Respiratory Model Architecture

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Objectives

- Respiratory modeling and animation is developed in the purpose of:
  - Construct level of detail of the respiratory modeling features such as:
    - Level of detail of structures (LOD-S) for the whole human respiratory system
    - Level of detail of inner surfaces (LOD-ISs) for the respiratory bronchiole tree
    - Level of detail of lungs (LOD-Lungs) for the lung segments
  - Give joint and segment names of each respiratory structure
  - Generate animation of the respiratory organs based on the modeling structure
    - Male respiratory animation
    - Female respiratory animation

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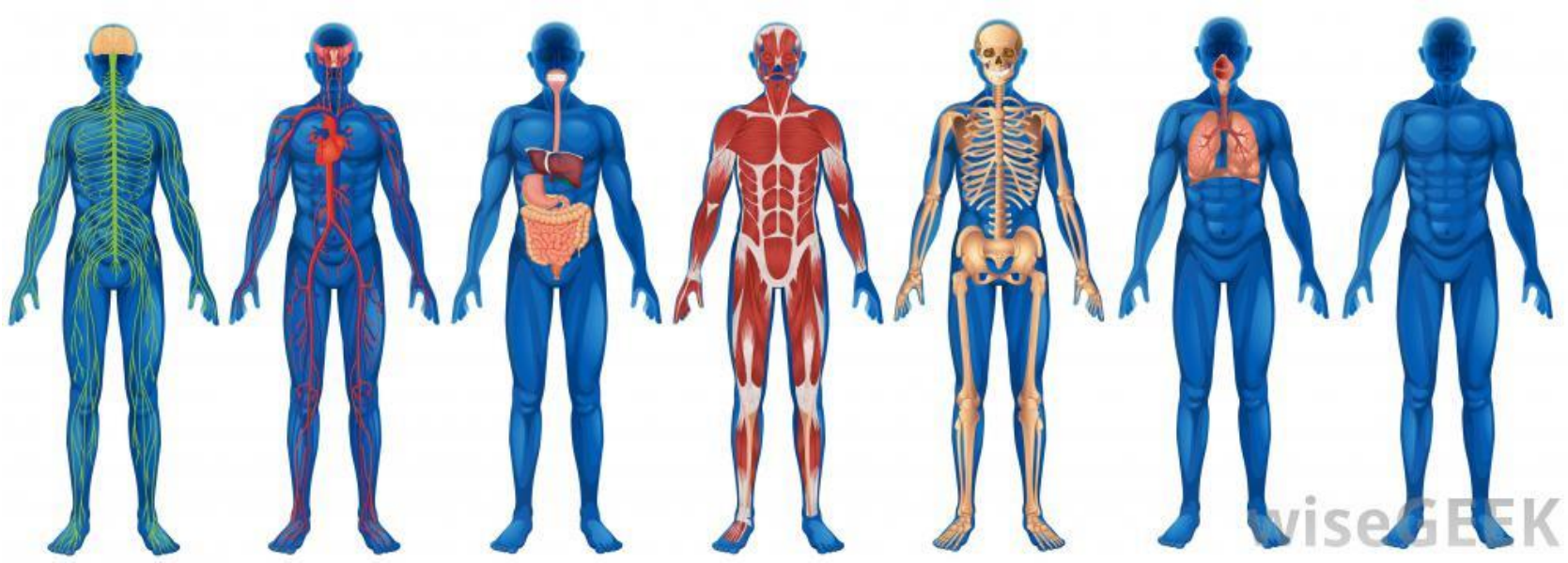
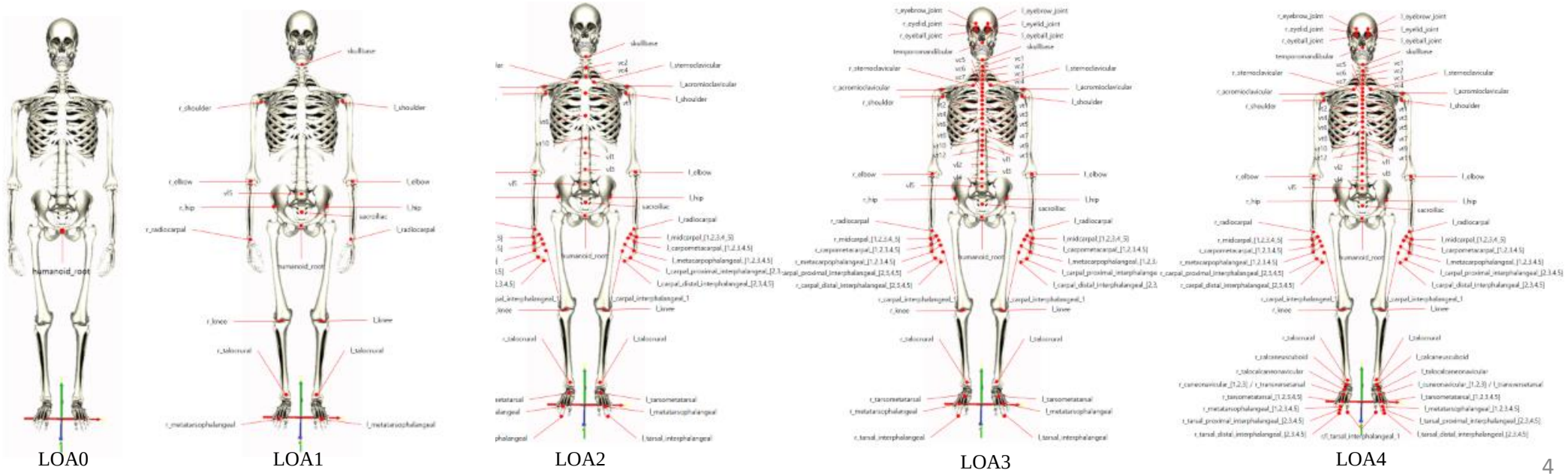
INTRODUCTION

- ***Human modeling*** represents for human body model, human behavior, and processes that can lead to make the ***animation*** to the human body.
- The human modeling can be parts of body modeling or anatomy modeling (skeleton, hand, muscles, etc.)



INTRODUCTION

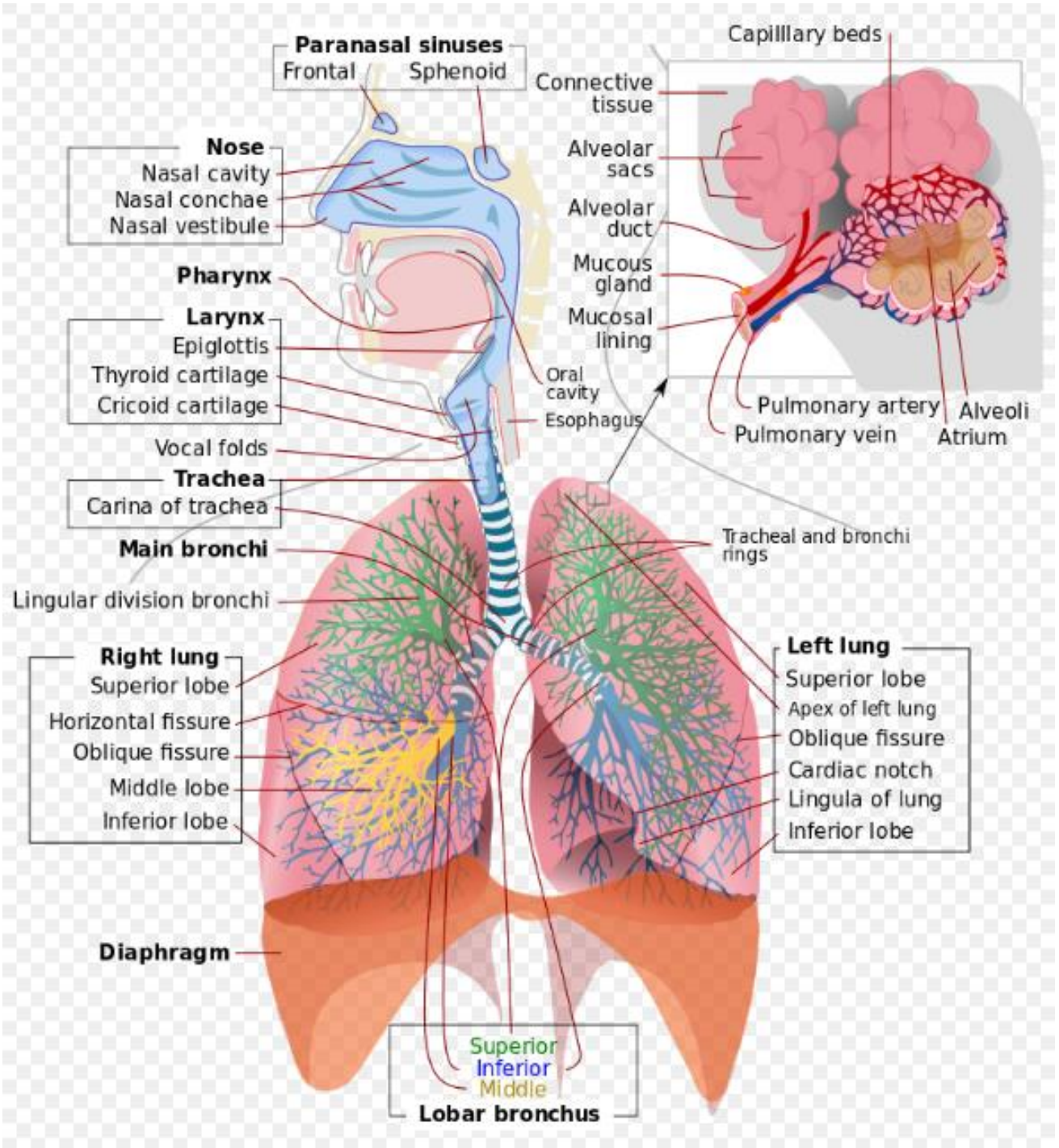
- H-Anim [1-2] – the International Standard structure for modeling the skeleton and skin, motion capture, and anatomical simulation of 3D human figures.
- The complexity of joints for a human skeletal hierarchy by levels of articulation (LOA) can generate motion of the skeletons.



INTRODUCTION

- Even though H-Anim can be used to construct the structure of the human body for giving the modeling and animation to the human figure, H-Anim nowadays is applied for only:
  - Hands
  - Feet
  - Face
  - Body model
- H-Anim hasn’t applied for the modeling and animation with human internal organ in 3D scenes yet.

Human respiration Organ



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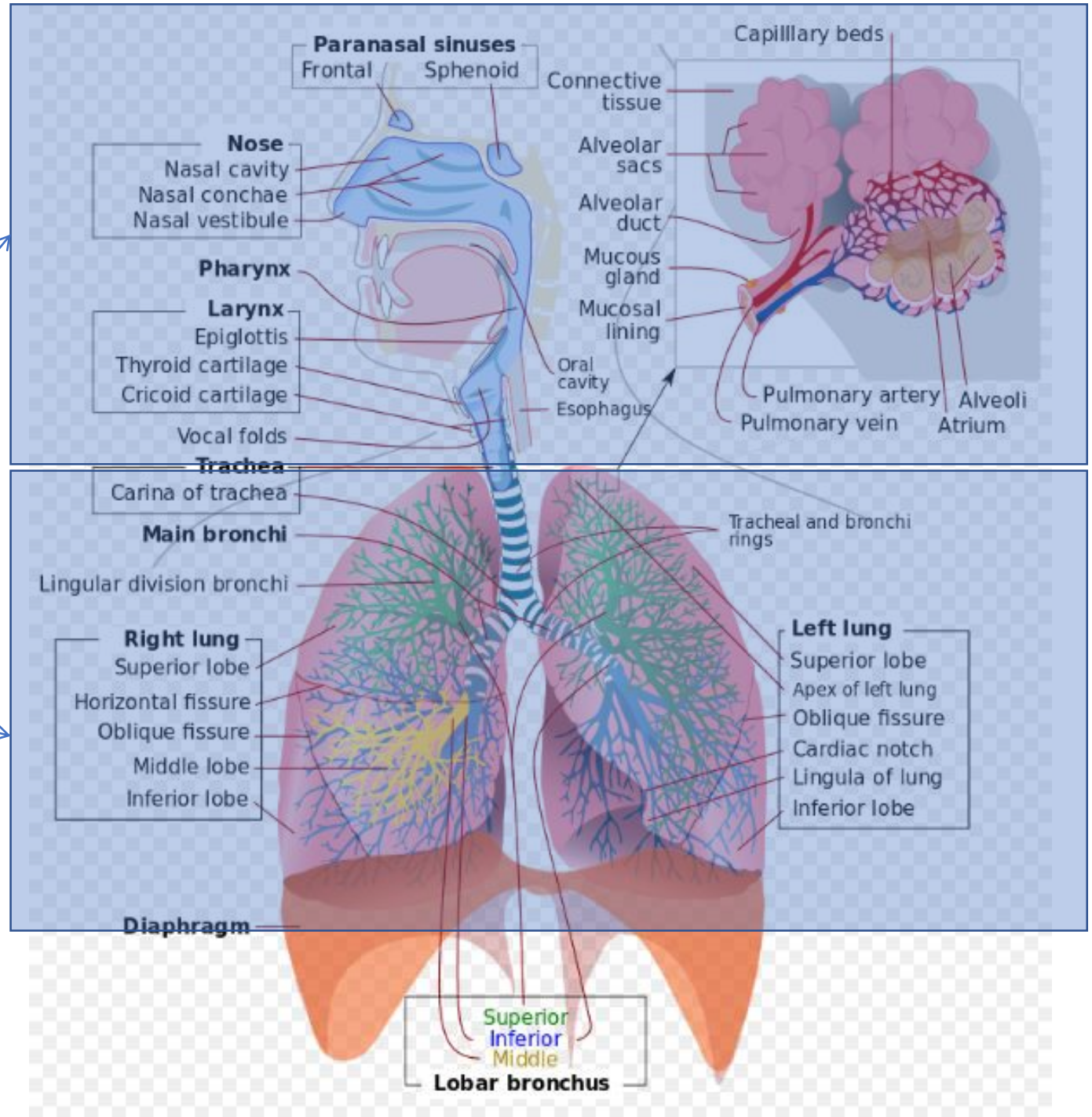
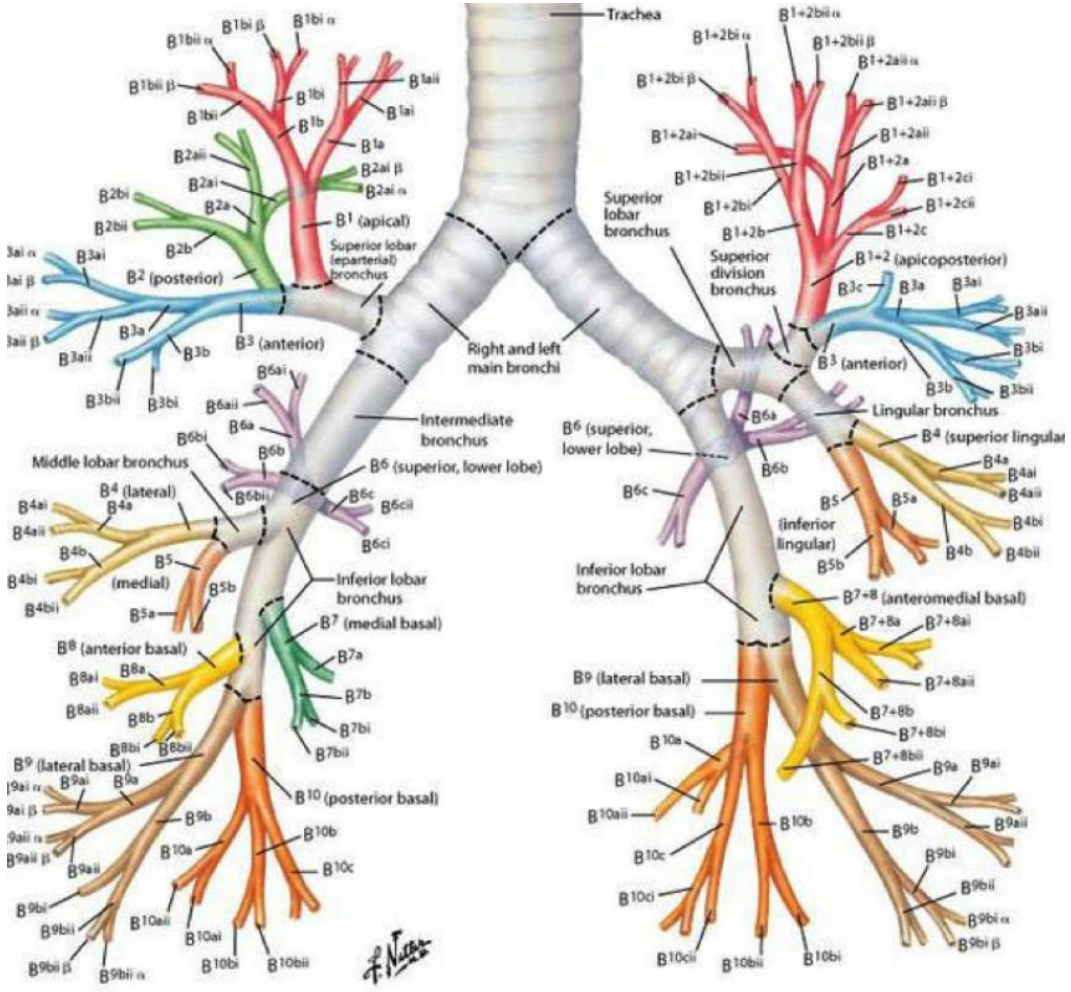
Human respiration Organ

