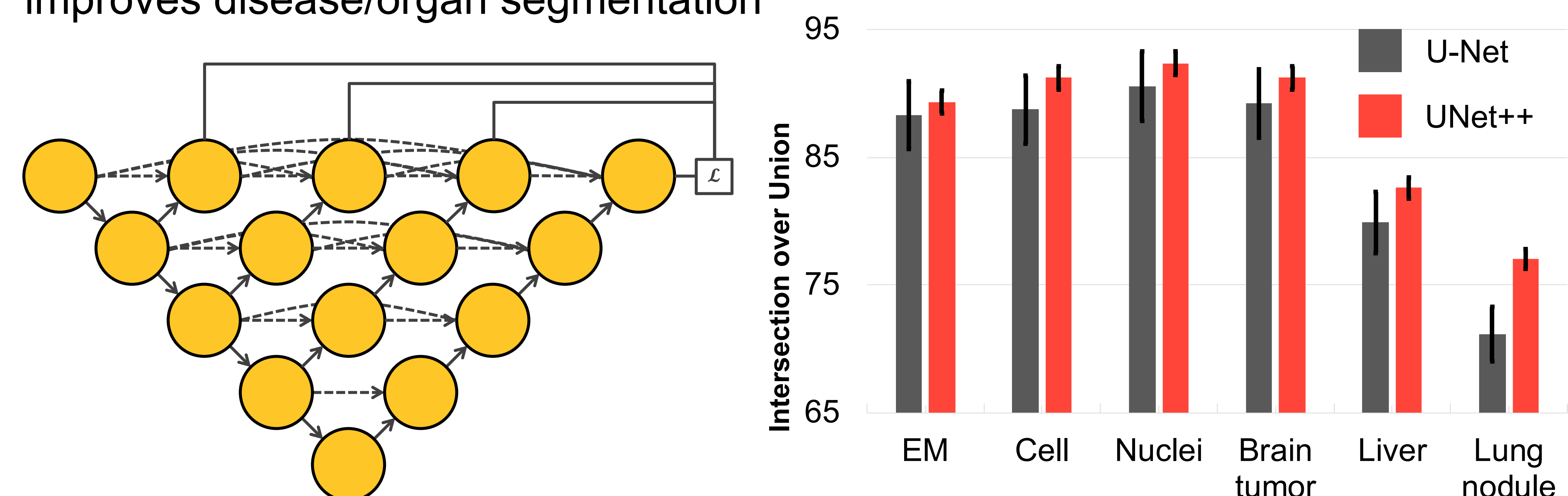
Method & Result 3: We built generic pre-trained 3D models that exceed publicly available pre-trained 3D models

Cardiomegaly — Effusion — Nodule — Pneumonia

Existing models — Models Genesis — NCC — NCS — ECC — LCS — BMS — Five target medical applications