



Toward a Human Reference Atlas: Anatomical Structures, Cell Types, and Biomarkers

Katy Börner | @katycns

Victor H. Yngve Distinguished Professor of
Intelligent Systems Engineering & Information Science
Luddy School of Informatics, Computing, and Engineering
Indiana University, Bloomington, IN



Spatial Biology Europe
Virtual Event

April 15, 2021

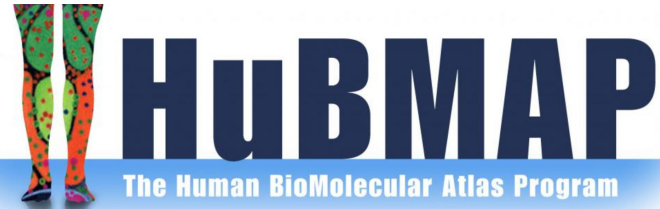
HuBMAP

Vision

Catalyze the development of an open, global framework for comprehensively mapping the human body at cellular resolution.

Goals

1. Accelerate the development of the next generation of tools and techniques for constructing high resolution spatial tissue maps
2. Generate foundational 3D tissue maps
3. Establish an open data platform
4. Coordinate and collaborate with other funding agencies, programs, and the biomedical research community
5. Support projects that demonstrate the value of the resources developed by the program



<https://commonfund.nih.gov/HuBMAP>

The Human Body at Cellular Resolution: The NIH Human Biomolecular Atlas Program.

Snyder et al. *Nature*. 574, p. 187-192.