For our human respiratory system model, it has separated into two parts of lower and upper respiration tracts.



RESPIRATORY SCHEMA



Nomenclature of bronchi schema

BRONCHIAL TREE

- Trachea

--< 2 primary bronchi (Lt/Rt)

--< 2/3 lobar bronchi

--< 8/10 times segments bronchi

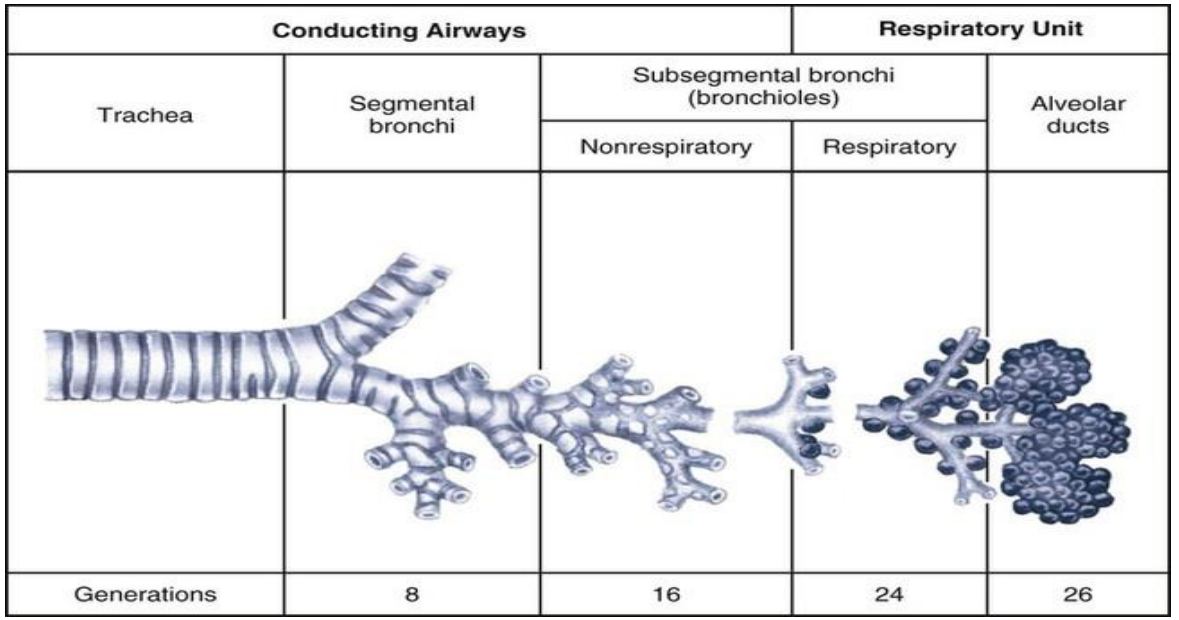
--< 10 times segments Bronchiole

(diameter < 1 mm)

--< 5-7 times segments

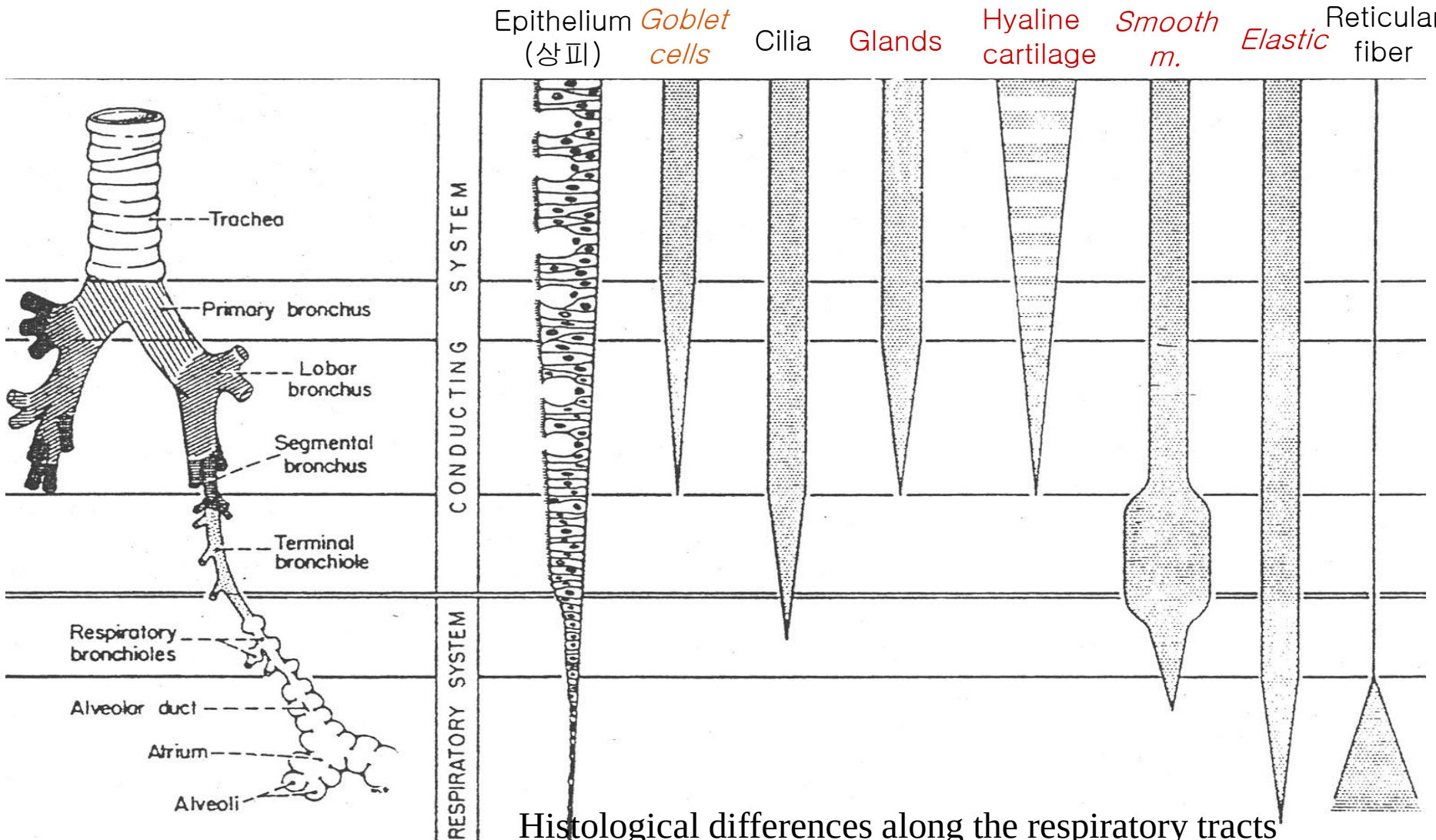
terminal bronchiole

--< 18 times segments alveoli



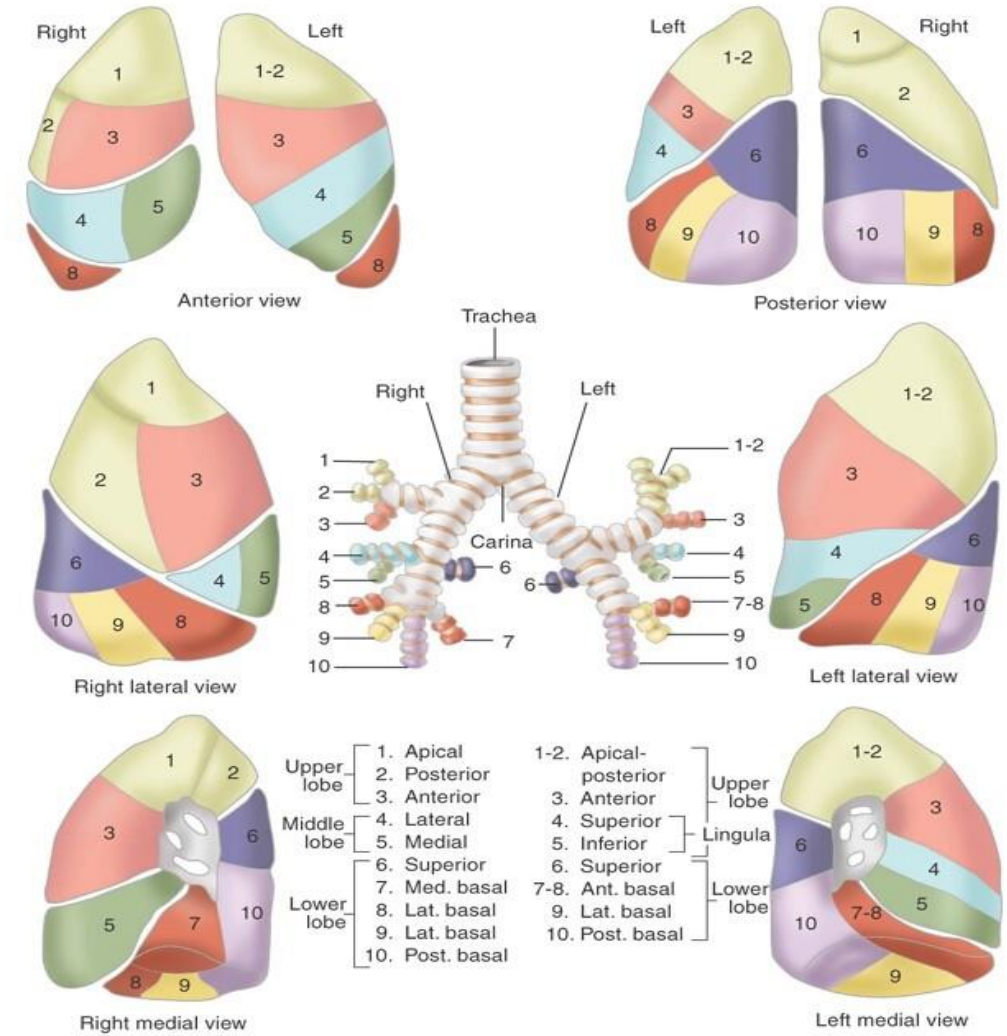
* Pulmonary lobule/ acinus

LEVEL OF DETAIL OF INNER SURFACES (LOD-ISs)



