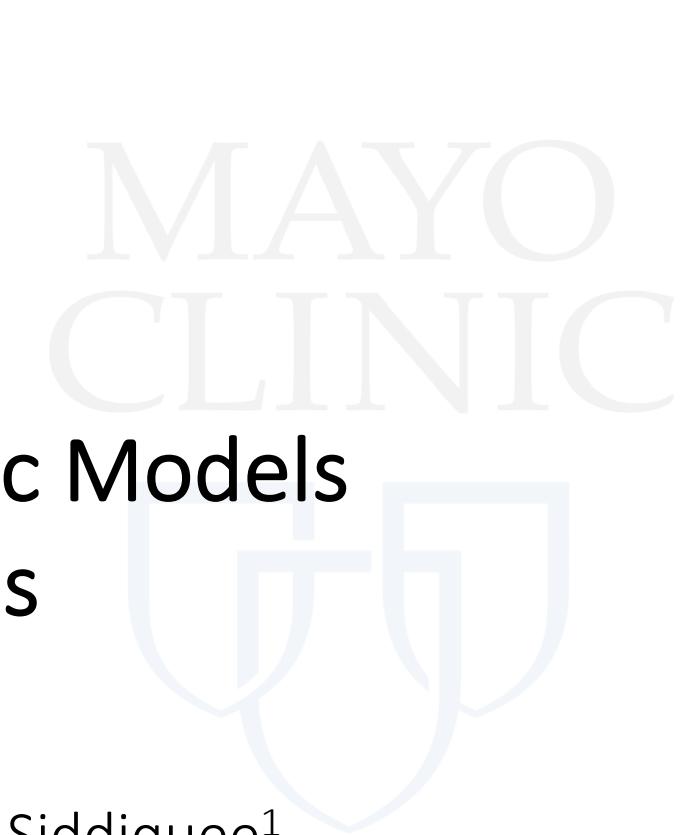
The seal of Arizona State University is a large, faint watermark in the background. It features a circular design with the text "ARIZONA STATE UNIVERSITY" around the top and "THE STATE OF ARIZONA" around the bottom. In the center is a sunburst with a figure holding a staff, and the year "1885" at the bottom.

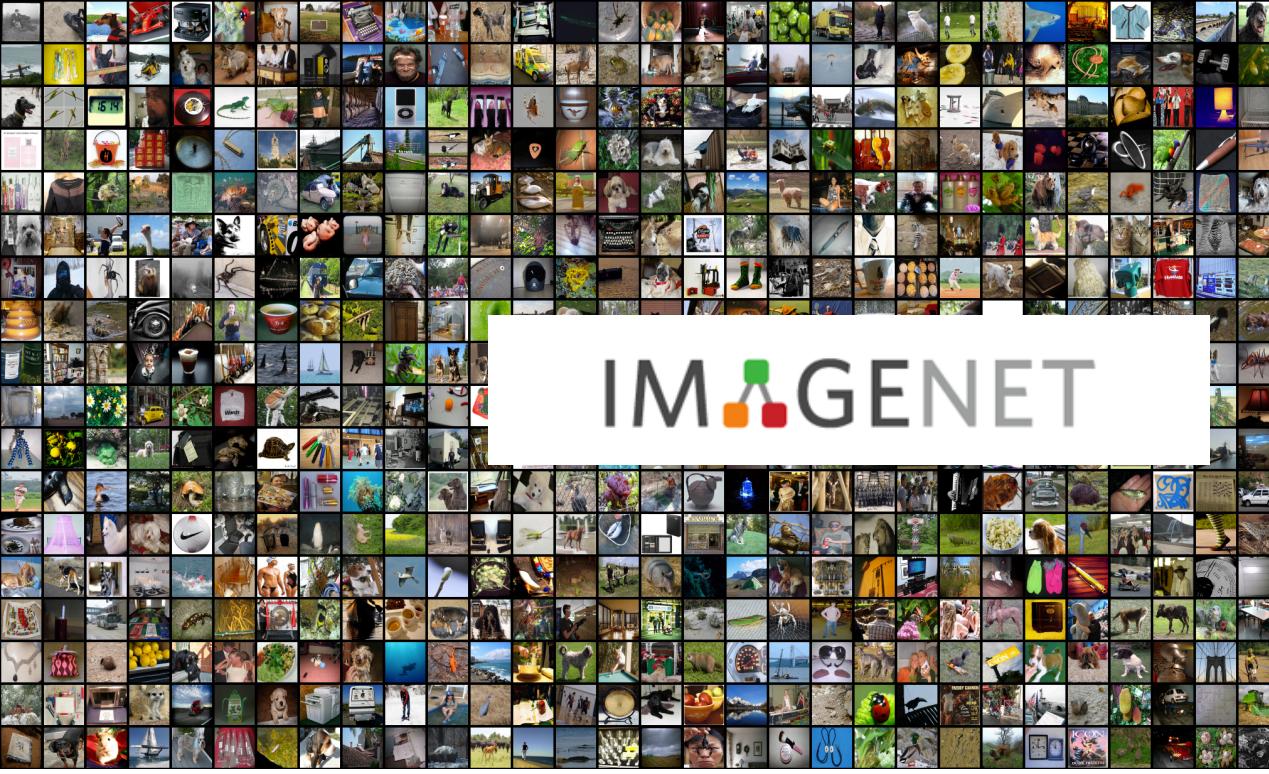
We provide pre-trained 3D models!

# Models Genesis: Generic Autodidactic Models for 3D Medical Image Analysis

The Mayo Clinic logo is a faint watermark in the background. It consists of the word "MAYO" in large letters above the word "CLINIC" in smaller letters, with a stylized shield icon below them.

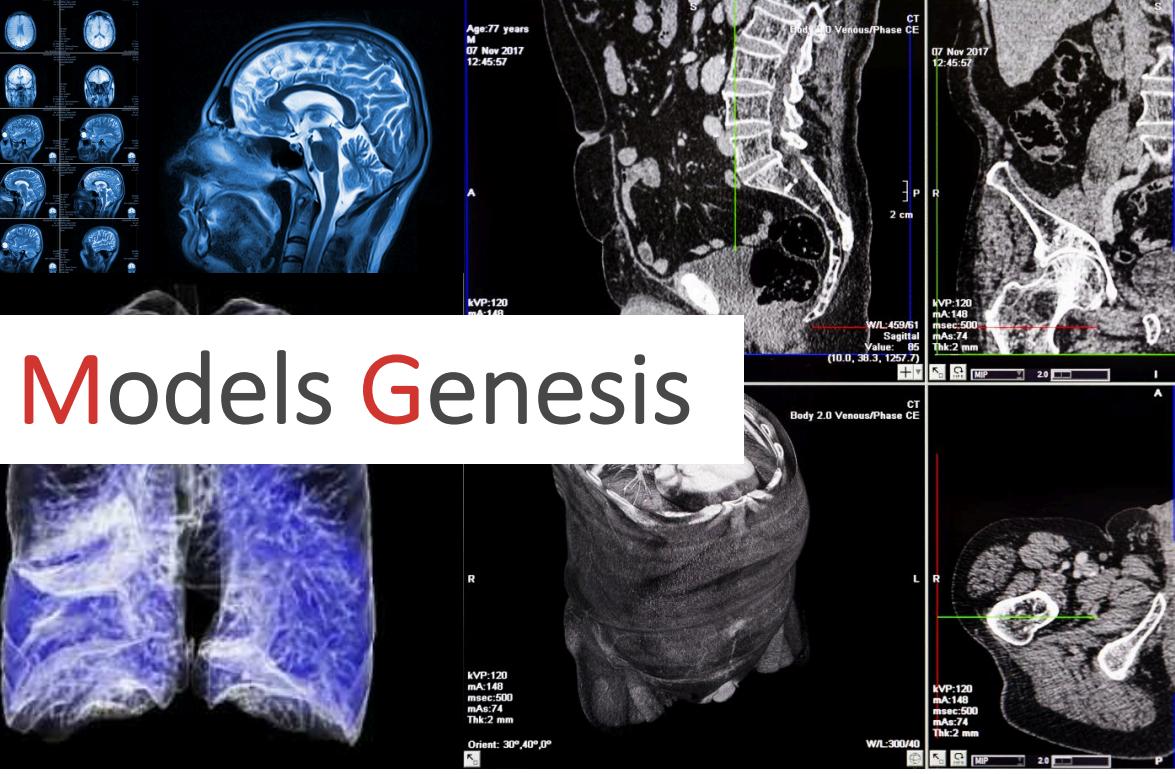
Zongwei Zhou<sup>1</sup>, Vatsal Sodha<sup>1</sup>, Md Mahfuzur Rahman Siddiquee<sup>1</sup>,  
Ruixin Feng<sup>1</sup>, Nima Tajbakhsh<sup>1</sup>, Michael B. Gotway<sup>2</sup>, and Jianming Liang<sup>1</sup>

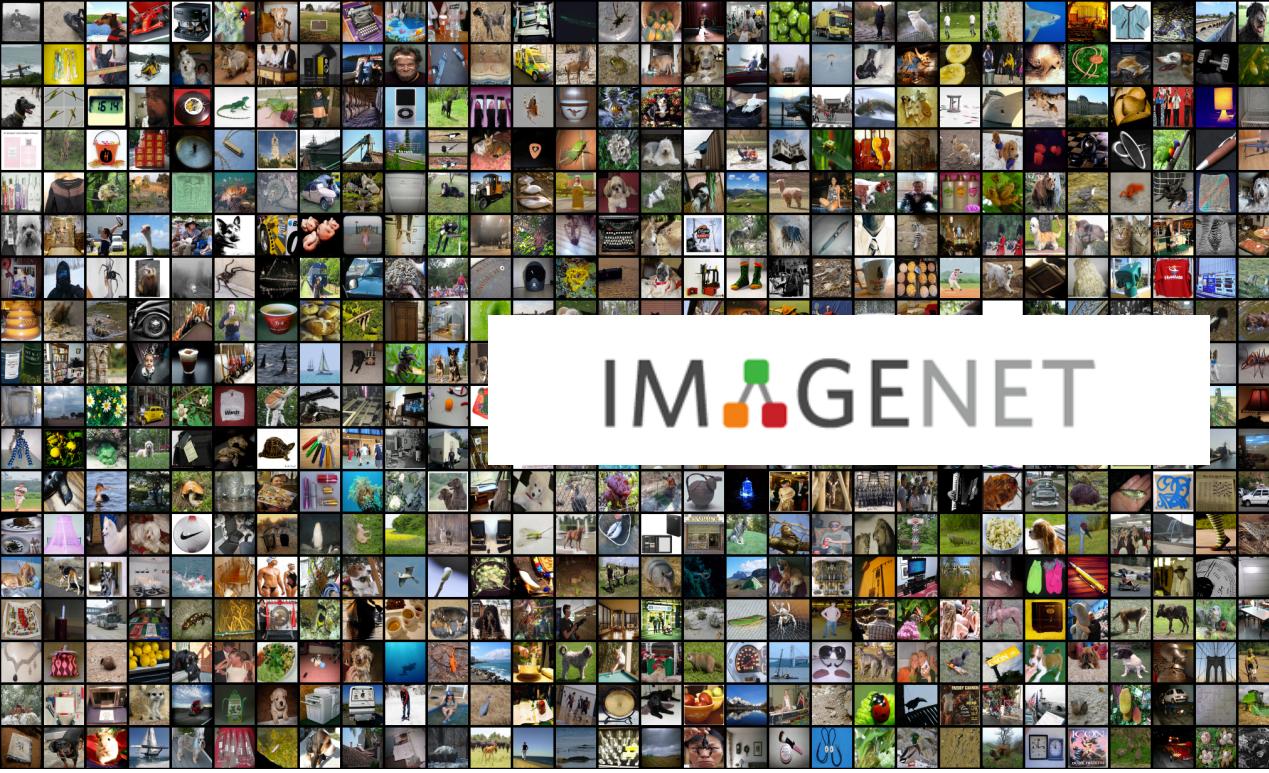
<sup>1</sup> Arizona State University      <sup>2</sup> Mayo Clinic