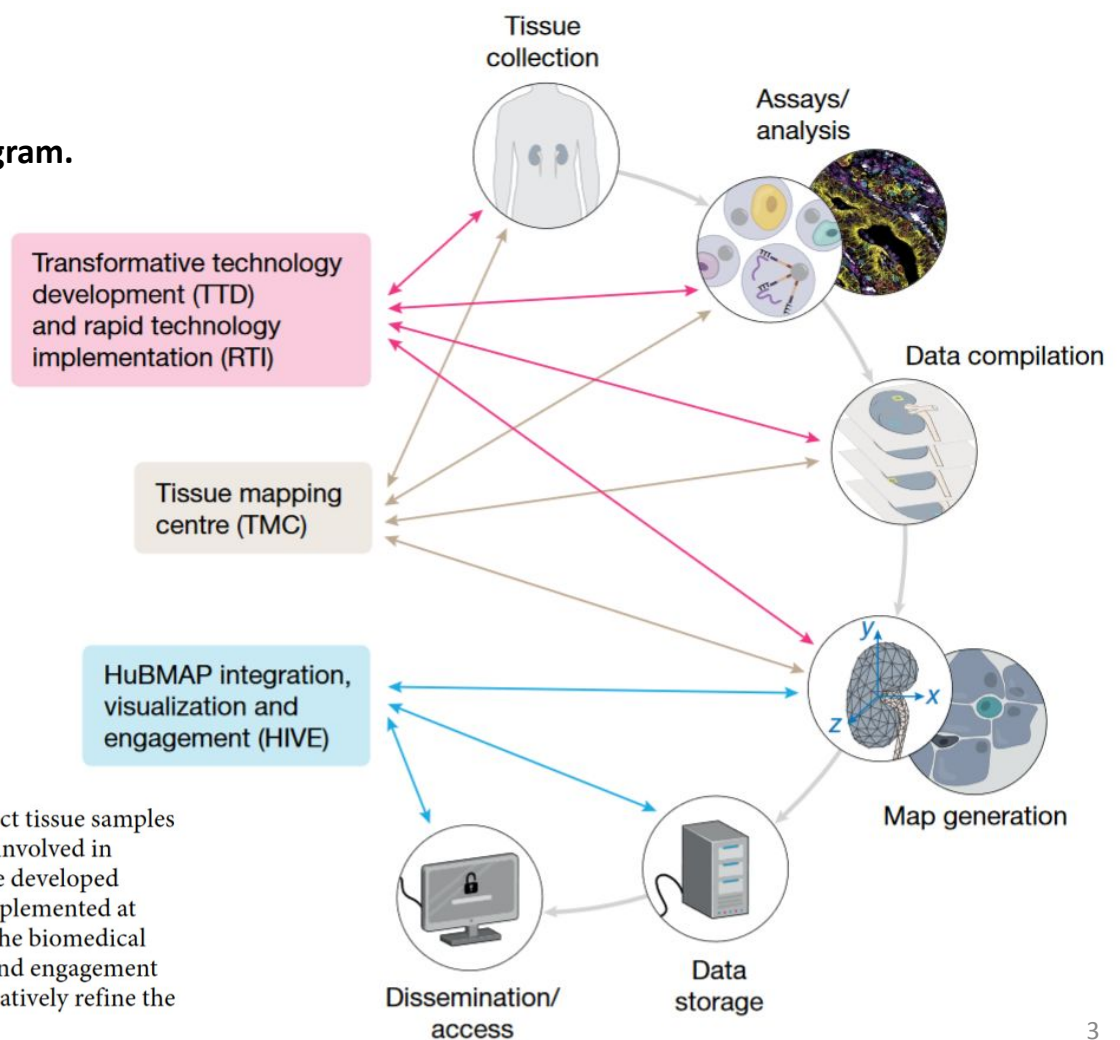


Fig. 1 | The HubMAP consortium. The TMCs will collect tissue samples and generate spatially resolved, single-cell data. Groups involved in TTD and RTI initiatives will develop emerging and more developed technologies, respectively; in later years, these will be implemented at scale. Data from all groups will be rendered useable for the biomedical community by the HuBMAP integration, visualization and engagement (HIVE) teams. The groups will collaborate closely to iteratively refine the atlas as it is gradually realized.

**The Human Body at Cellular Resolution:
The NIH Human Biomolecular Atlas Program.**
Snyder et al. *Nature*. 574, p. 187-192.

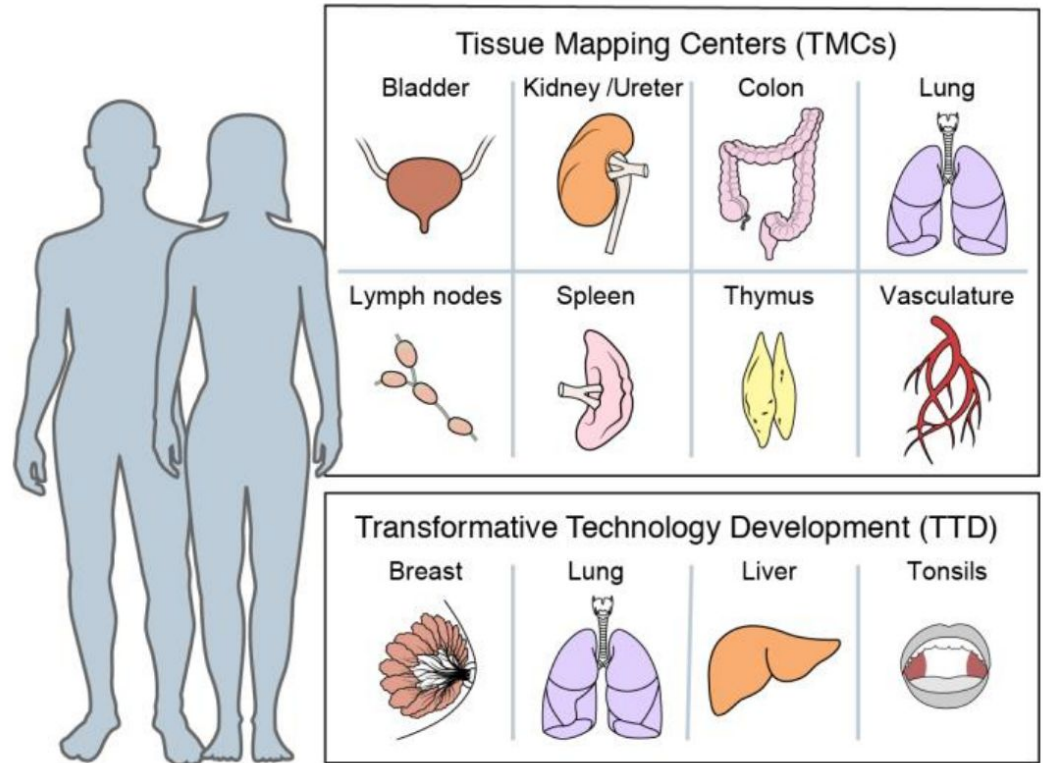


Fig. 2 | Key tissues and organs initially analysed by the consortium.
Using innovative, production-grade ('shovel ready') technologies, HuBMAP TMCs will generate data for single-cell, three-dimensional maps of various human tissues. In parallel, TTD projects (and later RTI projects) will refine assays and analysis tools on a largely distinct set of human tissues. Samples from individuals of both sexes and different ages will be studied. The range of tissues will be expanded throughout the program.