Histological differences along the respiratory tracts

Surfaces of left and right lungs



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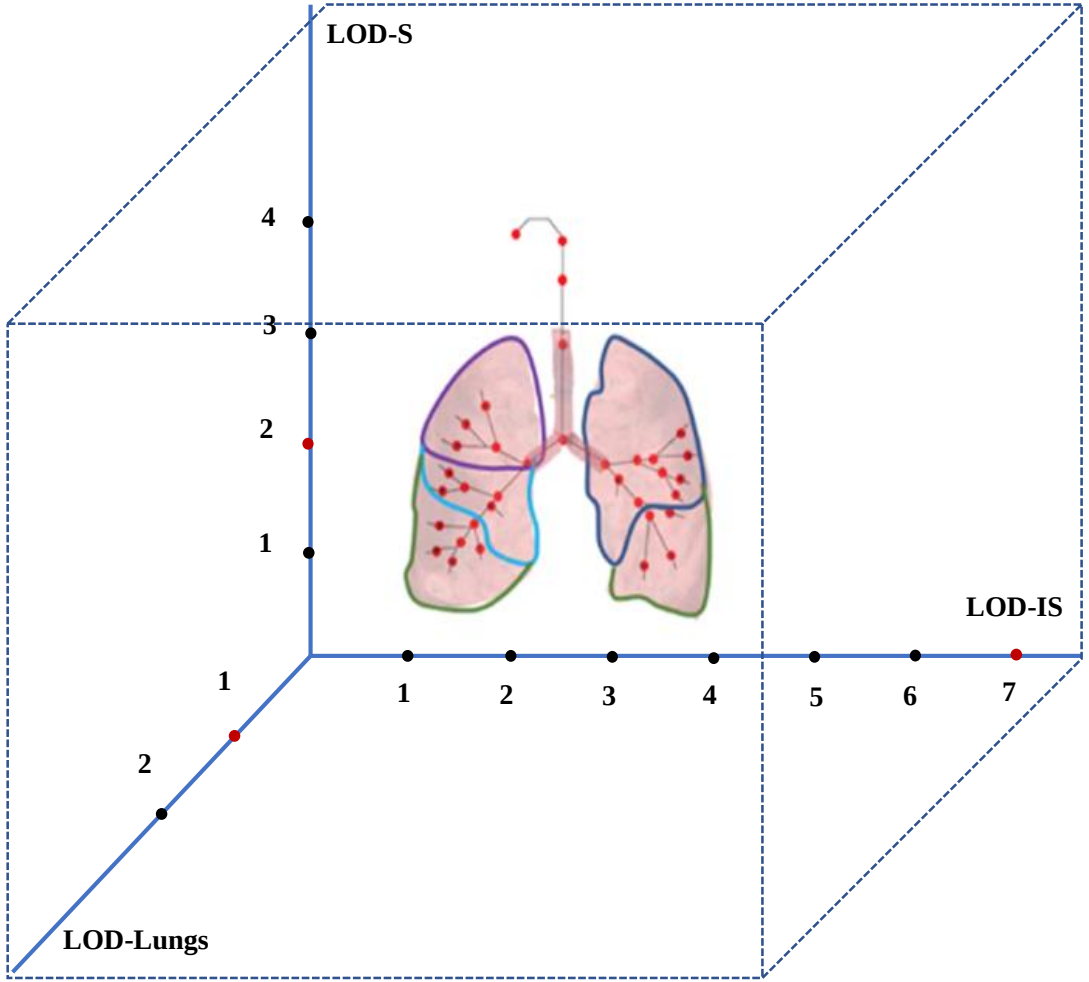
- Right lung has 10 segments:
  - The upper lobe contains 3 segments
  - The middle lobe contains 2 segments
  - The lower consists of 5 segments
- Left lung has 8 segments:
  - The upper lobe contains 2 segments with 2 lingula segments
  - The lower consists of 4 segments

Modeling Strategy for Respiratory organ

- **Give modeling of respiratory organ**:
  - Construct the level of detail of structure for respiratory skeleton
  - Define the level of detail of inner-surface for the internal organs
  - Define the level of detail of lungs
  - Define joint and segment names of the respiratory structures



- A concept of building the modeling of 3D respiratory organ with a respiratory modeling architecture is to model the organs and give the names of each organ by the combination of 3D axis which represents the level of detail such as:
  - Structures
  - Inner surfaces
  - Lungs

LEVEL OF DETAIL OF STRUCUTES (LOD-S)

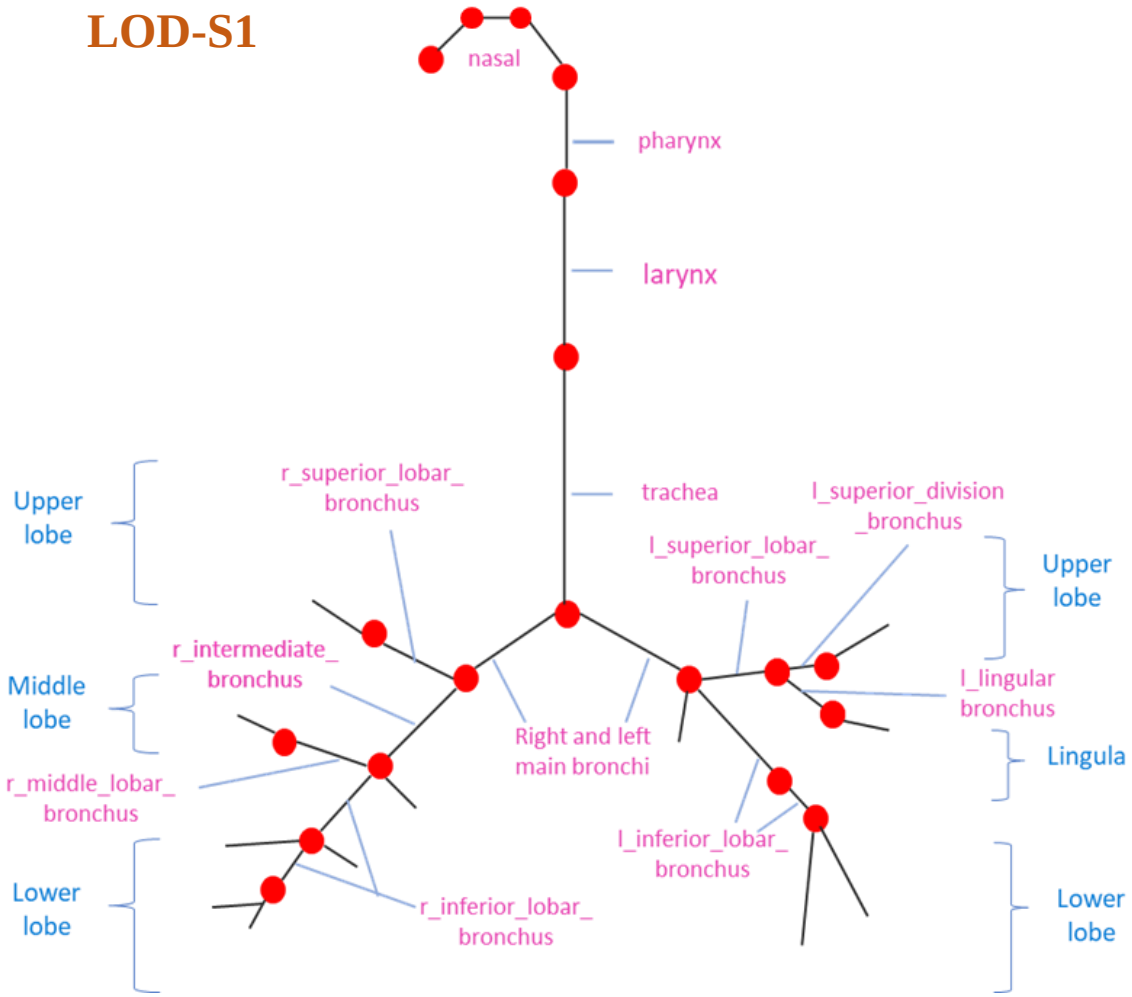
- It refers to structure which contains sets of joint and segment nodes with skin attachment for a humanoid figure.
  - Segments (trachea, larynx, pharynx, nose, bronchus, bronchi, etc.)
  - Joints (larynx-trachea, pharynx-larynx, nose-pharynx, etc.)
  - Skins:
    - Trachea: Epitelilum, Goblet cells, Cillia, Glands, Hyaline Cartilage, Smooth Muscle, Elastic, Reticular Fiber
    - Terminal Bronchus: Epitelilum, Cillia, Smooth Muscle, Elastic, Reticular Fiber

LEVEL OF DETAIL OF STRUCUTES (LOD-S)

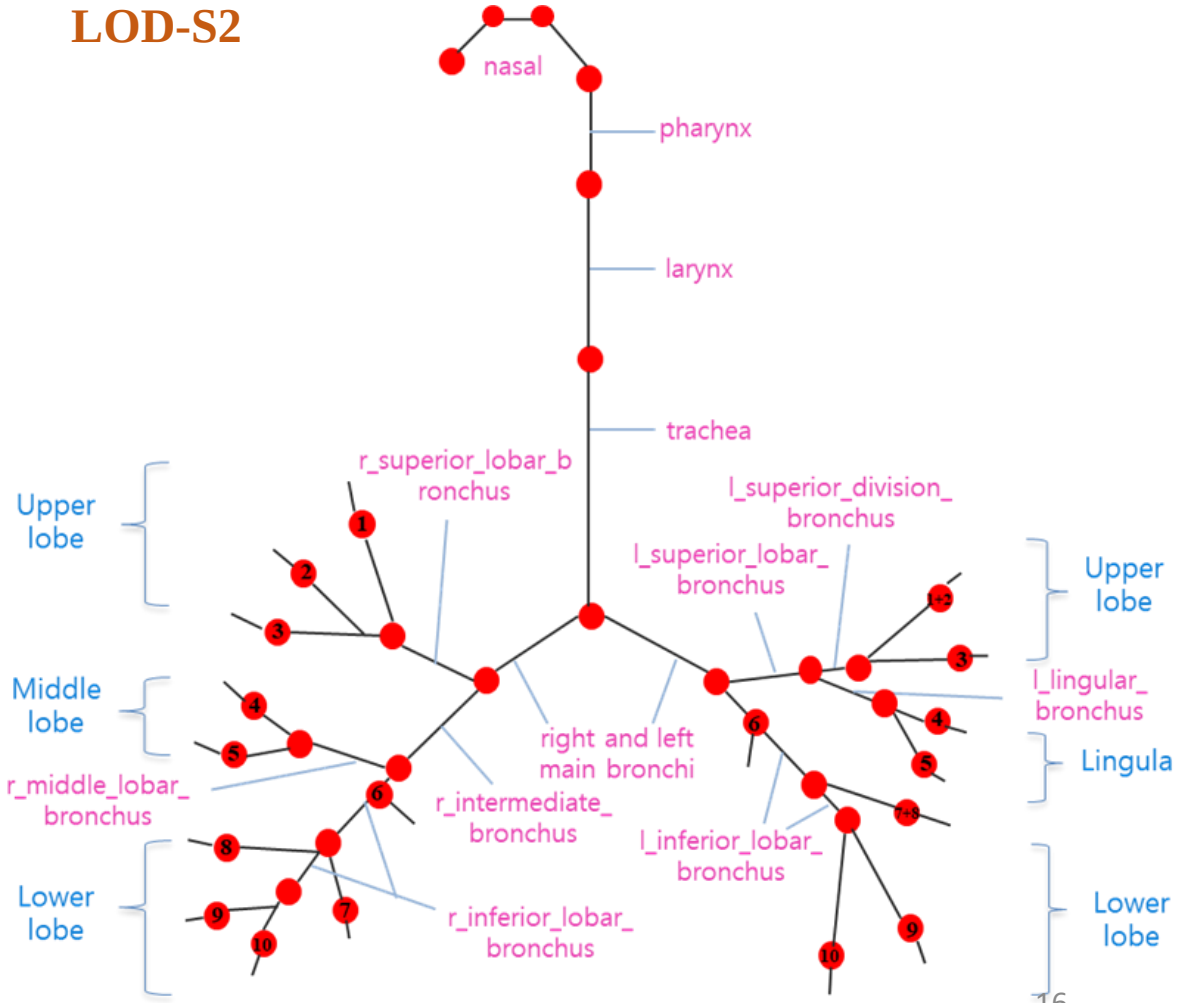
- ***LOD-S1*** specifies the simple joint nodes for the respiratory organ – *16 joints and 16 segments*.
- ***LOD-S2*** consists of *34 joints and 34 segments*.
- ***LOD-S3*** combines joints and segments of LOD-S2 with a bunch of bronchiole joints – *95 joints and 95 segments*.
- ***LOD-S4*** builds on LOD-S3 by *adding anatomical detail of each bronchiole tree segment* which leads into alveolus.

LEVEL OF DETAIL OF STRUCUTES (LOD-S)

