Common Coordinates and User Interfaces for Registering Human Tissue Data at Multiple Scales

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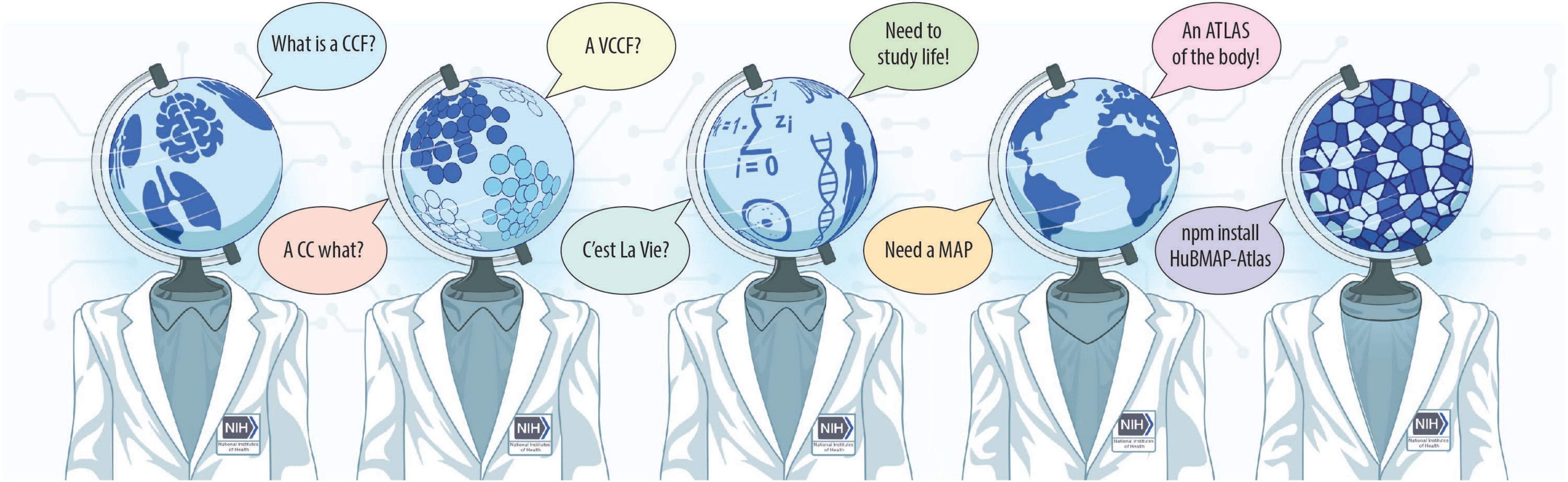

What is a CCF?
A CC what?
A VCCF?
C'est La Vie?
Need to study life!
Need a MAP
An ATLAS of the body!
npm install HuBMAP-Atlas
NIH

What is a CCF?

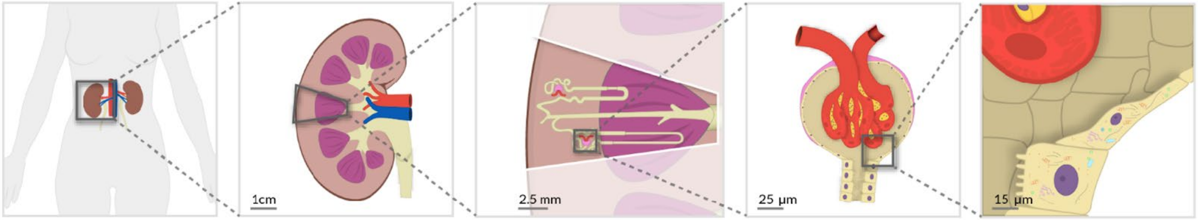
The Common Coordinate System (CCF) consists of ontologies and reference object libraries, computer software, e.g., user interfaces, and training materials that

- enable biomedical experts to semantically annotate tissue samples and to precisely describe their locations in the human body ("registration"),
- align multi-modal tissue data extracted from different individuals to a reference coordinate system ("mapping") and,
- provide tools for searching and browsing HuBMAP data at multiple levels, from the whole body down to single cells ("exploration").

CCF Requirements

The CCF must capture major **anatomical structures, cell types, and biomarkers** (ASCT+B) and their interrelations across **multiple levels of resolution** .

It should be **semantically explicit** (using existing ontologies, e.g., Uberon, CL) and **spatially explicit** (e.g., using 3D reference organs for registration and exploration).



Body
- Body
- Kidney (Left, Right)
- Aorta
- Renal artery
- Renal vein
- Ureter

Organ
- Renal capsule
- Renal pyramid
- Renal cortex
- Renal medulla
- Renal calyx
- Renal pelvis

Functional Tissue Unit
- Nephron
- Renal corpuscle
- Proximal convoluted tubule
- Loop of Henle
- Distal convoluted tubule
- Connecting tubule
- Collecting duct

FTU Sub-structure(s)
- Bowman's capsule
- Glomerulus
- Efferent arteriole
- Afferent arteriole

Cellular
- Parietal epithelial cell
- Capillary endothelial cell
- Mesangial cell
- Podocyte

ASCT Tables

Anatomical Structures and Cell Types (ASCT) tables aim to capture the partonomy of anatomical structures, cell types, and major biomarkers (genomic, epigenomic, transcriptomic, proteomic, lipidomic, and metabolomic).

Structure/Region	**Substructure/Subregion**	**Cell Type**	**Subset of Marker Genes**
Renal Corpuscle	Bowman's Capsule	Parietal epithelial cell	*CRB2*, CLDN1**
	Glomerulus	Podocyte	*NPHS2*, PODXL*, NPHS1**
		Capillary Endothelial Cell	*EHD3*, EMCN*, HECW2*, FLT1*, AQP1**
		Mesangial Cell	*POSTN*, PIEZO2*, ROBO1*, ITGA8**

Partial ASCT Table from

- El-Achkar et al. A Multimodal and Integrated Approach to Interrogate Human Kidney Biopsies with Rigor and Reproducibility: The Kidney Precision Medicine Project. bioRxiv. 2019; 828665. doi:10.1101/828665

Table 3: Cell types and associated markers from KPMP Pilot 1 transcriptomic studies. Asterisk denotes genes detected by more than one technology. *Italics*, genes detected by a single technology.