The Human Body at Cellular Resolution: The NIH Human Biomolecular Atlas Program.
 Snyder et al. *Nature*. 574, p. 187-192.

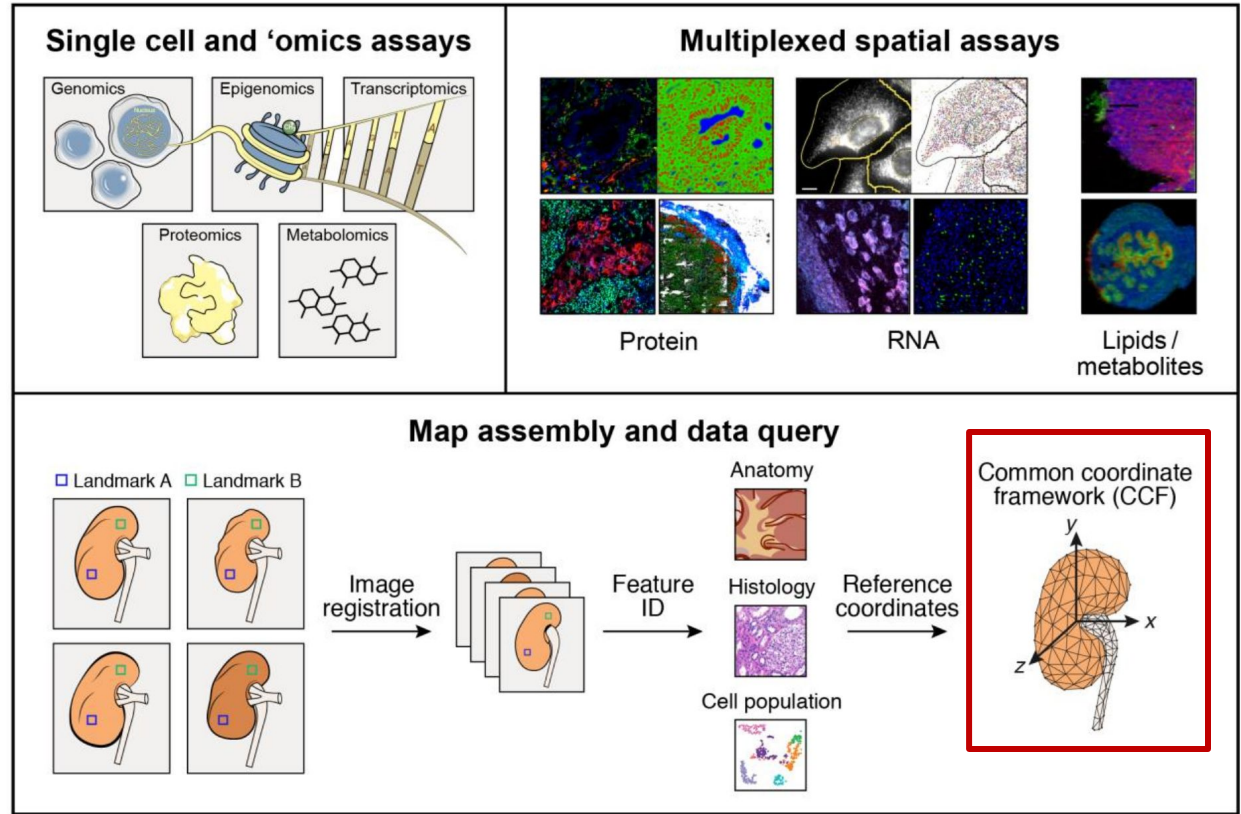


Fig. 3 | Map generation and assembly across cellular and spatial scales. HuBMAP aims to produce an atlas in which users can refer to a histological slide from a specific part of an organ and, in any given cell, understand its contents on multiple 'omic levels—genomic, epigenomic, transcriptomic, proteomic, and/or metabolomic. To achieve these ends, centres will apply a combination of imaging, 'omics and mass spectrometry

techniques to specimens collected in a reproducible manner from specific sites in the body. These data will be then be integrated to arrive at a high-resolution, high-content three-dimensional map for any given tissue. To ensure inter-individual differences will not be confounded with collection heterogeneity, a robust CCF will be developed.