IMAGENET

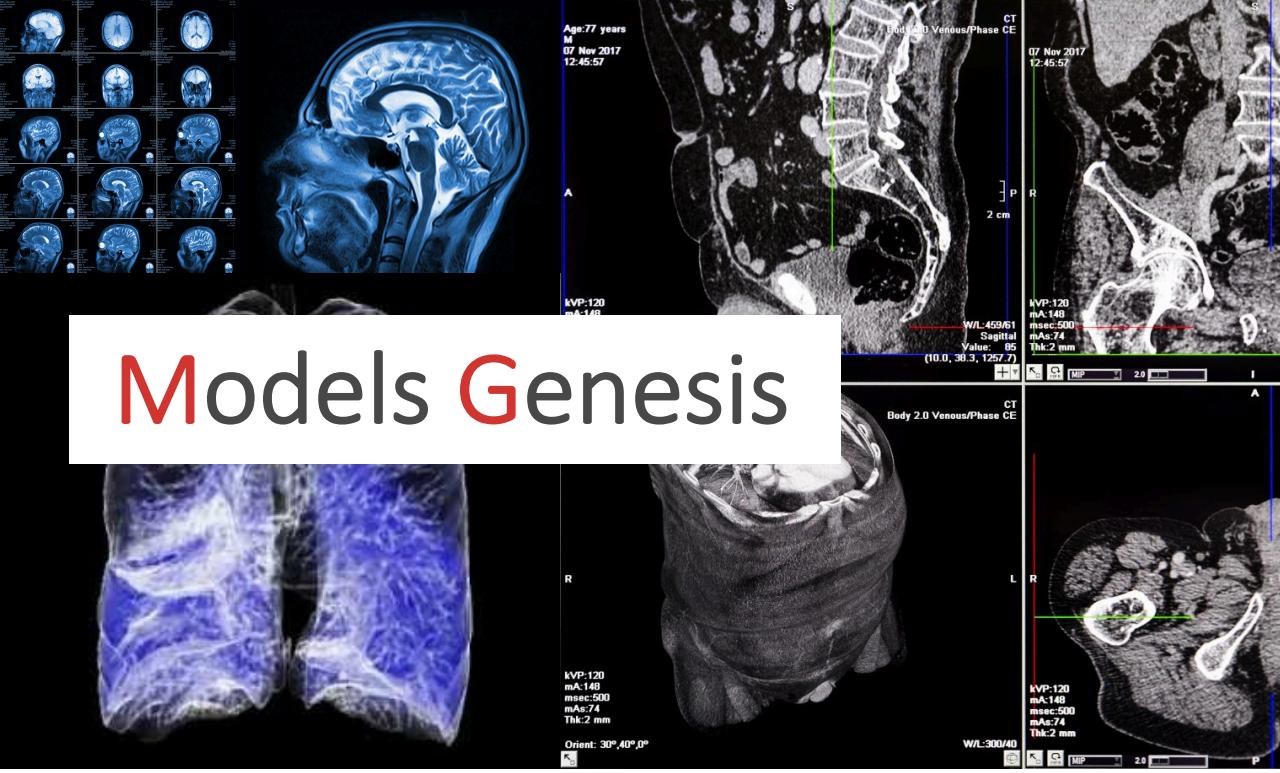
# Models Genesis





IMAGENET

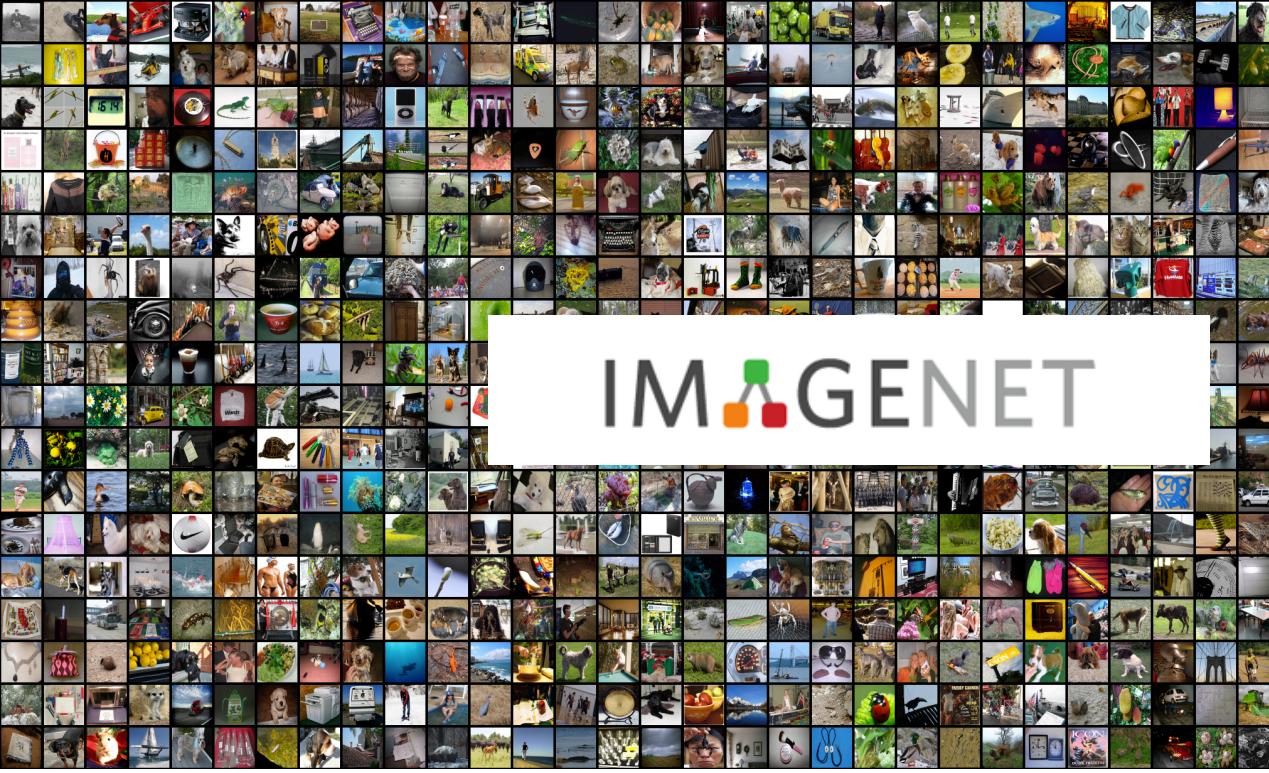
Natural images



Models Genesis

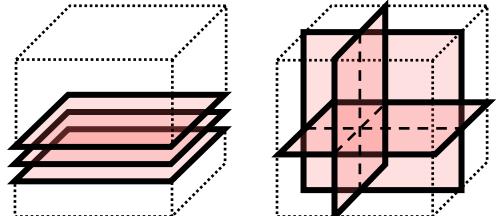


Transfer learning: medical images → medical images > natural images → medical images



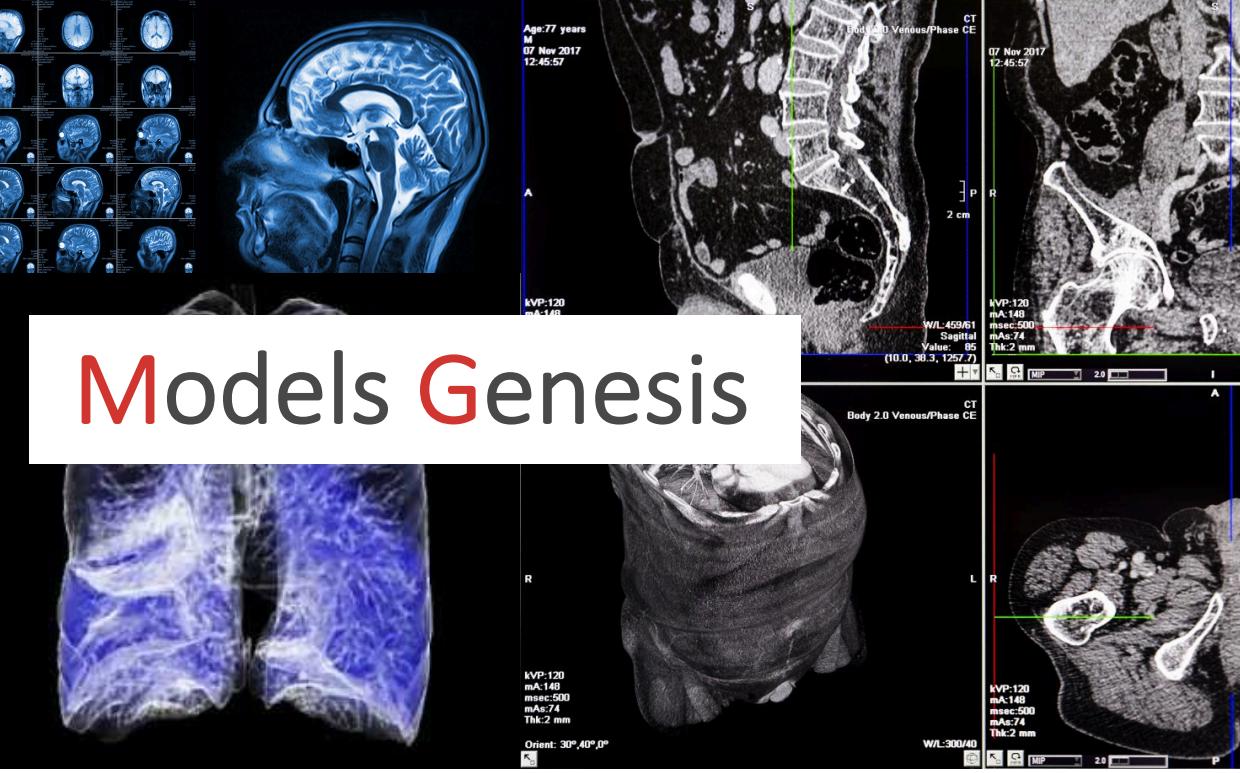
IMAGENET

Natural images

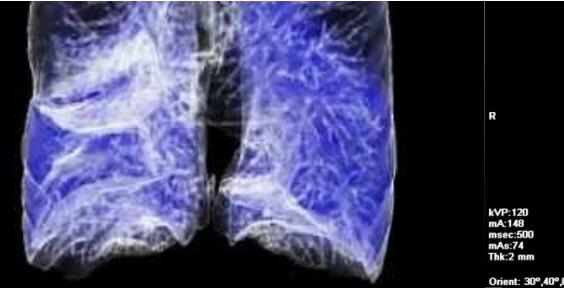
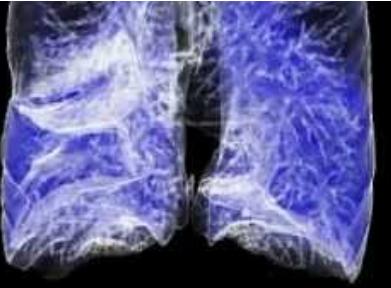


