

3-D Human Respiratory System Modeling Interface Instructions

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Human Respiratory System Modeling Interface

The U.S. EPA's Office of Research and Development (ORD) has developed a three-dimensional (3D) model of the human respiratory system from the nares to the alveolar region. This current model, based on human scan data, allows for model variability based on age, race, sex, height and weight. Output is in the form of an STL file of the 3-D surface mesh specific to the users inputs. This surface mesh can be used by itself for respiratory system visualization or can be used as a base model to support Computational Fluid Dynamics (CFD) studies of the human respiratory system.

This instruction document discusses the model and will guide the user through the interactive model interface, resulting in the individualized output file for download.

DISCLAIMER: This model download is free for general public use. The research/model described in this article has been funded wholly by the U.S. Environmental Protection Agency. It has been subject to the Agency's review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. Use of data generated by this model is the sole responsibility of the user, and not the U.S. EPA.

System Requirements

Before running the model, please verify that your system meets the following minimum requirements.

Compatible 64-bit operating systems:

- Windows 10 and up
- macOS 10.5 and up
- Linux

Hardware:

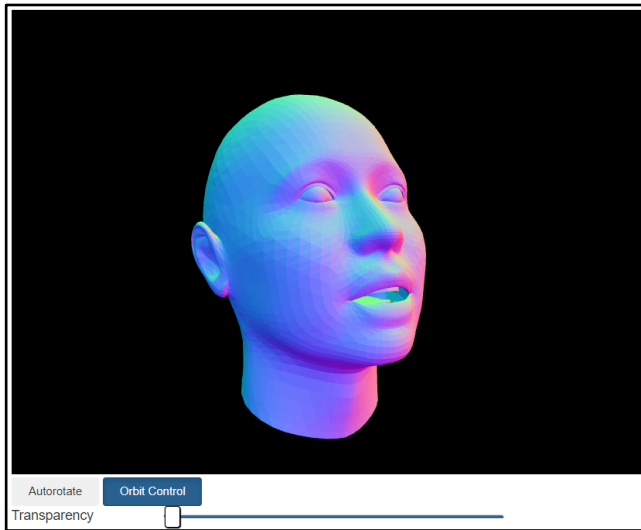
- 8 GB RAM (16 GB recommended for faster performance)
- Recommended: A dedicated graphics card with latest drivers and at least 1GB video RAM, capable of supporting OpenGL 4.5 and DirectX 11, or higher.

Web Browser: Google Chrome, Microsoft Edge, Mozilla Firefox, or other compatible modern browser.

Recommended: fast internet connection: A modeling file of ~100MB will be downloaded at the end of the session. A fast internet connection will speed the download.

The model creation process has three stages

STAGE 1 : MODEL OPTIONS



MODEL OPTIONS UPPER AIRWAY LOWER AIRWAY

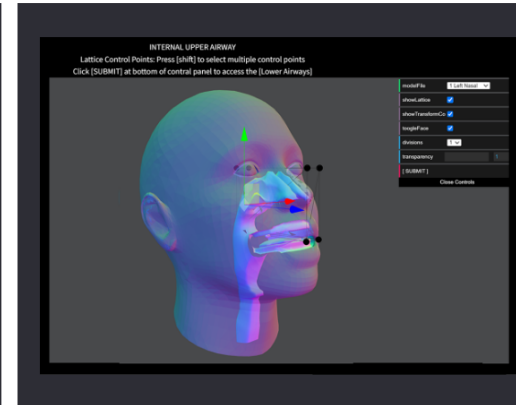
BASE MODEL Female Open Mouth

RACE [%]

African	<input type="range"/>	48
East Asian	<input type="range"/>	52
European	<input type="range"/>	0
South Asian	<input type="range"/>	0

AGE 61

STAGE 2: UPPER AIRWAY (OPTIONAL)



DEFAULT INTERNAL UPPER AIRWAYS

Nasal Cavity, Pharynx, Oral Cavity, Larynx, Upper Trachea

Use DEFAULT UPPER AIRWAYS

FREE-FORM DEFORMATION

FFD encloses one of the models within a cube and deforms the model by moving the control points of the cube.

Use FFD UPPER AIRWAYS

STAGE 3: LOWER AIRWAY



MODEL OPTIONS UPPER AIRWAY

LOWER AIRWAY

Height

Unit Meters Feet

Weight

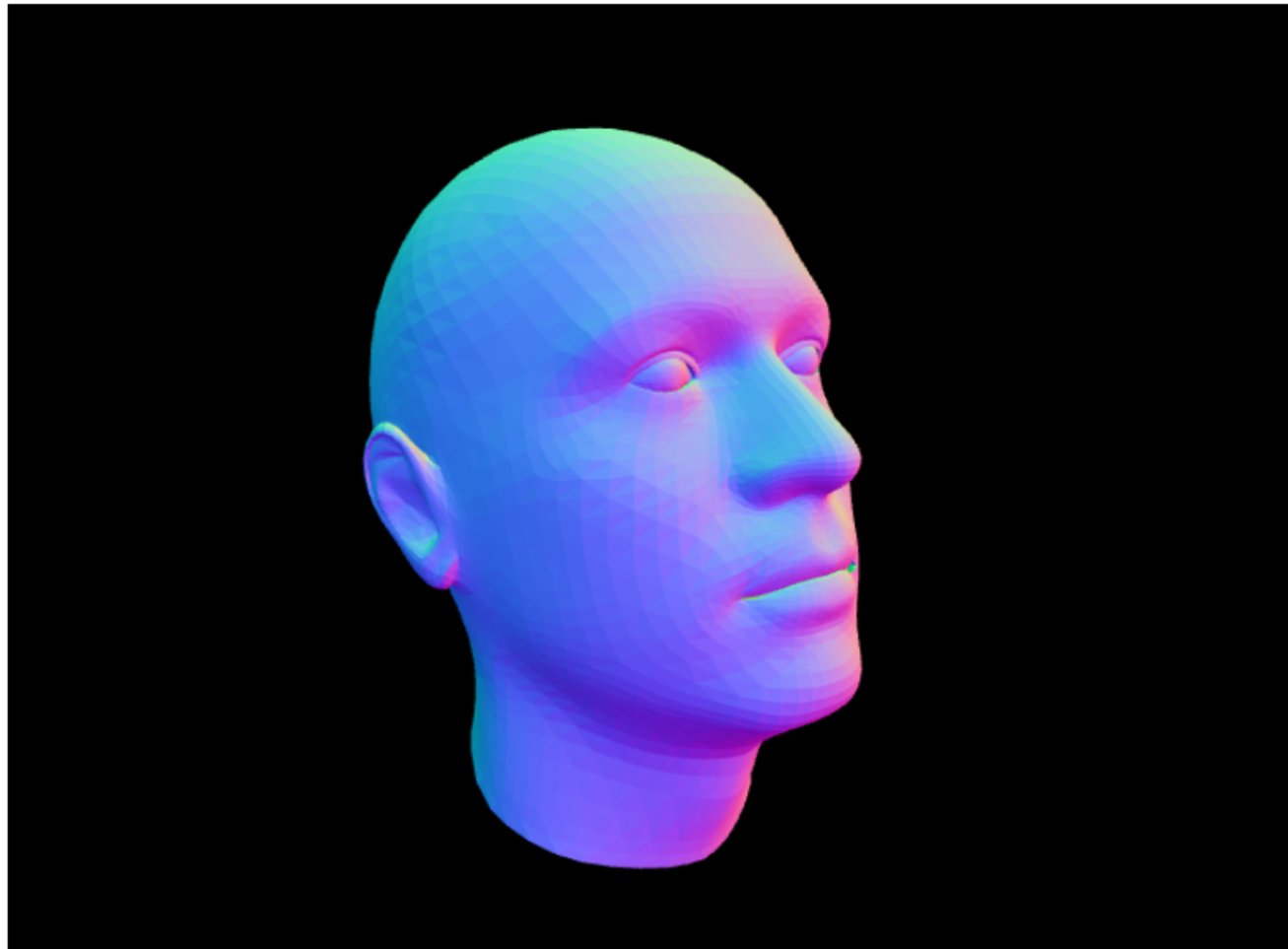
Unit Kilograms Pound

Selected Model Options

Base Model:	Female Open Mouth
African:	48
East Asian:	52
European:	0
South Asian:	0
Age	61

For a visual overview of the possible paths through the model creation process, see Appendix: Model Creation Pathway.

Stage 1: Model Options



MODEL OPTIONS

UPPER AIRWAY

LOWER AIRWAY

BASE MODEL

Male Closed Mouth



RACE [%]

African



0

East Asian



0

European



0

South Asian



0

AGE



20

Autorotate

Orbit Control

Transparency



Stage 1: Model Options: Specify A Base Model

Select a Base Model set that represents the facial features and biological attributes to be modeled.

Base Models are male and female, both open and closed mouth.

BASE MODEL

Female Closed Mouth

Male Closed Mouth

Female Closed Mouth

Male Open Mouth

Female Open Mouth



Stage 1: Model Options: Specify Race

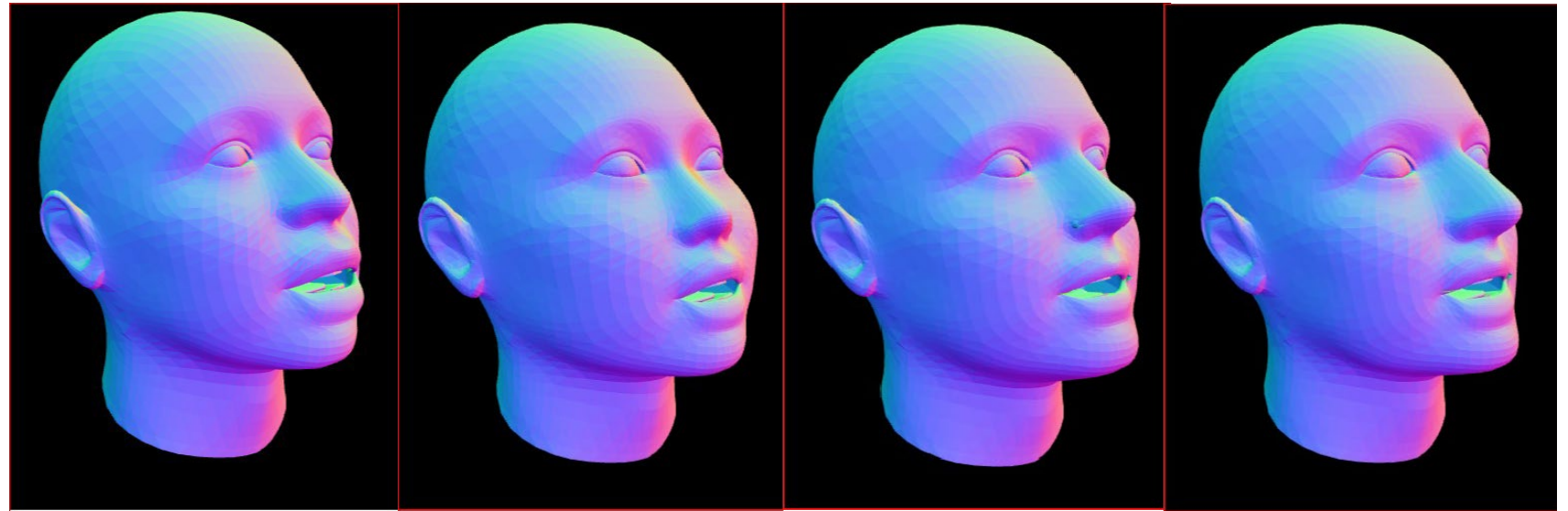
The Race categories are African, East Asian, European, and South Asian.