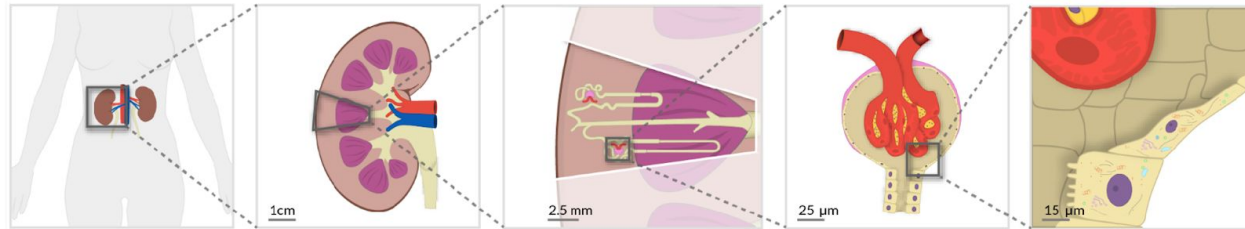


CCF ASCT+B Tables

CCF Requirements

The CCF must capture major **anatomical structures**, **cell types**, and **biomarkers** 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+B Tables

Anatomical Structures, Cell Types, and Biomarkers (ASCT+B) tables aim to capture the partonomy of anatomical structures, cell types, and major biomarkers (e.g., gene, protein, lipid or metabolic markers).

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

Partial ASCT+B 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, Updated Aug 2020. 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/R region	Sub structure/Sub region	Cell Type	Abbreviation	Subset of Marker Genes	Pertinent negatives/comments
Renal Corpuscle	Bowman's Capsule	Parietal epithelial cell	PEC	<i>CRB2*</i> , <i>CLDN1*</i>	
	Glomerulus	Podocyte	POD	<i>NPHS2*</i> , <i>PODXL*</i> , <i>NPHS1*</i>	
		Capillary Endothelial Cell	GC-EC	<i>EHD3*</i> , <i>EMCN*</i> , <i>HECW2*</i> , <i>FLT1*</i> , <i>AQP1*</i>	
		Mesangial Cell	MC	<i>POSTN*</i> , <i>PIEZO2*</i> , <i>ROBO1*</i> , <i>ITGA8*</i>	
Tubules	Proximal Tubule	Proximal Tubule Epithelial Cell (general)	PT	<i>CUBN*</i> , <i>LRF2*</i> , <i>SLC13A1*</i> , <i>ALDOB*</i> , <i>GATM*</i>	There is overlap among the segments
		Proximal Convoluted Tubule Epithelial Cell Segment 1	PT-S1	<i>SLC5A2*</i> , <i>SLC5A12*</i>	
		Proximal Tubule Epithelial Cell Segment 2	PT-S2	<i>SLC22A6*</i>	
		Proximal Tubule Cell Epithelial Segment 3	PT-S3	<i>PDZK1IP1*</i> , <i>MT1G*</i>	
	Loop of Henle, Thin Limb	Descending Thin Limb Cell (general)	DTL	<i>CRYAB*</i> , <i>VCAM1*</i> , <i>AQP1*</i> , <i>SPP1*</i>	<i>CLDN10</i> low
		Ascending Thin Limb Cell (general)	ATL	<i>CRYAB*</i> , <i>TACSTD2*</i> , <i>CLDN3*</i>	<i>AQP1</i> low to none
	Loop of Henle, Thick Limb	Thick Ascending Limb Cell (general)	TAL	<i>SLC12A1*</i> , <i>UMOD*</i>	<i>SLC12A3</i> low to none
		Cortex-TAL cell	C-TAL	<i>SLC12A1*</i> , <i>UMOD*</i>	
		Medulla-TAL cell	M-TAL	<i>SLC12A1*</i> , <i>UMOD*</i>	
		TAL-Macula Densa cell	TAL_MD	<i>NOS1*</i> , <i>SLC12A1*</i>	
Distal Convolution	Distal Convoluted Tubule Cell (general)	DCT	<i>SLC12A3*</i> , <i>TRPM6*</i>		
	DCT type 1 cell	DCT-1	<i>SLC12A3*</i> , <i>TRPM6</i>	<i>SLC8A1</i> , <i>HSD11B2</i> (low to none)	
	DCT type 2 cell	DCT-2	<i>SLC12A3*</i> , <i>SLC8A1*</i> , <i>HSD11B2</i>	Has CNT and DCT signature	
	Connecting Tubule	Connecting Tubule Cell (general)	CNT	<i>SLC8A1*</i> , <i>CALB1</i> , <i>TRPV5</i>	<i>SLC12A3</i> low to none. IC or PC without <i>SLC8A1</i> could be in the CNT structure
		CNT-Principal Cell	CNT-PC	<i>SLC8A1*</i> , <i>AQP2*</i> , <i>SCNN1G*</i>	
		CNT-Intercalated Cell	CNT-IC	<i>SLC8A1*</i> , <i>CA2</i> , <i>ATP6VOD2*</i>	
CNT-IC-A cell		CNT-IC-A	<i>SLC8A1*</i> , <i>SLC4A1*</i> , <i>SLC26A7*</i>		
	CNT-IC-B cell	CNT-IC-B	<i>SLC8A1*</i> , <i>SLC26A4*</i> , <i>SLC4A9*</i>		
Collecting Duct	Collecting duct (general) cell	CD	<i>GATA3*</i>	<i>GATA3</i> may be in subpopulation of DCT, CNT and vSMC/P. <i>SLC8A1</i> , <i>CALB1</i> , <i>TRPV5</i>	
	CD-PC (general)	CD-PC			
	C-CD-PC	C-CD-PC	<i>AQP2*</i> , <i>AQP3*</i> , <i>FXYD4*</i>		
	M-CD-PC	M-CD-PC	<i>SCNN1G*</i> , <i>GATA3*</i>		
	Outer medulla-CD-PC	OM-CD-PC			
	Inner Medulla-CD cell	IM-CD	<i>AQP2*</i> , <i>SLC14A2</i>		