Formed in 2D

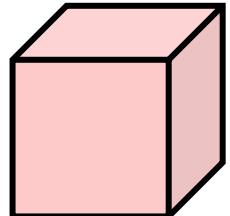
3D imaging tasks should be solved in 3D



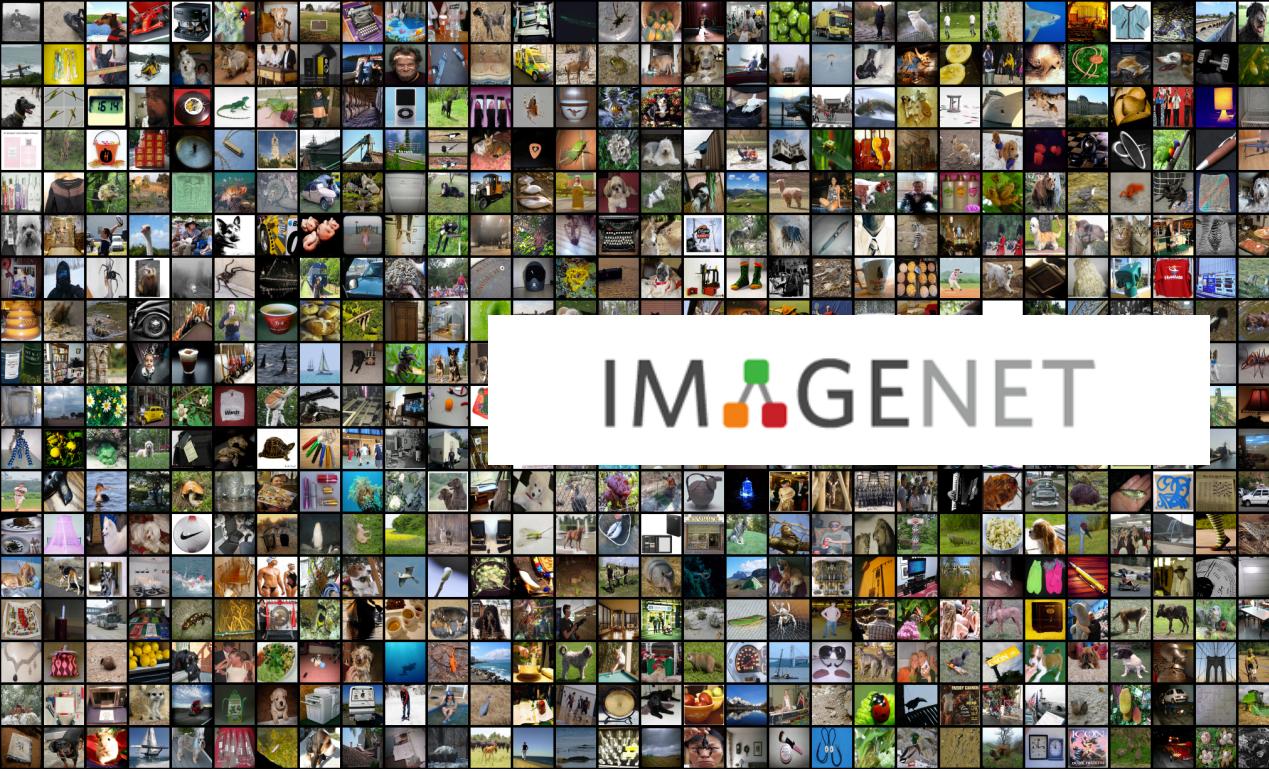
Models Genesis



Medical images



Formed in 3D

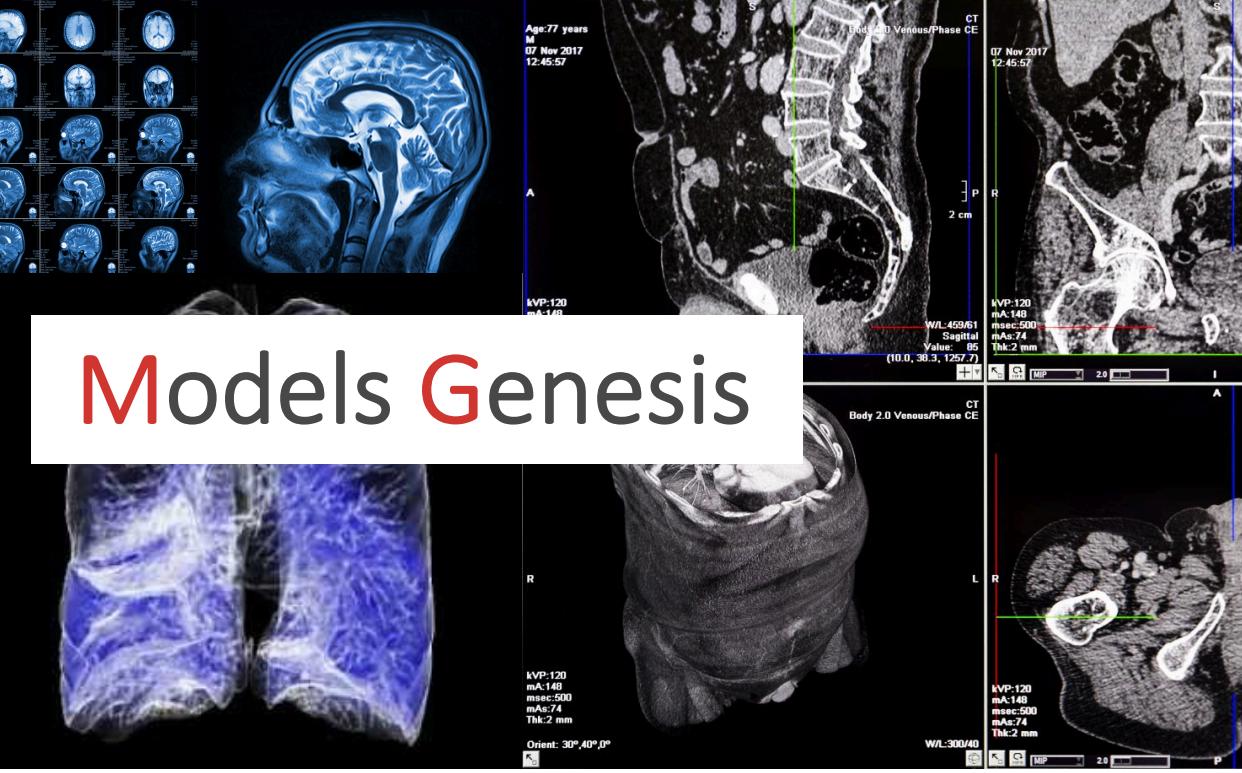


IMAGENET

Natural images

Formed in 2D

>14,000,000 annotation



Models Genesis



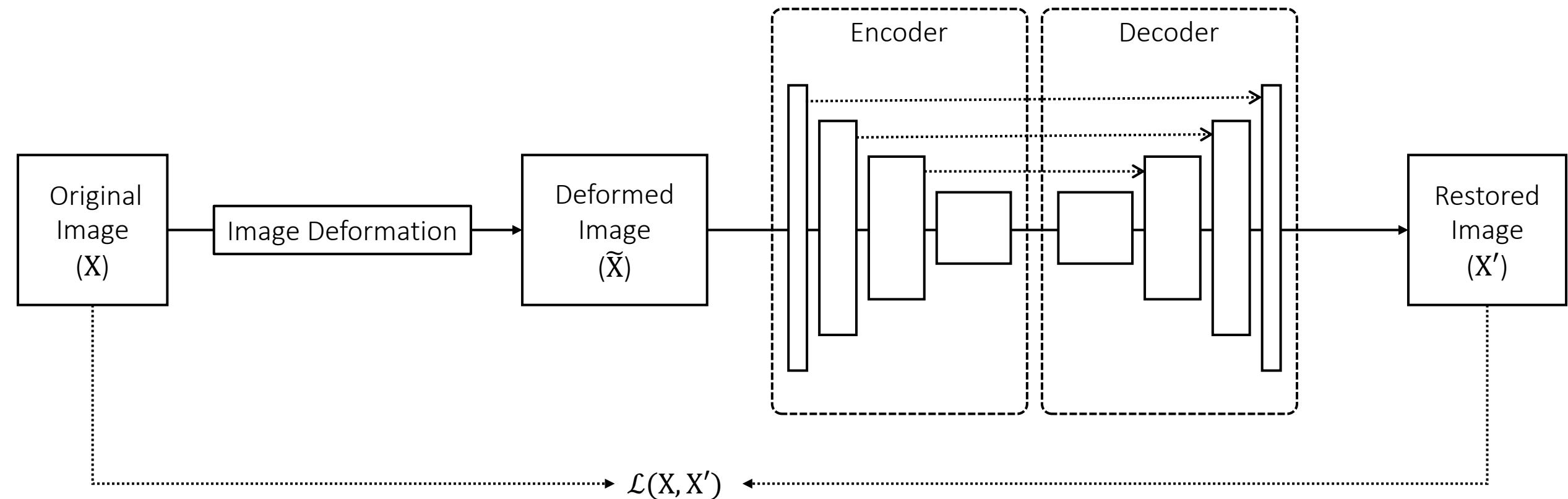
Medical images

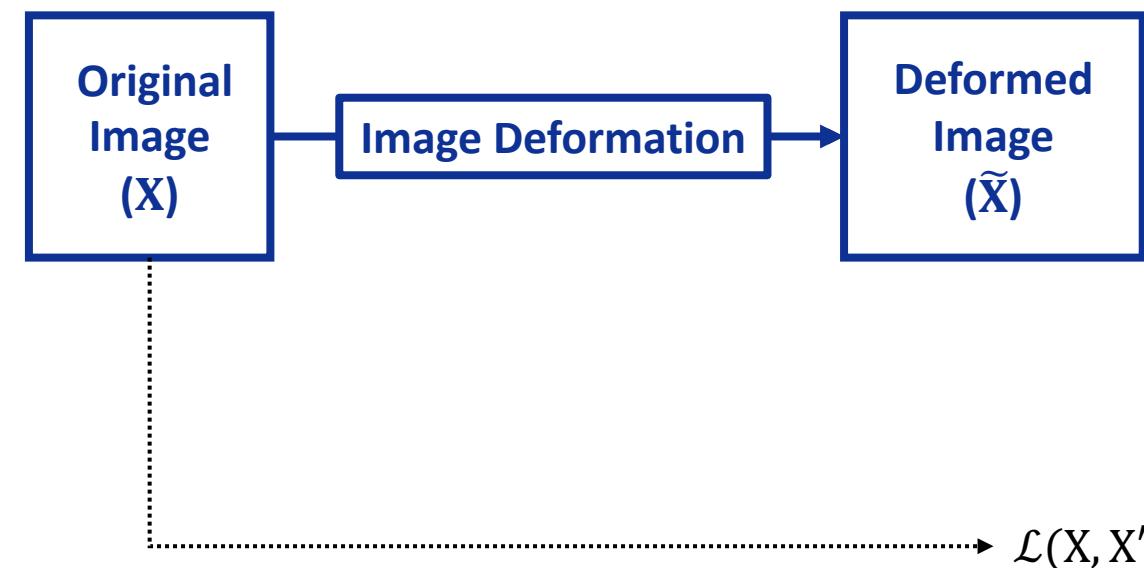
Formed in 3D

Zero annotation

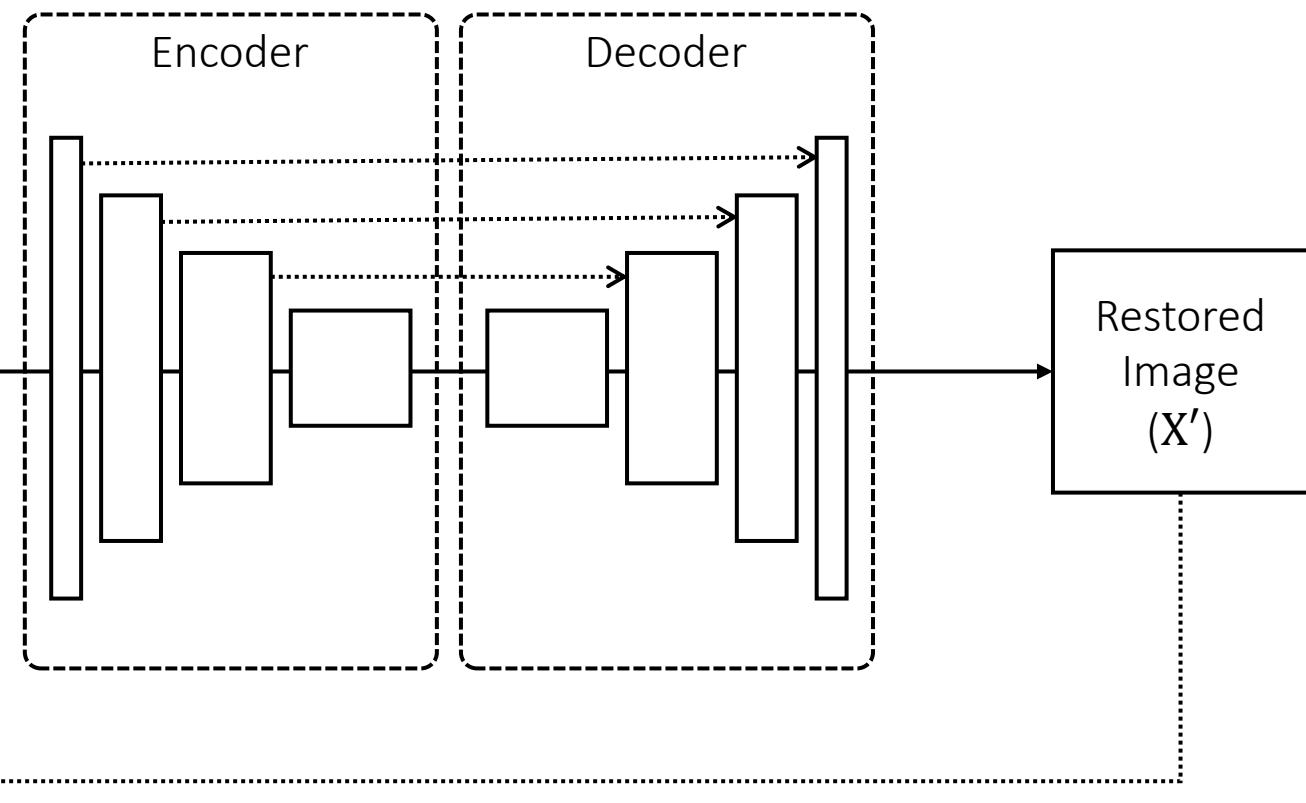
Annotating biomedical images is time consuming and demanding of costly, specialty-oriented knowledge

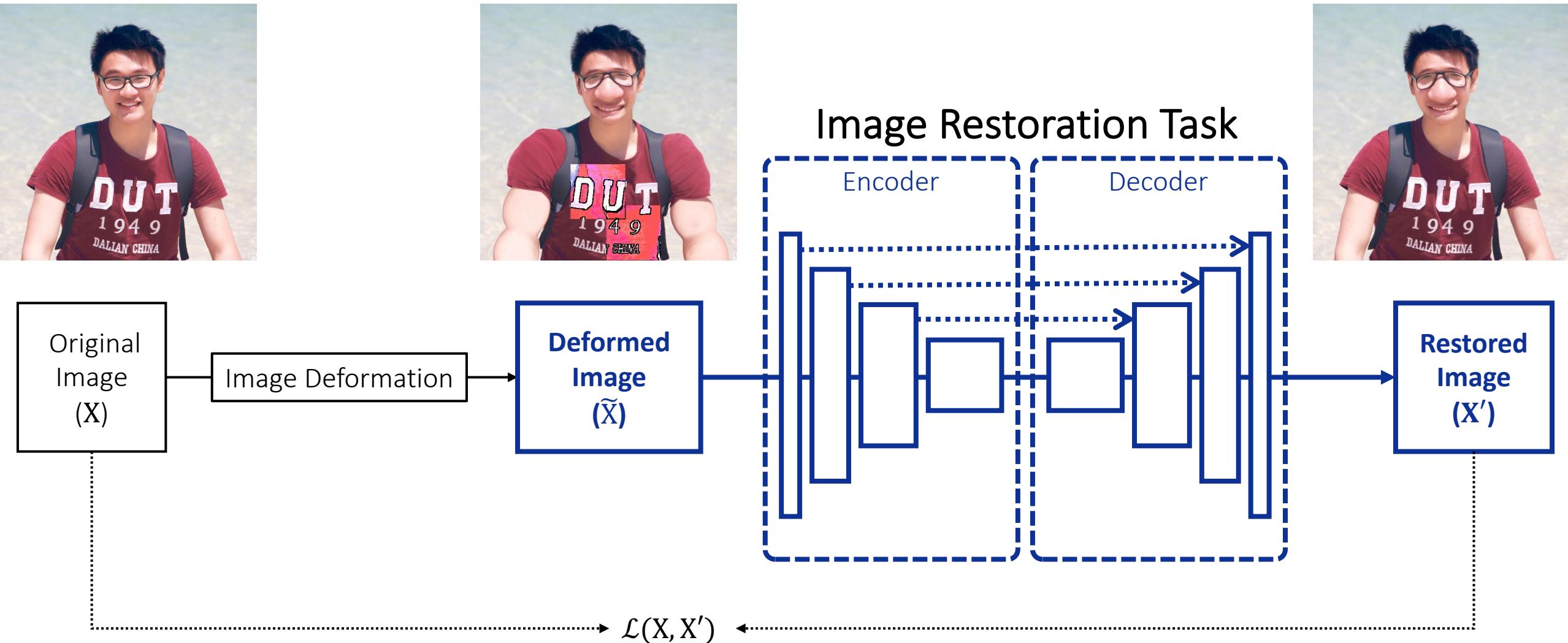
## Image Restoration Task



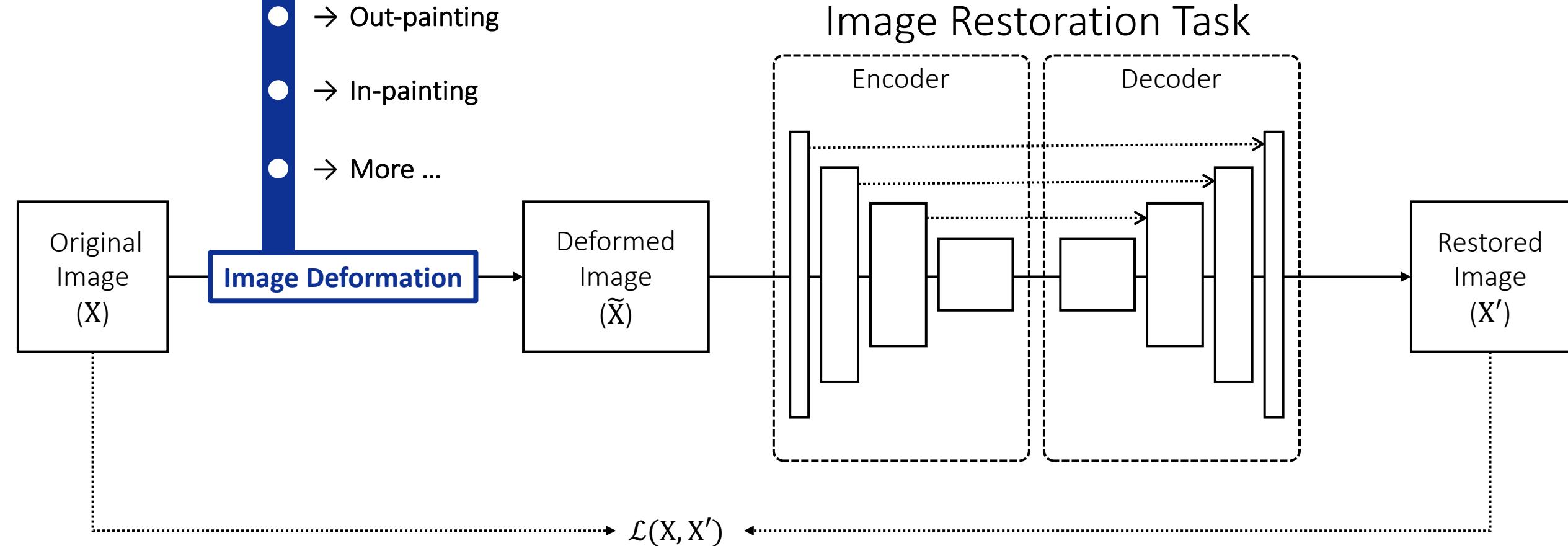


## Image Restoration Task





- → Non-linear
- → Local shuffling
- → Out-painting
- → In-painting
- → More ...



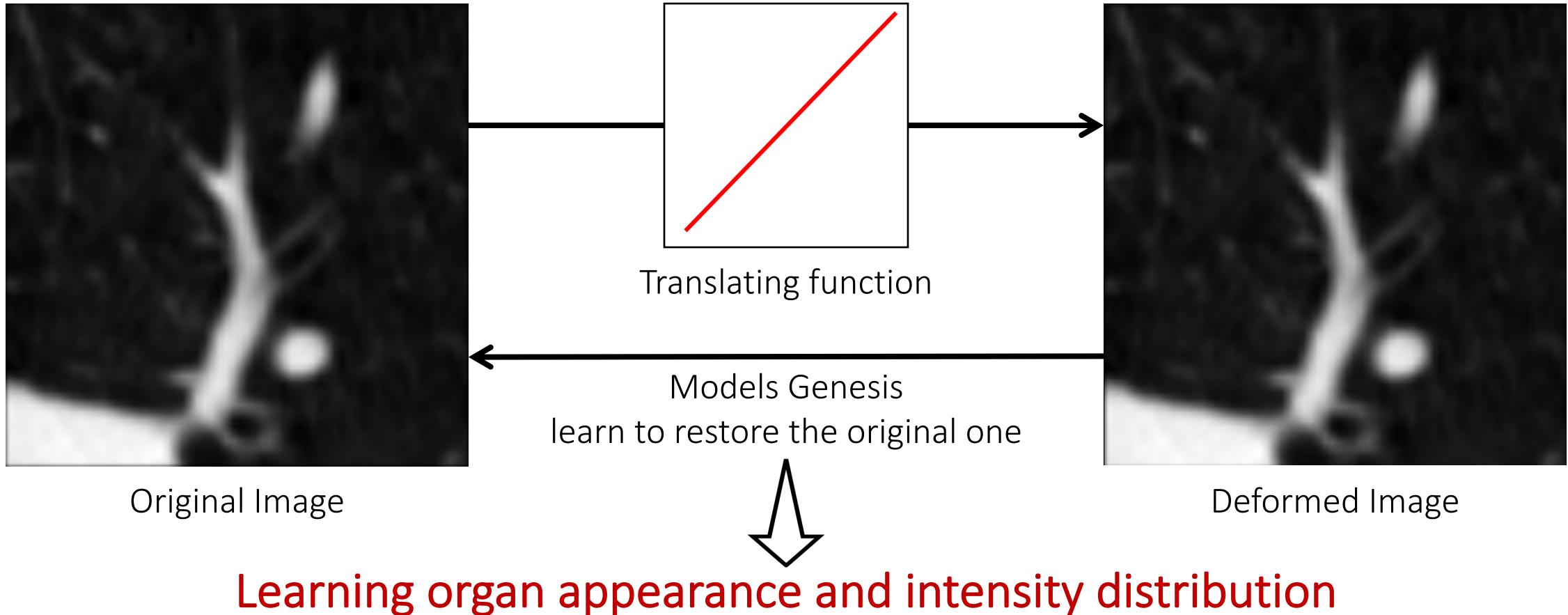
# I. Non-linear transformation

CT scan itself naturally comes with  
the *pixel-wise* annotation

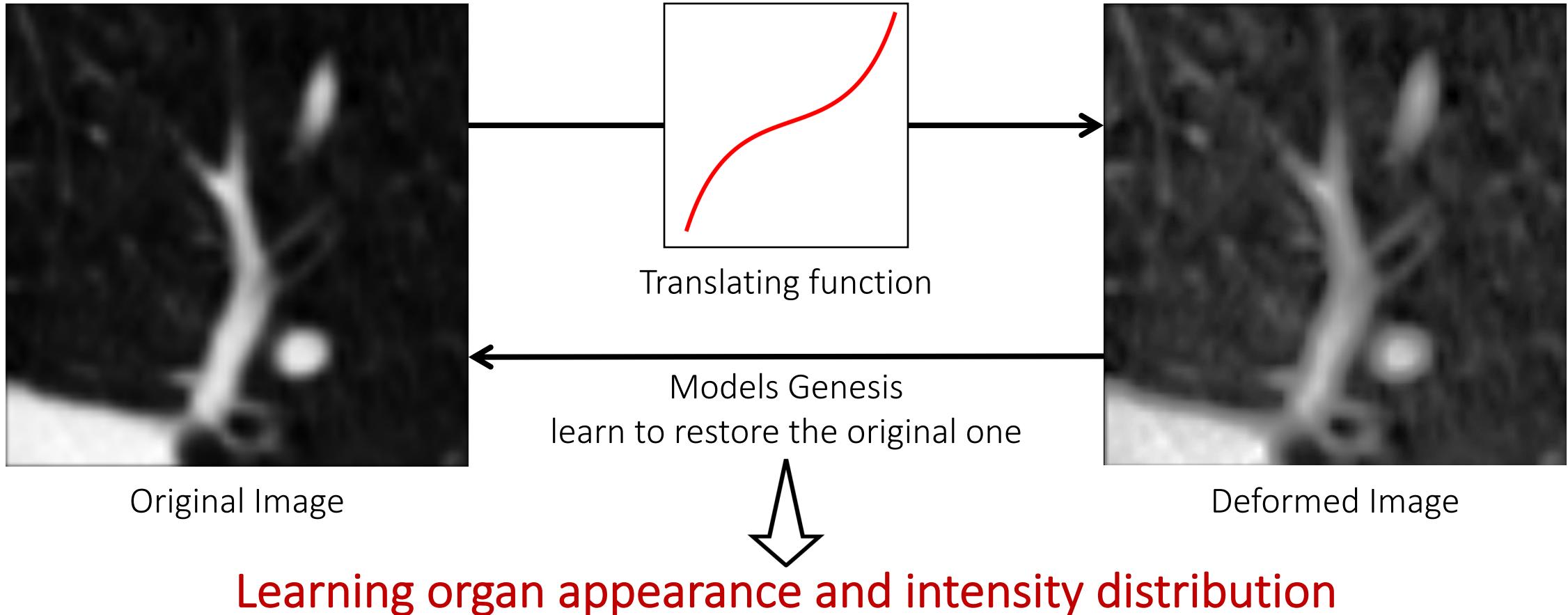
Substance	Hounsfield units (HU)
Air	-1000
Fat	-120 to -90
Water	0
Bone	Cancellous
	Cortical
Parenchyma	Lung
	Kidney
	Liver
	Lymph nodes
	Muscle