Structure/Region	Sub structure/Sub region	Cell Type	Abbreviation	Subset of Marker Genes	Pertinent negatives/comments
Renal Corpuscle	Bowman's Capsule	Parietal epithelial cell	PEC	CRB2*, CLDN1*	
	Glomerulus	Podocyte	POD	NPHS2*, PODXL*, NPHS1*	
		Capillary Endothelial Cell	GC-EC	EHD3*, EMCN*, HECW2*, FLT1*, AQP1*	
		Mesangial Cell	MC	POSTN*, PIEZO2*, ROBO1*, ITGA8*	
Tubules	Proximal Tubule	Proximal Tubule Epithelial Cell (general)	PT	CUBN*, LRP2*, SLC13A1*, ALDOB*, GATM*	
		Proximal Convoluted Tubule Epithelial Cell Segment 1	PT-S1	SLC5A2*, SLC5A12*	There is overlap among the segments
		Proximal Tubule Epithelial Cell Segment 2	PT-S2	SLC22A6*	
		Proximal Tubule Cell Epithelial Segment 3	PT-S3	PDZK1IP1*, MT1G*	
	Loop of Henle, Thin Limb	Descending Thin Limb Cell (general)	DTL	CRYAB*, VCAM1*, AQP1*, SPP1*	CLDN10 low
		Ascending Thin Limb Cell (general)	ATL	CRYAB*, TACSTD2*, CLDN3*	AQP1 low to none
	Loop of Henle, Thick Limb	Thick Ascending Limb Cell (general)	TAL	SLC12A1*, UMOD*	SLC12A3 low to none
		Cortex-TAL cell	C-TAL	SLC12A1*, UMOD*	
		Medulla-TAL cell	M-TAL	SLC12A1*, UMOD*	
		TAL-Macula Densa cell	TAL-MD	NOS1*, SLC12A1*	
	Distal Convolution	Distal Convoluted Tubule Cell (general)	DCT	SLC12A3*, TRPM6*	
		DCT type 1 cell	DCT-1	SLC12A3*, TRPM6	SLC8A1, HSD11B2 (low to none)
		DCT type 2 cell	DCT-2	SLC12A3*, SLC8A1*, HSD11B2	Has CNT and DCT signature
	Connecting Tubule	Connecting Tubule Cell (general)	CNT	SLC8A1*, CALB1, TRPV5	
		CNT-Principal Cell	CNT-PC	SLC8A1*, AQP2*, SCNN1G*	SLC12A3 low to none. IC or PC without SLC8A1 could be in the CNT structure
		CNT-Intercalated Cell	CNT-IC	SLC8A1*, CA2, ATP6VOD2*	
		CNT-IC-A cell	CNT-IC-A	SLC8A1*, SLC4A1*, SLC26A7*	
		CNT-IC-B cell	CNT-IC-B	SLC8A1*, SLC26A4*, SLC4A9*	
	Collecting Duct	Collecting duct (general) cell	CD	GATA3*	GATA3 may be in subpopulation of DCT, CNT and vSMC/P. SLC8A1, CALB1, TRPV5
		CD-PC (general)	CD-PC	AQP2*, AQP3*, FXYD4*, SCNN1G*, GATA3*	
		C-CD-PC	C-CD-PC		
		M-CD-PC	M-CD-PC		
		Outer medulla-CD-PC	OM-CD-PC		
		Inner Medulla-CD cell	IM-CD	AQP2*, SLC14A2	
		Transitional PC-IC cell	tPC-IC	FXYD4*, SLC4A9*/SLC26A7*	(low to none); Low to No CALCA and KIT in C-CD-IC-A. It may not be possible to assign IC or PC to CNT or CD structures without regional information of their source.
		CD-IC (general) cell	CD-IC	CA2, ATP6VOD2*	
		CD-IC-A (general) cell	CD-IC-A	SLC4A1, SLC26A7*, TMEM213*	
		C-CD-IC-A cell	C-CD-IC-A	SLC26A7*, SLC4A1*	
		M-CD-IC-A cell	M-CD-IC-A	SLC26A7*, SLC4A1, KIT*, CALCA	
		CD-IC-B (general) cell	CD-IC-B	SLC4A9*, SLC26A4*	
		C-CD-IC-B cell	C-CD-IC-B		
		M-CD-IC-B cell	M-CD-IC-B		
Vessels	Endothelial Cells (non-glomerular)	Endothelial Cell (general)	EC	EMCN*, PECAM1*, FLT1*	
		EC-Afferent/Efferent Arteriole	EC-AEA	SERPINE2*, TM4SF1*	likely PALMD
		EC-Peritubular capillaries	EC-PTC	PLVAP*	
		EC-Descending Vasa Recta	EC-DVR	TM4SF1*, PALMD	
		EC-Ascending Vasa Recta	EC-AVR	DNASEIL3*	low to none
		EC-Lymphatics	EC-LYM	MMRN1*, PROX1	
Structure/Region	**Sub structure/Sub region**	**Cell Type**	**Abbreviation**	**Subset of Marker Genes**	**Pertinent negatives/comments**
Interstitium	Stroma (non-glomerular)	Vascular Smooth Muscle/Pericyte (general)	vSMC/P	TAGLN*, ACTA2*, MYH11*, NTRK3, MCAM	
		vSMC/P-Renin	vSMC/P-REN	REN	
		Fibroblast	FIB	DCN*, ZEB2, C7, LUM	
	Immune	Macrophages-Resident	MAC-R	CD163*, IL7R*	
		Macrophage	MAC	S100A9	
		Natural Killer Cell	NKC	NKG7	
		Dendritic Cell	DC	APOE	
		Monocyte	MON	C1QA, HLA-DRA	
		T lymphocyte (general)	T	CD3	
		T Cytotoxic	T-CYT	GZMA	
		B lymphocyte	B	IGJ	

El-Achkar et al. A Multimodal and Integrated Approach to Interrogate Human Kidney Biopsies with Rigor and Reproducibility: The Kidney Precision Medicine Project. bioRxiv. 2019; 828665. doi:10.1101/828665

ASCT Table Meetings

Meetings take place monthly to

- Review and approve tables.
- Formalize and unify table design language.
- Discuss table usage.

We are working on

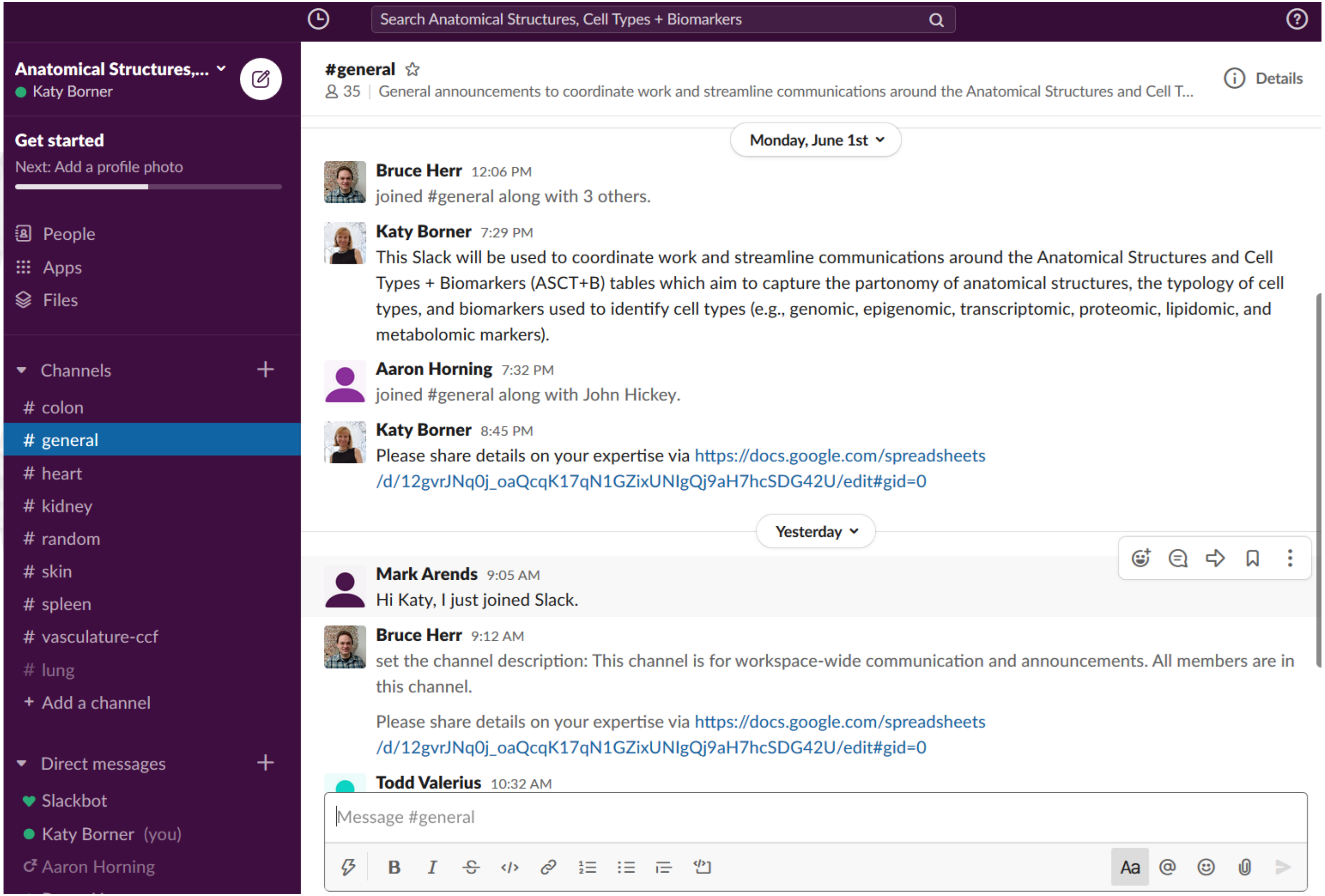
- Converting tables into machine readable formats.
- Compare tables against Uberon, CL, and other ontologies.
- Compare tables against cell types identified in harmonized HuBMAP data and data generated by other efforts.