LOD-S1

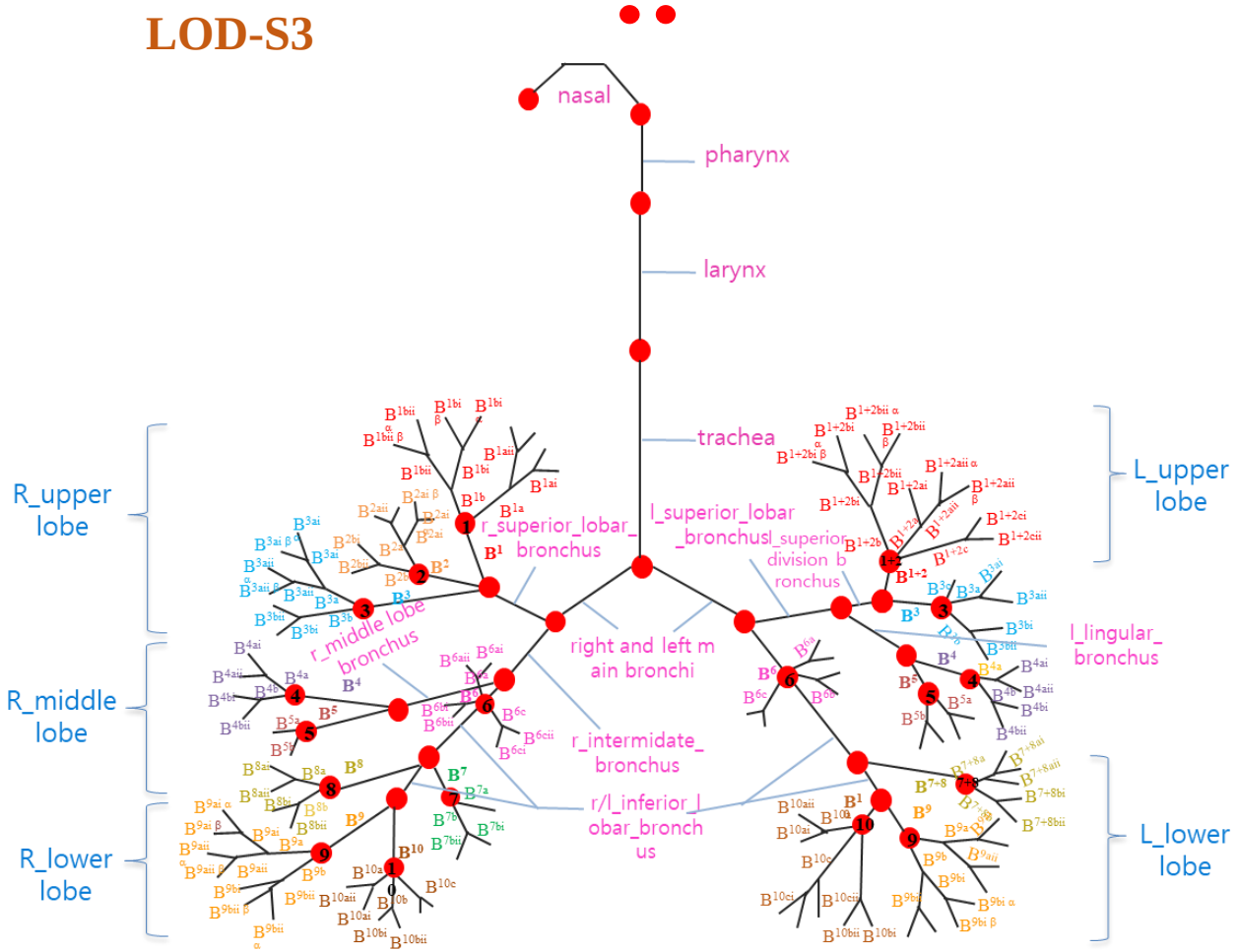


LOD-S2

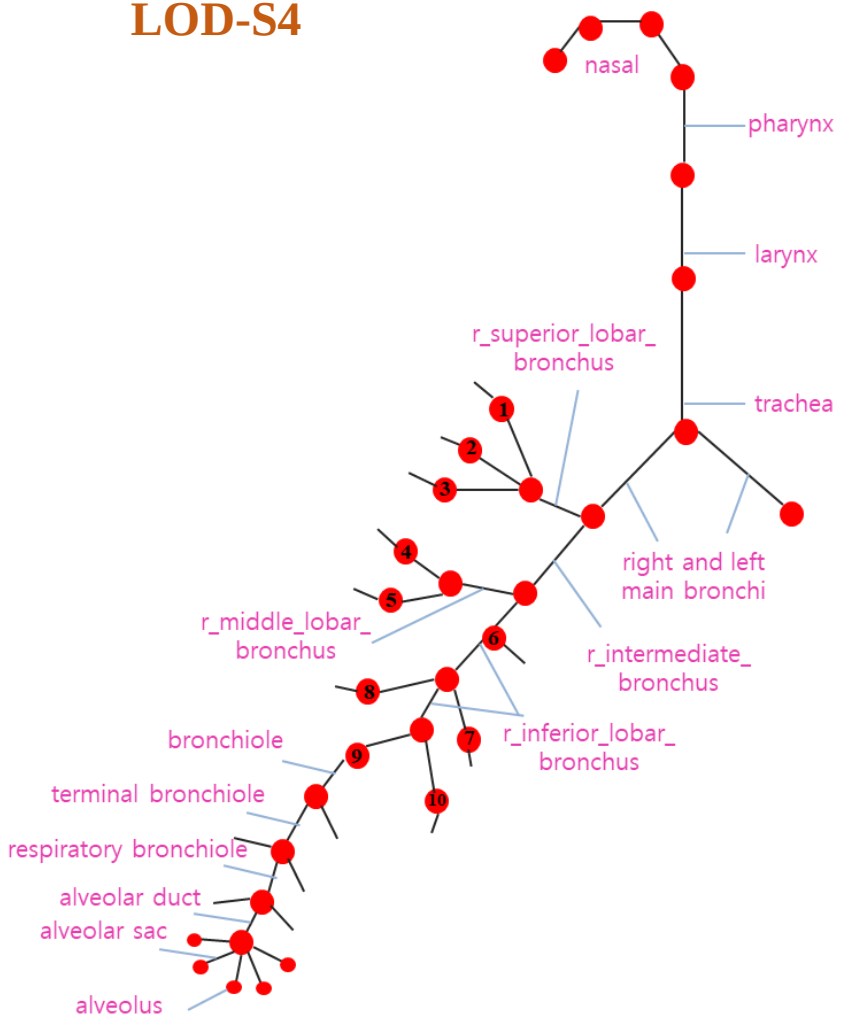


LEVEL OF DETAIL OF STRUCUTES (LOD-S)

LOD-S3

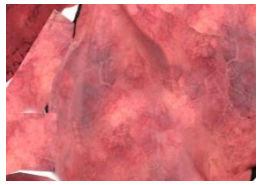


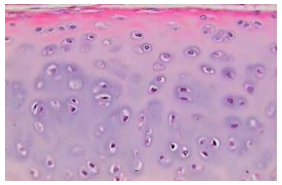
LOD-S4

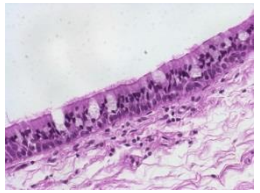


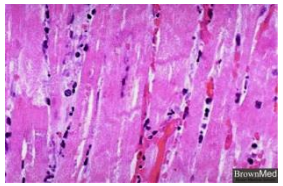
LEVEL OF DETAIL OF INNER SURFACES (LOD-ISs)

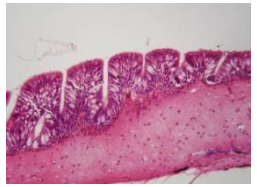
Textures

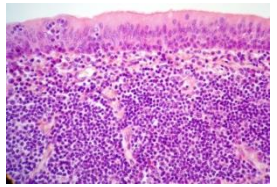

Epithelium

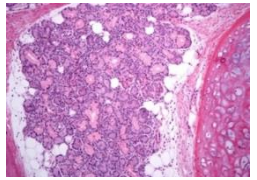

Hyaline cartilage

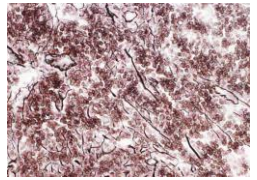

Goblet cells


Smooth m.

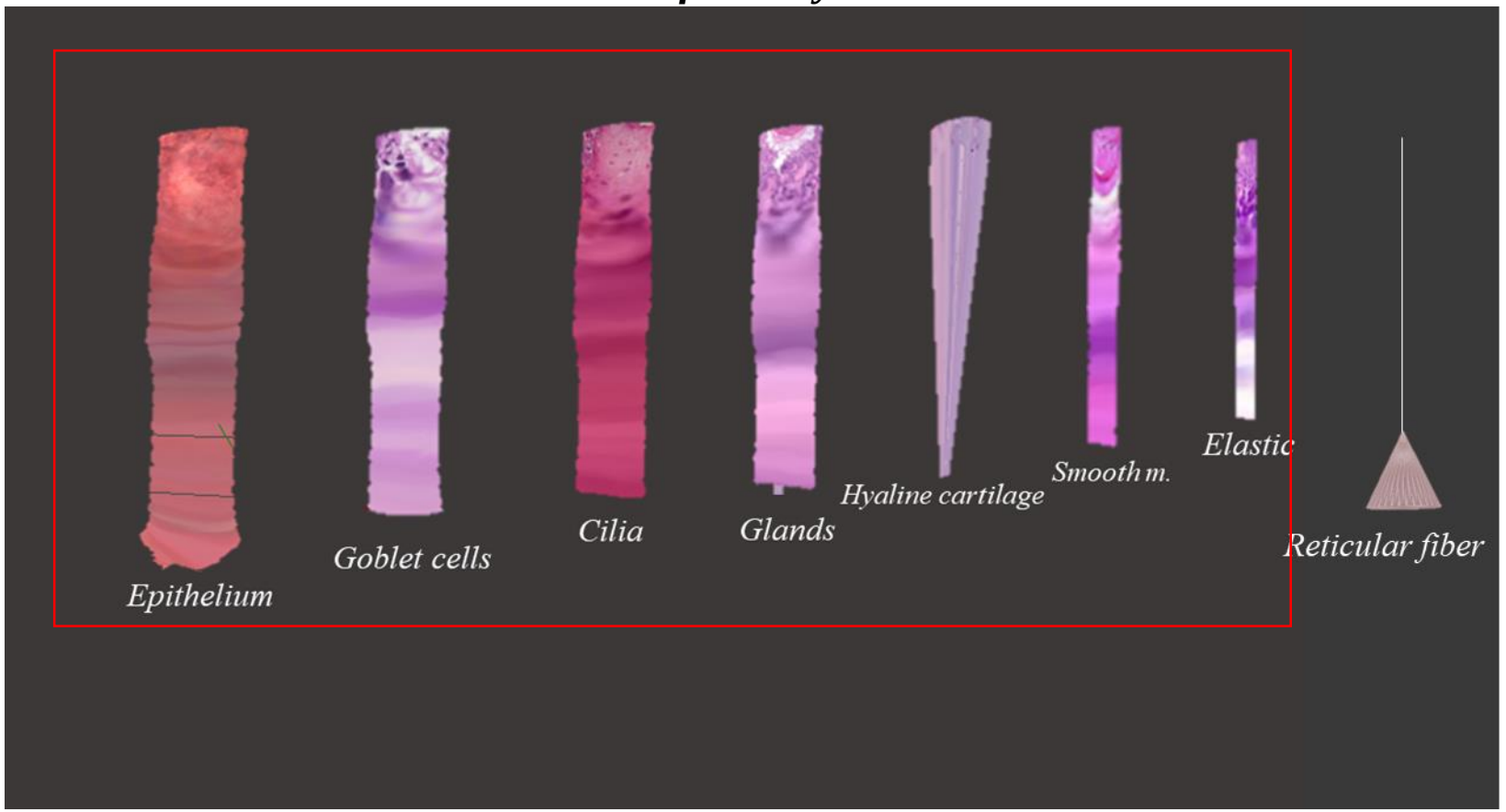

Cilia


Elastic


Glands

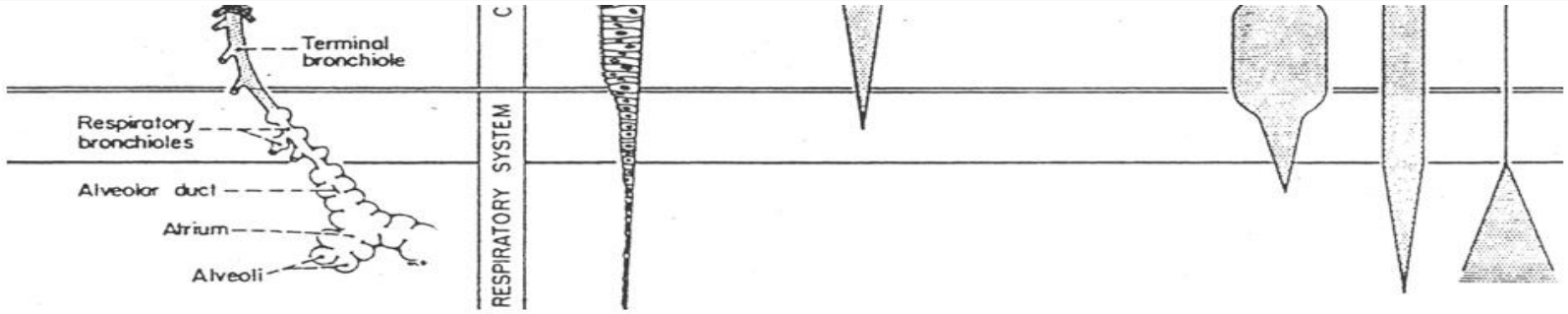

Reticular fiber

Surface Layers



Surface layers of the trachea, primary bronchus, lobar bronchus, and segmental bronchus contain 8 layers of surfaces by blender tool

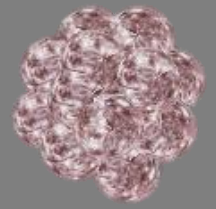
LEVEL OF DETAIL OF INNER SURFACES (LOD-ISs)



- Terminal bronchiole contains with 4 surface layers –
  - epithelium
  - cilia
  - smooth m.
  - elastic

- Respiratory bronchiole contains with 4 surface layers –
  - epithelium
  - cilia
  - smooth m.
  - elastic

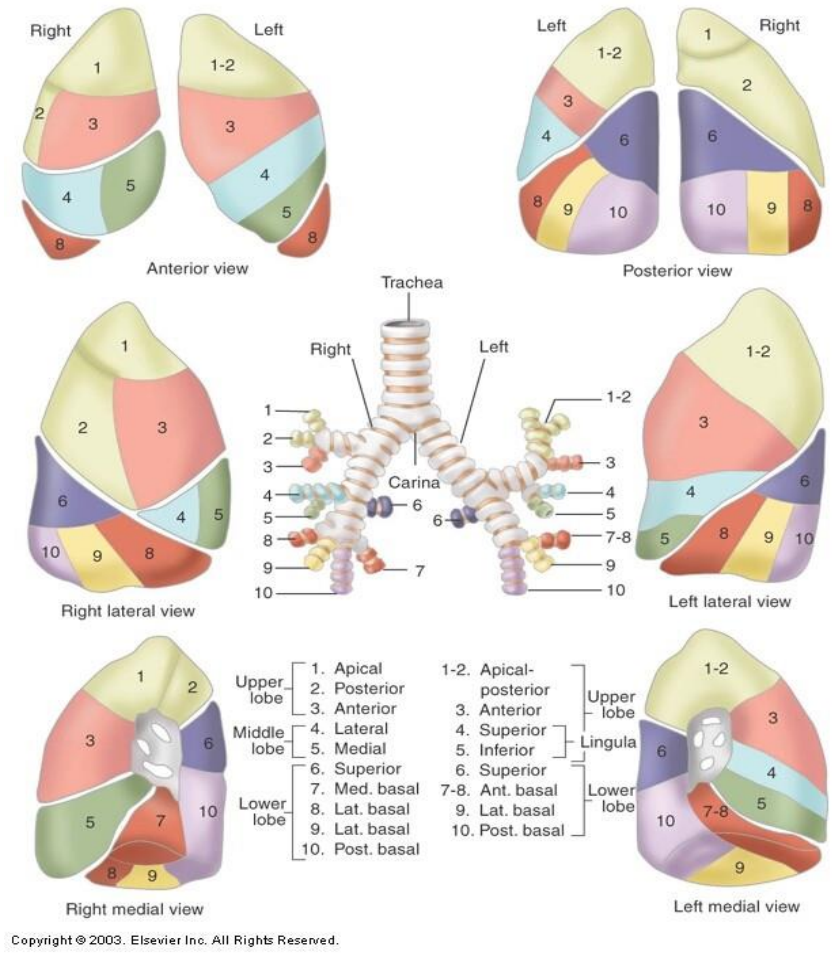
- Alveolar duct contains with 4 surface layers –
  - epithelium
  - smooth m.
  - elastic
  - reticular fiber



