

Human Reference Atlas

Standard Operating Procedure

Adding 3D Reference Objects to the Human Reference Atlas

Integrating 3D Reference Objects into RUI and EUI Tools

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Introduction

The procedures outlined in this document describe how 3D reference organ objects are integrated into the Human Reference Atlas (HRA). This includes making the published models (available in the ccf-releases Github repository for each HRA release) accessible via the Human Reference Atlas (HRA) portal at <https://humanatlas.io>. This SOP is written for users involved in HRA publication and users that would like to download the 3D Reference Objects for use in the HRA or other user interfaces.

Roles and Responsibilities

The **Medical Illustrator** builds 3D models, negotiates and implements suggested changes with SMEs, and shares the models via GitHub for use in HuBMAP services and user interfaces.

The **Principal Investigator (PI)** is responsible for delivering anatomically correct 3D models for use in the HuBMAP Human Reference Atlas construction effort. The PI approves budgets associated with the 3D reference object modeling and usage process, hires relevant experts, sets high-level goals and associated deadlines, attends meetings, and reviews notes and recordings from relevant meetings between the Senior Research Analyst-Biologist and other key personnel as outlined in this SOP.

The **Senior Research Analyst-Biologist** is the Medical Illustrator's main contact in the MC-IU team. They work with the Medical Illustrator to identify relevant ontology terms for all anatomical structures in the 3D models and work with subject matter experts to ensure 3D reference object nomenclature is consistent with ASCT+B tables. They also work closely with the System Architect to resolve problems in nomenclature or models and to upload crosswalks to the release GitHub repository for use in HRA releases.

The **Systems Architect** publishes the 3D reference objects on the HRA Portal and uses them in the Registration User Interface (RUI) and Exploration User Interface (EUI). The Systems Architect offers technical expertise in the areas of 3D model storage options and integrates the

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3D models into the HuBMAP ecosystem (e.g., how anatomical structures should be labeled to work well with existing ontology schemas).

Table 1. Roles, names, and email addresses of key personnel.

Role	Name	Email
Medical Illustrator	Heidi Schlehlein	hschleh@iu.edu
Senior Research Analyst-Biologist	Ellen M. Quardokus	ellenmq@iu.edu
Systems Architect	Bruce W. Herr II	bherr@iu.edu
Principal Investigator	Katy Börner	katy@iu.edu

Procedures

Updating the United Body File

- The Medical Illustrator shares all revised and new 3D reference objects in preparation of an HRA release.
- The Medical Illustrator updates the United body file, which contains all of the approved 3D reference objects built for the Visible Human Male (VHM) and Visible Human Female (VHF) bodies, with every newly approved organ or organ change, following the steps in the Standard Operating Procedure (SOP) on [3D Reference Object Approval](#) and the forthcoming SOP on 3D reference organ ontology crosswalks.
- The Medical Illustrator exports a node list for the Senior Research Analyst-Biologist and the Systems Architect. Maya node names begin with any character from a-z or A-Z and an underscore, followed by a sequence of characters from a-z or A-Z, underscore or numerals; Maya does not allow spaces or punctuation marks in the node names with the exception of the underscore _ or the pound sign #.
- The Senior Research Analyst-Biologist and the Medical Illustrator return the node list with ontology mappings, and any changes required to the node-names.
- The Medical Illustrator attaches the ontology IDs to models using a script written in the Maya Embedded Language (MEL), a programming language that interfaces with Maya, deposited here: <https://github.com/hubmapconsortium/ccf-3d-reference-object-library/tree/main/Metadata/Script>.
- The Medical Illustrator exports an updated node-list and provides it to the Systems Architect and the Senior Research Analyst-Biologist as a confirmation step to ensure changes are correctly captured.

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- The Senior Research Analyst-Biologist adds the necessary metadata and column headers to the node list for the downstream integration into RUI and EUI integration workflows.
- The Medical Illustrator saves the United body file as a low-polygon version. This version is saved in two file formats: .fbx and .glb.
- The Medical Illustrator then individually exports each organ from the United body file using this naming schema: 3d-dataInstitutionoriginABBR-sex-organ.glb or add hyphen between two part organ names
3d-dataInstitutionoriginABBR-sex-organpart1-organpart2.glb. See examples in Table 2.