Vessels	Endothelial Cells (non-glomerular)	Transitional PC-IC cell	IRC ₂ -IC	<i>FXYD4*</i> , <i>SLC4A9*/SLC26A7*</i>	(low to none), Low to No
		CD-IC (general) cell	CD-IC	<i>CA2</i> , <i>ATP6VOD2*</i>	<i>CALCA</i> and <i>KIT</i> in C-CD-IC-A. It may not be possible to assign IC or PC to <i>CNT</i> or CD structures without regional information of their source.
		CD-IC-A (general) cell	CD-IC-A	<i>SLC4A1</i> , <i>SLC26A7*</i> , <i>TMEM213*</i>	
		C-CD-IC-A cell	C-CD-IC-A	<i>SLC26A7*</i> , <i>SLC4A1*</i>	
		M-CD-IC-A cell	M-CD-IC-A	<i>SLC26A7*</i> , <i>SLC4A1</i> , <i>KIT*</i> , <i>CALCA</i>	
		CD-IC-B (general) cell	CD-IC-B		
		C-CD-IC-B cell	C-CD-IC-B		
		M-CD-IC-B cell	M-CD-IC-B	<i>SLC4A9*</i> , <i>SLC26A4*</i>	
		EC-IC-B cell	EC-IC-B		
		EC-IC-B cell	EC-IC-B		
Vessels	Endothelial Cells (non-glomerular)	Endothelial Cell (general)	EC	<i>EMCN*</i> , <i>PECAM1*</i> , <i>FLT1*</i>	
		EC-Afferent/Effluent Arteriole	EC-AEA	<i>SERPINE2*</i> , <i>TM4SF1*</i>	likely <i>PALMD</i>
		EC-Peritubular capillaries	EC-PTC	<i>PLVAP*</i>	
		EC-Descending Vasa Recta	EC-DVR	<i>TM4SF1*</i> , <i>PALMD</i>	
		EC-Ascending Vasa Recta	EC-AVR	<i>DNASEIL3*</i>	low to none
		EC-Lymphatics	EC-LYM	<i>MMRN1*</i> , <i>PROX1</i>	
Structure/R region	Sub structure/Sub region	Cell Type	Abbreviation	Subset of Marker Genes	Pertinent negatives/comments
Interstitial	Stroma (non-glomerular)	Vascular Smooth Muscle/Pericyte (general)	vSMC/P	<i>TAGLN*</i> , <i>ACTA2*</i> , <i>MYH11*</i> , <i>NTRK3</i> , <i>MCAM</i>	
		vSMC/P-Renin	vSMC/P-REN	<i>REN</i>	
		Fibroblast	FIB	<i>DCN*</i> , <i>ZEB2</i> , <i>C7</i> , <i>LUM</i>	
		Macrophages-Resident	MAC-R	<i>CD163*</i> , <i>IL7R*</i>	
	Macrophage	MAC	<i>ST00A9</i>		
	Natural Killer Cell	NKC	<i>NKG7</i>		
	Dendritic Cell	DC	<i>APOE</i>		
	Monocyte	MON	<i>CTQA</i> , <i>HLA-DRA</i>		
	T lymphocyte (general)	T	<i>CD3</i>		
	T Cytotoxic	T-CYT	<i>GZMA</i>		
B lymphocyte	B	<i>IGJ</i>			