- Alveoli contains with 4 surface layers –
  - epithelium
  - smooth m.
  - elastic
  - reticular fiber

Surface layers of the terminal bronchiole, respiratory bronchioles, alveolar duct and alveoli contain 4 layers of surfaces

LEVEL OF DETAIL OF LUNGS (LOD-Lungs)



Anatomy of lung segments

- Right lung has 10 segments:
  - The upper lobe contains 3 segments
  - The middle lobe contains 2 segments
  - The lower consists of 5 segments
- Left lung has 8 segments:
  - The upper lobe contains 2 segments with 2 lingula segments
  - The lower consists of 4 segments

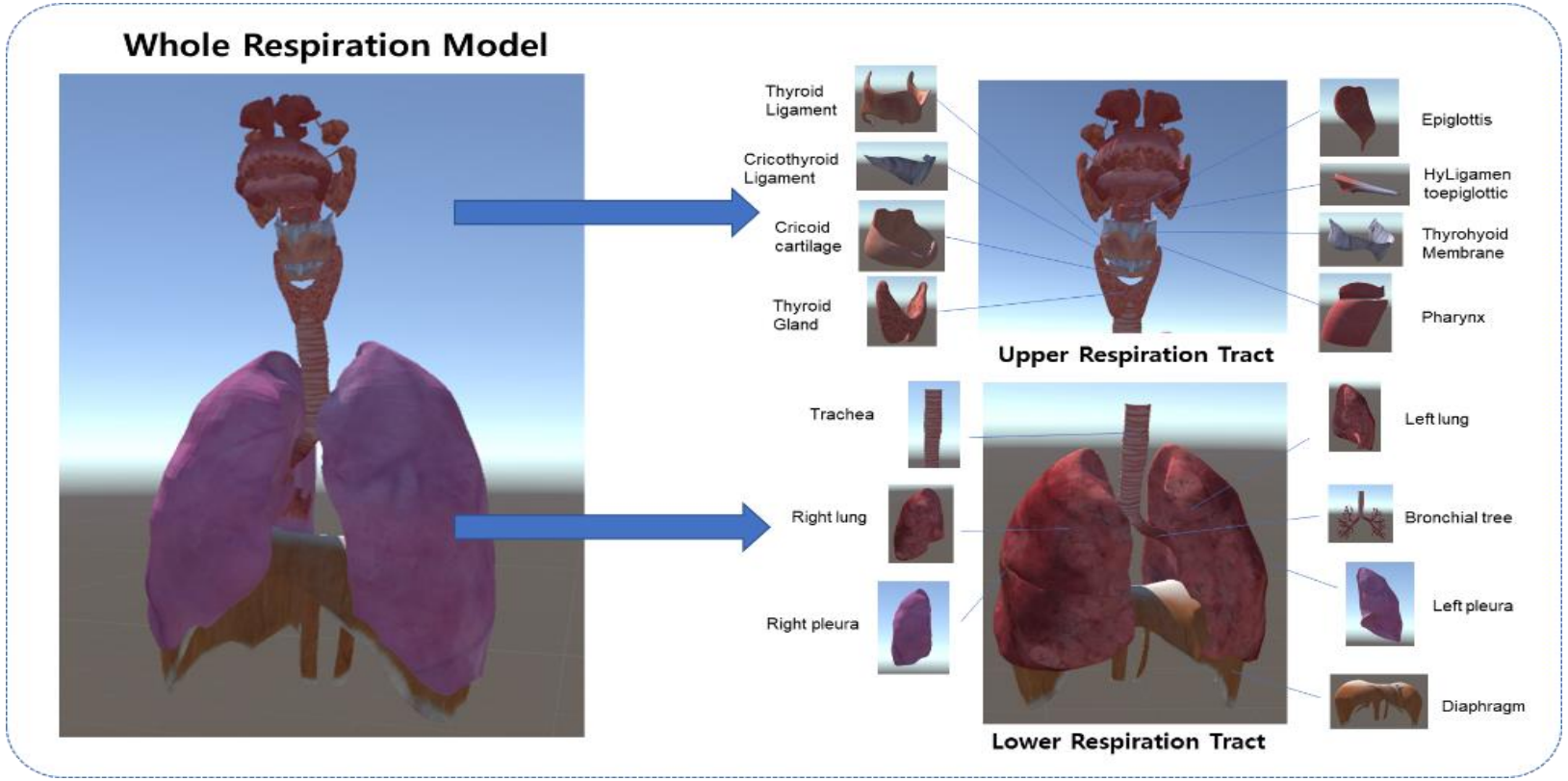
LEVEL OF DETAIL OF LUNGS (LOD-Lungs)

The detail of lungs

Right Lung	**Right Superior/Upper Lobar Bronchus**	**Right Middle Lobar Bronchus**	**Right Inferior/Lower Lobar Bronchus**
	1. Apical	4. Lateral	6. Superior
	2. Posterior	5. Medial	7. Medial Basal
	3. Anterior		8. Anterior Basal
			9. Lateral Basal
			10. Posterior Basal
Left Lung	**Left Superior/Upper Lobar Bronchus**	**Left Inferior/Lower Lobar Bronchus**	
	1+2. Apicoposterior	6. Superior	
	3. Anterior	7+8. Anterior Basal	
	4. Superior Lingula	9. Lateral Basal	
	5. Inferior Lingula	10. Posterior Basal	

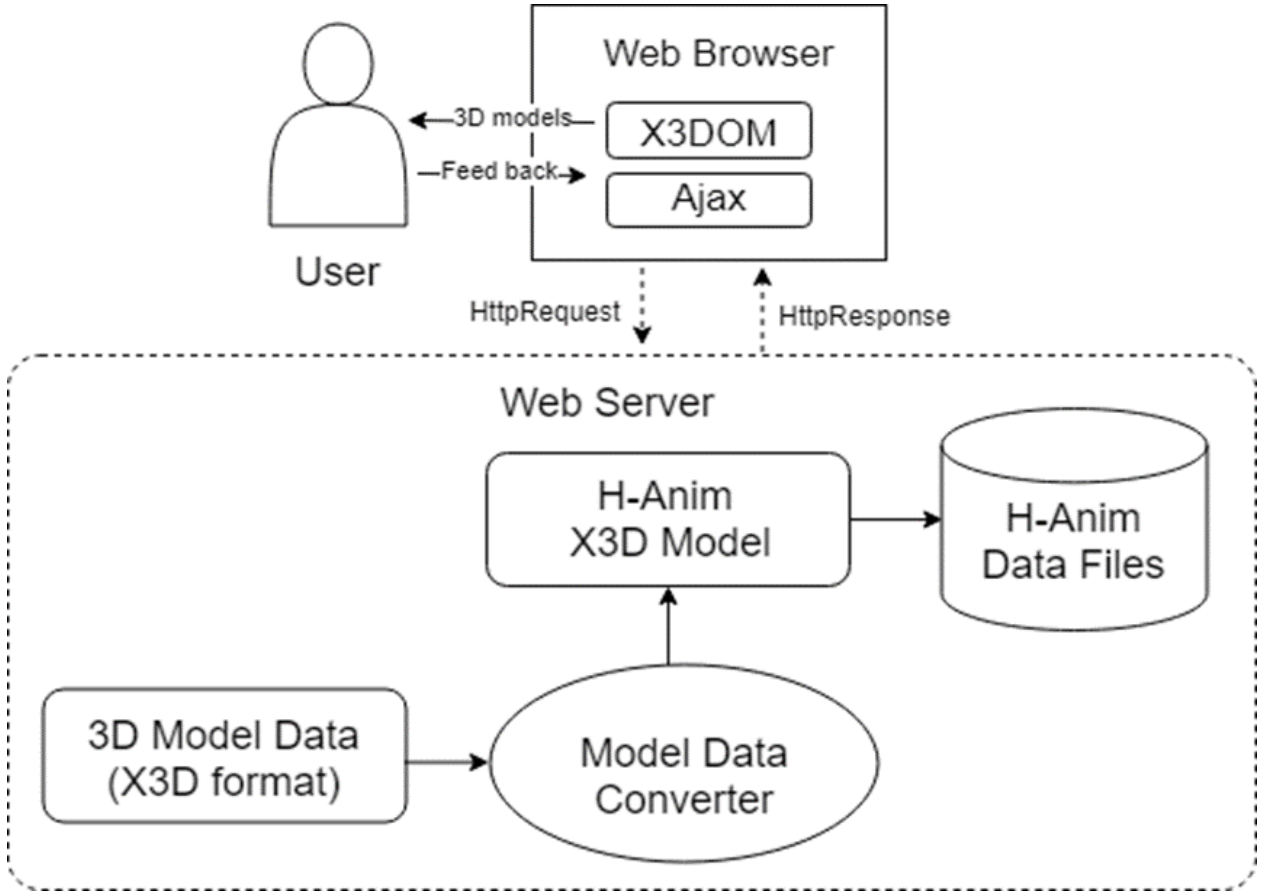
HUMAN RESPIRATORY SYSTEM

- For our human respiratory system model, it has separated into two parts of lower and upper respiration tracts.



- Organs involved in respiration system are:
  1) nose and nasal cavity
  2) pharynx
  3) larynx
  4) trachea
  5) bronchi
  6) lungs
  7) alveoli, etc.

SYSTEM MODELING ARCHITECTURE



The Respiratory Modeling Architecture

H-ANIM FOR COMPUTER RESPIRATORY MODELING

- To construct for skeletons and surfaces with X3D file format, there are three important nodes composed in H-Anim structure which are:
  - ***HAnimHumanoid****:* specify the root of H-Anim figure and provide all attachment framework for all part of human (e.g. parts of respiratory organ).
  - ***HAnimJoint****:* is used to create joint objects and define the relationship of each body segment.
  - ***HAnimSegment****:* stores each body segment and is a grouping node to create the 3D skeleton and surface model.

The modeling with X3D H-Anim

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       </Shape>
      </Transform>
     </HAnimSegment>
    </HAnimJoint>
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  </HAnimHumanoid>
 </Scene>
</X3D>
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The modeling and animation with HTML5

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<body>
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<div class="col-md-9 content-model" id="model-3d">
 <div class="btn-group" role="group" aria-label="Basic example" style="margin-top:10px;">
  <button type="button" id="btnJoint" class="btn btn-secondary">Joint Names</button>
   <button type="button" id="btnSegment" class="btn btn-secondary">Segment Names</button>
    <button type="button" id="btnSurface" class="btn btn-secondary">Surface</button>
 </div>
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   <scene>
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      <inline id="load_speed4" load='false' nameSpaceName="aaa" mapDEFToID="true" url="MALE-RIB-RES_Animation-Speed2.x3d"> </inline>
      <inline id="load_speed1-female" load='false' nameSpaceName="aaa" mapDEFToID="true" url="RES_Animation-Speed1-SeparatedKey.x3d"> </inline>

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  </x3d>
</div>
<!--X3D Content-->
</body>
</html>
```

HANIM-X3D STRUCUTURI

HAnimHumanoid object is the root of an H-Anim figure and provides the attachment framewo

HAnimJoint node is used to define the relationship of each body segment to its imm

HAnimSegment node stores each body segment and is a grouping node that conta