Experts are welcome to register.

ASCT Table Design

The CCF Session at the NIH-HCA meeting—co-organized with Peter Hunter (SPARC) and James Gee (BICCN)—brought together experts across consortia.

In follow up meetings, 10 ASCT tables have been created via collaborations across consortia. Ontology experts, including Chris Mungall and Mark Musen, provided expert comments.



asct-b.slack.com

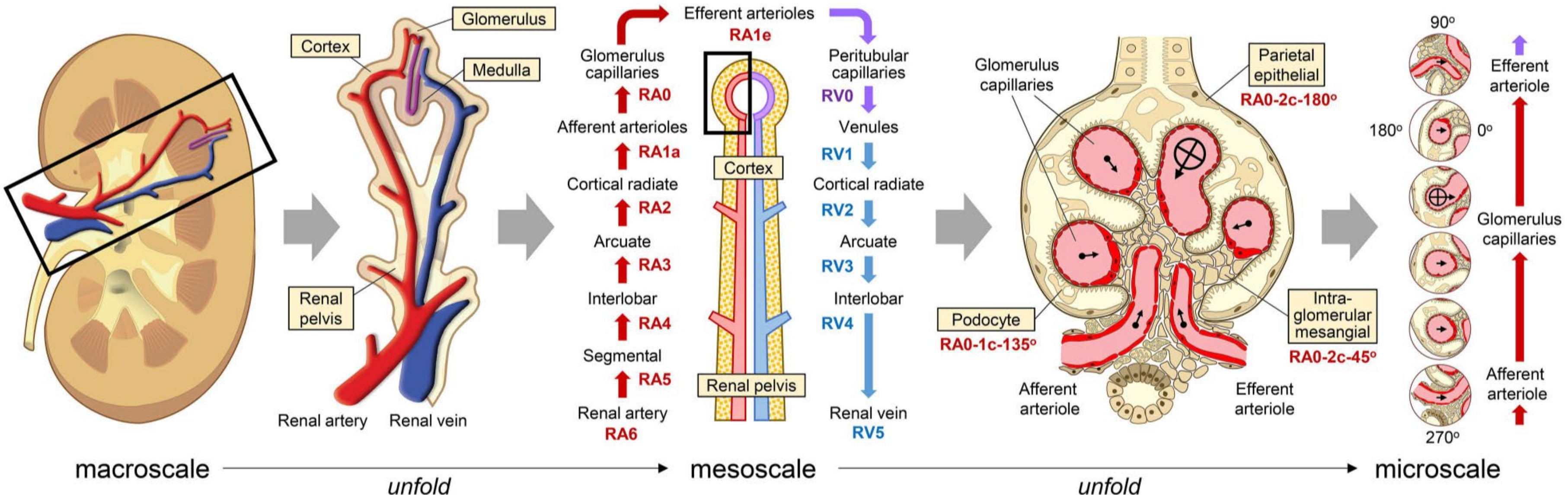
	HuBMAP	RBK	KPMP	SPARC	LungMAP	HTAN	HCA	GUDMAP	Gut Cell Atlas	BICCN	Allen Brain	TCGA	Wellcome	MRC	H2020	GTEx	Total
Kidney	1	1	1	0	0	0	1	1	0	0	0	1	1	1	0	1	9
Liver	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	3
Spleen	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	4
Heart	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	4
Lung	1	0	0	1	1	1	1	0	0	0	0	1	1	1	1	1	10
L intestine/Colon	1	0	0	1	0	1	1	0	1	0	0	1	0	0	0	1	7
S intestine	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Bladder	1	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	5
Ureters	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Thymus	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Lymph nodes	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
mediastinal lymph node	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Eye	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	3
Brain	0	0	0	0	0	0	1	0	0	1	1	1	0	0	1	1	6
Brain stem	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Cerebellum	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	3
Spinal cord	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2
Pancreas	0	0	0	0	0	1	1	0	0	0	0	1	0	0	1	1	5
Breast	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	1	5
Skin	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	3
Pediatric systems	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	2
Ovaries	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Testes	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Cervix	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Uterus	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	5
Blood	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	2
Bone	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Placenta	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Decidua	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Embryo	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
esophagus	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	3
hematopoietic system	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2
immune system bulk	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Stomach	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	3
Thyroid	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Prostate	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	3
Adrenal gland	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	3
Totals	11	1	1	7	1	6	21	4	1	2	2	20	7	5	4	21	114

Example: Converting tables into machine readable formats– Kidney vasculature

Vasculature	renal atery [L/R]				Endothelial Cell (general)	EC	*EMCN*, PECAM1*, FLT1**
		segmental arteries [superior, inferior, anterior, posterior]					
		interlobar aterties					
		arcuate aterties					
		cortical radiate ateries {cortex}					
			afferent arterioles {nephron}		EC-Afferent/Efferent Arteriole	EC-AEA	*SERPINE2*, TM4SF1**
				glomerulus capillaries {glomerulus}	Capillary Endothelial Cell	GC-EC	*EHD3*, EMCN*, HECW2*, FLT1*, AQP1**
			efferent arterioles {nephron}		EC-Afferent/Efferent Arteriole	EC-AEA	*SERPINE2*, TM4SF1**
				peritubular capillaries	EC-Peritubular capillaries	EC-PTC	*PLVAP**
				descending vasa recta	EC-Descending Vasa Recta	EC-DVR	*TM4SF1*, PALMD*
				ascending vasa recta	EC-Ascending Vasa Recta	EC-AVR	*DNASEIL3**
	renal vein [L/R]	cortical radiate veins {cortex}	venules		Endothelial Cell (general)	EC	*EMCN*, PECAM1*, FLT1**
		arcuate veins					
		interlobar veins					

Vasculature	renal artery [L/R]				Endothelial Cell (general)	EC	EMCN*, PECAM1*, FLT1*
Vasculature	renal artery [L/R]	segmental arteries [superior, inferior, anterior, posterior]			Endothelial Cell (general)	EC	EMCN*, PECAM1*, FLT1*
Vasculature	renal artery [L/R]	interlobar arteries			Endothelial Cell (general)	EC	EMCN*, PECAM1*, FLT1*
Vasculature	renal artery [L/R]	arcuate arteries			Endothelial Cell (general)	EC	EMCN*, PECAM1*, FLT1*
Vasculature	renal artery [L/R]	cortical radiate arteries {cortex}			Endothelial Cell (general)	EC	EMCN*, PECAM1*, FLT1*
Vasculature	renal artery [L/R]	cortical radiate arteries {cortex}	afferent arterioles {nephron}		EC-Afferent/Efferent Arteriole	EC-AEA	SERPINE2*, TM4SF1*
Vasculature	renal artery [L/R]	cortical radiate arteries {cortex}	afferent arterioles {nephron}	glomerulus capillaries {glomerulus}	Capillary Endothelial Cell	GC-EC	EHD3*, EMCN*, HECW2*, FLT1*, AQP1*
Vasculature	renal artery [L/R]	cortical radiate arteries {cortex}	efferent arterioles {nephron}		EC-Afferent/Efferent Arteriole	EC-AEA	SERPINE2*, TM4SF1*
Vasculature	renal artery [L/R]	cortical radiate arteries {cortex}	efferent arterioles {nephron}	peritubular capillaries	EC-Peritubular capillaries	EC-PTC	PLVAP*
Vasculature	renal artery [L/R]	cortical radiate arteries {cortex}	efferent arterioles {nephron}	descending vasa recta	EC-Descending Vasa Recta	EC-DVR	TM4SF1*, PALMD
Vasculature	renal artery [L/R]	cortical radiate arteries {cortex}	efferent arterioles {nephron}	ascending vasa recta	EC-Ascending Vasa Recta	EC-AVR	DNASEIL3*
Vasculature	renal vein [L/R]	cortical radiate veins {cortex}	venules {nephron}		Endothelial Cell (general)	EC	EMCN*, PECAM1*, FLT1*
Vasculature	renal vein [L/R]	cortical radiate veins {cortex}			Endothelial Cell (general)	EC	EMCN*, PECAM1*, FLT1*
Vasculature	renal vein [L/R]	arcuate veins			Endothelial Cell (general)	EC	EMCN*, PECAM1*, FLT1*
Vasculature	renal vein [L/R]	interlobar veins			Endothelial Cell (general)	EC	EMCN*, PECAM1*, FLT1*

Capturing vasculature details is critically important for a vasculature based CCF



Weber, Griffin M, Yingnan Ju, and Katy Börner. 2020. "Considerations for Using the Vasculature as a Coordinate System to Map All the Cells in the Human Body". *Frontiers in Cardiovascular Medicine* 7 (29): doi: 10.3389/fcvm.2020.00029.