The categories are not an attempt to define race biologically, anthropologically, or genetically.

Percentages (from zero to 100%) can be combined to indicate a racial mixture. Each race category percentage can be modified either by the slider or an integer value.

Percentages should total 100%.

RACE [%]	
African	<input type="range" value="48"/> 48
East Asian	<input type="range" value="52"/> 52
European	<input type="range" value="0"/> 0
South Asian	<input type="range" value="0"/> 0



The model display updates based on the parameter settings.

Stage 1: Model Options: Specify Age

The final parameter affects the current model by age; the selectable age range is from 18–70.

The default value is 20 years of age.

The age can be modified either by the slider or an integer value.

The model display changes based on the Age setting.

AGE

Stage 1: Model Options: Manipulate the Model



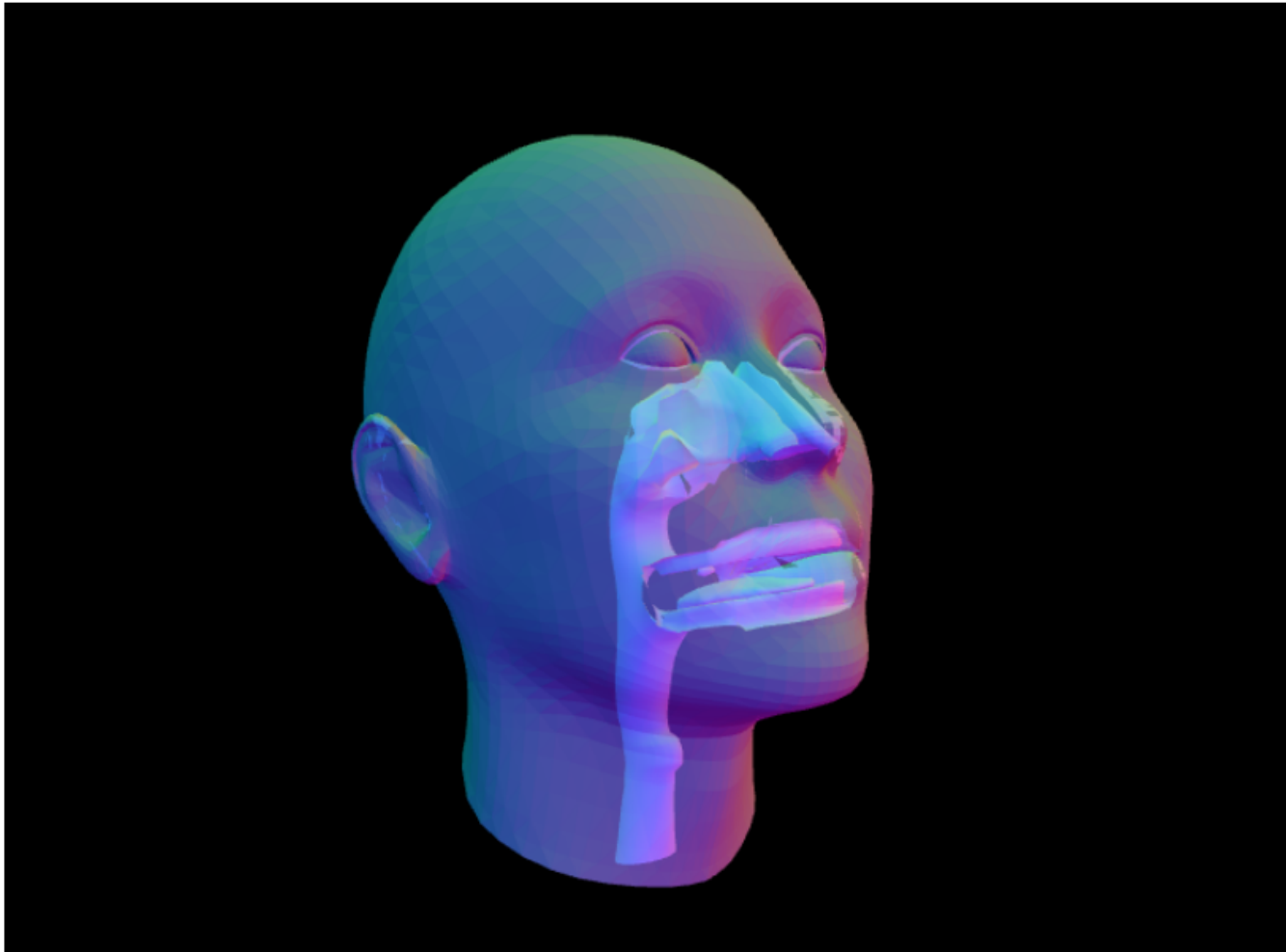
***Autorotate** activates a 360-degree rotation of the model at the current camera perspective. Select **Autorotate** to toggle On or Off (default).*

*Move the **Transparency** slider to the left to make the model opaque and solid. Move the **Transparency** slider to the right to make the model transparent, so the upper airways are visible.*

*Toggle the **Orbit Control** button (On by default) to manipulate the model in 3D space with the mouse pointer. See the [Appendix](#) for instructions.*



Stage 1: Model Options: When you have completed your choices on this page, choose Upper Airway.



MODEL OPTIONS UPPER AIRWAY LOWER AIRWAY

BASE MODEL

RACE [%]

African	<input type="range" value="48"/>	<input type="text" value="48"/>
East Asian	<input type="range" value="52"/>	<input type="text" value="52"/>
European	<input type="range" value="0"/>	<input type="text" value="0"/>
South Asian	<input type="range" value="0"/>	<input type="text" value="0"/>

AGE

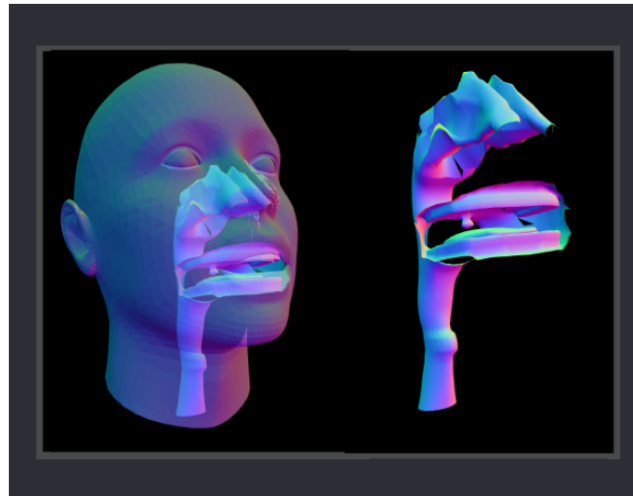
Autorotate

Orbit Control

Transparency

Stage 2: Upper Airway (Optional) 1

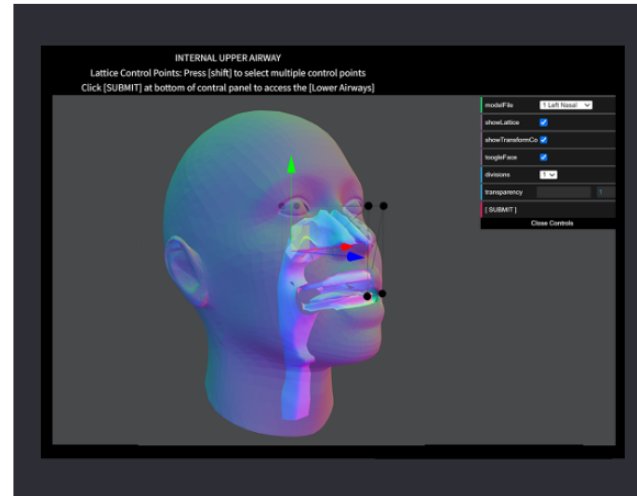
*The Internal Upper Airway stage provides an interface to modify the internal upper airway morphology to match external facial features, allowing customization of the left and right nasal passages, the oral cavity, pharynx, larynx, and upper trachea. ***Note: Due to current computational issues, if you do not wish to change the upper airway structure, please do not use the default airways at this time but instead click through the Free-Form Deformation with no changes.***



DEFAULT INTERNAL UPPER AIRWAYS

Nasal Cavity, Pharynx, Oral Cavity, Larynx, Upper Trachea

Use DEFAULT UPPER AIRWAYS



FREE-FORM DEFORMATION

FFD encloses one of the models within a cube and deforms the model by moving the control points of the cube.

Use FFD UPPER AIRWAYS

Stage 2: Upper Airway (Optional) 2

**Select the “Use DEFAULT UPPER AIRWAYS” button to bypass Stage 2 and go directly to [Stage 3: Lower Airway](#).*

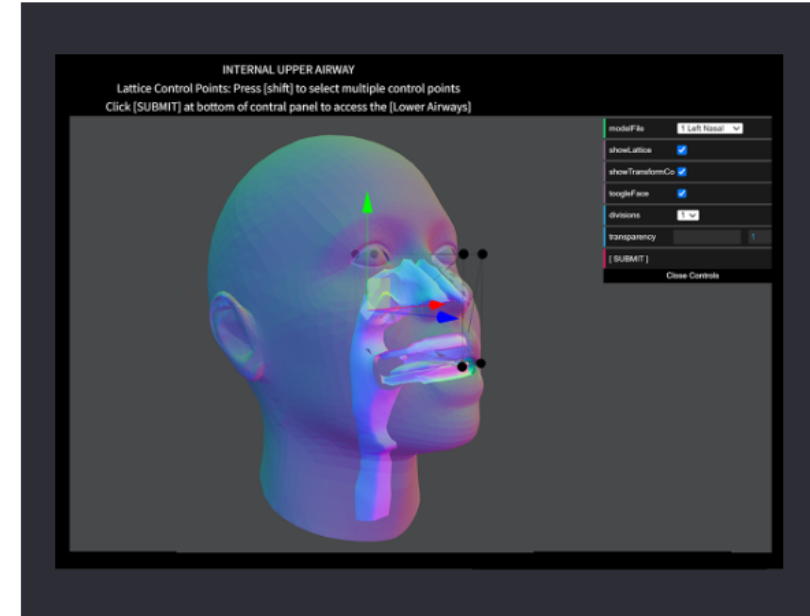


DEFAULT INTERNAL UPPER AIRWAYS

Nasal Cavity, Pharynx, Oral Cavity, Larynx, Upper Trachea

Use DEFAULT UPPER AIRWAYS

Select the “Use FFD UPPER AIRWAYS” button to open a new page where you can manually [manipulate the airway model](#).