```
<Scene>
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      <Viewpoint centerOfR
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              </Shape>
            </Transform>
          </HAnimSegment>
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                </Shape>
              </Transform>
            </HAnimSegment>
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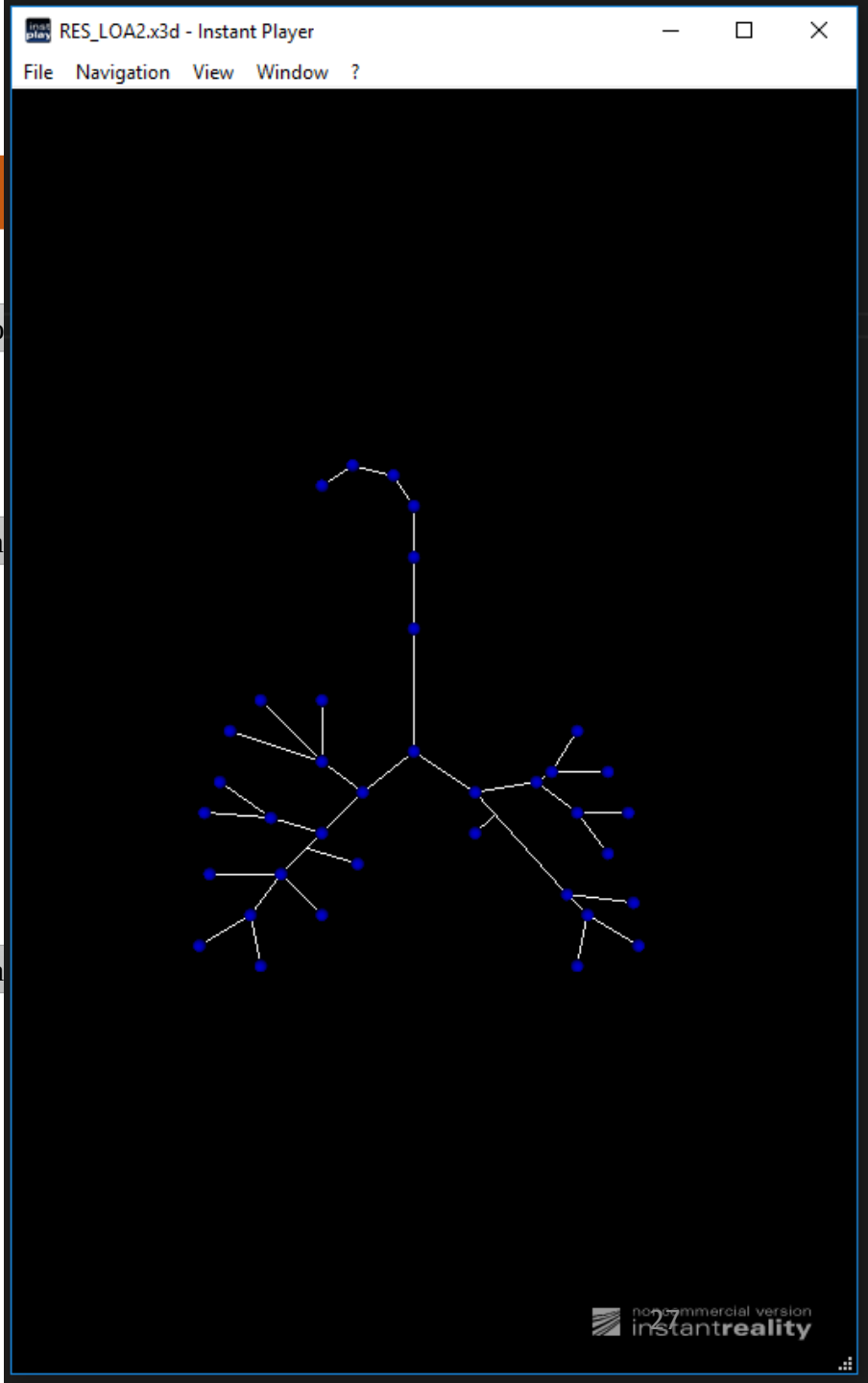
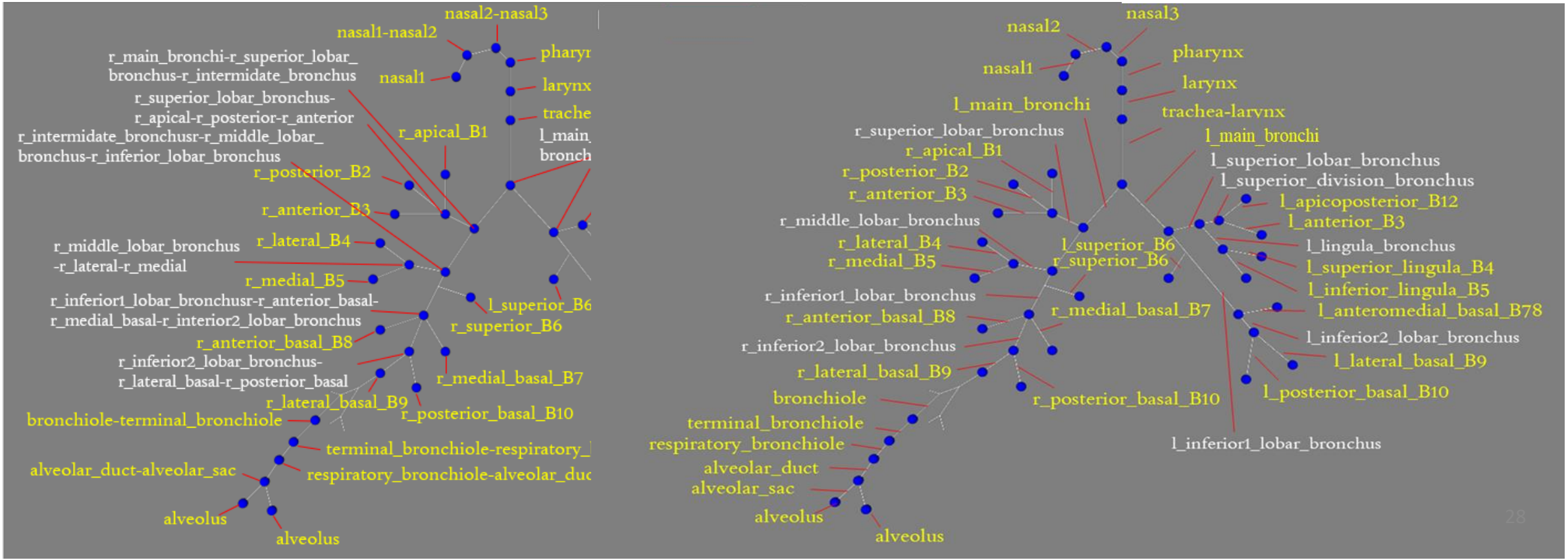
        </HAnimJoint>
      </HAnimHumanoid>
</Scene>
```



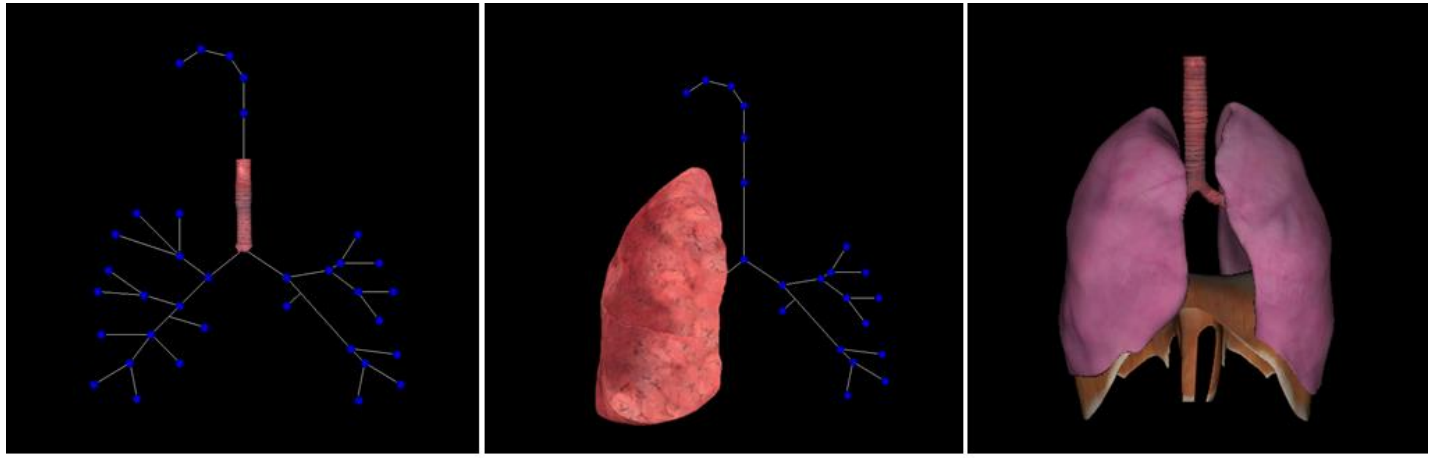
CRITICAL NAMES OF STRUCTURE ORGANS

- By using joint and segment nodes of H-Anim structure, we can define the labels of JOINT and SEGMENT names of each internal organ for the 4 levels of detail of structures.



SKINS AND TEXTURES ATTACH

- ***IndexedFaceSet*** also contains *Coordinate* and *TextureCoordinate* node.
  - **Coordinate** node is used to construct faces (polygons).
  - **TextureCoordinate** is applied to define a set of 2D texture coordinates used by nodes of vertex-based geometry to map textures to vertices.



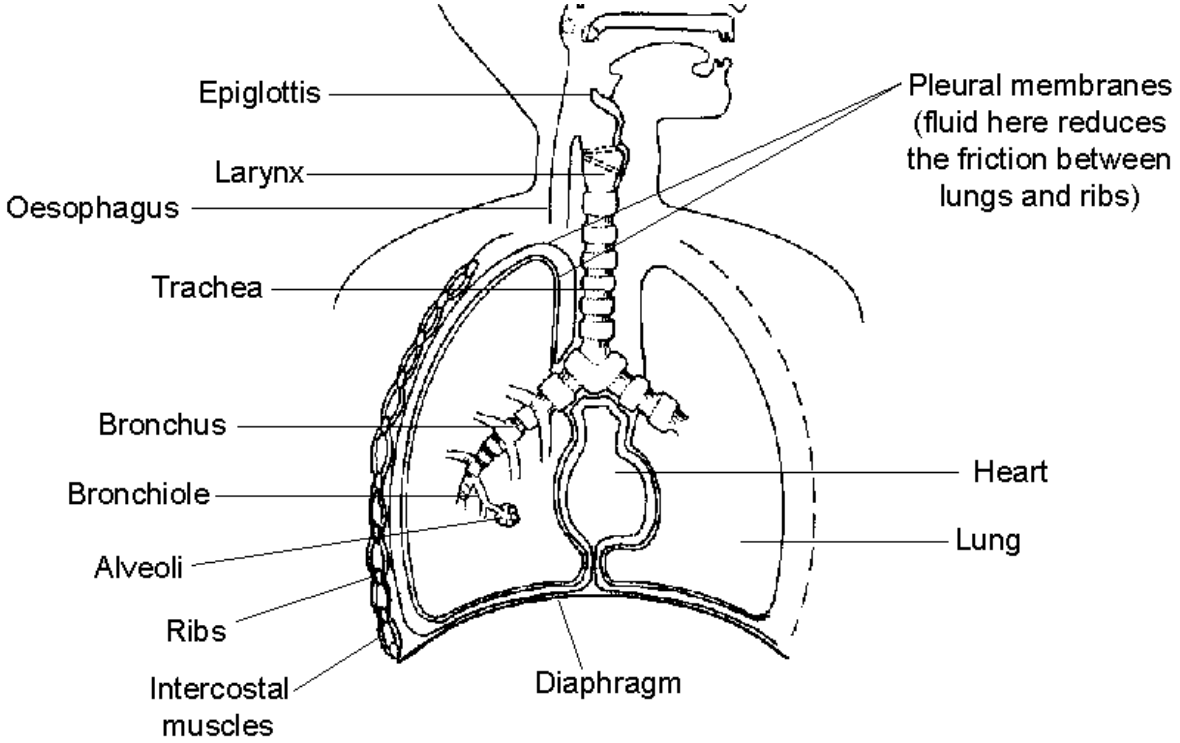
(a) (b) (c)

Results of skins and surface attach of (a) trachea, (b) lungs, and (c) whole respiratory organ

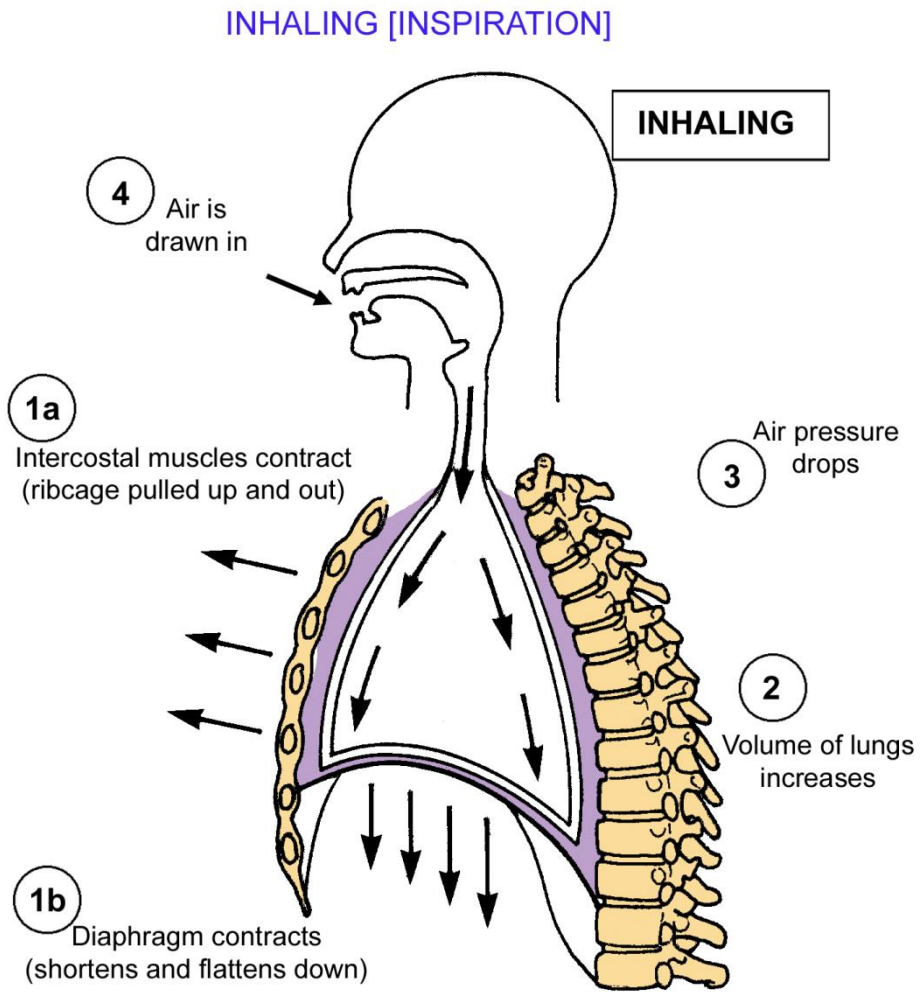
COMPUTER ANIMATION WITH KERYFRAME ANIMATION

RESPIRATORY SYSTEM

- Lungs are enclosed (along with the heart) between the ribs and the diaphragm.
- The ribs form a protective cage of twelve pairs of bones.
- Intercostal muscles, attached between the ribs to move the ribcage up or down.
- The diaphragm is a sheet of muscle at the base of the ribcage.

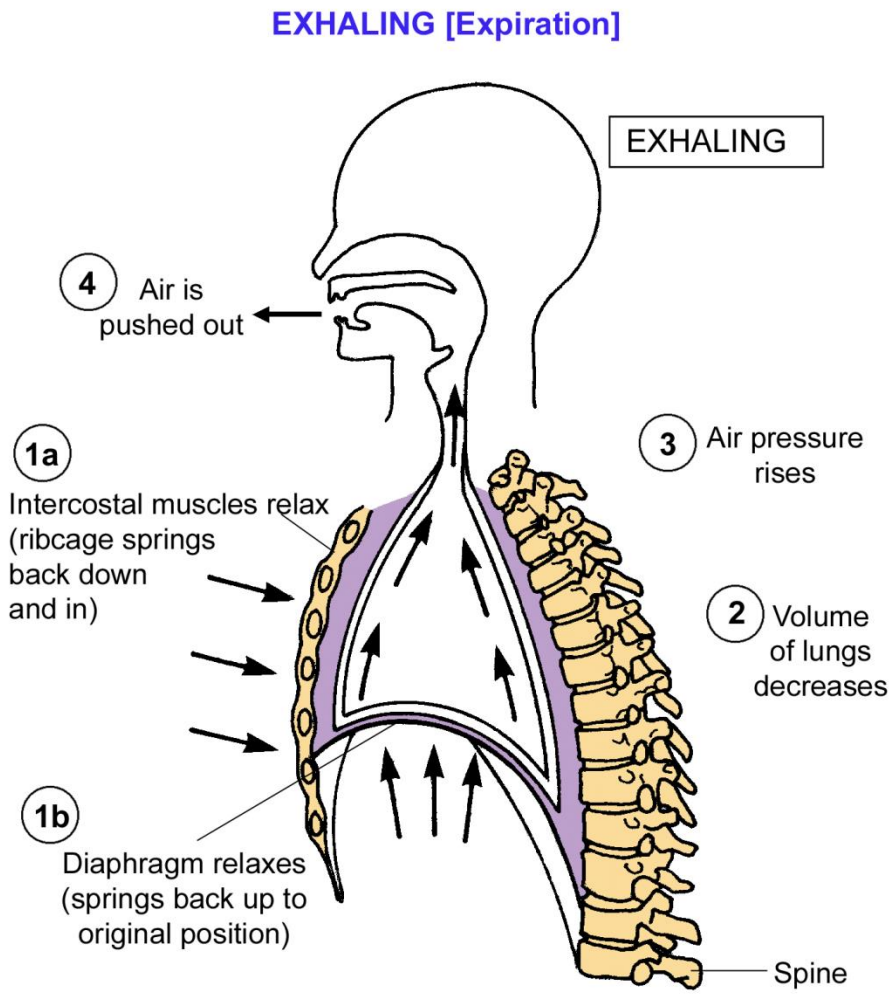


MECHANICS OF RESPIRATION



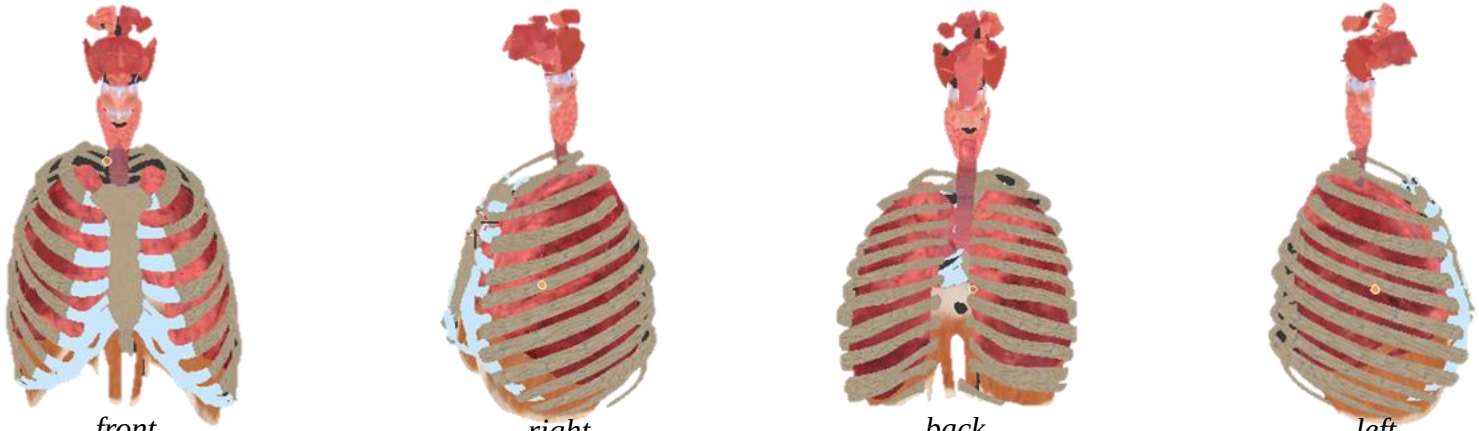
- Inhaling means breathing in.
- The brain sends signals to the rib muscles and diaphragm to contract.
- The ribs are pulled up and out, and the diaphragm also starts flattening downwards.
- The chest volume increases, so the air pressure drops, and air is moved into the lungs and alveoli.

MECHANICS OF RESPIRATION



- Exhaling means breathing out.
- The rib muscles and diaphragm relax and move back to the original positions.
- So, air pressure in the lungs increases, and is pushed out from the alveoli.

COMPUTER RESPIRATORY ANIMATION



whole human respiratory internal organ for making respiratory animation

Process of breathing in details

Air → Breathing in

Enters via nose or mouth → Travels down to → **Pharynx and Larynx** → Enters into → **Trachea** → Enters into → **Left and right bronchi** → Enters into → **Bronchioles** → Passes through → **The Alveoli** → Finally enters into → **The blood capillaries** → makes →

- *Air pressure drops*
- *Lungs volume increases*
- *Ribs and diaphragm contract*

COMPUTER ANIMATION WITH KEYFRAME ANIMATION

➢To create computer animation for human respiratory internal organs, we use two types of keyframe animation method that integrate with X3D file format.

1. **keyframes applied for a whole internal organ**– generates the movements of lungs, ribs and diaphragm during breathing by using one interpolation node with the keyframe values for a whole organ.
2. **different keyframes applied for the separated organs**– generates the movements of the respiratory organs with surfaces from trachea to alveoli, which connects with the lung surfaces and makes a contraction of diaphragm during inhaling by using multiple interpolation nodes with the separated keyframe values for each organ.

X3D KEYFRMAE ANIMATION (1/2)

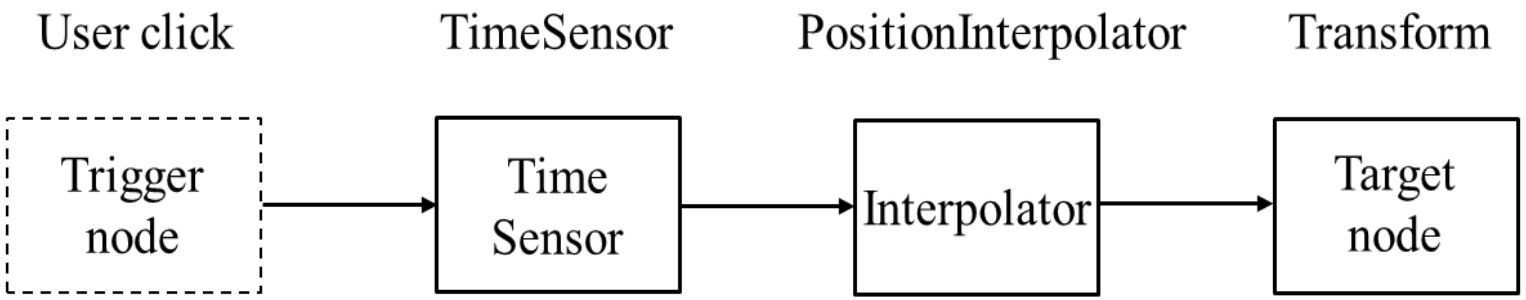


Figure 22. X3DOM keyframe animation routing event model

➢ How does keyframe animation work for computer respiratory animation?

1. the user simply uses HTML events as *onclick* event on his/her nodes to start a timer clock of *timeSensor.*
2. Use *timeSensor* node for generating events as time passes and outputting the new event at start of each frame with ***cycleInterval*** field for duration interval of animation.