Source from [en.wikipedia.org/wiki/Hounsfield\\_scale](https://en.wikipedia.org/wiki/Hounsfield_scale)

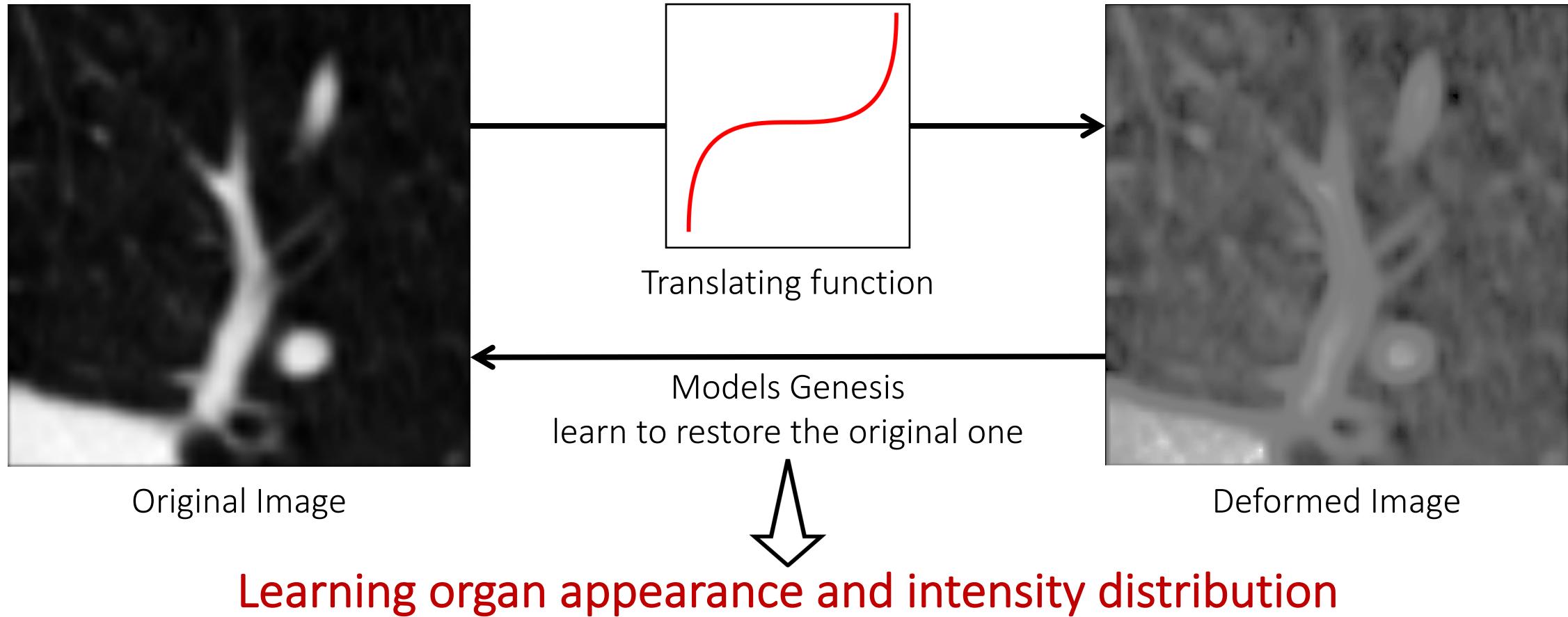
# I. Non-linear transformation



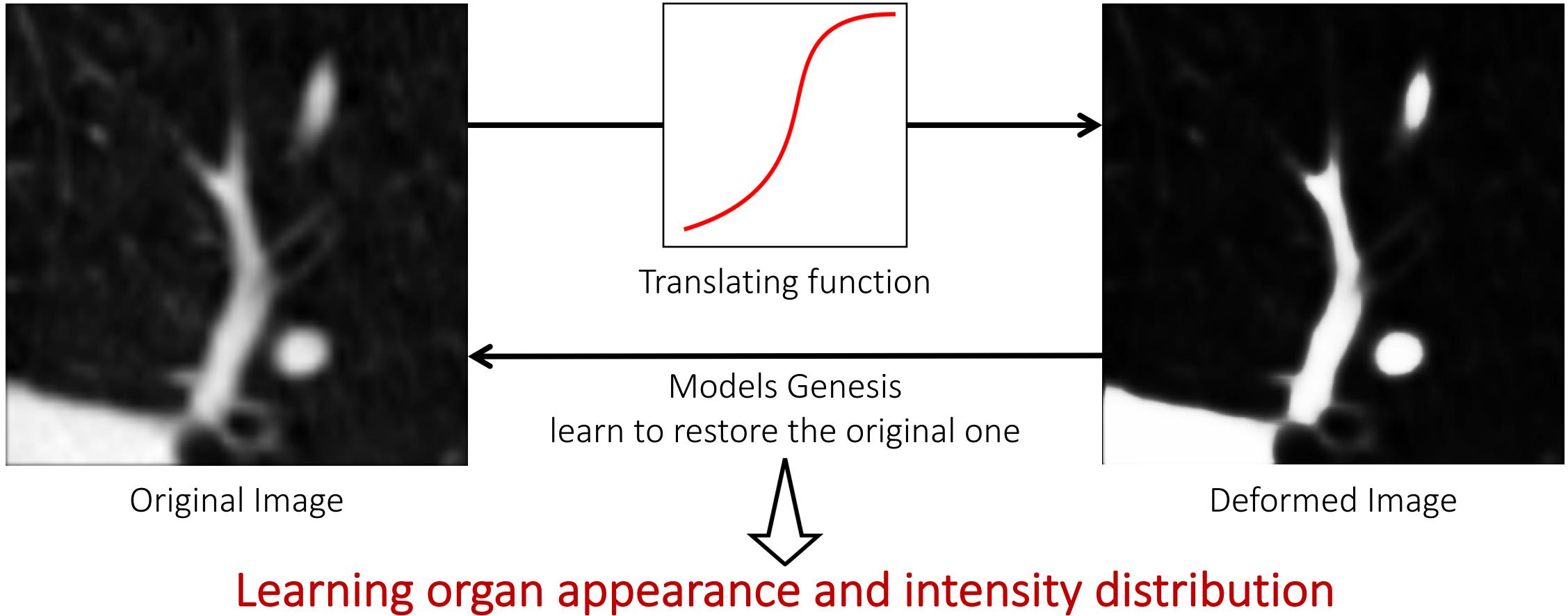
# I. Non-linear transformation



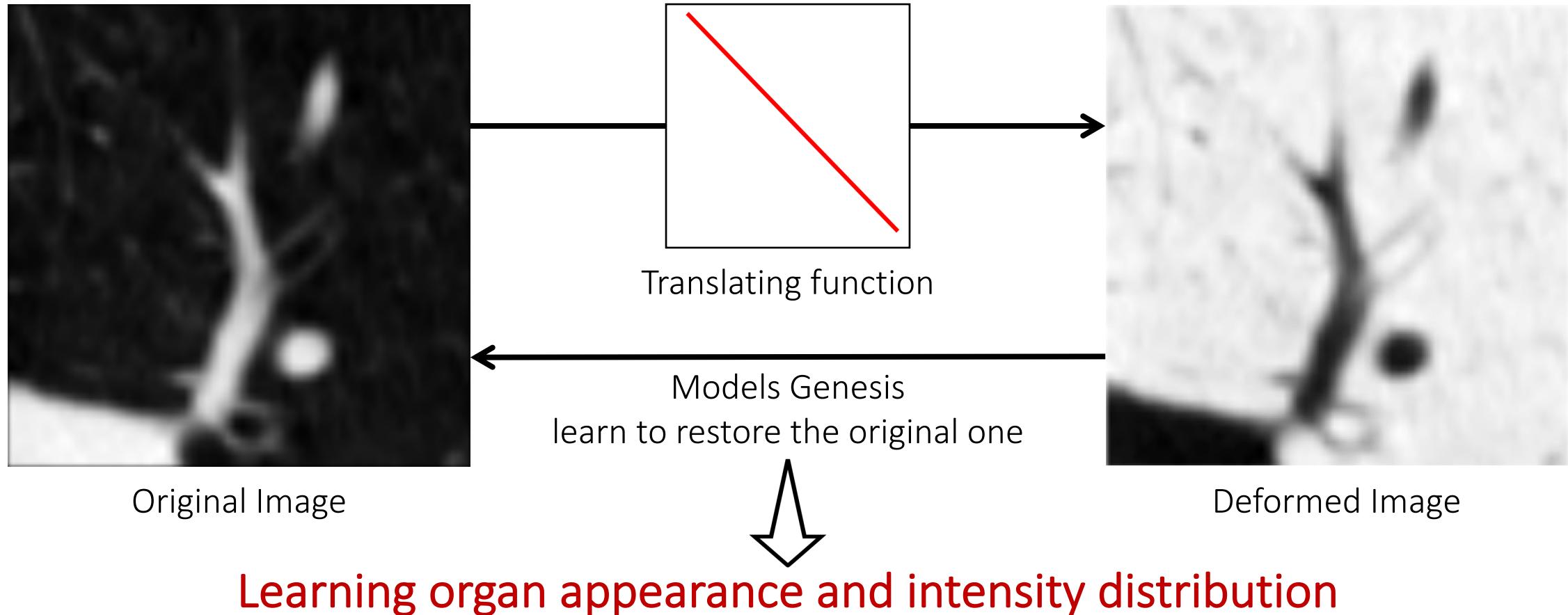
# I. Non-linear transformation



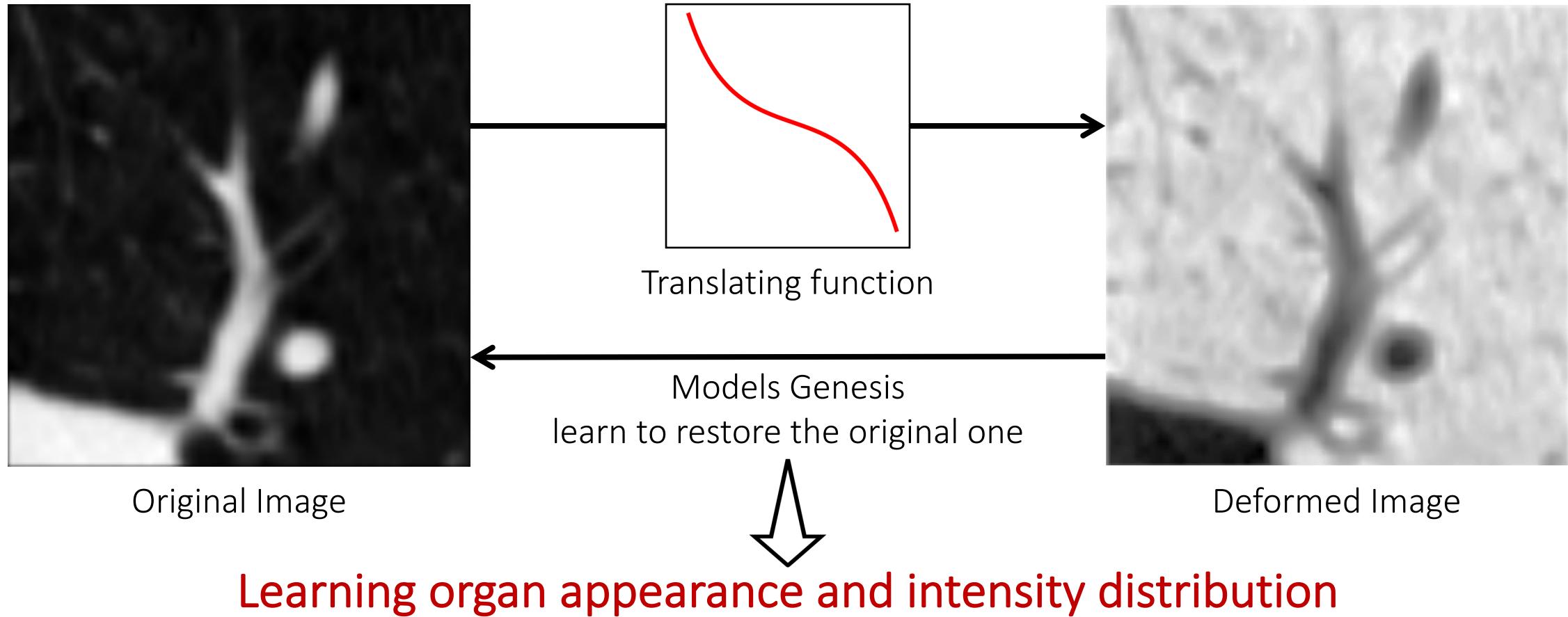
# I. Non-linear transformation



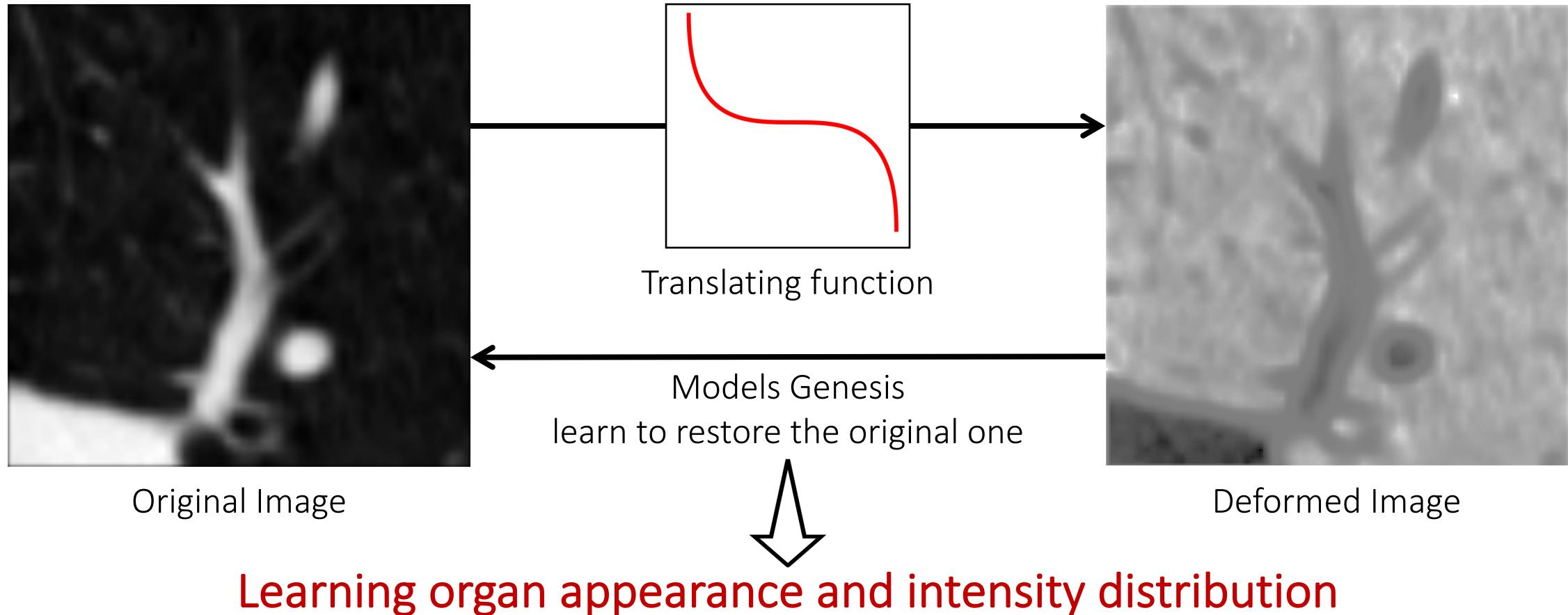
# I. Non-linear transformation



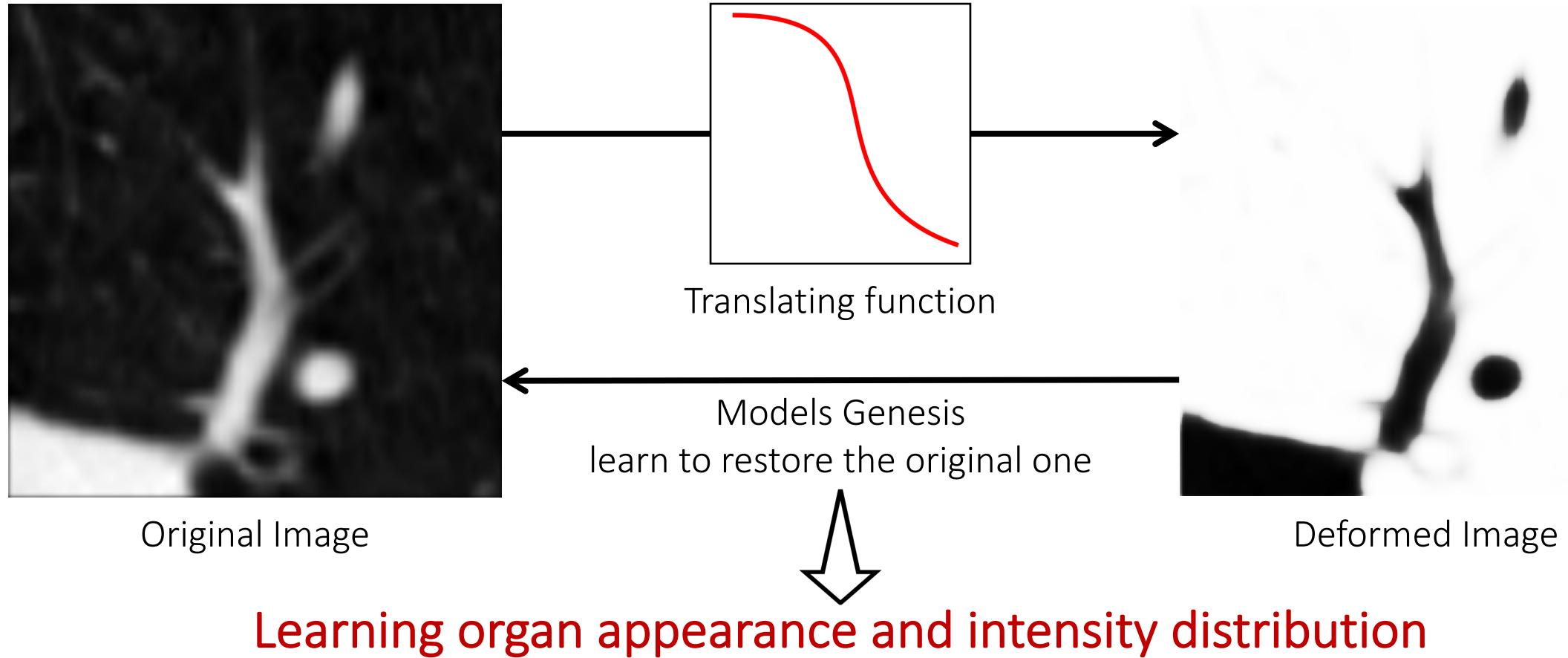
# I. Non-linear transformation



# I. Non-linear transformation



# I. Non-linear transformation



## II. Local pixel shuffling

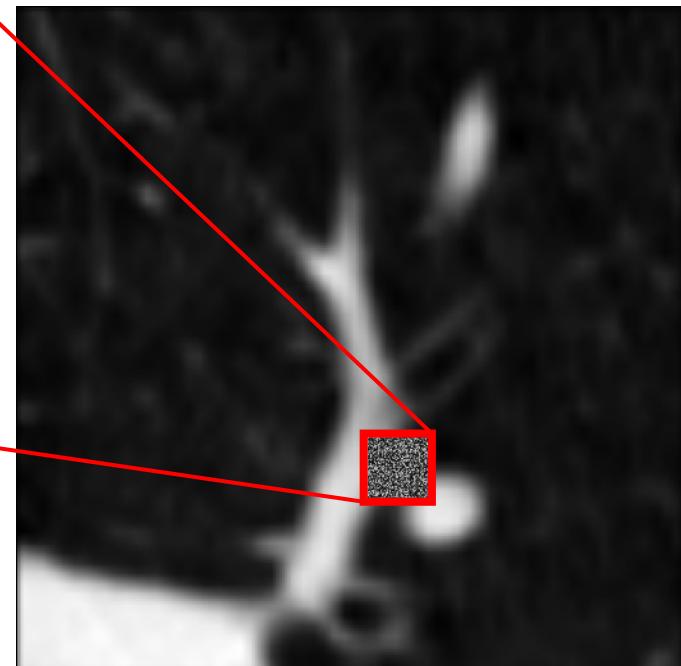


Original Image