ASCT Table Usage

ASCT tables guide **CCF Ontology** and **3D Reference Object Library** design that semantically name and spatially place tissue data from different individuals into one CCF (i.e., mapping).

ASCT Table

Structure/Region	Sub structure/Sub region	Cell Type
Renal Corpuscle	Bowman's Capsule	Parietal epithelial Cell
	Glomerulus	Podocyte
		Capillary Endothelial Cell
		Mesangial Cell
	Proximal Tubule	Proximal Tubule Epithelial Cell (general)
		Proximal Convoluted Tubule Epithelial Cell Segment 1
		Proximal Tubule Epithelial Cell Segment 2
		Proximal Tubule Epithelial Cell Segment 2
	Loop of Henle, Thin Limb	Descending Thin Limb Cell (general)
		Ascending Thin Limb Cell (general)
	Loop of Henle, Thick Limb	Thick Ascending Limb Cell (general)
		Cortex-TAL Cell
		Medulla-TAL Cell
		TAL-Macula Densa Cell
	Distal Convolution	Distal Convoluted Tubule Cell (general)
		DCT Type 1 Cell
		DCT Type 2 Cell
	Connecting Tubule	Connecting Tubule Cell (general)
		CNT-Principal Cell

Ontology

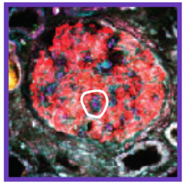
Anatomical Structures Partonomy

- kidney
  - kidney capsule
  - cortex of kidney
    - outer cortex of kidney
  - renal medulla

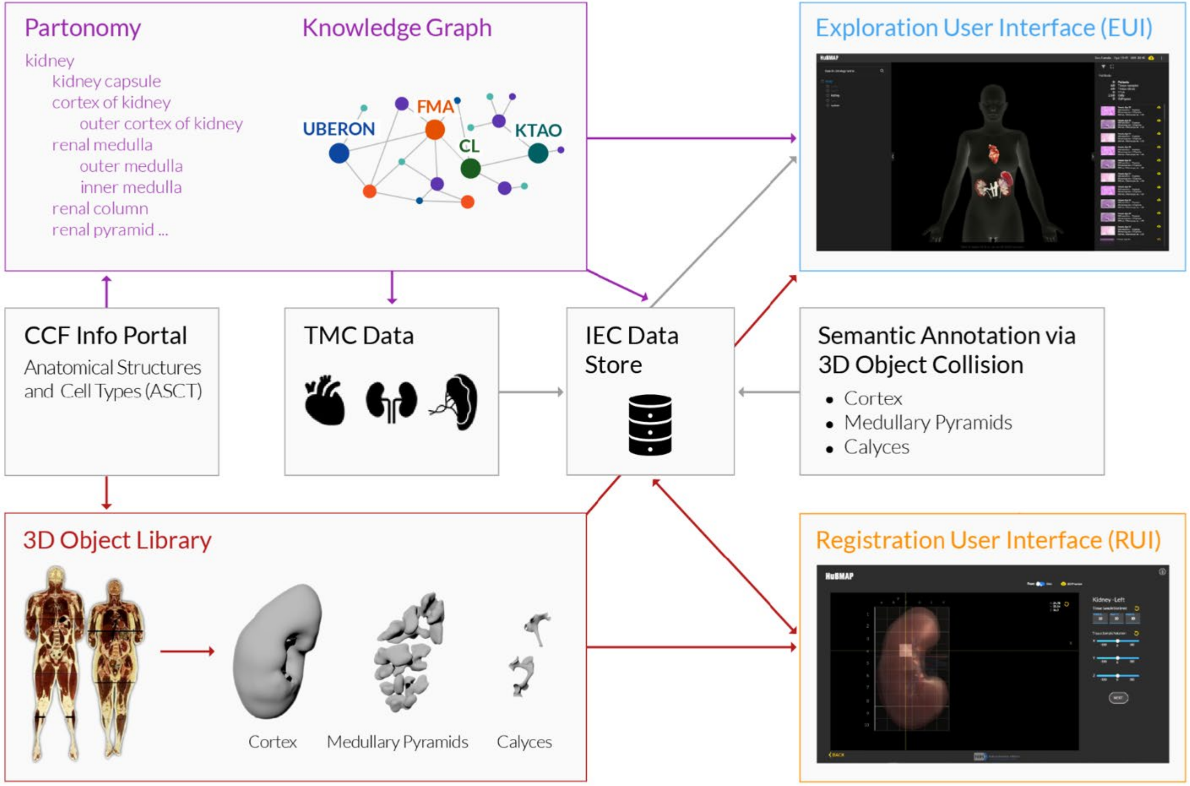
Cell Types Ontology

- connective tissue cell
  - pericyte cell
    - mesangial cell
      - extraglomerular mesangial cell
      - glomerular mesangial cell

3D Reference Object Library



Tissue blocks are registered into the CCF using the Registration User Interface (RUI), and they can be explored via the Exploration User Interface (EUI).



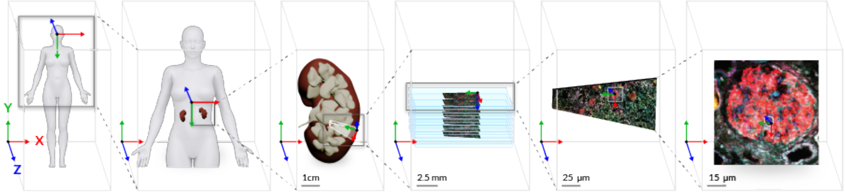
Data gathered in the ASCT tables is used in **Ontology Design** (top-left) and **3D Object Library** (bottom-left).

Two interfaces on right: **Registration User Interface (RUI)** supports semantic and spatial annotation of tissue data.

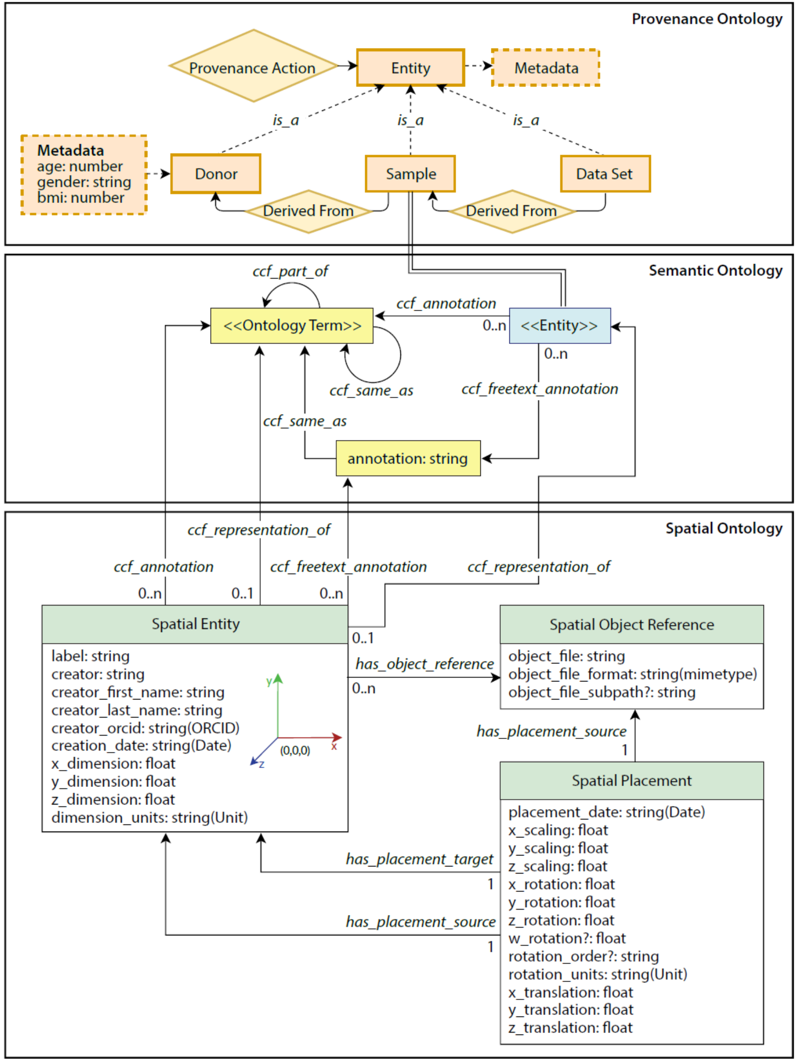
Exploration User Interface (EUI) supports semantic and spatial exploration of tissue data.