```
<timeSensor DEF="time" cycleInterval="0.2" loop="true"> </timeSensor>
```

X3D KEYFRMAE ANIMATION (2/2)

3. X3D Interpolator node provides feature of how to use the output to generate by one object to control other objects with X3DOM.

1. **Using one interpolation with the keyframe values for a whole organ**

<PositionInterpolator DEF="animation" key="0.0 0.2 0.45 0.65 1.0" keyValue="1.0 1.0 1.0, 1.10 1.10 1.10, 1.20 1.20 1.20, 1.30 1.30 1.30, 1.0 1.0 1.0" onoutputchange="diaphragmDown"> </PositionInterpolator>

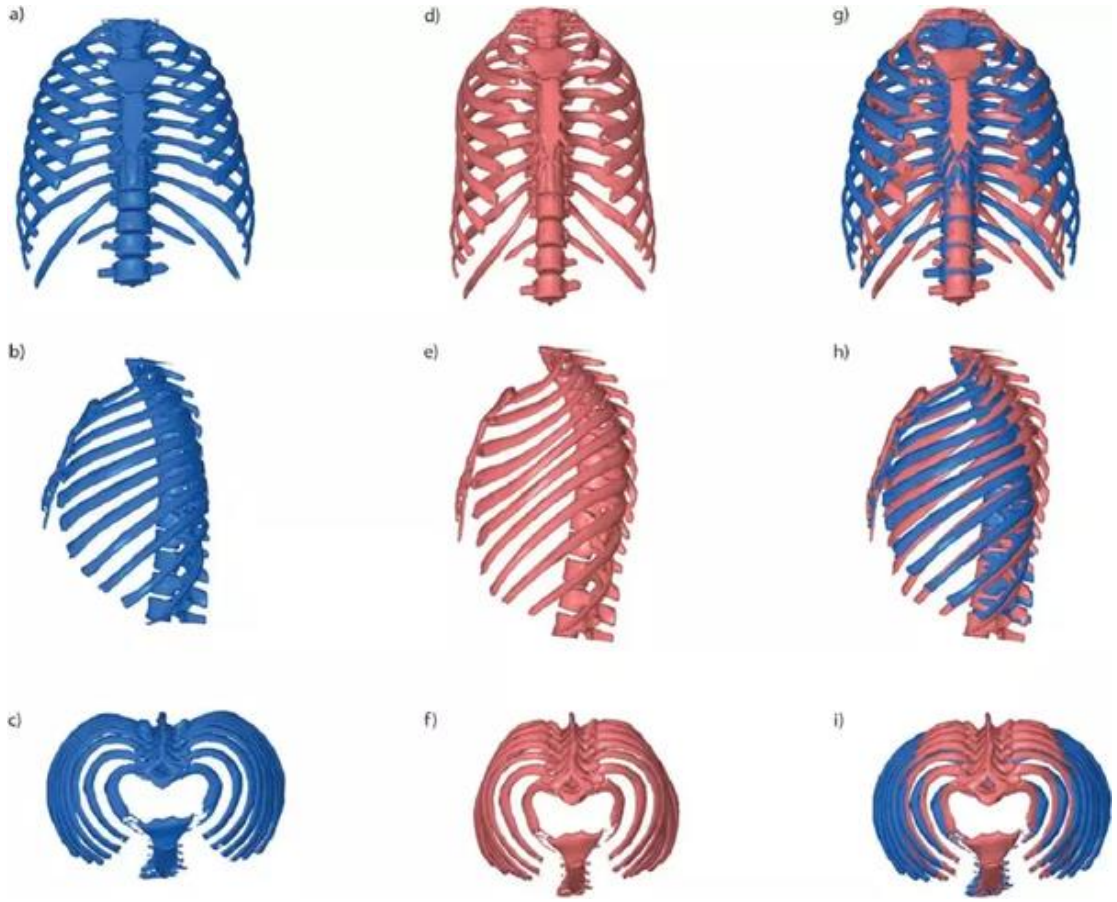
2. **Using the separated interpolations with different keyframe values for each organ**