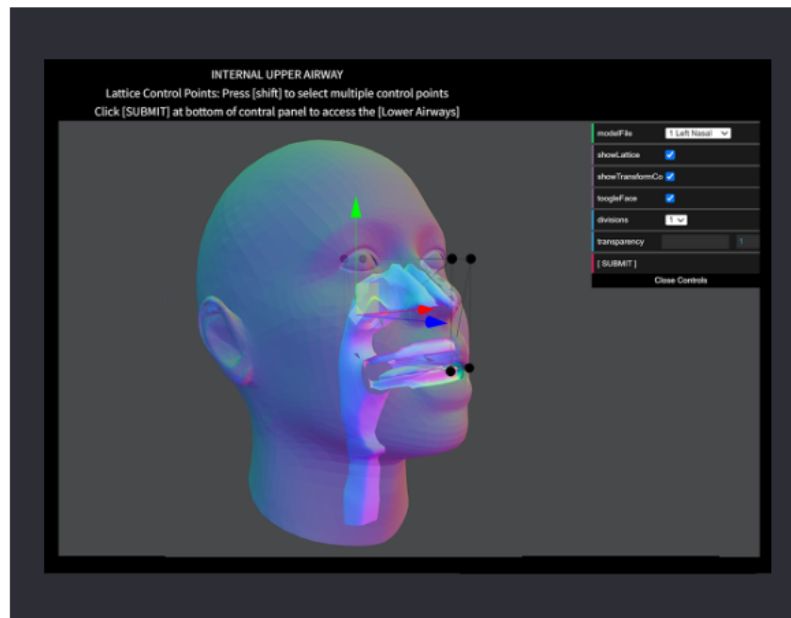
FREE-FORM DEFORMATION

FFD encloses one of the models within a cube and deforms the model by moving the control points of the cube.

Use FFD UPPER AIRWAYS

Stage 2: Upper Airway (Optional) 3

**The rest of this section focuses on how to use the free-form deformation interface. If you will not be customizing the upper airway model, skip to [Stage 3: Lower Airway](#).*



FREE-FORM DEFORMATION

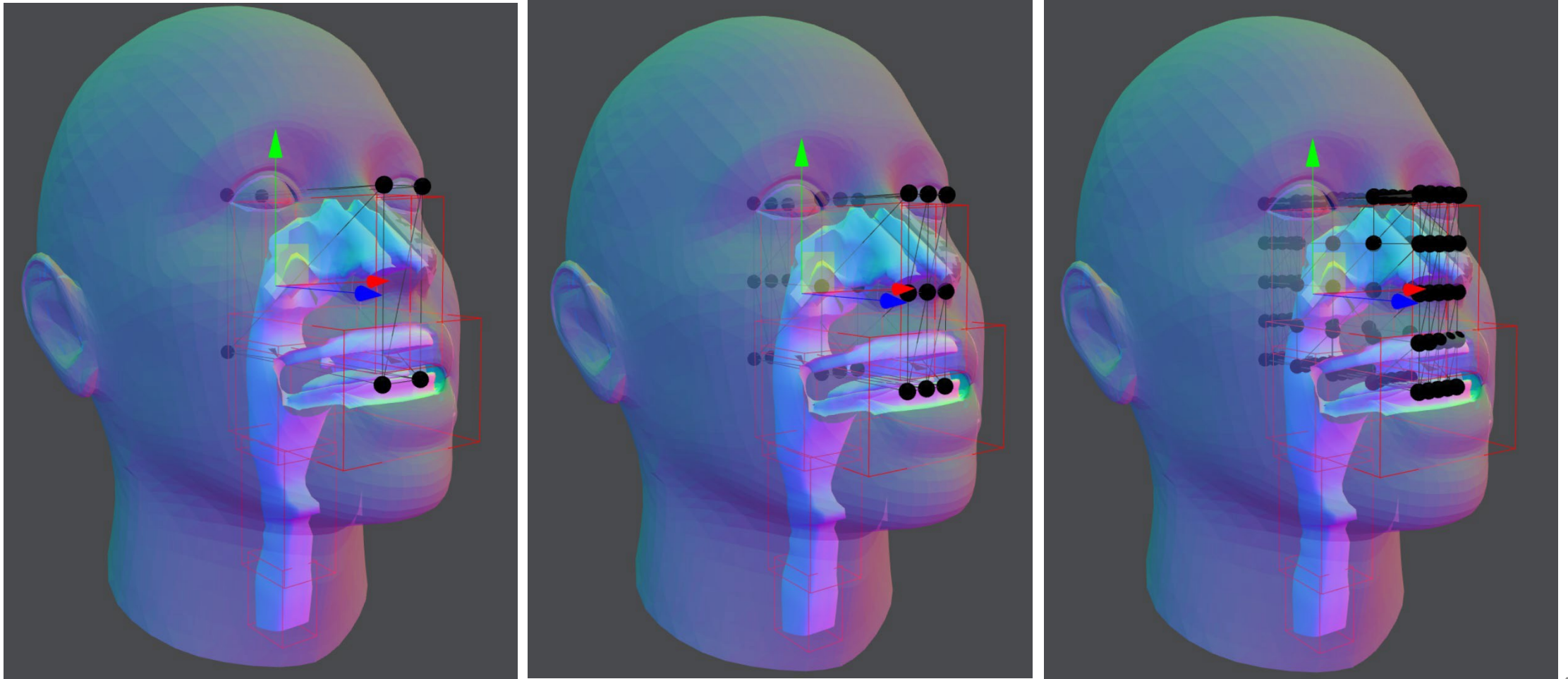
FFD encloses one of the models within a cube and deforms the model by moving the control points of the cube.

Use FFD UPPER AIRWAYS

For a visual overview of the possible paths through the model creation process, see [Appendix: Model Creation Pathway](#).

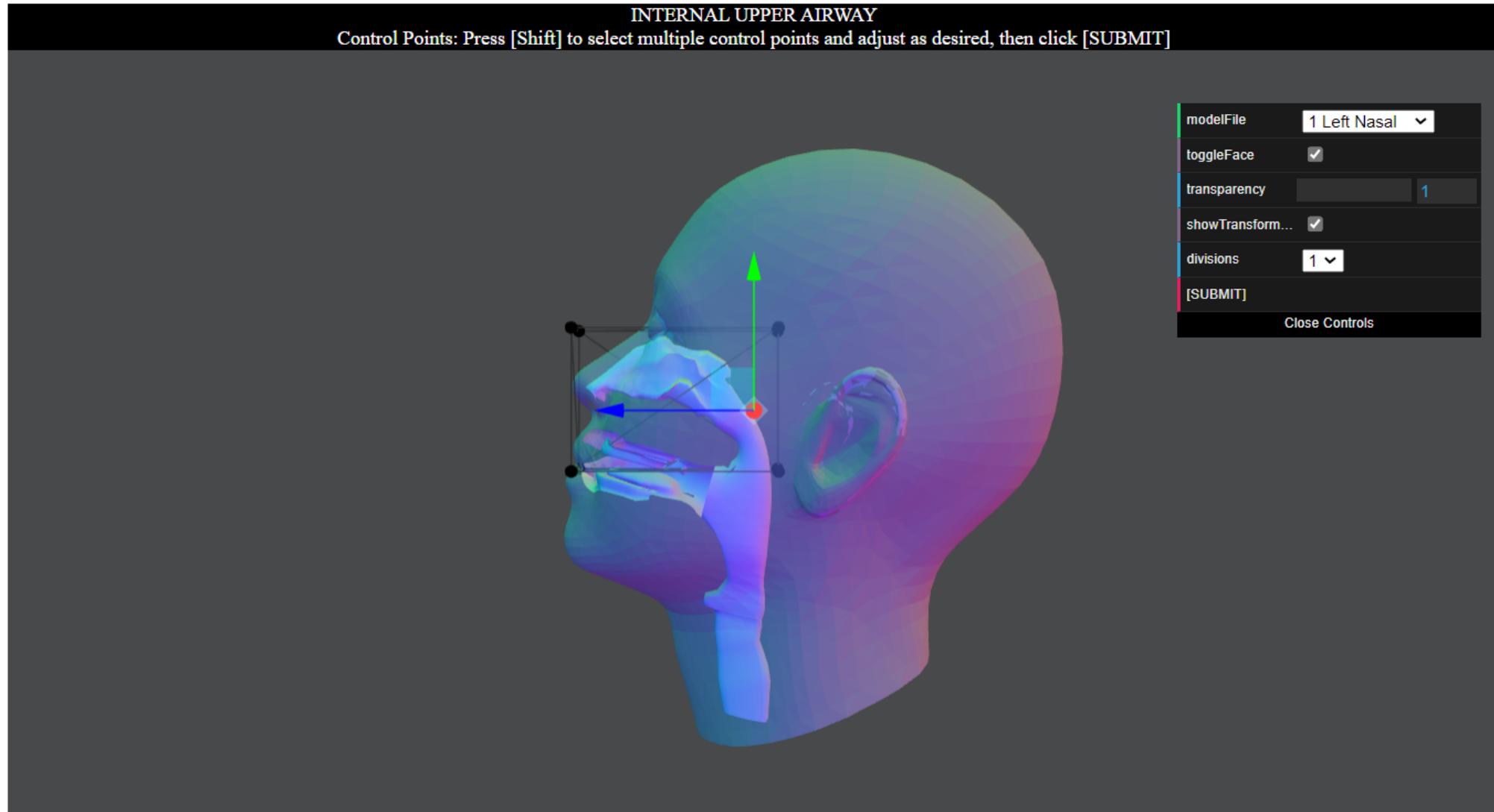
Stage 2: Upper Airway: Free-Form Deformation 1

Free-Form Deformation (FFD) is a method used to deform a rigid object. Based on the concept of enclosing an object within a cube or lattice, the object within the box is deformed by moving the control points of the lattice. More control points on the lattice results in finer detail of the deformation.



Stage 2: Upper Airway: Free-Form Deformation 2

Selecting the “Use FFD UPPER AIRWAYS” button displays the following interface for customizing the airways model. The Controls panel affects different parts of the display.



Stage 2: Upper Airway: Free-Form Deformation 3

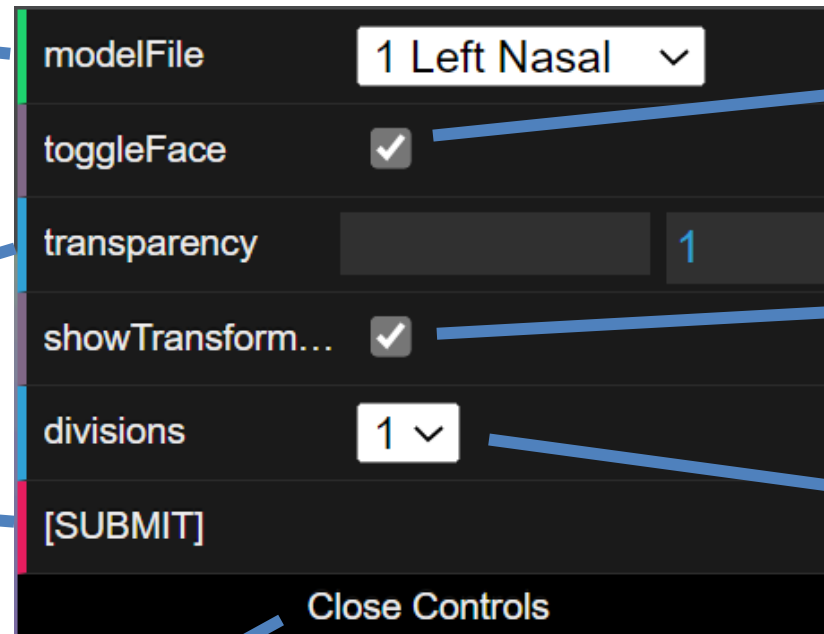
The Controls panel affects different parts of the display, as follows.

Select from six internal airway elements to adjust and edit. [See Page 17 for details.](#)

Adjust transparency of external model by clicking in slider area or entering a number from 1-50.

