



Human BioMolecular Atlas Program (HuBMAP): 3D Human Reference Atlas construction and usage

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Supplemental Tables

Supplemental Table 1: Experimental Data, HRA Data and Cell Type Annotation by Organ. Number of sc/snRNA-seq datasets per organ vs. number of 3D reference organs plus anatomical structure and unique cell types in ASCT+B tables vs. number of cell types that different cell type annotation tools can assign across all annotation levels.

Organ	Datasets with H5AD File	ASCT+B and 3D Reference Organs			Cell Type Annotation Tools		
		#AS in 3D (Male+Female)	#AS	#CT	Azimuth	CellTypist	popV
blood	2,501	none	1	29	41	26	18
blood vasculature	3	244	1,054	10	0	0	14
bone marrow	131	none	1	47	43	39	14
brain*	656	210	188	625	0	0	0
brain > motor cortex*	Part of 656	4**	1	139	20	0	0
brain > hippocampus*	Part of 656	12**	4	45	0	20	0
breast/mammary gland	1	18	3	10	0	0	14
eye	192	96	39	55	0	0	27
heart	254	34	52	28	25	49	6
kidney	207	116	61	70	58	34	0
large intestine	140	22	54	58	0	0	16
liver	70	46	17	30	25	35	12
lung	531	141	54	74	78	71	36
lymph node***	16	16	34	45	0	28	22
pancreas	14	11	31	30	11	9	14
prostate gland	34	18	13	19	0	0	13
skin of body	53	2	15	35	0	23	21
small intestine	177	23	39	34	0	0	16
spleen	39	12	37	59	0	32	22
thymus	47	6	18	50	0	0	21
trachea	29	8	20	17	0	0	18
urinary bladder	0	15	16	15	0	0	14
uterus	23	10	61	18	0	0	13
Total (sum, not unique)	5,118	1,064	1,810	1,542	301	366	331

* Azimuth and CellTypist focus on the motor cortex and hippocampus, respectively. The 3D Reference Object and ASCT+B Table of the brain in the HRA focus on the entire organ.

** Primary motor cortex is part of the precentral gyrus and hippocampus has three (head, body, tail) 3D reference objects in each hemisphere in male and female.

*** The 3D lymph node is generic and was placed in the mesenteric region as all HuBMAP data is from that region.

Supplemental Table 2: Primary and Secondary HRA Data Repositories. The rightmost column shows data used in: HuBMAP Data Portal (H), HRA Portal (A), demonstration previews (P), and external code (E).

Object Type	Primary data repository	Data mirrors	Type
UBKG	https://ubkg.docs.xconsortia.org		H
HuBMAP Ontology API	https://smart-api.info/ui/d10ff85265d8b749fbe3ad7b51d0bf0a		H
CCF.OWL v2.3.0	https://lod.humanatlas.io/graph/ccf	https://www.ebi.ac.uk/ols/ontologies/ccf https://bioportal.bioontology.org/ontologies/CCF https://ontobee.org/ontology/CCFO	A
HRA KG	https://lod.humanatlas.io		A
HRA ASCT+B Tables	https://humanatlas.io/asctb-tables	https://commons.datacite.org/repositories/8orcvek https://datasetsearch.research.google.com/search?query=HuBMAP	A
HRA OMAPs	https://humanatlas.io/omap	https://cdn.humanatlas.io/hra-releases	A
AVRs	https://avr.hubmapconsortium.org	https://cdn.humanatlas.io/hra-releases	H
HRA 2D references	https://humanatlas.io/2d-ftu-illustrations	https://cdn.humanatlas.io/hra-releases	A
HRA 3D references	https://humanatlas.io/3d-reference-library	https://cdn.humanatlas.io/hra-releases NIH3D: https://3d.nih.gov/collections/hra EMBL: https://www.ebi.ac.uk/ols4/ontologies/ccf , e.g., brain is at http://purl.obolibrary.org/obo/UBERON_0000955	A
HRA VCCF	https://humanatlas.io/vccf	https://cdn.humanatlas.io/hra-releases	A
Azimuth	https://azimuth.hubmapconsortium.org		H
CellTypist	https://www.celltypist.org/models	https://pypi.org/project/celltypist/	E
popV	https://github.com/YosefLab/PopV	https://zenodo.org/records/7580707	E
FTU Segmentation training data	HuBMAP Collection doi:10.35079/hbm925.sgxl.596	https://zenodo.org/records/7729610 https://zenodo.org/records/7545745	H
“Hierarchical cell type populations within FTUs” data	https://portal.hubmapconsortium.org/browse/publication/77ab35880329b5932380104aa58795a4	https://doi.org/10.5061/dryad.pk0p2ngrf https://doi.org/10.5061/dryad.76hdr7t1p (Part 1) https://doi.org/10.5061/dryad.gmsbcc2sq (Part 2)	P
“Perivascular immune cells in lung” data	https://drive.google.com/drive/folders/1SPbN6_0C-mVWbfE5r2QTVZLMxBjiEKnl?usp=sharing		P

Supplemental Table 3: HRA Code Repositories. The rightmost column shows data used in: HuBMAP Data Portal (H), HRA Portal (A), demonstration previews (P), and external code (E).