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

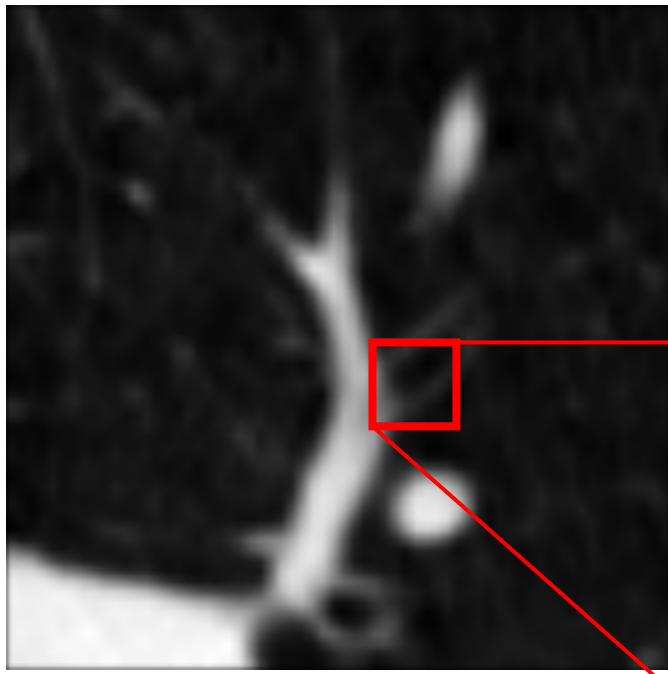
18	4	21	13	8
2	10	15	6	14
24	16	7	1	12
18	3	11	20	17
23	9	25	19	5

shuffling



Deformed Image

## II. Local pixel shuffling

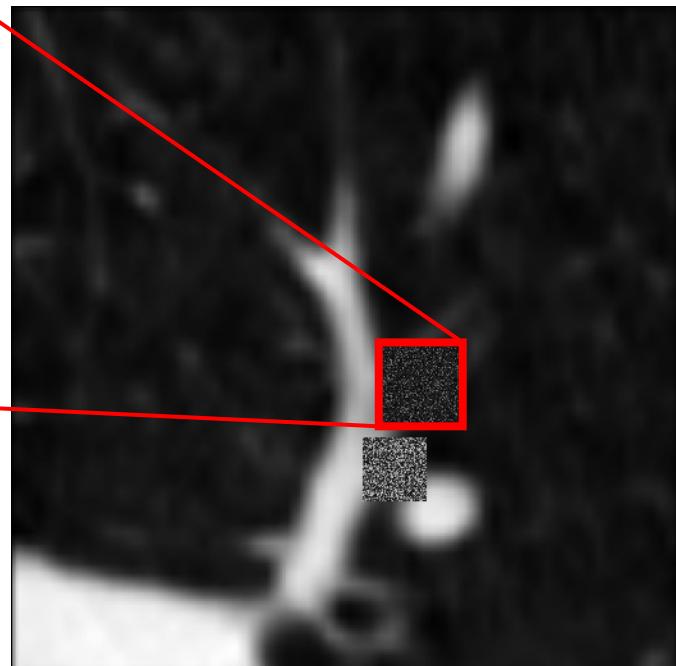


Original Image

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

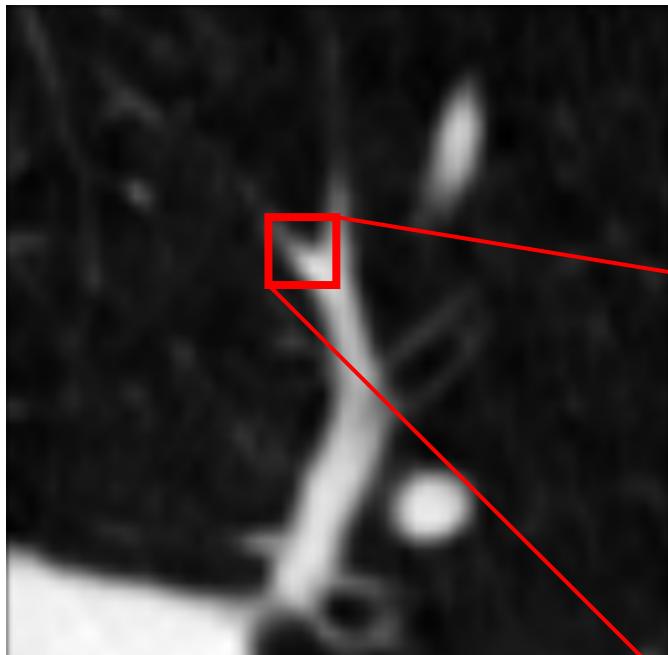
12	18	15	22	3
1	11	5	16	23
21	13	7	10	4
17	2	9	19	25
8	20	6	24	14

shuffling



Deformed Image

## II. Local pixel shuffling

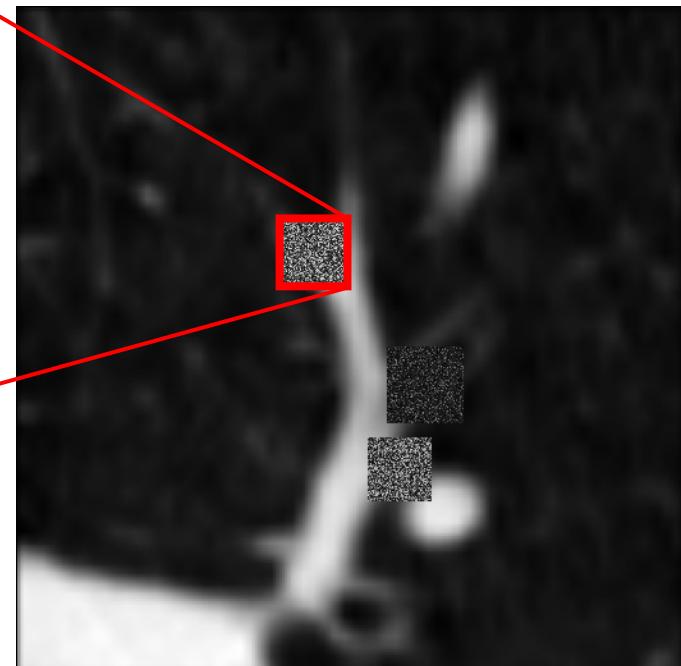


Original Image

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

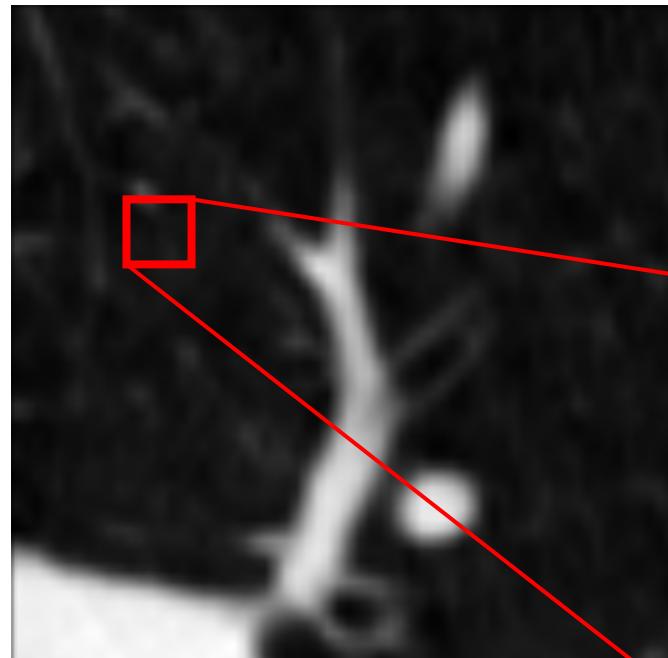
8	15	11	1	20
2	7	24	14	18
22	12	3	19	5
16	4	13	25	10
23	21	9	6	17