```
<PositionInterpolator DEF='RLUNG' key='0.0 0.25 0.50 0.75 1.0' keyValue='1.0 1.0 1.0, 1.1 1.1 1.1, 1.17 1.17 1.17, 1.1 1.1 1.1, 1.0 1.0 1.0'/>
<PositionInterpolator DEF='LLUNG' key='0.0 0.50 1.0' keyValue='1.0 1.0 1.0, 1.2 1.2 1.2, 1.0 1.0 1.0'/>
<PositionInterpolator DEF='DIAPHRAGM' key='0.0 0.50 1.0' keyValue='1.134895 1.264895 1.054895, 1.134895 0.94895 1.054895,
                                1.134895 1.264895 1.054895'/>
<PositionInterpolator DEF='RIBCAGE' key='0.0 0.50 1.0' keyValue='0.53 0.53 0.53, 0.63 0.63 0.63, 0.53 0.53 0.53'/>
```

4. ROUTES are used to connect an output field of one node to the input field of another node.

MALE RIBS AND FEMALE RESPIRATORY

- Female respiratory system has smaller radial ribcage, greater inclination of ribs, short diaphragm length, shorter inspiratory time, shorter expiratory time than male respiratory system.
- With this different shape of the respiratory organ, the respiratory organ of male and female performs animation in different ways.



COMPUTER RESPIRATORY MODELING

My first X3DOM page

127.0.0.1:8080/index.html#

3D RESPIRATORY VISUALIZATION

Level of Detail - Structure 3

Respiratory Model Architecture (RMA)

Refresh

- Level of Detail - Structures
  - LOD-S1
  - LOD-S2
  - LOD-S3
  - LOD-S4
- Level of Detail - Inner Surfaces
- Level of Detail - Lungs

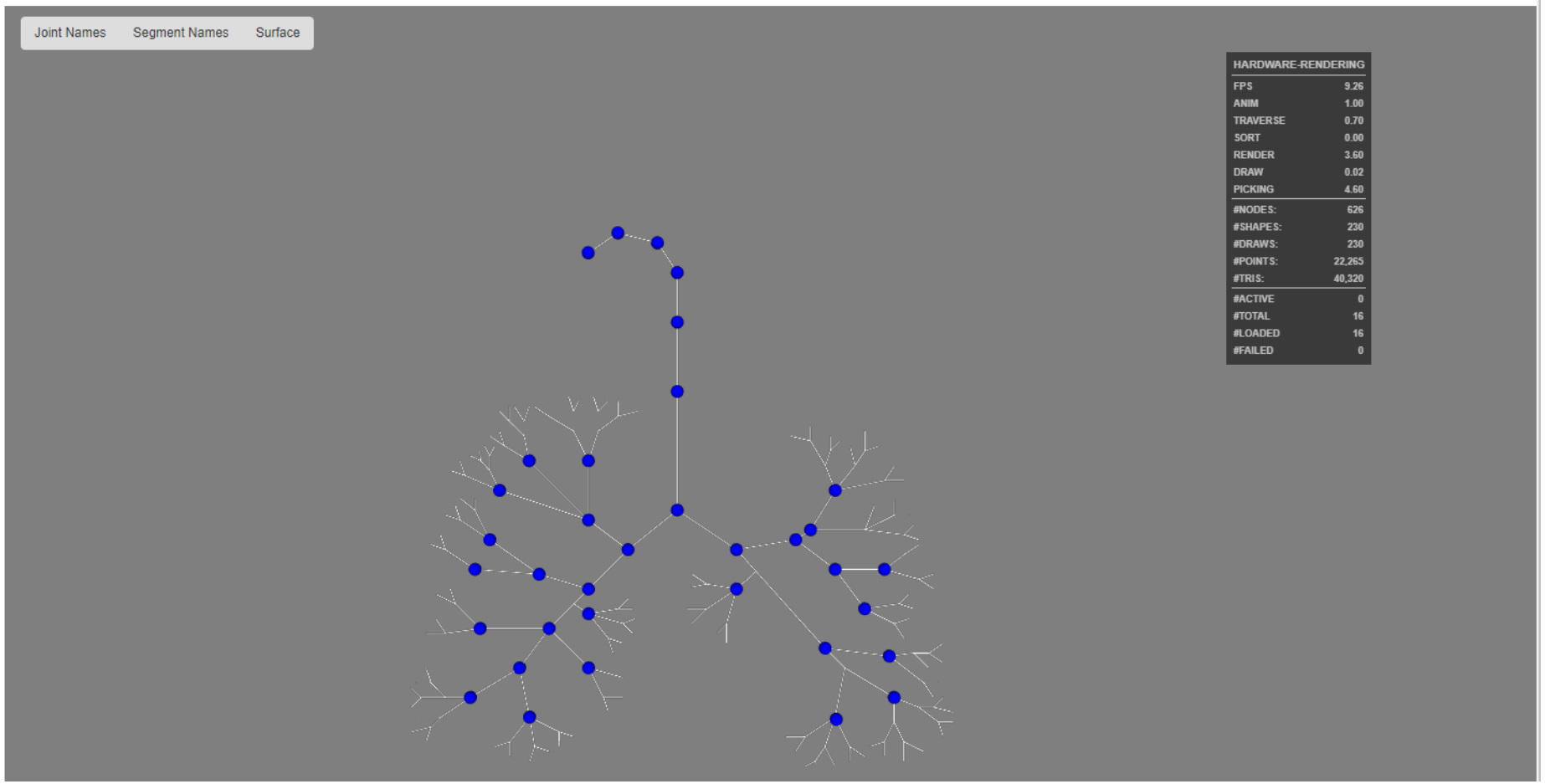
Respiratory Keyframe Animation

» **Male breathing animation with a single keyframe**

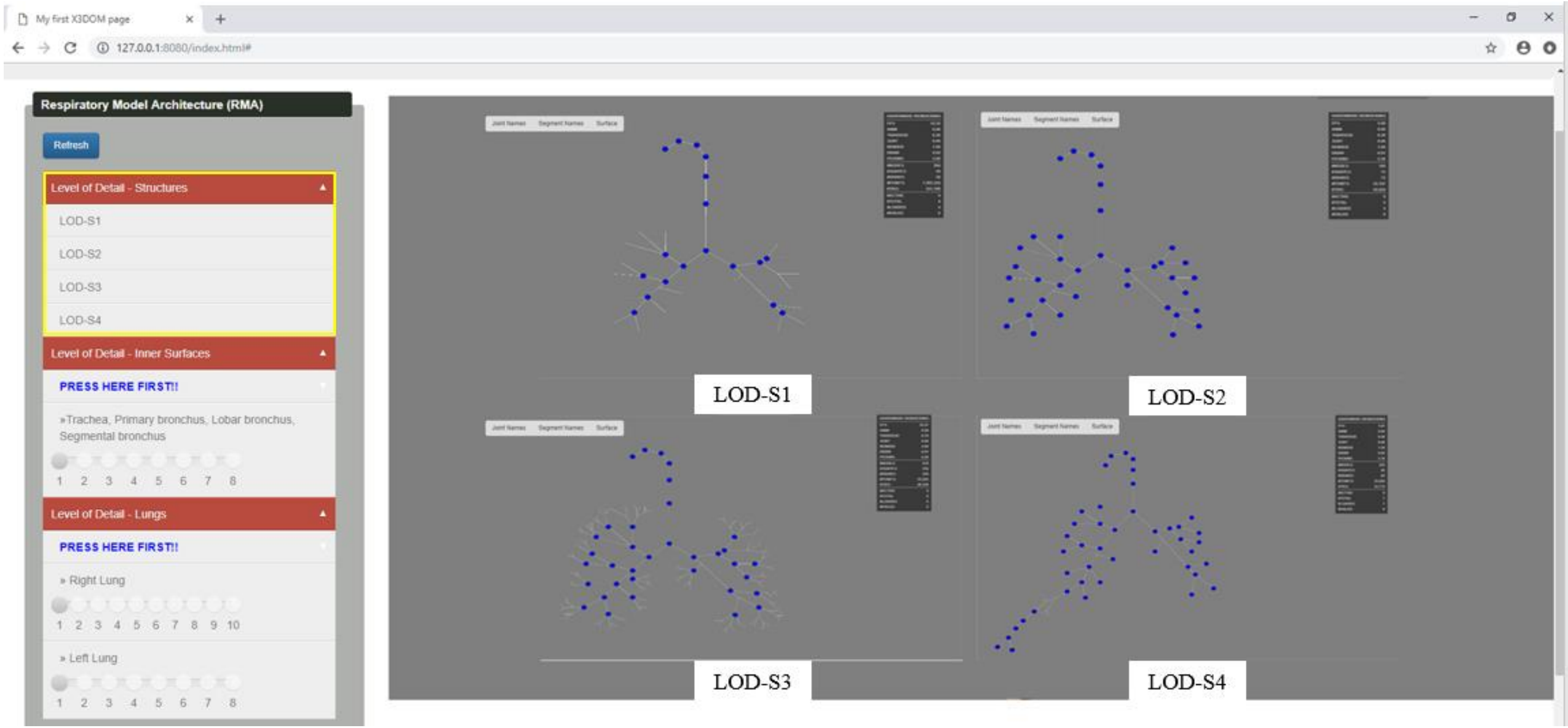
- Slow breathing
- Fast breathing

» **Female breathing animation with the separated keyframes**

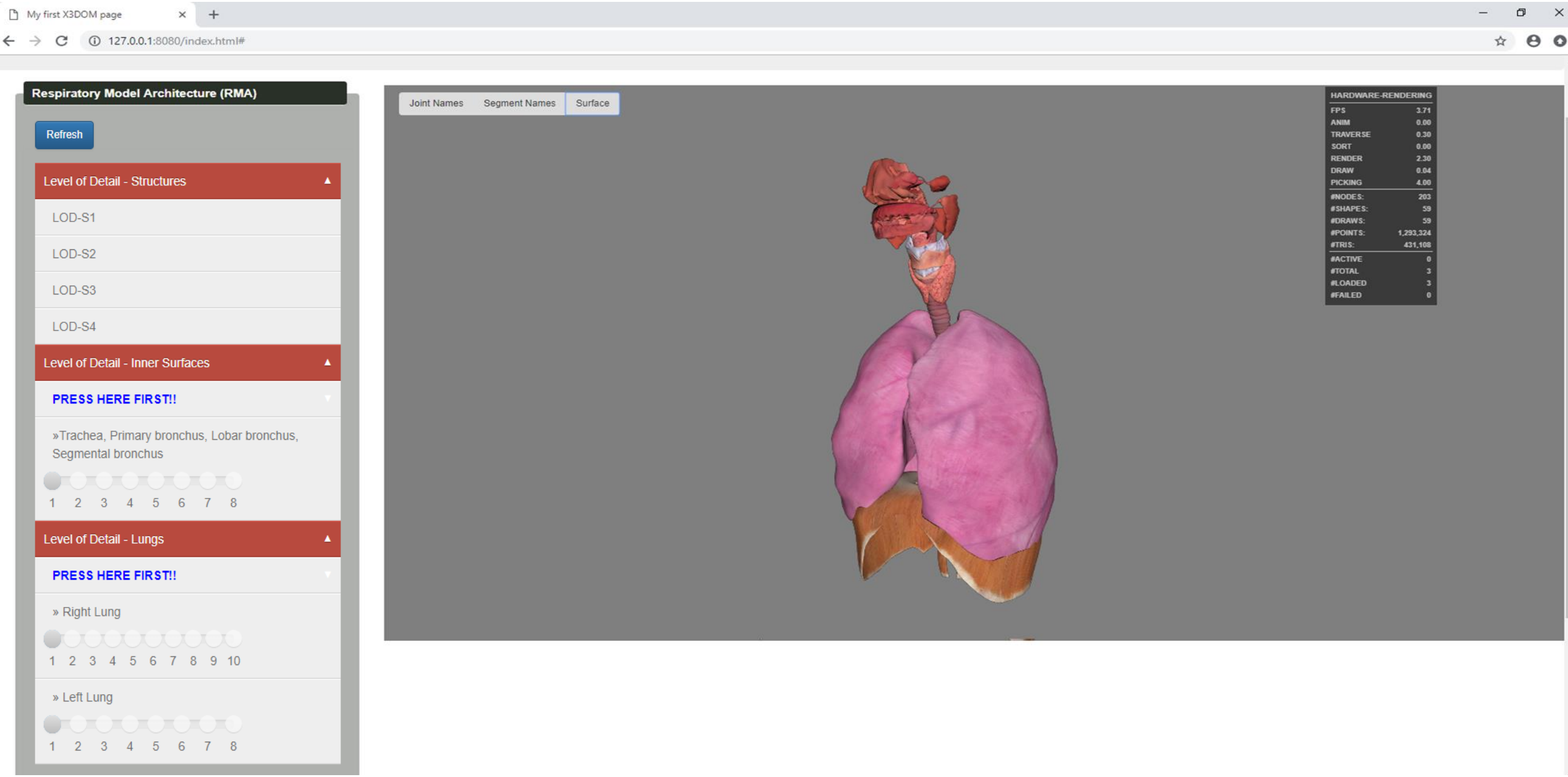
- Slow breathing



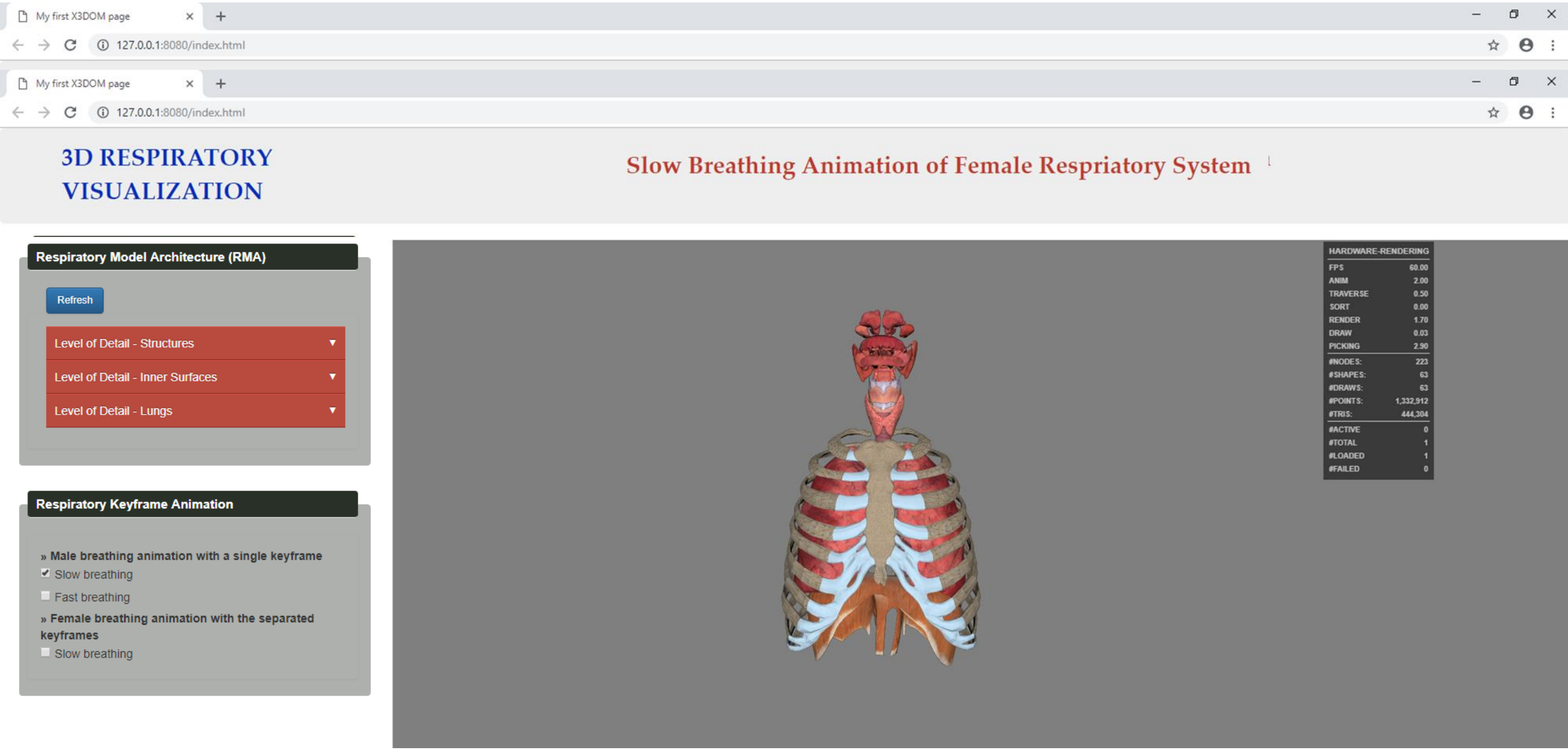
4 Levels of Detail of Structures



Computer Modeling of Respiratory Internal Organ with Surface



Computer Animation of Respiratory Internal Organ



CONCLUSION AND FUTURE WORK

- Our proposed methods will create a computer modeling and animation for the human respiratory internal organ.
- We use H-Anim to construct the level of detail of structures, inner surfaces, lungs, and give the names to each structure of joint and segment.
- We use single interpolation and the separated interpolation from keyframe animation to generate respiratory animation.
- We use X3DOM framework for computer respiratory modeling and animation.

THANK YOU!