Select [SUBMIT] to start compiling the edited airways model

Expand or shrink the Controls display



The screenshot shows a dark-themed 'Controls' panel with several settings. On the left side, there is a vertical bar with colored segments: green, purple, blue, and red. Blue lines connect these segments to text annotations. The settings are as follows:

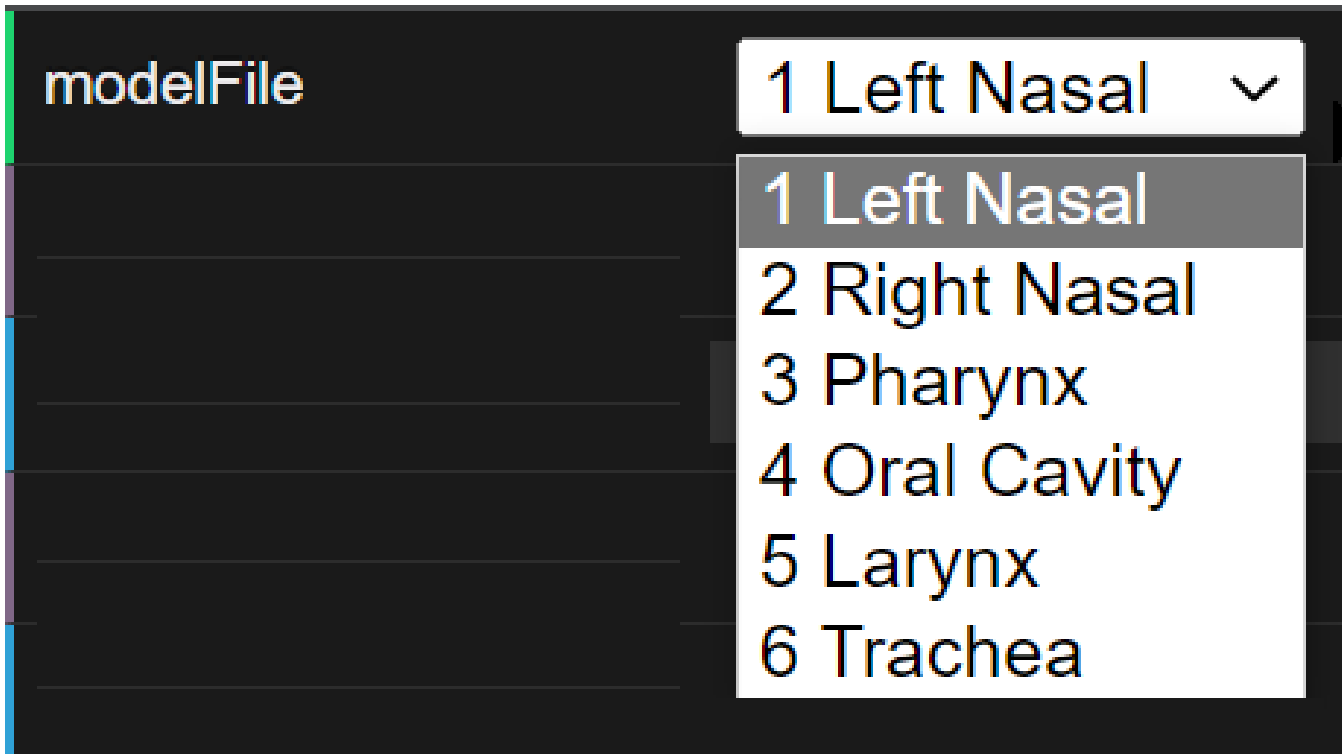
modelFile	1 Left Nasal	▼
toggleFace	<input checked="" type="checkbox"/>	
transparency	<input type="text" value="1"/>	
showTransform...	<input checked="" type="checkbox"/>	
divisions	1	▼
[SUBMIT]		
Close Controls		

Toggle the external model display, allowing focus on the airway.

Toggles display of the red, green, and yellow arrows showing direction in 3D space.

The Divisions value (1-4) controls subdividing the control box around the selected model; the higher the number, the more control points are provided. [See Page 20 for details.](#)

Stage 2: Upper Airway: Free-Form Deformation 4



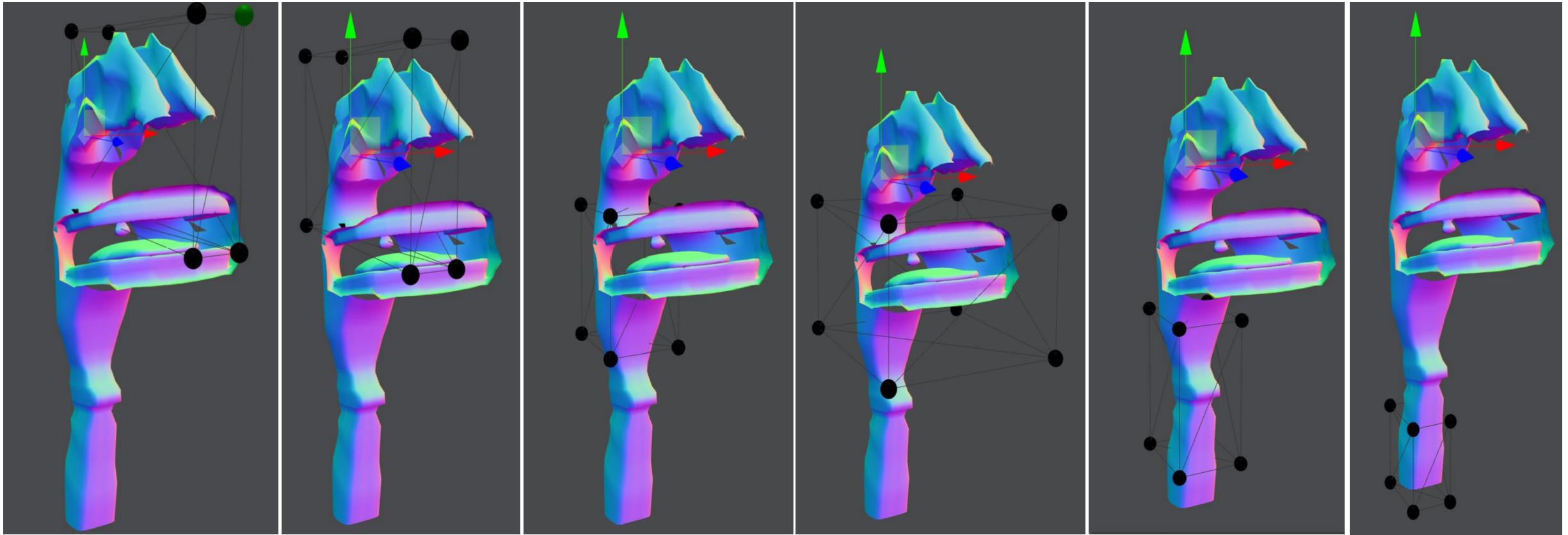
The modelFile control offers six parameters for adjusting and editing the Internal upper airway elements.

Select a parameter to display a bounding box of control points in the display for that airway element.

See [Page 18](#) for examples of how these selections look in the interface.

Stage 2: Upper Airway: Free-Form Deformation 5

Each of the six elements of the internal upper airway system, selectable from the modelFile control, are shown enclosed within a cube or lattice, with a minimum of 8 control points used to deform the enclosed element.



Left nasal

Right nasal

Oral cavity

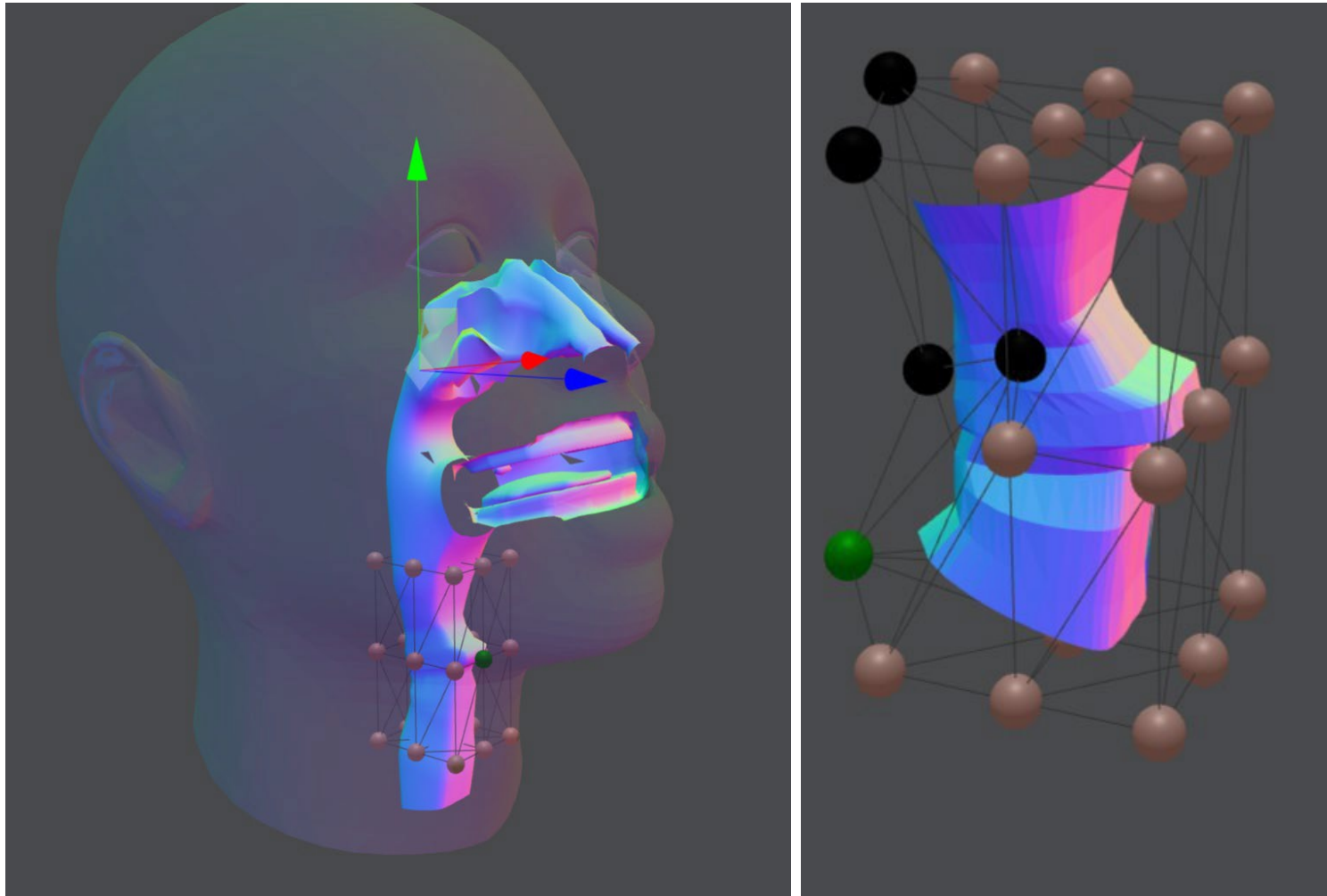
Pharynx

Larynx

Upper trachea

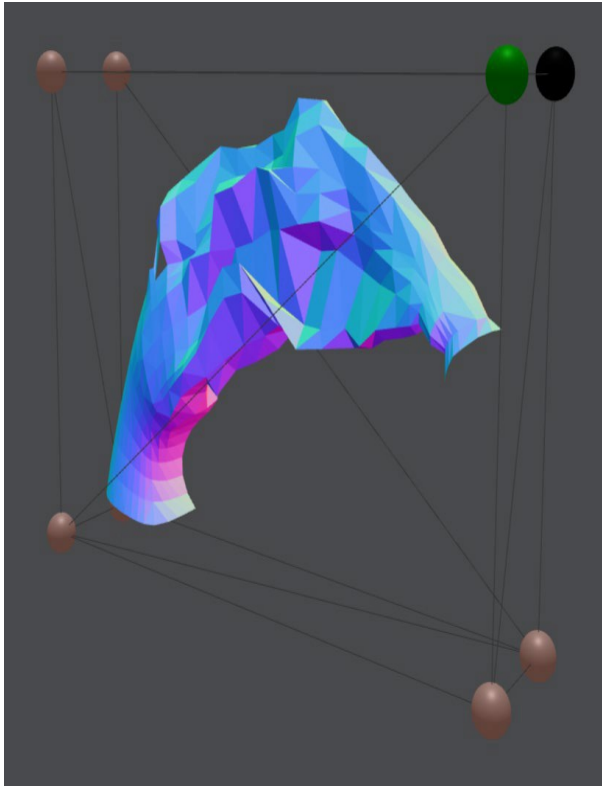
Stage 2: Upper Airway: Free-Form Deformation 6

Select and move the control points of the lattice to deform the underlying object. Use the Shift key to select multiple control points.