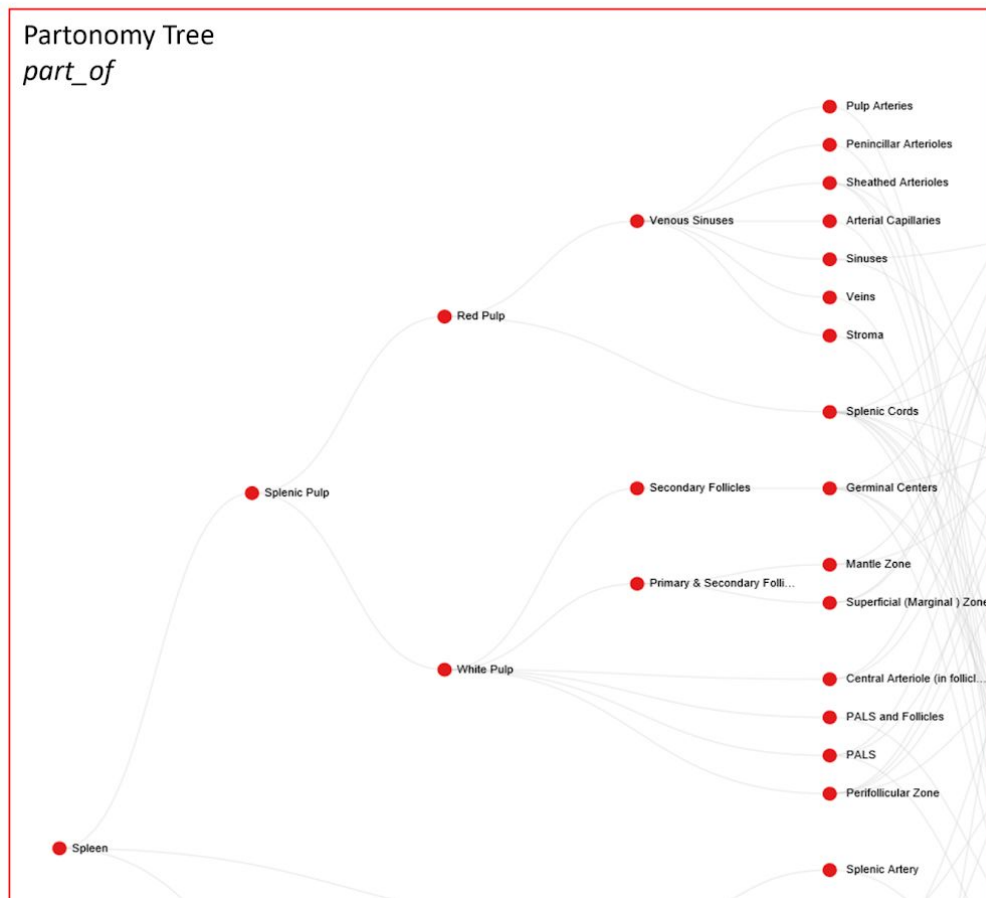
El-Achkar et al. A Multimodal and Integrated Approach to Interrogate Human Kidney Biopsies with Rigor and Reproducibility: The Kidney Precision Medicine Project. bioRxiv. 2019, Updated Aug 2020. doi:10.1101/828665