Code Type and Name	GitHub Repository	Type
Data processing		
QuPath Manual Segmentation Tool (0.5.1)	https://qupath.github.io	E
Azimuth (0.4.6)	https://github.com/hubmapconsortium/azimuth-annotate	H
CellTypist (1.6)	https://github.com/Teichlab/celltypist	E
popV (0.9)	https://github.com/YosefLab/PopV	E
Van Valen Tools	https://github.com/vanvalenlab?q=deep	E
Van Valen's Cell Type Annotation (HuBMAP internal)	https://github.com/vanvalenlab/deepcell-types	E
HuBMAP sc/snRNA-seq and CODEX pipelines	https://github.com/hubmapconsortium/salmon-rnaseq https://github.com/hubmapconsortium/codex-pipeline	H
3DCellComposer (1.2)	https://github.com/murphygroup/3DCellComposer	P
CytoSpatio (1.0.0)	https://github.com/murphygroup/CytoSpatio	P
PanelOptimizer	https://github.com/murphygroup/CODEXPanelOptimization	P
CellSegmentationEvaluator (1.5)	https://github.com/murphygroup/CellSegmentationEvaluator	H
FTU segmentation via Kaggle #1-2 Competitions	https://github.com/hubmapconsortium/pas-ftu-segmentation-pipeline https://github.com/cns-iu/hra-multiftu-segmentation-pipeline	H
Cell Neighborhood Analysis	https://github.com/HickeyLab/Hierarchical-Tissue-Unit-Annotation	P
STELLAR	https://github.com/snap-stanford/stellar	P
STalign (1.0.1)	https://github.com/JEFworks-Lab/STalign	P
HRA Dataset Graphs Library (1.0)	https://github.com/hubmapconsortium/hra-rui-locations-processor	A
HRA Digital Object Processor	https://github.com/hubmapconsortium/hra-do-processor	A
HRA Workflows	https://github.com/hubmapconsortium/hra-workflows	A
HRA Workflows Runner	https://github.com/hubmapconsortium/hra-workflows-runner	A
HRA Multi-LOD Renderer (1.0.0)	https://github.com/cns-iu/hra-multi-lod	A
HRA AMAP	https://github.com/cns-iu/hra-amap	P
VCCF Visualizations	https://github.com/cns-iu/hra-vccf-cell-distance-visualizations	P
Vascular distance for 3D reconstruction of skin and spatial mapping of immune cell density	https://github.com/hubmapconsortium/vccf-visualization-2022	P
EBI ASCT+B Table Validation (2024-07-11)	https://github.com/hubmapconsortium/ccf-validation-tools	A
HRA 3D Reference Organ Validation	https://github.com/hubmapconsortium/hra-ref-organ-validation	A
API for data access		
HuBMAP Cells API	https://github.com/hubmapconsortium/cross_modality_query	H

HuBMAP Cells API (Python Client) (0.0.11)	https://github.com/hubmapconsortium/hubmap-api-py-client	H
HuBMAP Entity API (2.3.15)	https://github.com/hubmapconsortium/entity-api	H
HuBMAP Ingest API (2.3.17)	https://github.com/hubmapconsortium/ingest-api	H
HuBMAP Search API (3.3.12)	https://github.com/hubmapconsortium/search-api	H
API and SPARQL queries using the HRA-KG	https://github.com/hubmapconsortium/ccf-grlc	A
Ontology API for HuBMAP and SenNet applications (2.0.3) (extends UBKG API [2.1.4])	https://github.com/x-atlas-consortia/hs-ontology-api https://github.com/x-atlas-consortia/ubkg-api	H
HuBMAP UUID API (2.4.3)	https://github.com/x-atlas-consortia/uuid-api	H
HRA API (0.8.0)	https://github.com/x-atlas-consortia/hra-api	A
Tissue Block Annotation (1.0.0)	https://github.com/hubmapconsortium/hra-tissue-block-annotation	A
User interfaces		
HuBMAP Consortium	https://hubmapconsortium.org	H
HuBMAP Data Portal (0.102.5)	https://github.com/hubmapconsortium/portal-ui , https://portal.hubmapconsortium.org	H
HRA Portal	https://github.com/hubmapconsortium/hra-ui/tree/main/apps/humanatlas.io	A
Vitessce (3.4.6)	https://github.com/vitessce/vitessce	H
ASCT+B Reporter (2.8)	https://github.com/hubmapconsortium/hra-ui	A
EUI (3.8)	https://github.com/hubmapconsortium/hra-ui	H
RUI (3.8)	https://github.com/hubmapconsortium/hra-ui	H
FTU Explorer (0.5.0)	https://github.com/hubmapconsortium/hra-ui	P
HRA Organ Gallery (0.11.2)	https://github.com/cns-iu/hra-organ-gallery-in-vr	P
HRA Data Dashboard (0.1.0)	https://github.com/hubmapconsortium/hra-data-dashboard	P
VCCF Cell Distance Visualizations (0.1.0)	https://github.com/hubmapconsortium/hra-ui	P
Learn about the HRA through scrollytelling!	https://github.com/cns-iu/hra-scrollytelling	P
HRA Pilot Previews	https://github.com/hubmapconsortium/hra-previews	P
Data / Ontologies		
HuBMAP Ontology (CCF v1.x)	https://github.com/hubmapconsortium/hubmap-ontology	
Human Reference Atlas Knowledge Graph (HRA-KG)	https://github.com/hubmapconsortium/hra-kg	
HRA Vasculature CCF	https://github.com/hubmapconsortium/hra-vccf	P
HRA Vocabulary (2.5.10)	https://github.com/hubmapconsortium/hra-vocab	P
HRAlit (0.5)	https://github.com/cns-iu/hra-literature	P