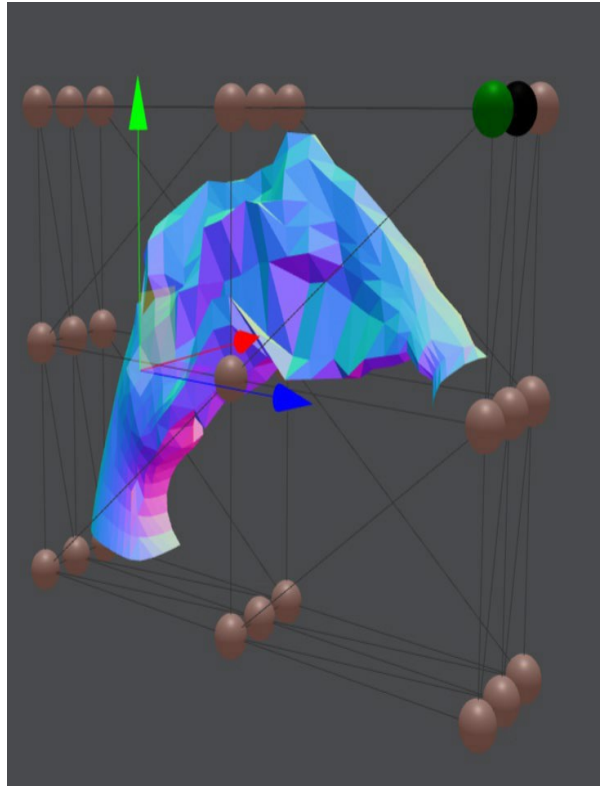


Stage 2: Upper Airway: Free-Form Deformation 7

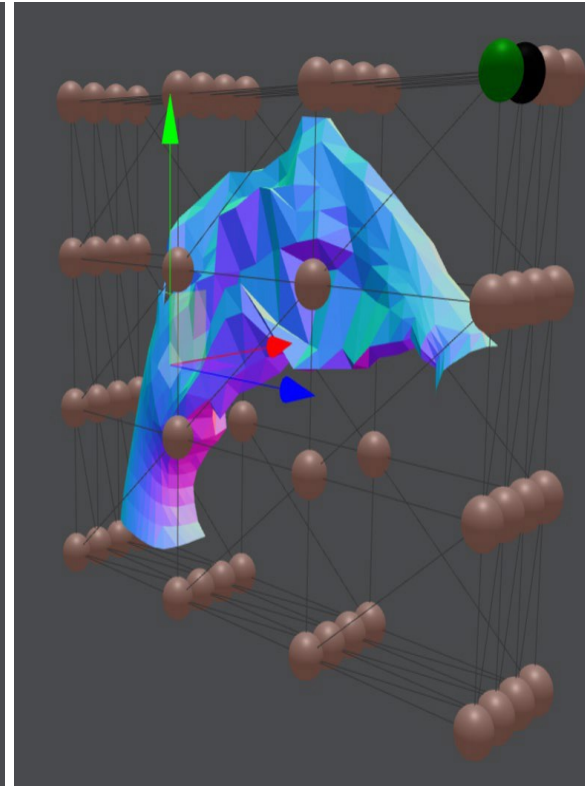
To add more control points, increase the divisions control parameter. Allowed values are 1-4. More control points on the lattice results in finer detail in the deformation. [Back to Page 16.](#)



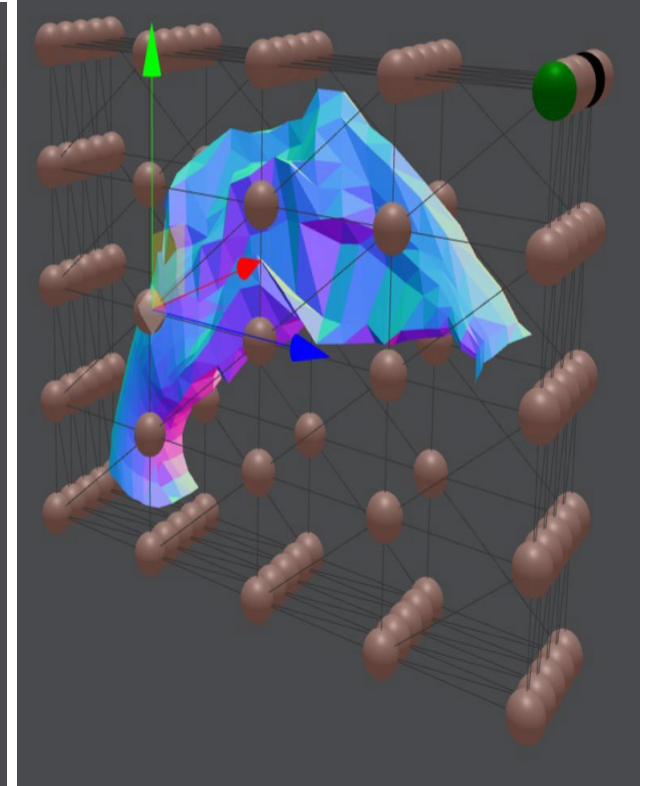
The right nasal passage is enclosed in a lattice with 8 control points



The right nasal passage is enclosed in a lattice with 27 control points



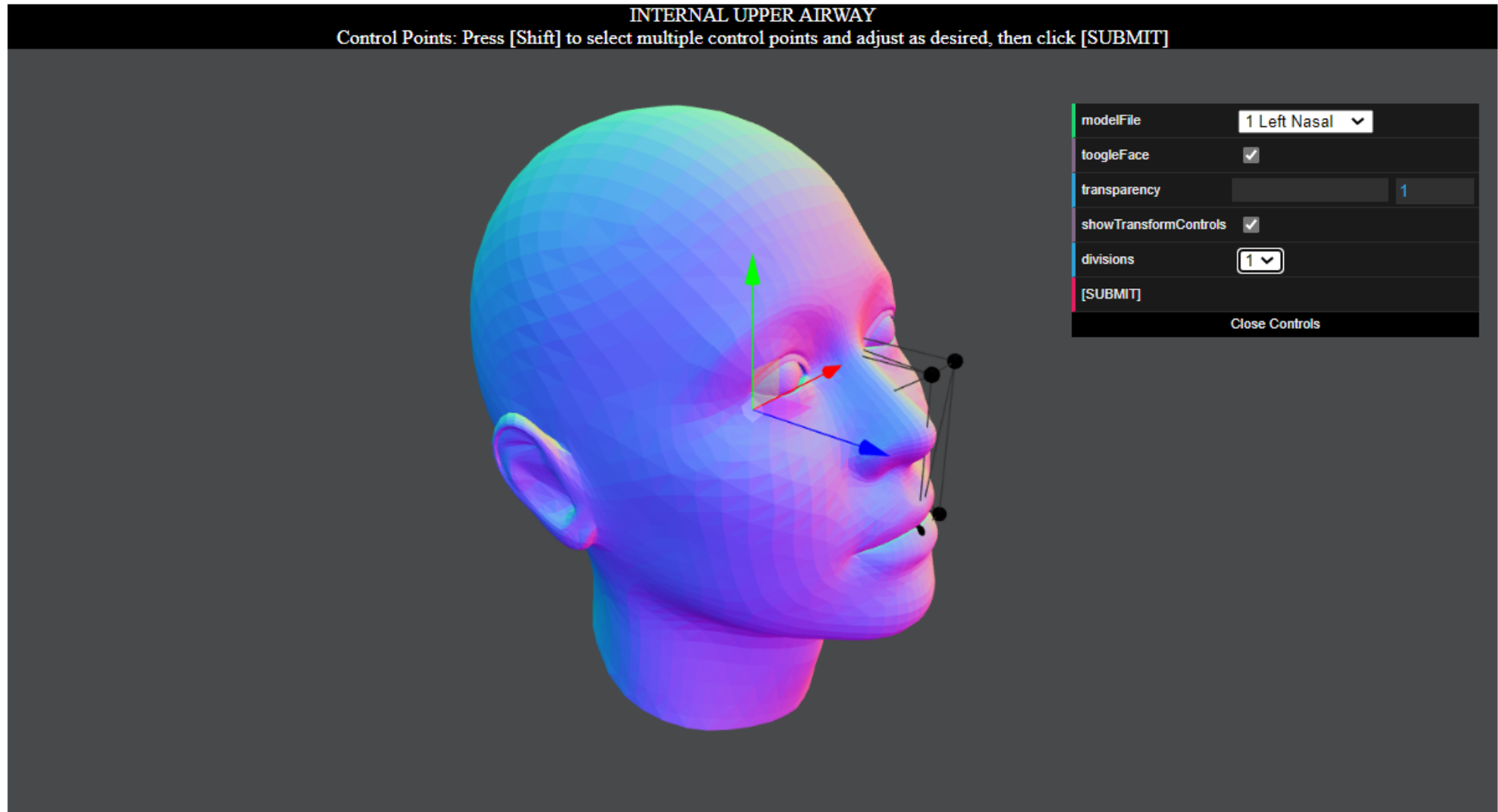
The right nasal passage is enclosed in a lattice with 64 control points