Construction and Usage of a Human Body Common Coordinate Framework Containing Provenance, Semantic, and Spatial Ontologies

Documentation of three CCF ontologies



Börner K, Quardokus EM, Herr, II BW, Cross LE, Record EG, Ju Y, Bueckle A, Sluka JP, Silverstein J, Browne K, Jain S, Wasserfall CH, Jorgensen ML, Spraggins JM, Patterson NH, Weber GM. 2020. Conceptualization, Construction, and Usage of a Human Body Common Coordinate Framework. In preparation.



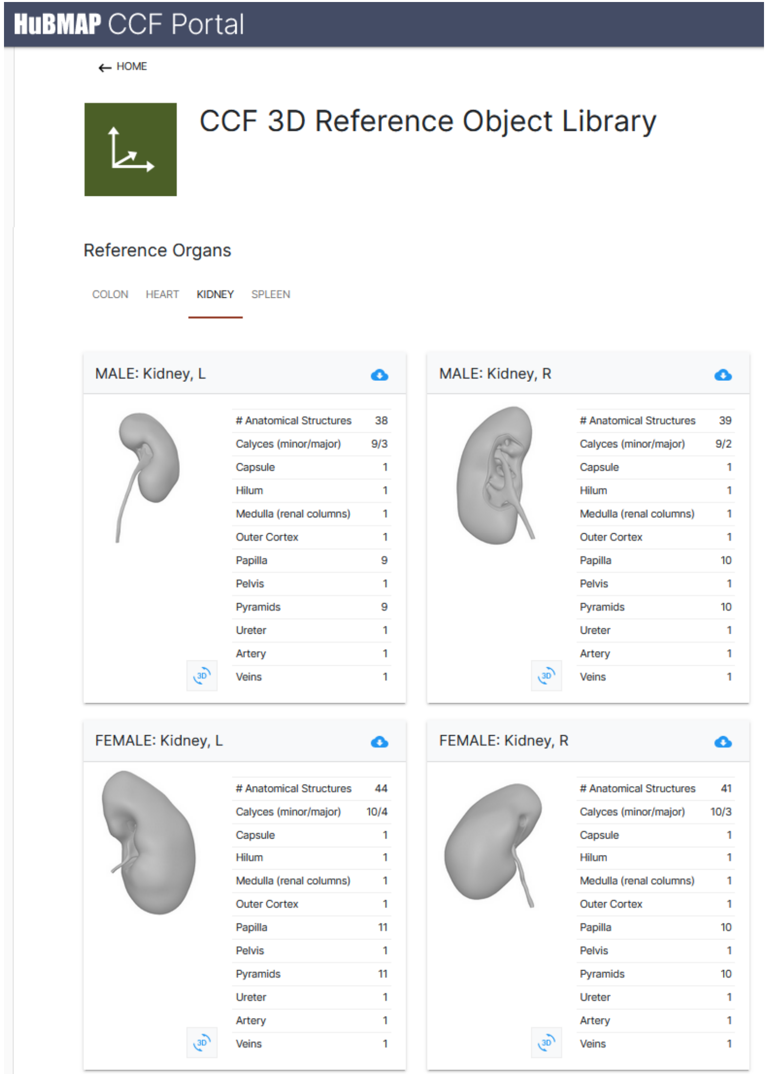
3D Object Library

The CCF 3D Reference Object Library provides anatomically correct reference organs. The organs are developed by a specialist in 3D medical illustration and approved by organ experts.

Initially, reference objects were created using data from the Visible Human male and female datasets provided by the National Library of Medicine.

For the 1st HuBMAP Portal Release, kidney and spleen reference organs are freely available in GLB format.

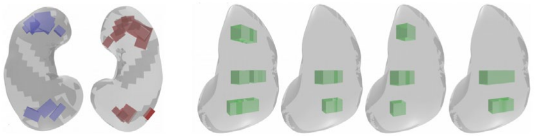
https://hubmapconsortium.github.io/ccf/pages/ccf-3d-reference-library.html

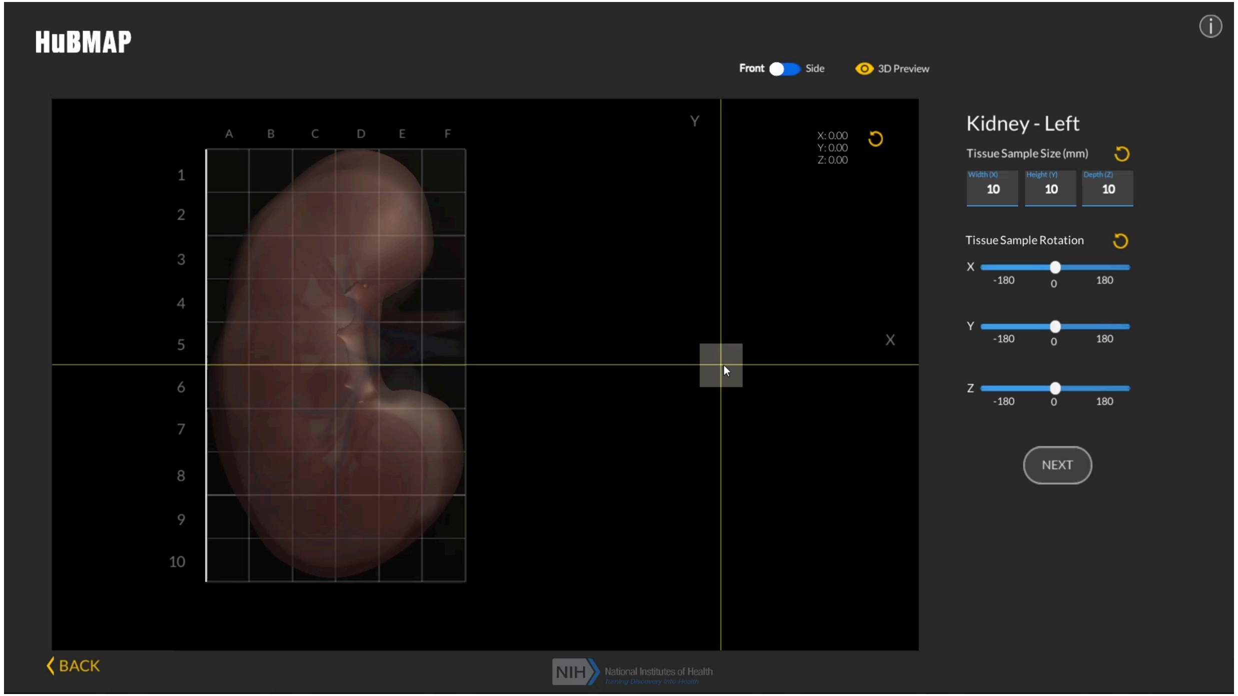


CCF Registration

Registration User Interface (RUI) is used to document the tissue extraction site by registering tissue blocks within a 3D reference organ.