shuffling



Deformed Image

## II. Local pixel shuffling

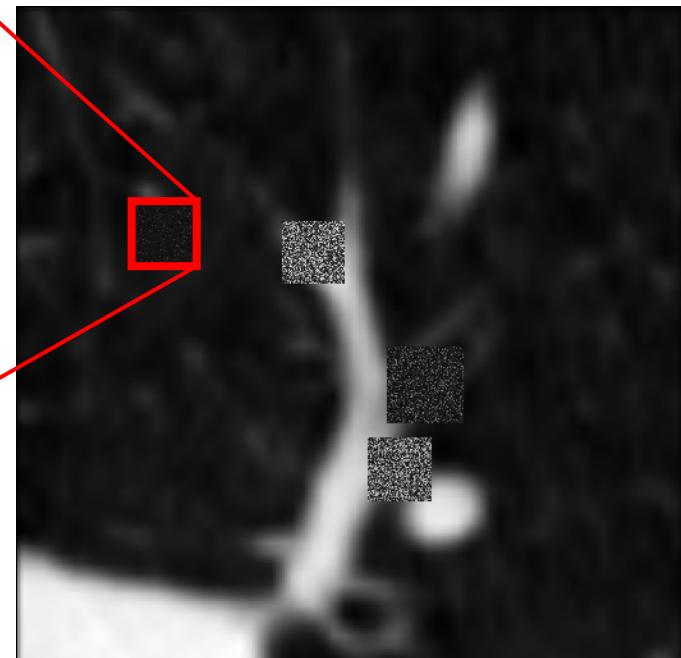


Original Image

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

4	11	22	3	17
10	2	18	14	8
21	16	12	5	23
9	20	1	24	15
13	6	25	19	7

shuffling



Deformed Image

## II. Local pixel shuffling

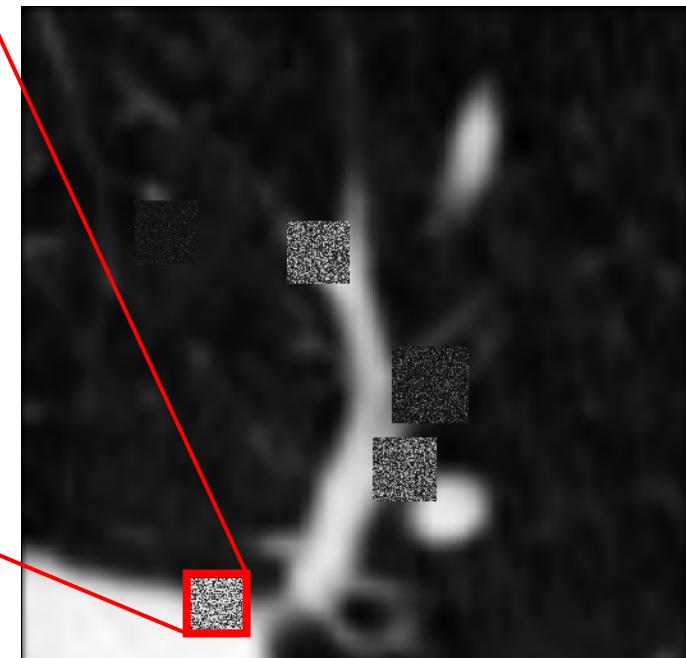


Original Image

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

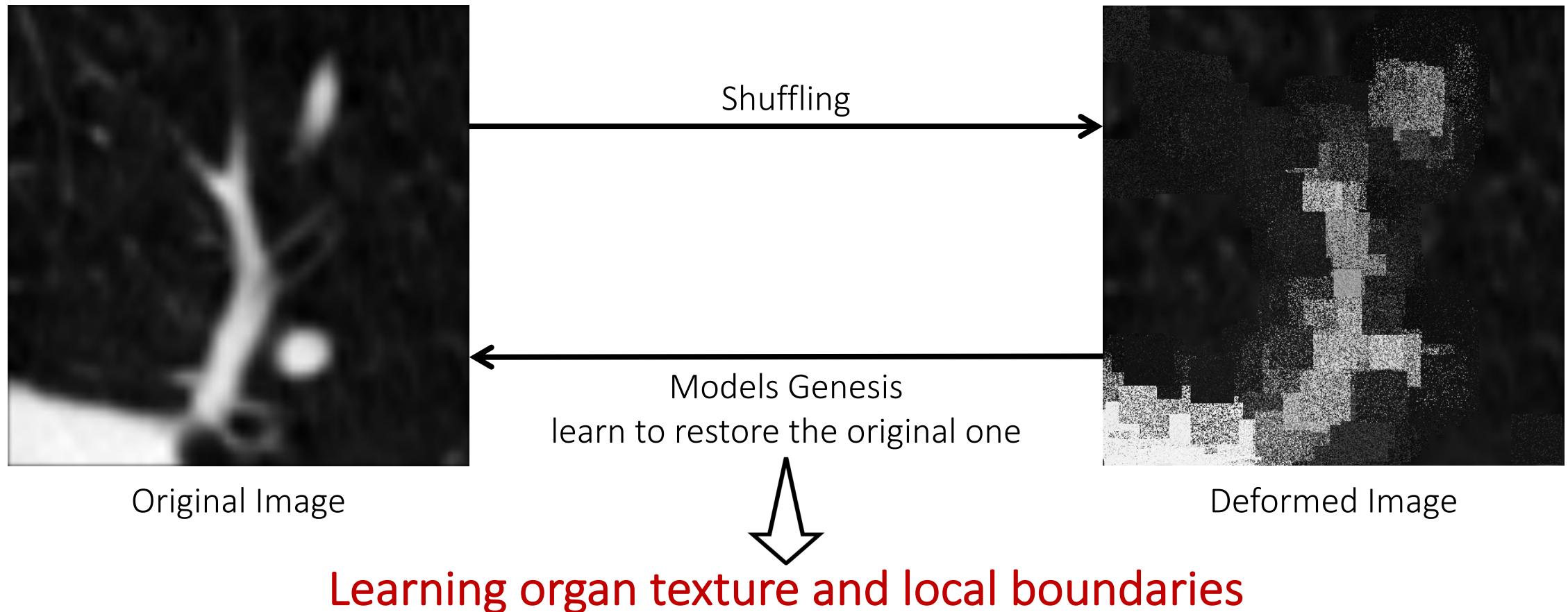
5	13	16	6	19
10	22	2	18	12
21	3	23	11	17
7	15	4	1	25
9	20	8	14	24