The right nasal passage is enclosed in a lattice with 125 control points

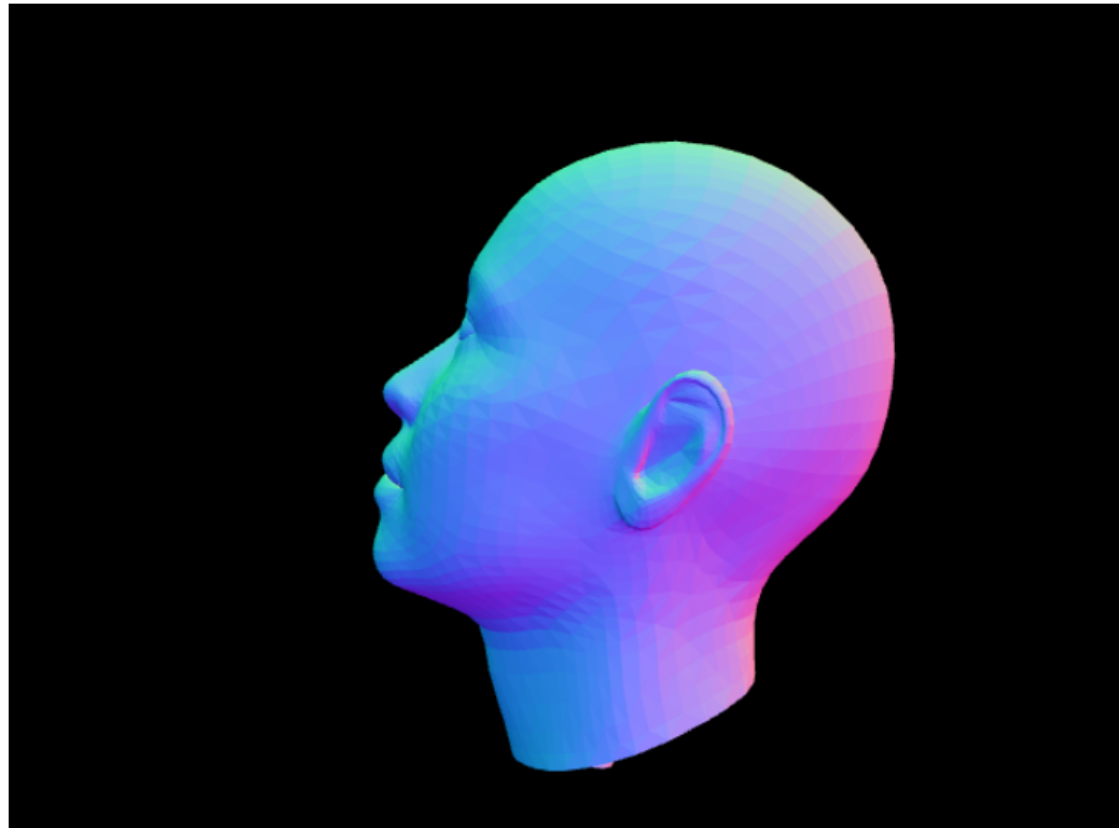
Stage 2: Upper Airway: Free-Form Deformation 8

After all the editing has been performed on the airway system, select [SUBMIT] in the Controls both to start the computational transformations of the model and to display Stage 3: Lower Airway.



Stage 3: Lower Airway 1

The Lower Airway page is displayed either by selecting the [default upper airway choice](#) or after [submitting](#) the free-form deformation upper airway. Model Options selected in Stage 1 are shown at the bottom of the page.



MODEL OPTIONS UPPER AIRWAY LOWER AIRWAY

Height

Unit Meters Feet

Weight

Unit Kilograms Pound

Selected Model Options

Base Model: Female Closed Mouth
African: 48
East Asian: 52
European: 0
South Asian: 0
Age: 20

SUBMIT

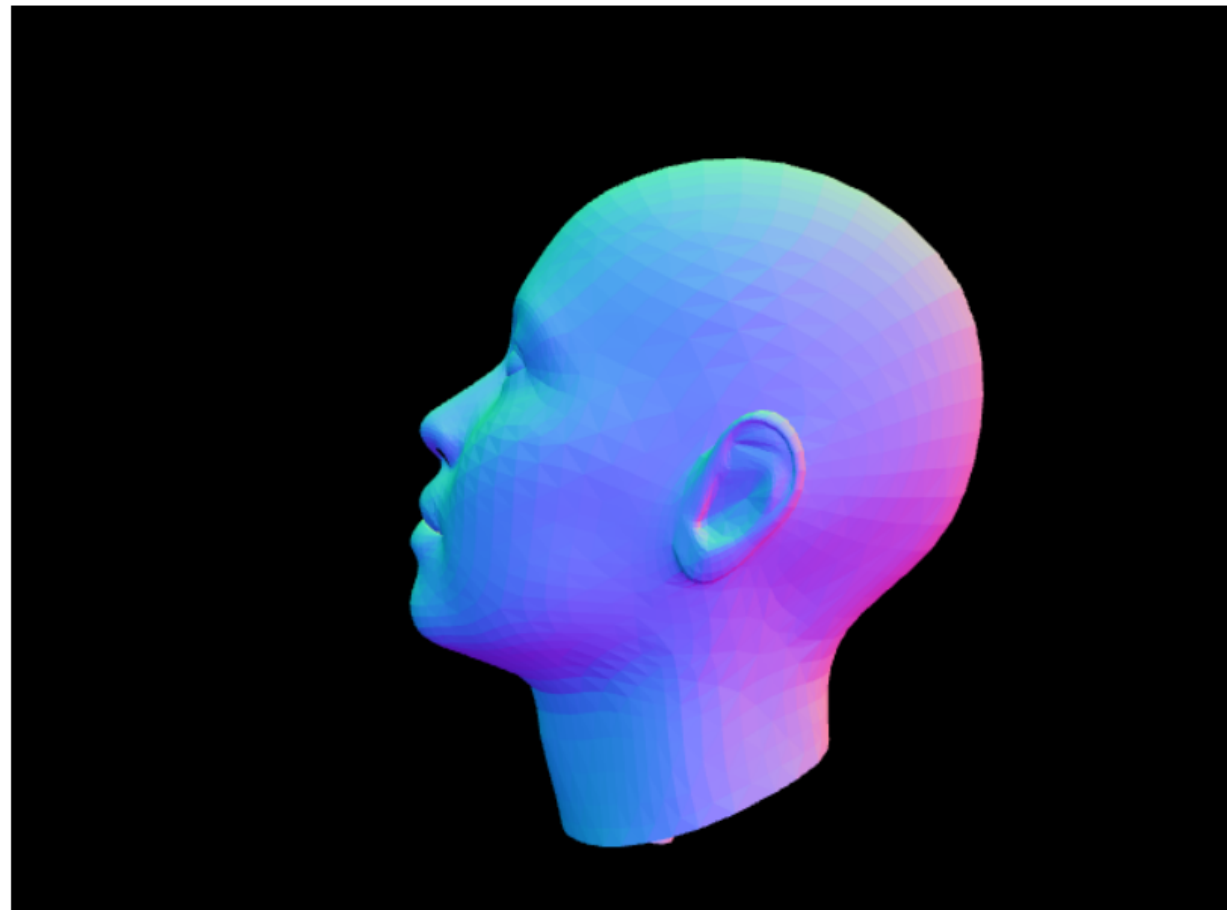
Stage 3: Lower Airway 2: Specify Height & Weight

On the Lower Airway page, enter the height and weight of the subject. Units are meters or feet for height, and pounds or kilograms for weight.

Height	<input type="text" value="1.62"/>
Unit	<input checked="" type="radio"/> Meters <input type="radio"/> Feet
Weight	<input type="text" value="58.74"/>
Unit	<input checked="" type="radio"/> Kilograms <input type="radio"/> Pound

Stage 3: Lower Airway 3

After entering the height and weight, and confirming the Model Options from Stage 1, click the Accept button at the bottom of the page.



Autorotate Orbit Control

Transparency

MODEL OPTIONS UPPER AIRWAY LOWER AIRWAY

Height

Unit Meters Feet

Weight

Unit Kilograms Pound

Selected Model Options

Base Model: Female Closed Mouth

African: 48

East Asian: 35

European: 0

South Asian: 0

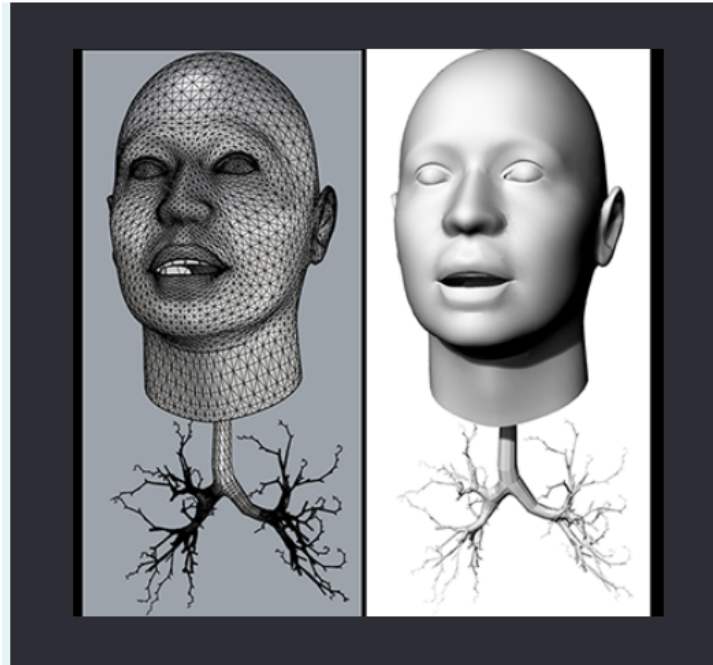
Age: 20

Click ACCEPT to save and continue

ACCEPT

Surface Model Options

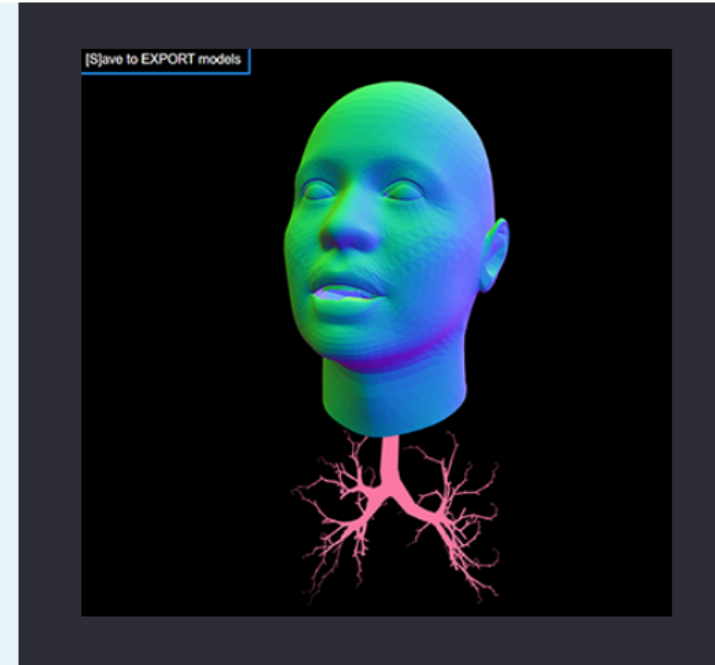
After selecting Accept, choose either of the following options: select [SAVE FILE](#) to save the model file to a computer for use in other applications, or select [VIEW IN WEB BROWSER](#) to display and optionally save the generated model.



SAVE SURFACE MODEL

The final surface model is stored in a stereolithography (STL) file also referred to as Standard Triangle Language or Standard Tessellation Language.

SAVE FILE



VIEW SURFACE MODEL IN WEB BROWSER

This may take some time to display.

VIEW IN WEB BROWSER

For a visual overview of the possible paths through the model creation process, see [Appendix: Model Creation Pathway](#).