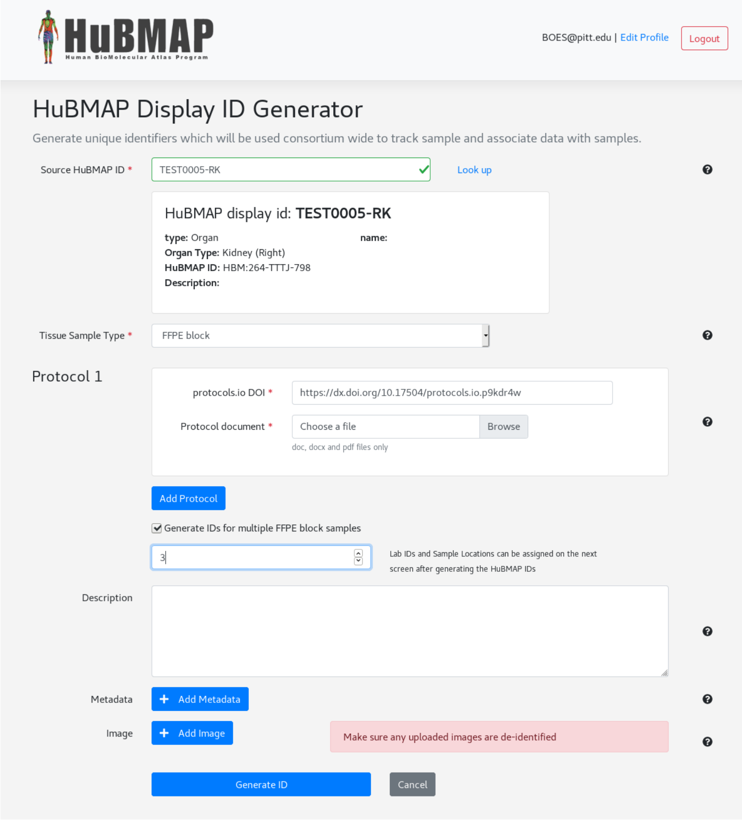
24 kidney and 24 spleen tissue blocks have been registered.

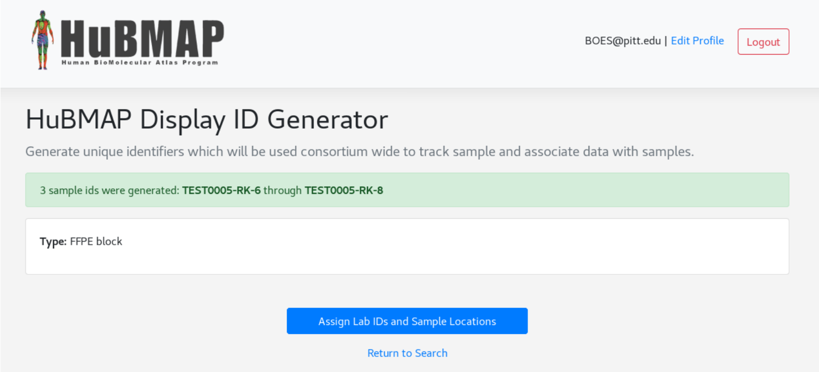


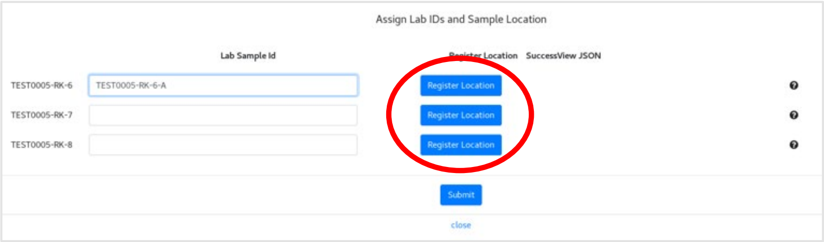


https://hubmapconsortium.github.io/ccf-3d-registration

1st Portal Release: Upload Portal





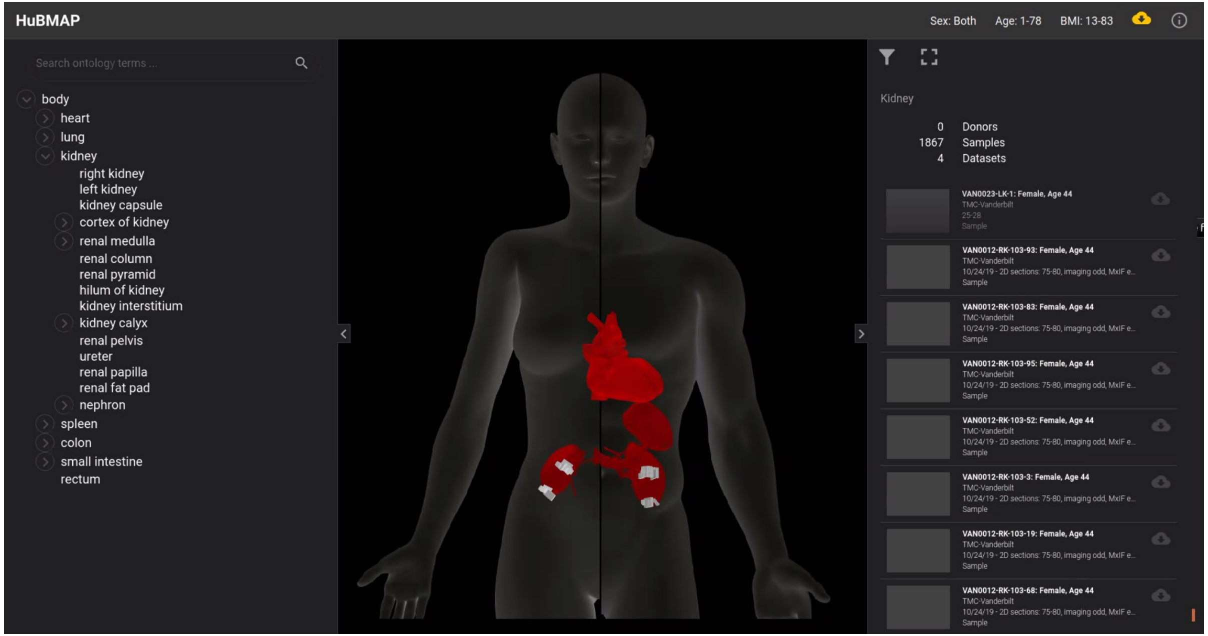


Thanks go to the IEC for providing screenshots

CCF Exploration

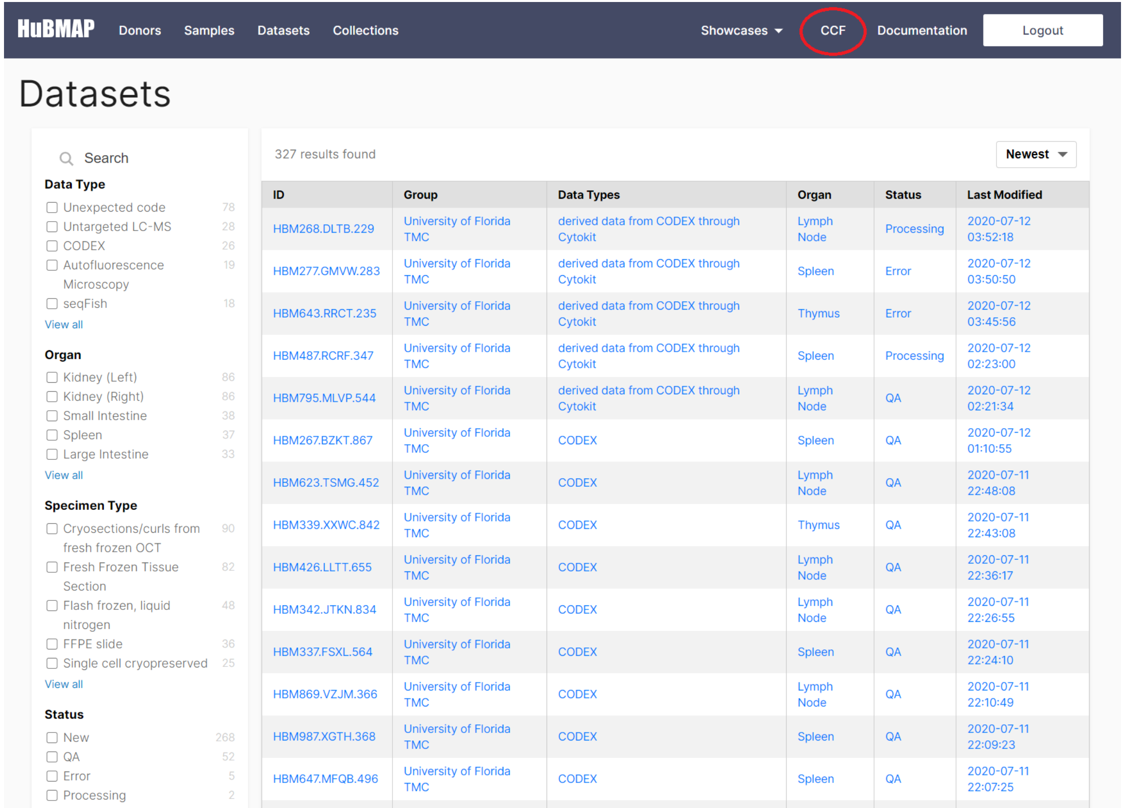
Exploration User Interface (EUI) supports exploring 2D/3D tissue samples across multiple scales using spatial, semantic, clinical, and provenance data.