Table 2. File naming schema examples

Data Institution Origin Abbreviation	Sex: Male (M) or Female (F) Abbreviation	Organ Name	Laterality if applicable Left or Right	File format .glb, .fbx	Example
Allen Institute (Allen)	F	Brain		.glb	3d-allen-f-brain.glb
NIH	F	Lymph_node		.glb	3d-nih-f-lymph-node.glb
Stony Brook University (SBU)	F	Large_intestine		.glb	3d-sbu-f-large-intestine.glb
Visible Human (VH)	F	Kidney	Left	.glb	3d-vh-f-kidney-left.glb
Crosswalk file containing scene node names and ontology mapping	-	-	-	.csv	asct-b-3d-models-crosswalk.csv

- The Medical Illustrator pushes the models to the CCF 3D Reference Object Library repository on GitHub: <https://github.com/hubmapconsortium/ccf-3d-reference-object-library>. If the zipped United file is close to the GitHub size limit for files, the file is uploaded to Google Drive in the Design/releaseX folder as an intermediate step.
- The Medical Illustrator notifies the Systems Architect, Senior Research Analyst-Biologist and the PI via email of new organ additions.

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- The Senior Research Analyst-Biologist keeps a local clone of the repository to track changes for their own records.
- The Systems Architect adds the new United body file to the HRA Knowledge Graph.

Adding Organs to the HRA Portal

- The HRA Portal contains a landing page with links to the ccf-releases GitHub repository per release version <https://github.com/hubmapconsortium/ccf-releases> per organ model. Reference organs are shown in a preview window and may be rotated in 3D. Direct links for downloading the corresponding object on GitHub appear next to the organ.
- The Systems Architect adds all final organs to the HRA Portal and ccf-releases GitHub Repository <https://github.com/hubmapconsortium/ccf-releases>.

References and Resources

The below references and resources were used in writing this Standard Operating Procedure.

- The [CCF 3D Reference Object Library repository](#) on GitHub is where the Medical Illustrator uploads their unpublished models.
- The [ccf-releases GitHub repository](#) where the DOI registered models are uploaded for each HRA release.
- [GitHub Desktop](#) can be used by the Senior Research Analyst-Biologist and/or the Medical Illustrator to commit and review changes to the models.
- The [HRA Portal](#) is the central hub for the HRA effort with links to resources such as the ASCT+B Tables, the 3D Reference Object Library, the HRA Knowledge Graph and more.
- [3D Reference Object Approval](#) Standard Operating Procedures

Glossary

3D model: A 3D model is a digital object, consisting of vertices and edges, who, when taken together, can form a potentially endless variety of primitive (e.g., cubes, spheres, cones) and complex shapes (such as organs). 3D models come in many formats with various capabilities and limitations (OBJ, FBX, GLB, see below). We use GLB and FBX as output formats.

ASCT+B Tables: Anatomical Structures, Cell Types and Biomarkers (ASCT+B) Tables are authored by multiple experts across many consortia. Tables capture the partonomy of anatomical structures, cell types, and major biomarkers (e.g., gene, protein, lipid or metabolic markers).

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Common Coordinate Framework (CCF): This consists of ontologies and reference object libraries, computer software (e.g., user interfaces) and training materials that (1) enable biomedical experts to semantically annotate tissue samples and to precisely describe their locations in the human body (“registration”), (2) align multi-modal tissue data extracted from different individuals to a reference coordinate system (“mapping”) , and to (3) provide tools for searching and browsing HuBMAP data at multiple levels from the whole body down to single cells (“exploration”). See also <https://humanatlas.io>.

Exploration User Interface (EUI): An interface developed by MC-IU to explore tissue, see <https://portal.hubmapconsortium.org/ccf-eui>.

FBX (Filmbox) file format: A proprietary file format (.fbx) developed by Kaydara and owned by Autodesk since 2006. It is used to provide interoperability between digital content creation applications.

GitHub: An online service for version control and code-sharing.

GLB file format: Also called GL Transmission Format Binary file (.glb), this is a 3D file format specification, see <https://docs.fileformat.com/3d/glb>.

Human Reference Atlas (HRA): The HRA is a comprehensive, high-resolution, three-dimensional atlas of all the cells in the healthy human body. The HRA provides standard terminologies and data structures for describing specimens, biological structures, and spatial positions linked to existing ontologies.

OBJ file format: 3D file format specification, see <https://www.cs.cmu.edu/~mbz/personal/graphics/obj.html>.

Registration User Interface (RUI): Registration user interface developed by MC-IU to 3D register human tissue, available via HuBMAP Data Ingest Portal and <https://hubmapconsortium.github.io/ccf-ui/rui/>.

Standard Operating Procedures (SOPs): SOPs are issued to specifically instruct team members in areas of responsibility, procedural steps, appropriate specifications and required records. SOPs outline procedures, which must be followed to support the reproducibility of scientific research. Procedures can take the form of a narrative, a flow chart, a process map, computer screen printouts or combination of all or any other suitable form, however must be written in appropriate, effective grammatical style (e.g., plain English).

United File: The United File is a GLB 3D object that contains all the modeled organs in the Human Reference Atlas. It is hosted on GitHub and used in the Exploration User Interface to display registered tissue blocks. The United file is thus a compound file with all 3D organ objects combined.

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