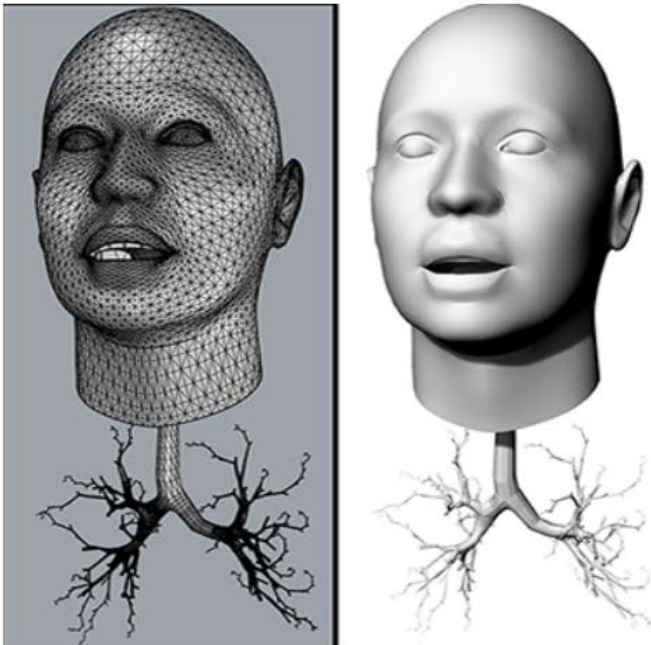
Save Surface Model File 1

After selecting SAVE FILE, a static image is displayed showing what the downloaded STL file would look like in a 3D capable application.

Above the static image is a progress bar that reports, in real time, each step as the model is computed and built.

Creating major airway passages of the lungs (bronchi)

Generating surfaces: 156 of 563 complete



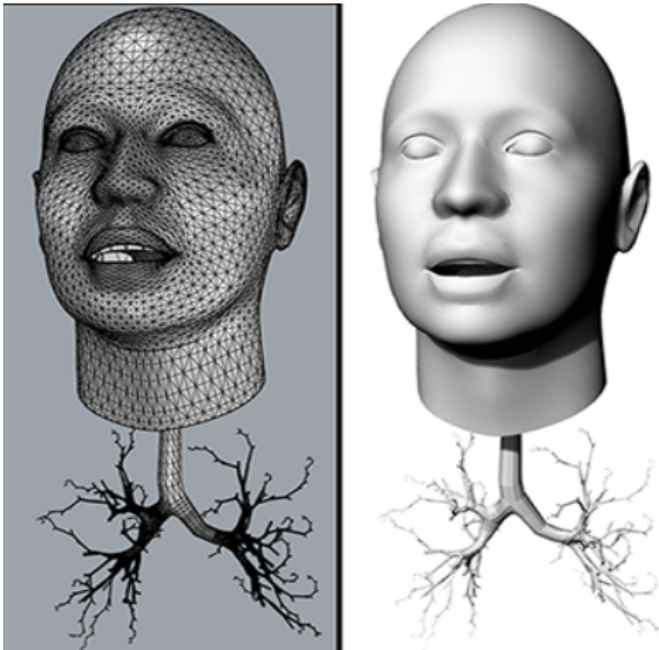
Save Surface Model File 2

When the progress bar reports “Complete”, the STL file is ready for download. Depending on the browser settings, the browser may prompt you for a download location.

The downloaded STL file can be imported into 3D viewer and design applications for further customization or experimentation.

Creating major airway passages of the lungs (bronchi)

Complete

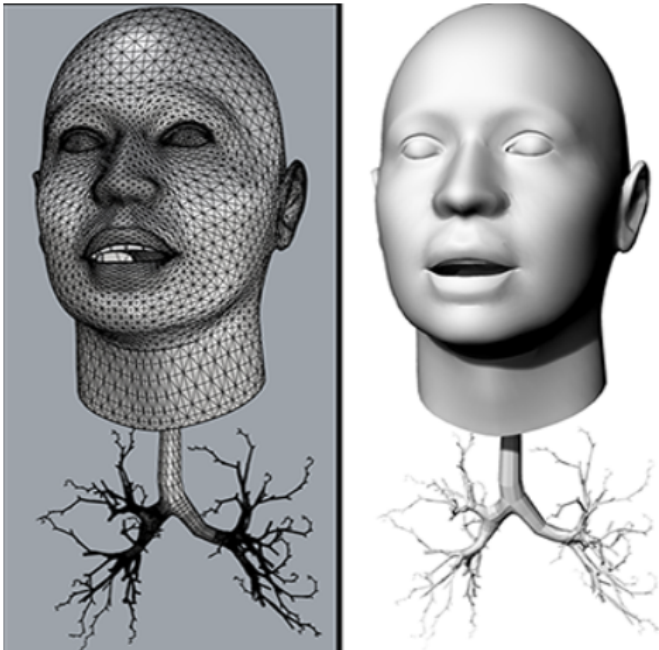


Save Surface Model File 3

After downloading the file, select the browser's *Back* button to return to the [Surface Model Options page](#), and optionally view the model in the web browser.

Creating major airway passages of the lungs (bronchi)

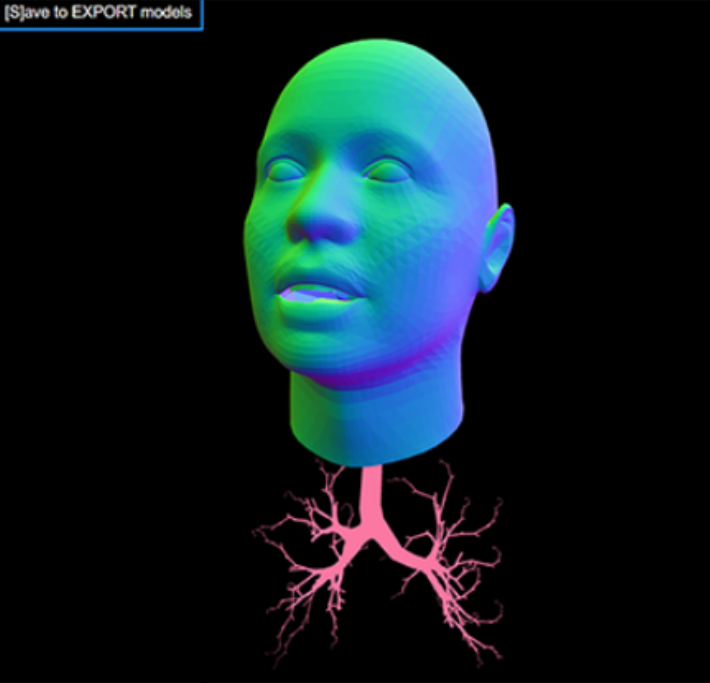
Complete



View Surface Model in Web Browser 1

Select VIEW IN WEB BROWSER to open a new page showing the display window where the generated model will appear.

Depending on your browser settings, internet connection speed, and the complexity of the model, model generation and viewing may take several minutes.



[Save to EXPORT models]

VIEW SURFACE MODEL IN
WEB BROWSER

This may take some time to display.

VIEW IN WEB BROWSER

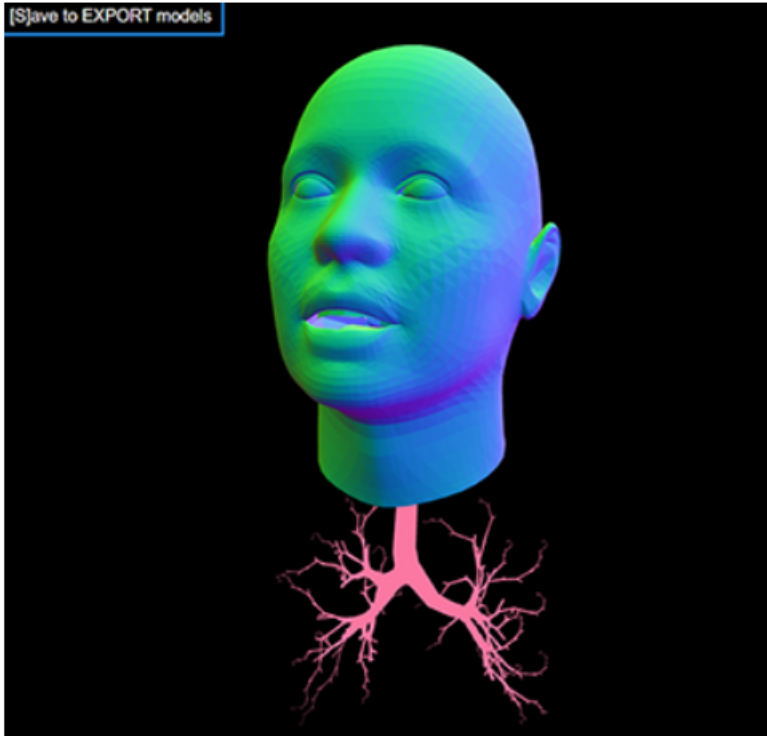
View Surface Model in Web Browser 2

The progress bar indicator includes details of the generation process before displaying the completed model. Below the progress bar is a static image of a completed model with airways.

Please wait while your model is generated

Generating surfaces: 225 of 563 complete

[S]ave to EXPORT models



View Surface Model in Web Browser 3

The fully rendered model will appear in the display window.

Rotate the model in the window via the [Orbit Control](#).

*Press “s” (for “save”) to export the model data to a stereolithography file (STL), with the default filename **all_models.stl**. (A 3D application is needed to open, view, and manipulate STL files.)*

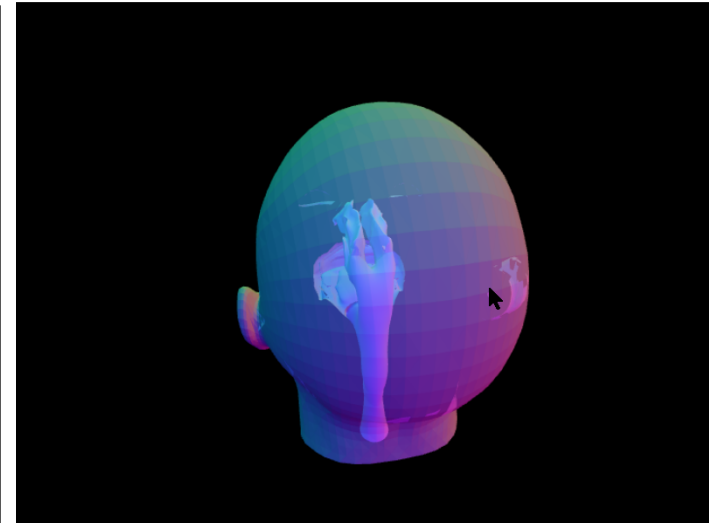
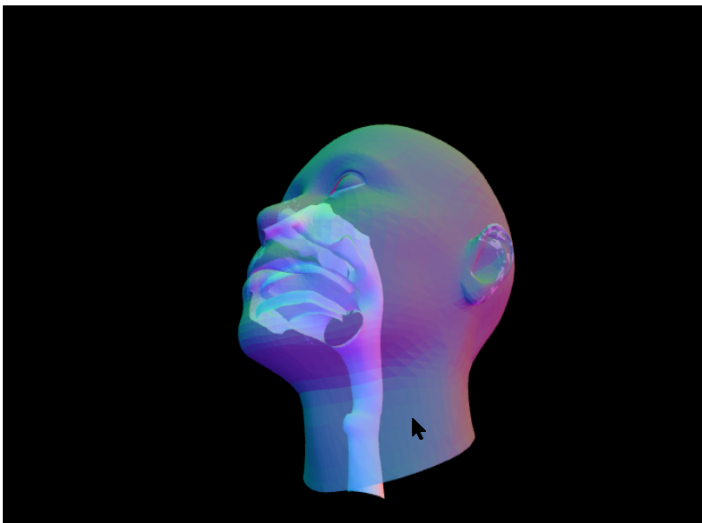
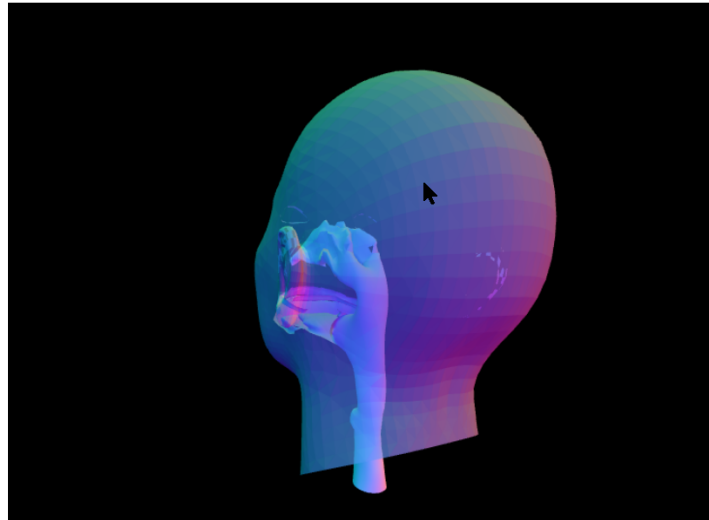
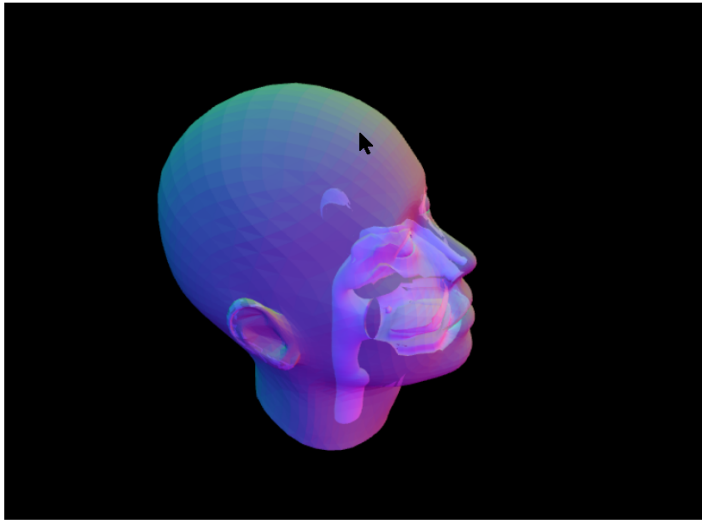
Depending on the browser settings, the browser may prompt you for a download location.