Version 1.0.0 will features the HuBMAP Tissue Viewer



Version 1.0.0
Previous version is at https://hubmapconsortium.github.io/ccf-ui/

1st Portal Release



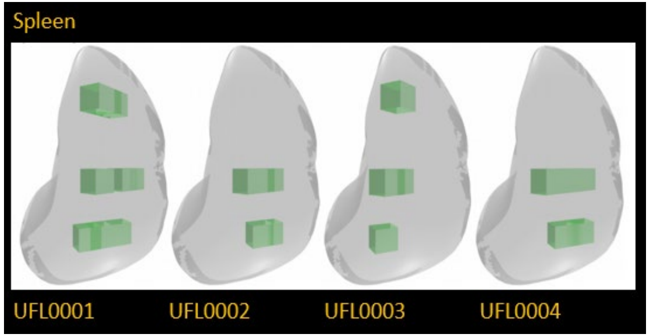
ID	Group	Data Types	Organ	Status	Last Modified
HBM268.DLTB.229	University of Florida TMC	derived data from CODEX through Cytokit	Lymph Node	Processing	2020-07-12 03:52:18
HBM277.GMVW.283	University of Florida TMC	derived data from CODEX through Cytokit	Spleen	Error	2020-07-12 03:50:50
HBM643.RRCT.235	University of Florida TMC	derived data from CODEX through Cytokit	Thymus	Error	2020-07-12 03:45:56
HBM487.RCRF.347	University of Florida TMC	derived data from CODEX through Cytokit	Spleen	Processing	2020-07-12 02:23:00
HBM795.MLVP.544	University of Florida TMC	derived data from CODEX through Cytokit	Lymph Node	QA	2020-07-12 02:21:34
HBM267.BZKT.867	University of Florida TMC	CODEX	Spleen	QA	2020-07-12 01:10:55
HBM623.TSMG.452	University of Florida TMC	CODEX	Lymph Node	QA	2020-07-11 22:48:08
HBM339.XXWC.842	University of Florida TMC	CODEX	Thymus	QA	2020-07-11 22:43:08
HBM426.LLTT.655	University of Florida TMC	CODEX	Lymph Node	QA	2020-07-11 22:36:17
HBM342.JTKN.834	University of Florida TMC	CODEX	Lymph Node	QA	2020-07-11 22:26:55
HBM337.FSXL.564	University of Florida TMC	CODEX	Spleen	QA	2020-07-11 22:24:10
HBM869.VZJM.366	University of Florida TMC	CODEX	Lymph Node	QA	2020-07-11 22:10:49
HBM987.XGTH.368	University of Florida TMC	CODEX	Spleen	QA	2020-07-11 22:09:23
HBM647.MFQB.496	University of Florida TMC	CODEX	Spleen	QA	2020-07-11 22:07:25

Early draft of HuBMAP interface.

Official first release is on Aug 4, 2020.

Exemplary Use Case

Compare cell types in ASCT tables with cell types identified in HuBMAP data.
Spleen example: Data from five tissue blocks from 4 spleens were harmonized.



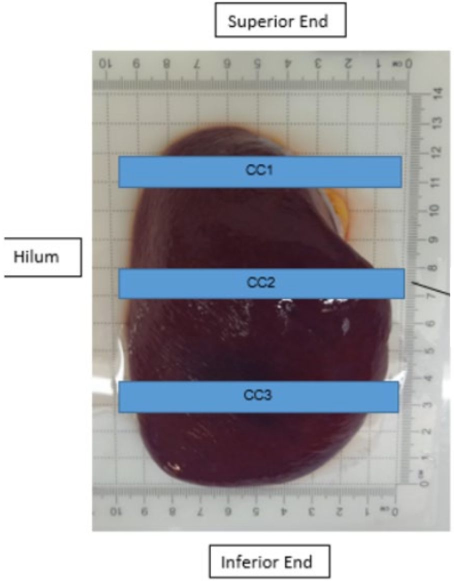
UFL0001-SP-2-8, cube 1
UFL0001-SP-3-4, cube 3

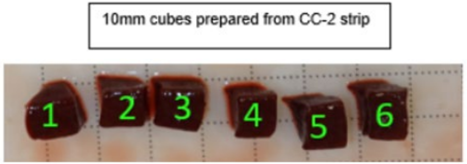
UFL0002-SP-2-2, cube 3

UFL0003-SP-2-2, cube 1

UFL0004-SP-2-1, cube 4

UFL0001	UFL0002	UFL0003	UFL0004
14 years Female	11m Male	18y Male	18y Male





Data provided by TMC-UFL

Exemplary Use Case

Seurat harmonization results: Cell counts and prediction scores

UFL0001-SP-3-4, cube 3		UFL0003-SP-2-2, cube 1		UFL0002-SP-2-2, cube 3		UFL0001-SP-2-8, cube 1		UFL0004-SP-2-1, cube 4	
HBM336.FWTN.636	**6010**	**HBM396.RPRR.624**	**9382**	**HBM472.NTNN.543**	**8738**	**HBM556.QMSM.776**	**5273**	**HBM984.GRBB.858**	**6328**
alpha-beta T cell	372	alpha-beta T cell	773	alpha-beta T cell	1497	alpha-beta T cell	515	alpha-beta T cell	878
B cell	1349	B cell	4463	B cell	6550	B cell	1407	B cell	2803
CD141-positive myeloid dendritic cell	55	CD141-positive myeloid dendritic cell	89	CD141-positive myeloid dendritic cell	19	CD141-positive myeloid dendritic cell	44	CD141-positive myeloid dendritic cell	17
CD14-positive monocyte	1851	CD14-positive monocyte	2242	CD14-positive monocyte	238	CD14-positive monocyte	872	CD14-positive monocyte	802
CD1c-positive myeloid dendritic cell	185	CD1c-positive myeloid dendritic cell	18			CD1c-positive myeloid dendritic cell	162	CD1c-positive myeloid dendritic cell	19
erythroblast	177	erythroblast	42	erythroblast	17	erythroblast	89		
gamma-delta T cell	151	gamma-delta T cell	57	gamma-delta T cell	30	gamma-delta T cell	176	gamma-delta T cell	1241
hematopoietic stem cell	73	hematopoietic stem cell	84	hematopoietic stem cell	56	hematopoietic stem cell	79	hematopoietic stem cell	30
low-quality	93	low-quality	71	low-quality	94	low-quality	129	low-quality	131
natural killer cell	594	natural killer cell	1307	natural killer cell	84	natural killer cell	460	natural killer cell	267
plasma cell	460	plasma cell	171	plasma cell	101	plasma cell	360	plasma cell	75
plasmablast	22	plasmablast	7	plasmablast	28	plasmablast	1	plasmablast	36
splenic endothelial cell	424	splenic endothelial cell	47	splenic endothelial cell	6	splenic endothelial cell	588	splenic endothelial cell	1
splenic fibroblast	15	splenic fibroblast	5	splenic fibroblast	6	splenic fibroblast	20	splenic fibroblast	2
splenic macrophage	189	splenic macrophage	6	splenic macrophage	12	splenic macrophage	371	splenic macrophage	26