shuffling

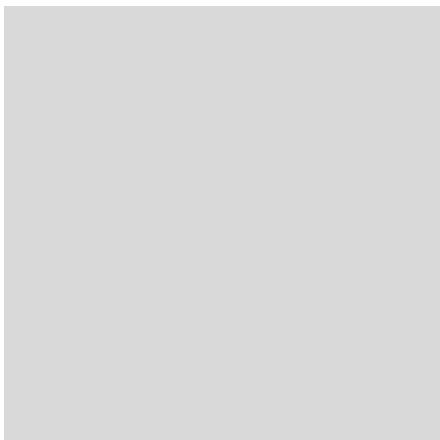


Deformed Image

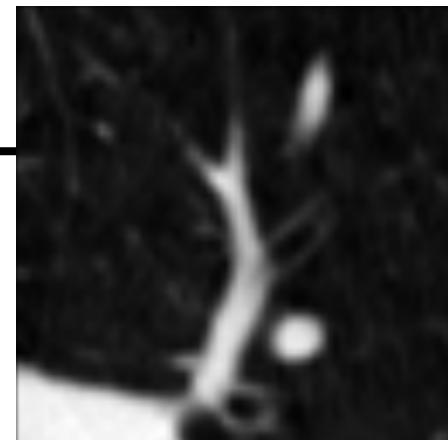
## II. Local pixel shuffling



### III. Out-painting

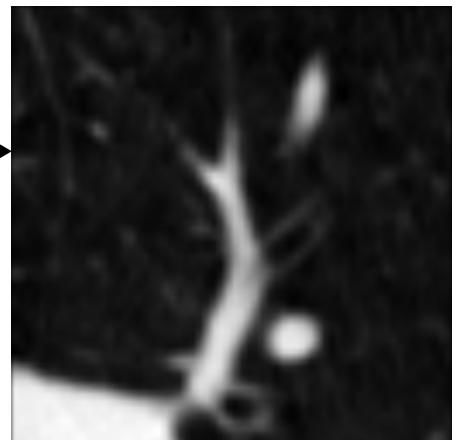


Deformed Image



Original Image

### IV. In-painting



Deformed Image

### III. Out-painting



Deformed Image

← Reveal one window



Original Image

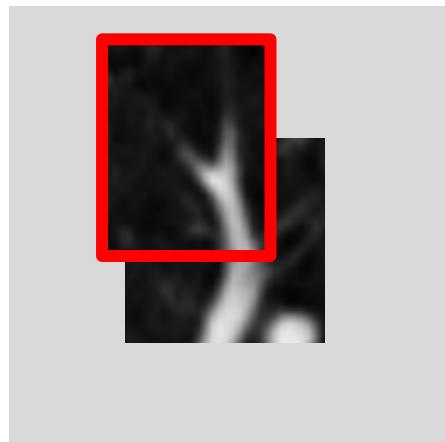
Remove one window →



Deformed Image

### IV. In-painting

### III. Out-painting



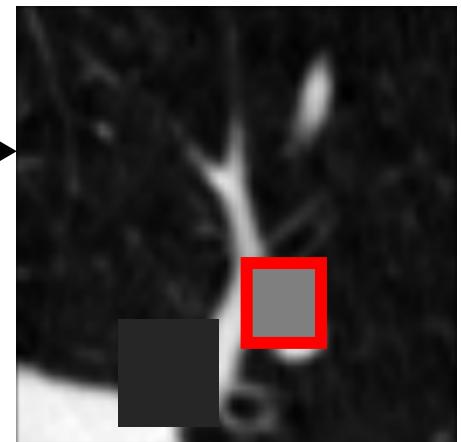
Deformed Image

← Reveal one window



Original Image

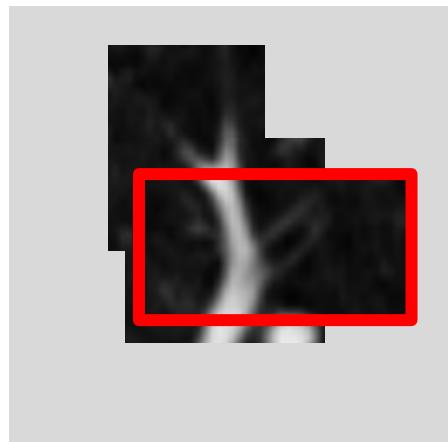
### IV. In-painting



Deformed Image

→ Remove one window

### III. Out-painting



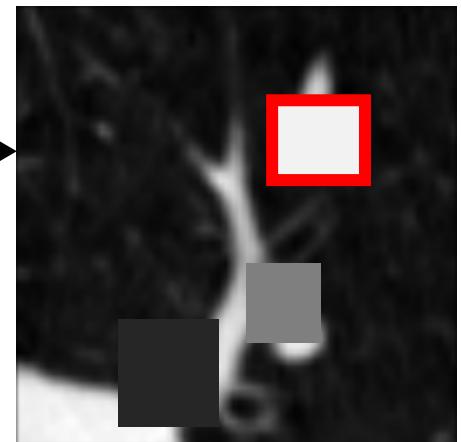
Deformed Image

Reveal one window



Original Image

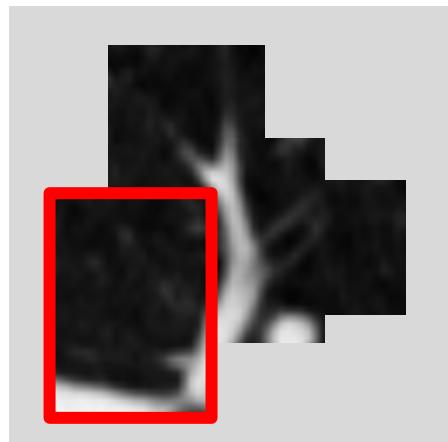
### IV. In-painting



Deformed Image

Remove one window

### III. Out-painting



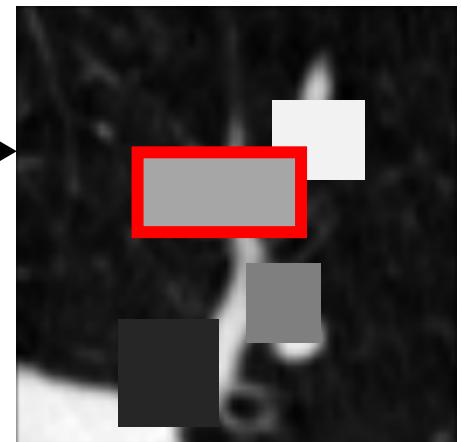
Deformed Image

Reveal one window



Original Image

### IV. In-painting



Deformed Image

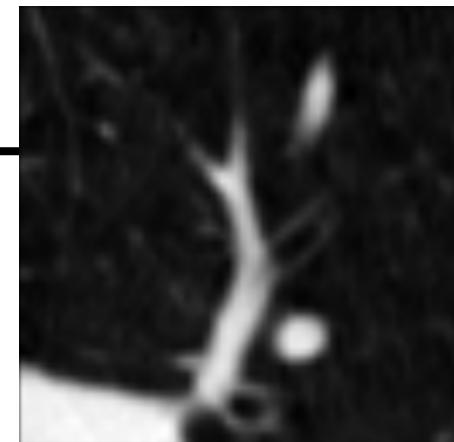
Remove one window

### III. Out-painting



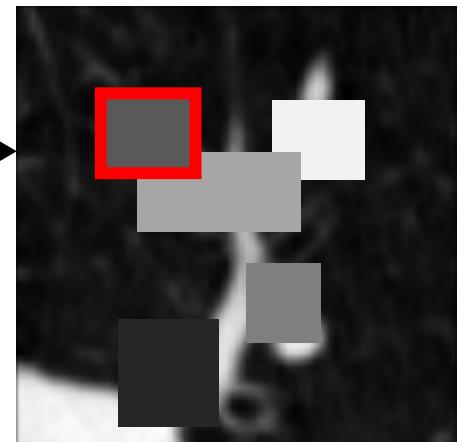
Deformed Image

← Reveal one window



Original Image

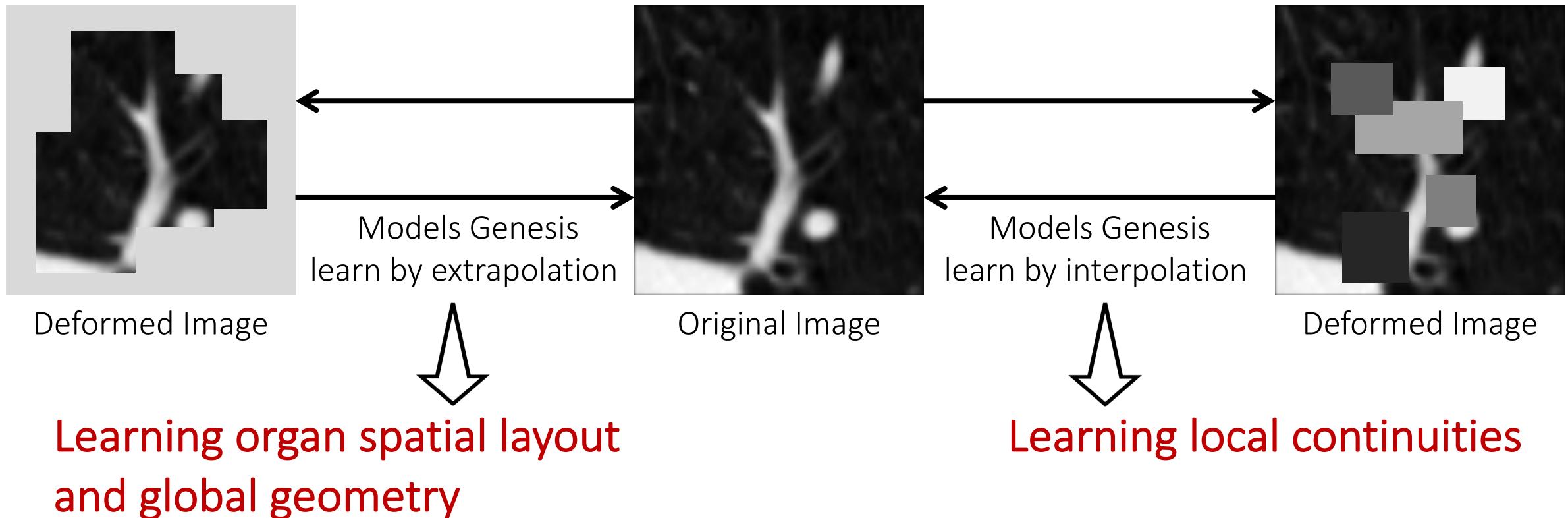
### IV. In-painting



Deformed Image

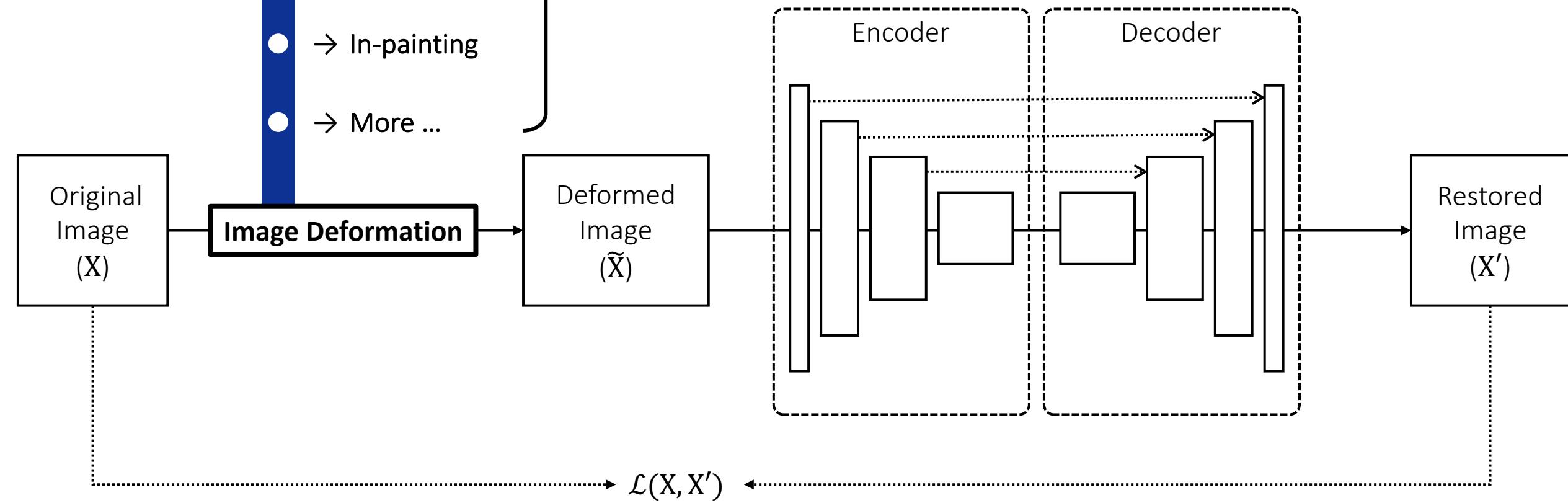
Remove one window →

### III. Out-painting

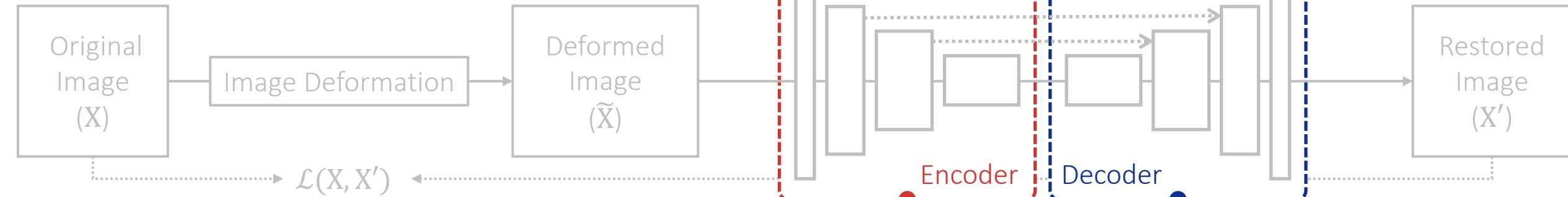
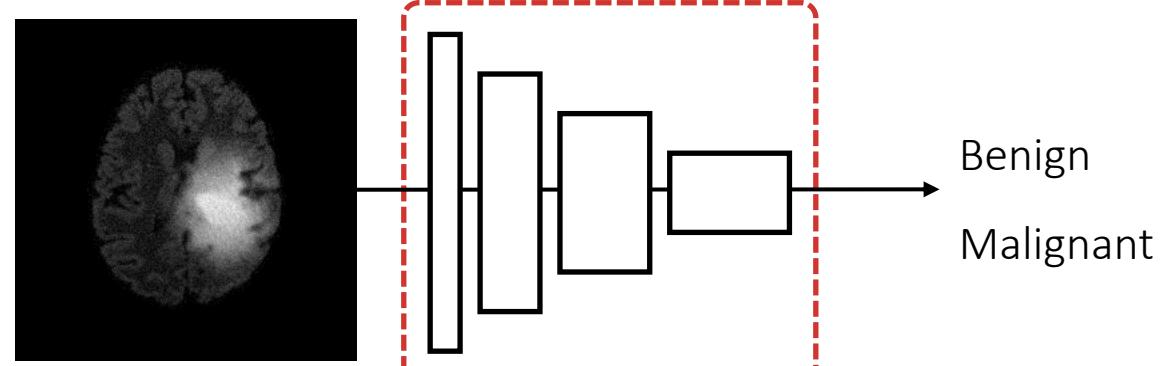


- → Non-linear
- → Local shuffling
- → Out-painting
- → In-painting
- → More ...

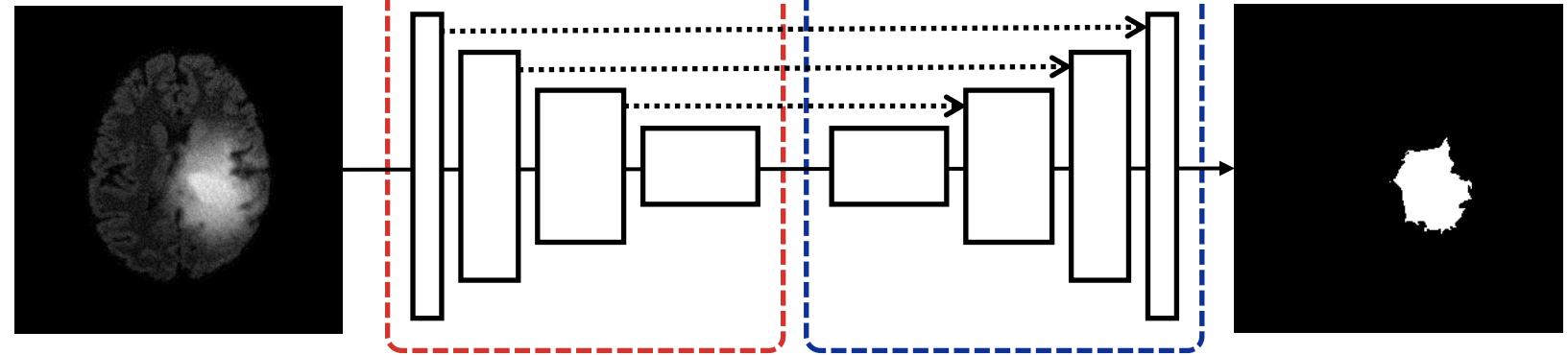
**Combination: learning from multiple perspectives**  
e.g., organ appearance, texture, boundary, global geometry, and local continuity



Once pre-trained,  
the **encoder** could be used  
for target classification tasks  
*e.g.*, brain tumor classification;

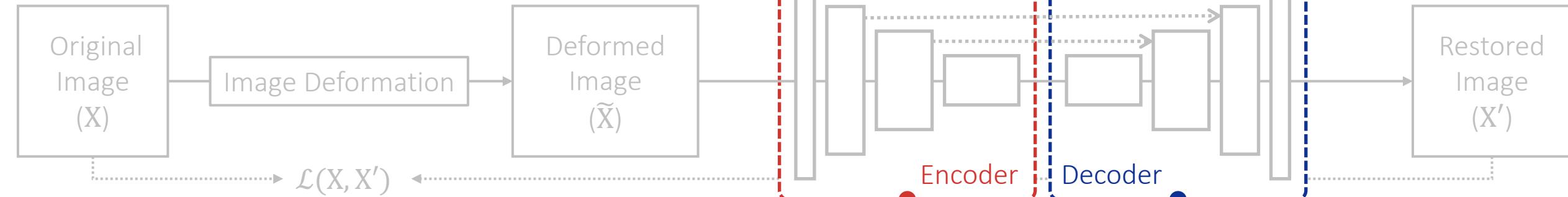


the **encoder-decoder** could be used  
for target segmentation tasks  
*e.g.*, brain tumor segmentation



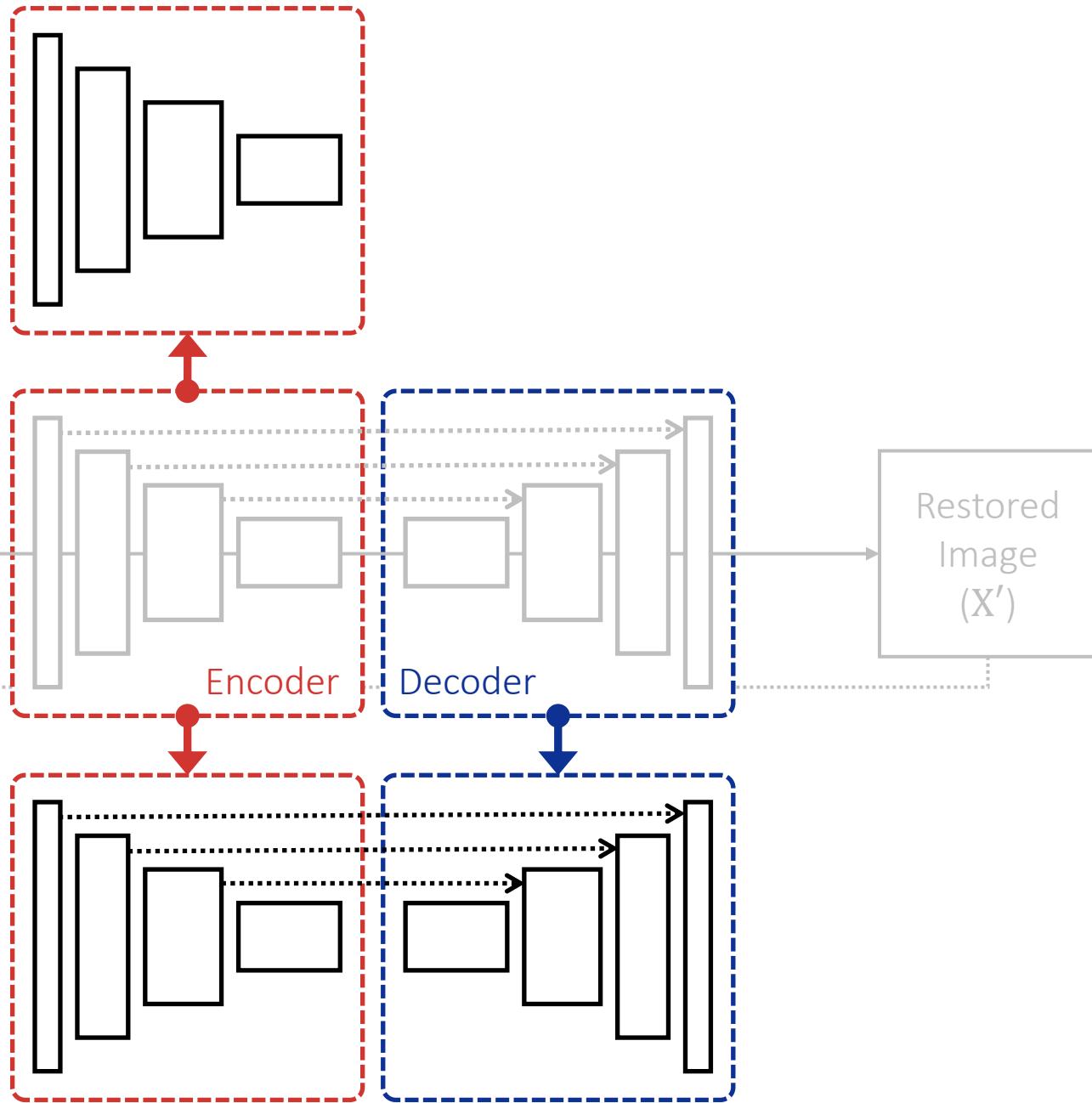
## Four classification applications

1. Lung nodule false positive reduction (CT)
2. PE false positive reduction 3D CT (CT)
3. Eight pulmonary diseases classification (X-ray)
4. Roi/bulb/background classification (Ultrasound)



## Three segmentation applications

1. Lung nodule segmentation (CT)
2. Liver segmentation (CT)
3. Brain tumor segmentation (MRI)

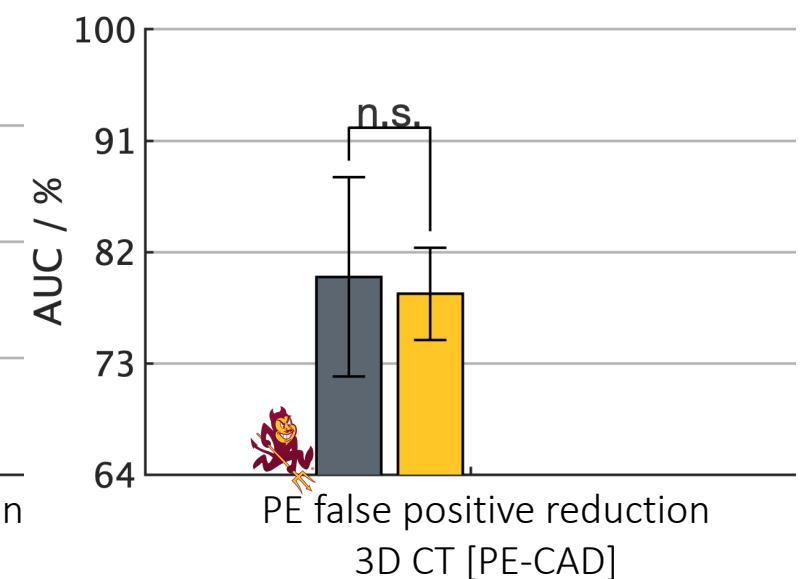
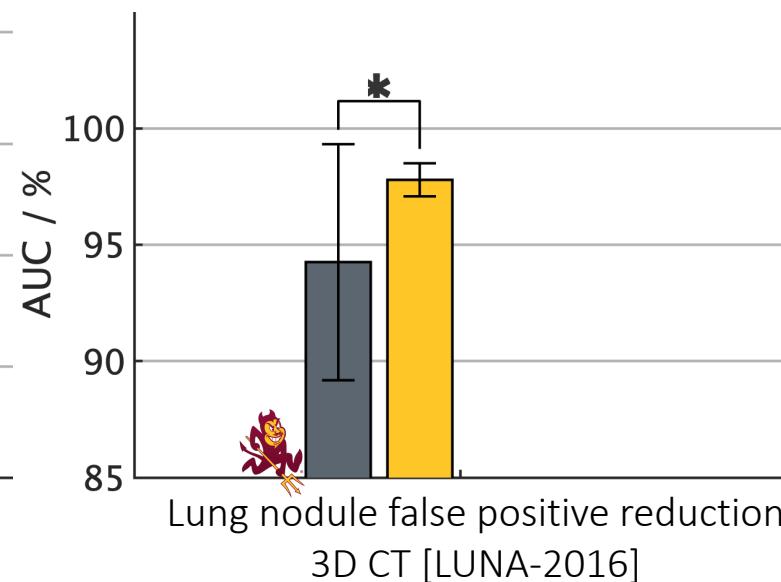
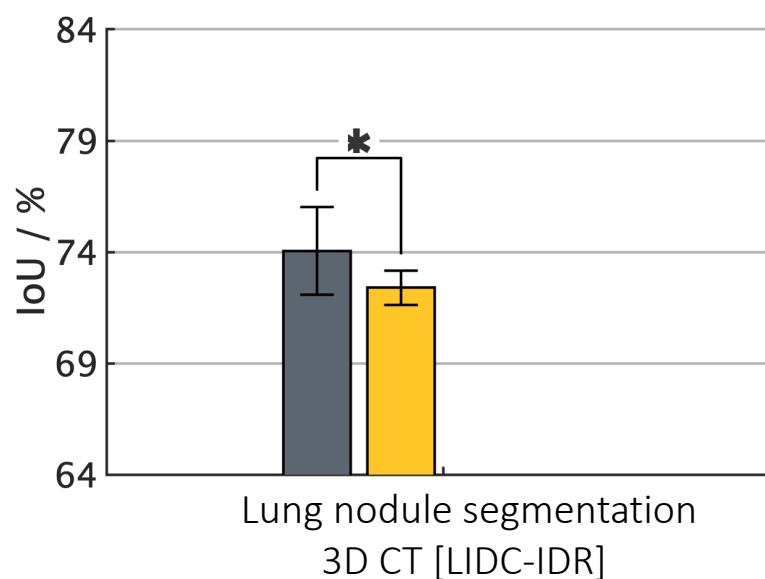