Click the browser’s Refresh button to [begin work on a new model](#).



Questions? Refer back to the EPA webpage for references and more information or contact Dr. Jacky Rosati Rowe at rosati.jacky@epa.gov

Appendix: Orbit Control



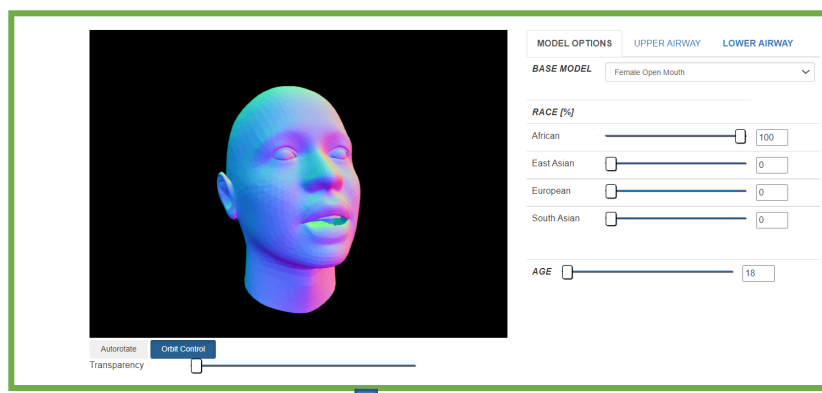
To manipulate the model in 3D space, the mouse pointer should be in the Model Display area. The following controls work whenever you see the model onscreen:*

- **Left mouse button:** Press and hold to rotate the model up, down, left, or right.
- **Right mouse button:** Press and hold to pan the model left and right.
- **Center mouse wheel:** Scroll the wheel up to zoom in; scroll the wheel down to zoom out.

** For Model Options and Lower Airways, the **Orbit Control** button should be toggled to On.*

Appendix: Model Creation Pathway

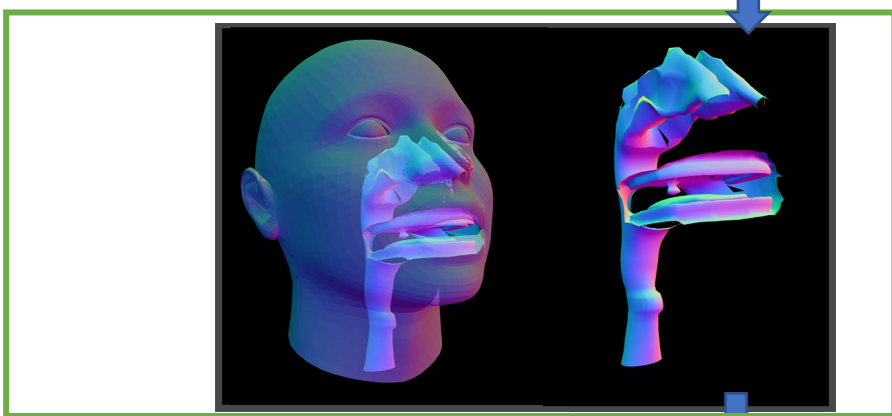
MODEL OPTIONS



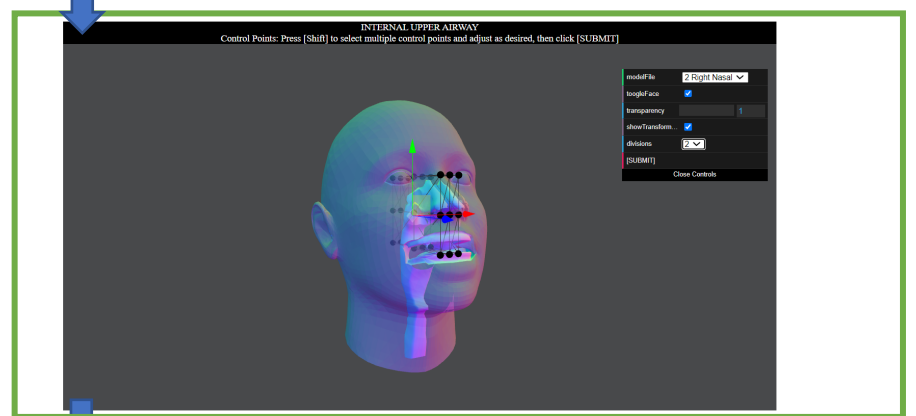
UPPER AIRWAYS



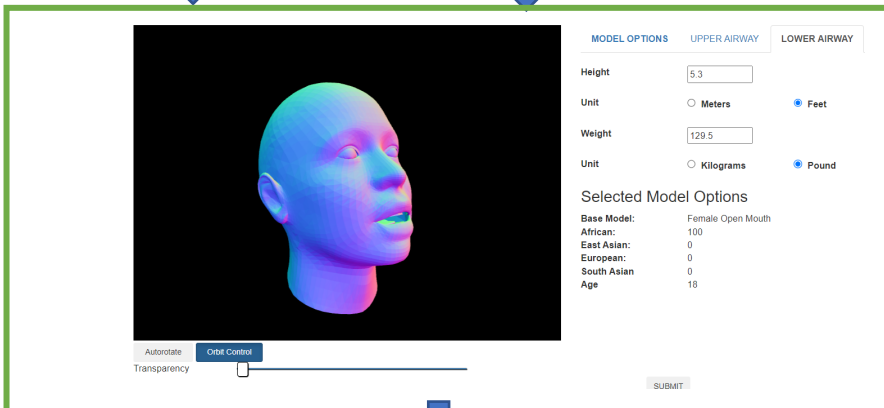
UPPER AIRWAYS DEFAULT



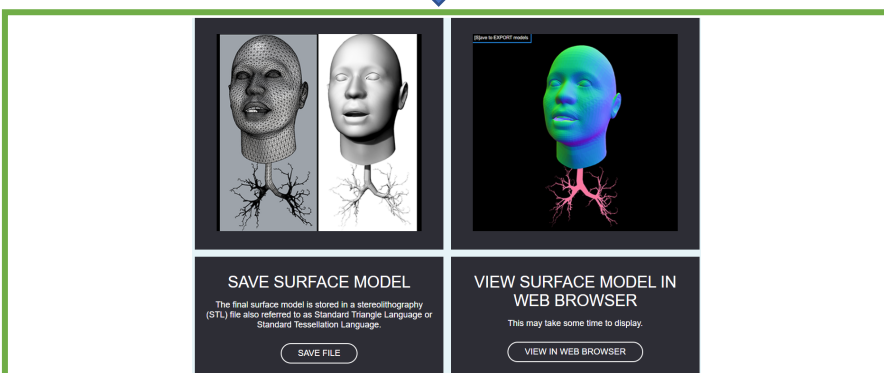
UPPER AIRWAYS FREE-FORM DEFORMATION



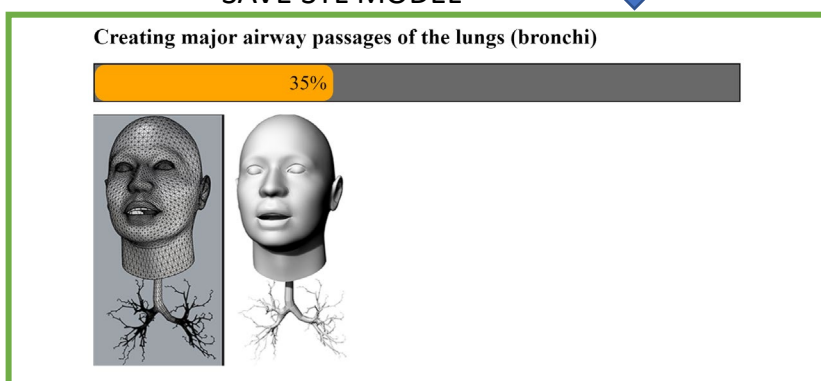
LOWER AIRWAYS



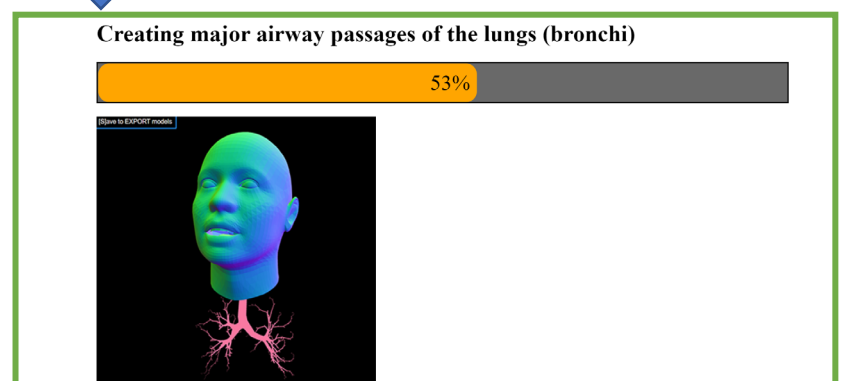
SURFACE MODEL



SAVE STL MODEL



VIEW and SAVE STL MODEL



STL MODEL OUTPUT
as displayed in STL-
compatible application