HBM336.FWTN.636	1	HBM396.RPRR.624		HBM472.NTNN.543		HBM556.QMSM.776		HBM984.GRBB.858	
alpha-beta T cell	1	alpha-beta T cell	0.81531392	alpha-beta T cell	0.935717083	alpha-beta T cell	0.852839869	alpha-beta T cell	0.819379533
B cell	1	B cell	0.966724409	B cell	0.978509075	B cell	0.958394632	B cell	0.963947327
CD141-positive myeloid dendritic cell	1	CD141-positive myeloid dendritic cell	0.714928889	CD141-positive myeloid dendritic cell	0.870885148	CD141-positive myeloid dendritic cell	0.890455775	CD141-positive myeloid dendritic cell	0.615445273
CD14-positive monocyte	1	CD14-positive monocyte	0.940118127	CD14-positive monocyte	0.937989865	CD14-positive monocyte	0.938657155	CD14-positive monocyte	0.963592885
CD1c-positive myeloid dendritic cell	1	CD1c-positive myeloid dendritic cell	0.563719677			CD1c-positive myeloid dendritic cell	0.803740621	CD1c-positive myeloid dendritic cell	0.783471674
erythroblast	1	erythroblast	0.532657229	erythroblast	0.694290983	erythroblast	0.978894926		
gamma-delta T cell	1	gamma-delta T cell	0.539497766	gamma-delta T cell	0.502216796	gamma-delta T cell	0.740586674	gamma-delta T cell	0.904053159
hematopoietic stem cell	1	hematopoietic stem cell	0.726385726	hematopoietic stem cell	0.764763311	hematopoietic stem cell	0.75724491	hematopoietic stem cell	0.648865012
low-quality	1	low-quality	0.680657174	low-quality	0.68445931	low-quality	0.649134708	low-quality	0.728998052
natural killer cell	1	natural killer cell	0.770988817	natural killer cell	0.623959124	natural killer cell	0.833128238	natural killer cell	0.718629642
plasma cell	1	plasma cell	0.945743141	plasma cell	0.947816498	plasma cell	0.954210246	plasma cell	0.82474102
plasmablast	1	plasmablast	0.445989963	plasmablast	0.593308367	plasmablast	0.535441087	plasmablast	0.558989332
splenic endothelial cell	1	splenic endothelial cell	0.921750546	splenic endothelial cell	0.649250648	splenic endothelial cell	0.949515886	splenic endothelial cell	0.555504115
splenic fibroblast	1	splenic fibroblast	0.883399167	splenic fibroblast	0.886345281	splenic fibroblast	0.878256094	splenic fibroblast	0.820886903
splenic macrophage	1	splenic macrophage	0.646221909	splenic macrophage	0.827945537	splenic macrophage	0.853436501	splenic macrophage	0.880481635

Data provided by MC-NYGC

HuBMAP Visible Human MOOC

Starts Aug 4, 2020

Register via:
https://tinyurl.com/vhmooc

INDIANA UNIVERSITY

Course Introduction

** **Enrollment is currently closed and begins July 20, 2020.** **

This 10h course introduces the HuBMAP project which aims to create an open, global reference atlas of the human body at the cellular level. Among others, the course describes the compilation and coverage of HuBMAP data, demonstrates new single-cell analysis and mapping techniques, and introduces major features of the HuBMAP portal.

Delivered entirely online, all coursework can be completed asynchronously to fit busy schedules.

Learning Outcomes

- Theoretical and practical understanding of different single-cell tissue analysis techniques.
- Expertise in single-cell data harmonization used to federate data from different individuals analyzed using different technologies in diverse labs.
- Hands-on skills in the design and usage of semantic ontologies that describe human anatomy, cell types, and biomarkers (e.g., marker genes or proteins).
- Knowledge on the design and usage of a semantically annotated three-dimensional reference system for the healthy human body.
- An understanding of how the HuBMAP reference atlas might be used to understand human health but also to diagnose and treat disease.

Module Topics Include

- HuBMAP Overview: Project Goals, Setup, and Ambitions
- Tissue Data Acquisition and Analysis
- Biomolecular Data Harmonization
- Ontology, 3D Reference Objects, and User Interfaces
- HuBMAP Portal Design and Usage

Meet the Instructors

Katy Börner, Victor H. Yngve Distinguished Professor of Engineering and Information Science. Founding Director of the Cyberinfrastructure for Network Science Center at Indiana University.

Ellen M. Quardokus, staff in the Chemistry Department and research scientist, Cyberinfrastructure for Network Science Center, SICE with expertise in molecular biology, microscopy, anatomy, and interdisciplinary communication.

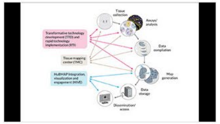
Andreas Bueckle, PhD Candidate in Information Science, performing research on information visualization, specifically virtual and augmented reality.

Length: 10 hours

Department: Cyberinfrastructure Network Science

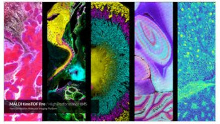
Credit: None

Audience: Biomedical students and professionals interested in single-cell tissue analysis and visualization



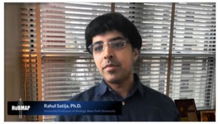
HuBMAP Overview

- Project Goals, Setup, and Ambitions



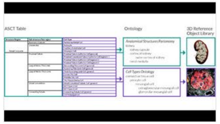
Tissue Data Acquisition and Analysis

- Behind the Scenes at Vanderbilt University



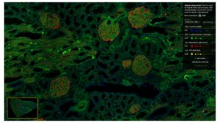
Biomolecular Data Harmonization

- An Introduction to Seurat



CCF Ontology, 3D Reference Objects, and User Interfaces

- Creating an Atlas of the Human Body



Portal Design and Usage

- Datasets and Software in the 1st HuBMAP Portal Release

Open Consent Your Data

- In Support of Research

HuBMAP-Postdoc Position

The Department of Intelligent Systems Engineering at Indiana University, Bloomington, is seeking a Postdoctoral Fellow within the NIH funded Human BioMolecular Atlas Program (HuBMAP). The postdoctoral fellow will help identify and catalog knowledge about the structure of the vascular pathways in the human body (arteries, veins, capillaries, and lymph vessels). This will be conducted primarily through a literature search to find (1) descriptions of the named vascular pathways and microvascular architecture in different organs of the body; (2) descriptions of the variability of the vascular system across different individuals; (3) imaging studies that show the physical 3D structure of vascular pathways; and (4) studies that identify biomolecular signatures unique to different parts of the vascular system, such as how gene expression varies in endothelial cells across the body. The postdoctoral fellow should have a background in human anatomy or related fields such as systems biology, cell biology, radiology, or pathology.

To apply, please contact Katy Borner, katy@indiana.edu

Acknowledgements

HuBMAP Consortium (https://hubmapconsortium.org)

TMCs

Jeffrey Spraggins
TMC-Vanderbilt
Vanderbilt University

Sanjay Jain
TMC-UCSD
Washington University,
St. Louis

Clive Wasserfall
TMC-UFL
University of Florida

Marda Jorgensen
TMC-UFL
University of Florida

3D Models

Kristen Browne
Medical Imaging and
3D Modeling Specialist
NIAID

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Harvard Medical School

Lisel Record
MC-IU PM
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Bruce Herr II
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Ellen Quardokus
Sr. Research Analyst

Yingnan Ju
PhD Candidate

Andreas Bueckle
PhD Candidate

Leonard Cross
Sr. UX/UI Designer

Matthew Martindale
Center Assistant

Daniel Bolin
Software Developer

Adam Phillips
Software Developer

Thanks go to all the **patients** that agreed to volunteer healthy tissue and open use of their data.

NIH National Institutes of Health

Opportunity Pool Awardee
KIDNEY PRECISION MEDICINE PROJECT
kpmp.org

NSF

Q&A