# Devils in 3D Models

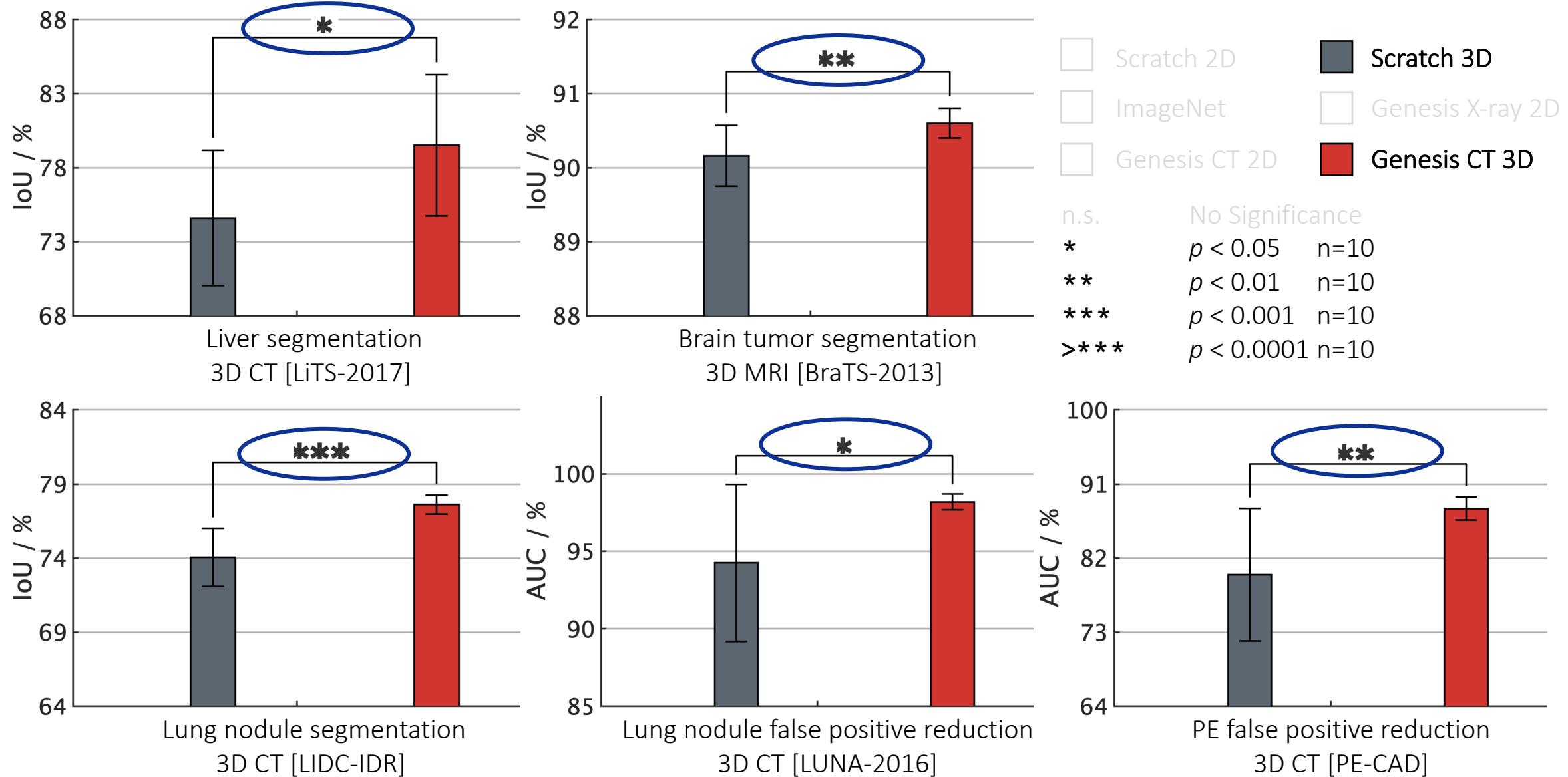


: Learning from scratch *simply* in 3D may not necessarily yield performance better than fine-tuning from ImageNet in 2D

	Scratch 2D	Scratch 3D
	ImageNet	Genesis X-ray 2D
	Genesis CT 2D	Genesis CT 3D
n.s.	No Significance	
*	$p < 0.05$	$n=10$
**	$p < 0.01$	$n=10$
***	$p < 0.001$	$n=10$
>***	$p < 0.0001$	$n=10$



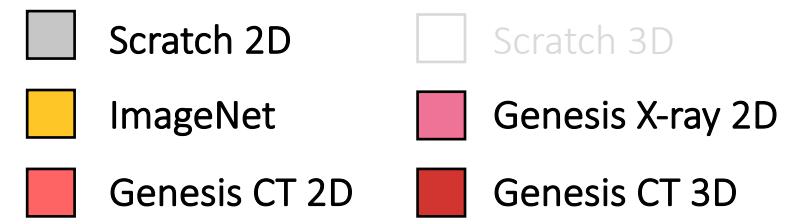
# Result I: Models Genesis outperform 3D models trained from scratch



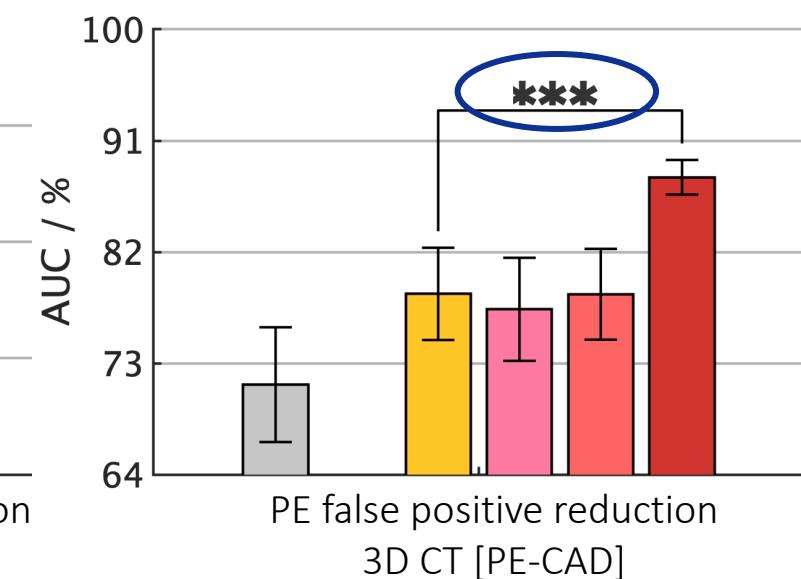
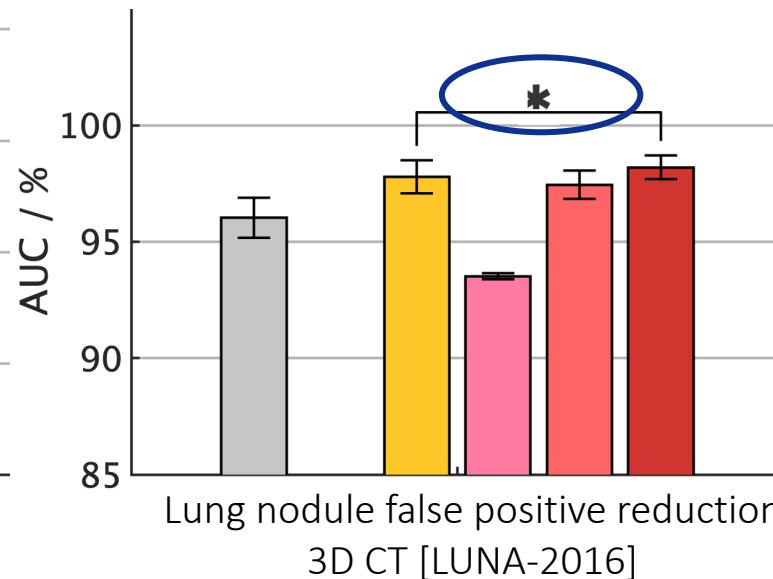
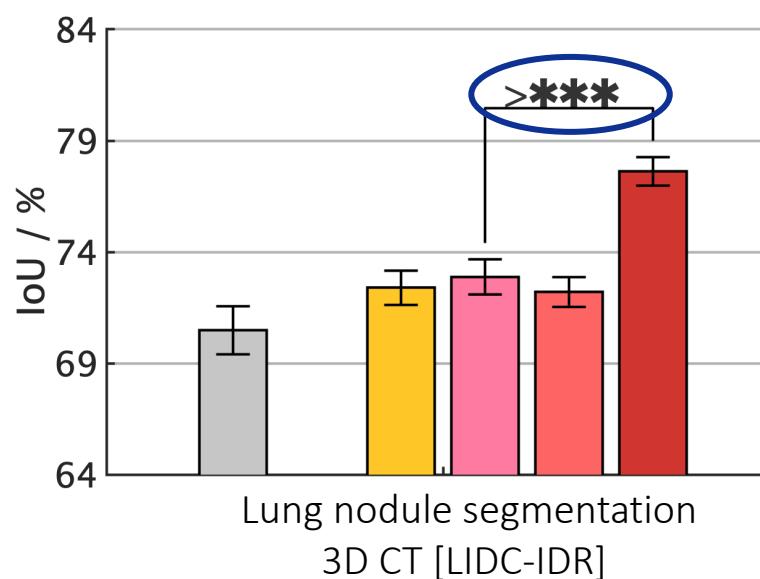
## Result II: Models Genesis consistently outperform any 2D approaches

including

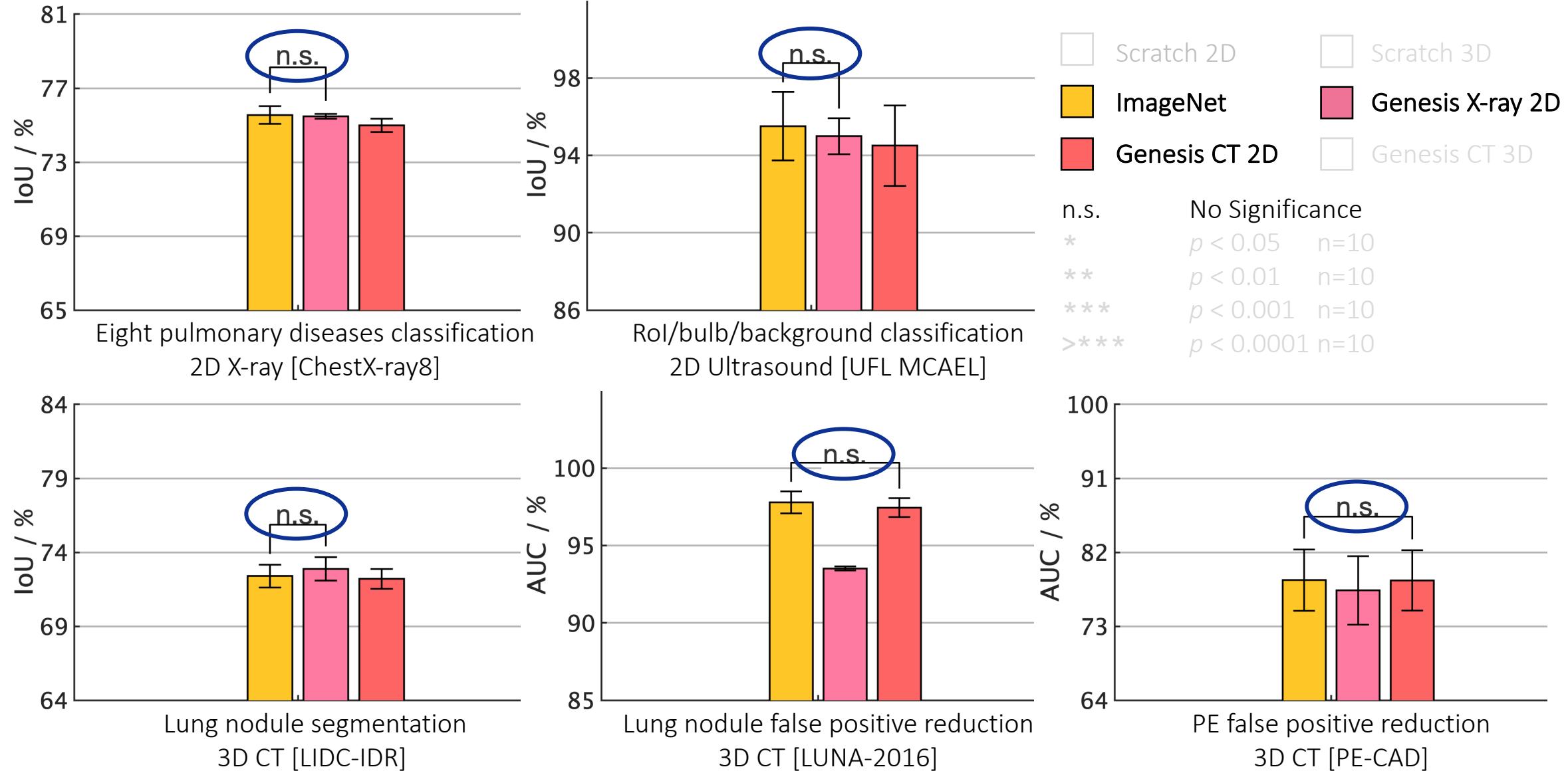
1. ImageNet (state-of-the-art)
2. Models Genesis 2D (degraded)
  - Genesis X-ray 2D: pre-trained on NIH X-ray dataset
  - Genesis CT 2D: pre-trained on LUNA-2016 dataset



n.s.	No Significance		
*	$p < 0.05$	$n=10$	
**	$p < 0.01$	$n=10$	
***	$p < 0.001$	$n=10$	
>***	$p < 0.0001$	$n=10$	



# Result III: Models Genesis 2D (self-supervised) $\approx$ ImageNet (supervised)



# Models Genesis: Generic Autodidactic Models for 3D Medical Image Analysis

We offer a set of powerful pre-trained 3D models, concluding that

1. Models Genesis outperform 3D models trained from scratch
2. Models Genesis consistently outperform any 2D approaches
3. Models Genesis (2D) offer performances equivalent to supervised pre-trained models

**Genesis Chest CT**  
Genesis X-ray

# Models Genesis: Generic Autodidactic Models for 3D Medical Image Analysis

A word cloud visualization where words represent different models or concepts related to 'Models Genesis'. The size of each word indicates its frequency or importance. The words are color-coded and arranged in a roughly circular pattern.

- Transfer learning
- Genesis Ultrasound
- Genesis Heart
- Genesis MRI
- Genesis CT
- Generic Autodidactic Models
- Genesis Lung
- Genesis Chest CT
- Models Genesis
- Genesis X-ray
- Medical ImageNet
- Holy Grail
- Self-taught
- Transfer learning
- Genesis Brain
- ImageNet
- Ex nihilo
- Generic
- Eclectic
- Unified
- Scalable
- Robust
- Genesis Liver CT
- Genesis Brain MRI

# Models Genesis: Generic Autodidactic Models for 3D Medical Image Analysis

Poster session

Tuesday, October 15  
13:00 – 14:00

Poster T-5-B-013

Try it for yourself

Code, data, and models  
are available online



[github.com/MrGiovanni/ModelsGenesis](https://github.com/MrGiovanni/ModelsGenesis)