Anatomical Structures (AS)

Cell Types (CT)

Biomarkers (B)

Partonomy Tree
part_of



Bimodal network describing which CT are located_in what AS

Typology Tree
is_a

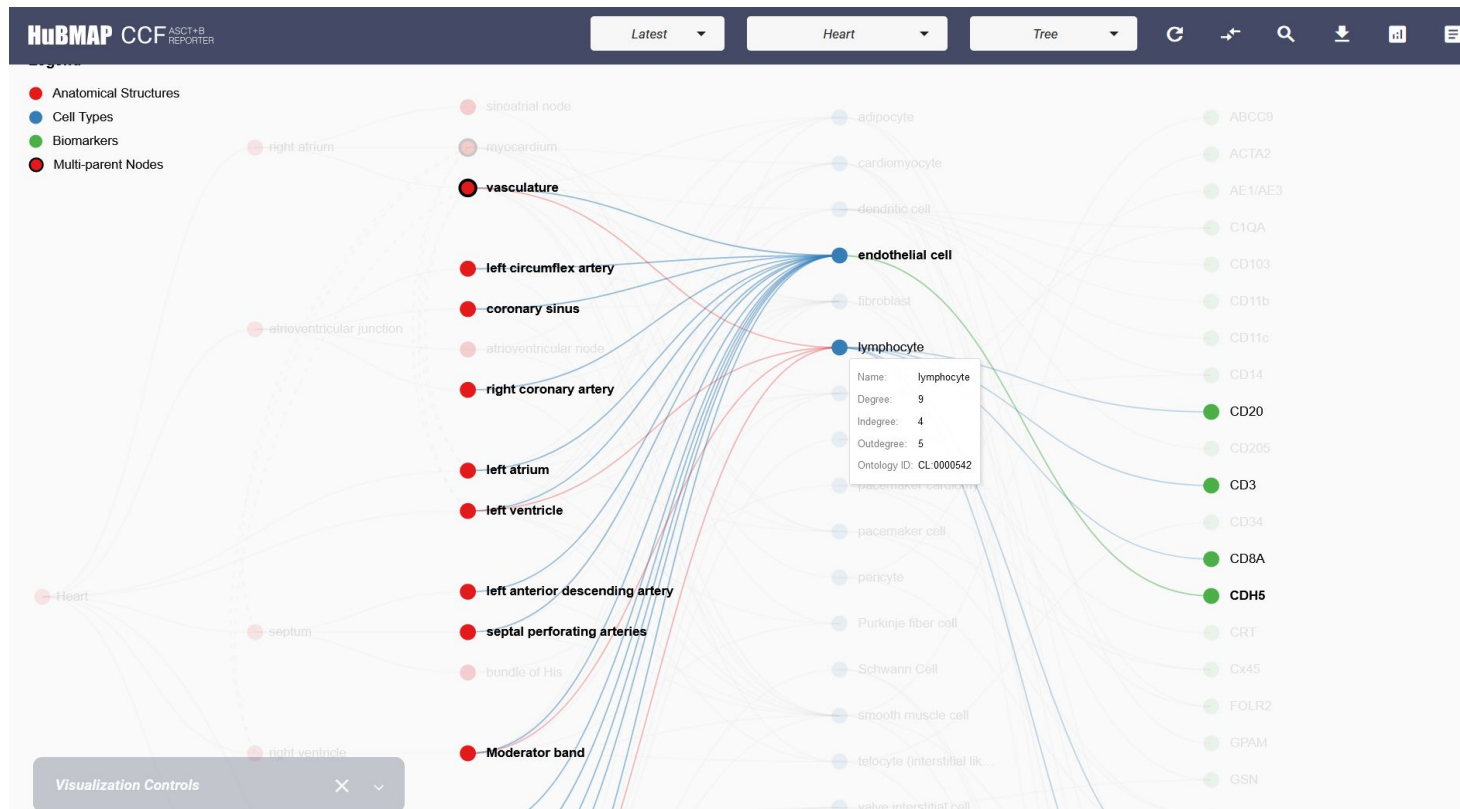
- adventitial stromal cell
- B cell
- Dendritic cell
- Endothelial
- Endothelial cell
- Erythrocytes
- fibroblast
- Fibroblastic reticular cell
- Follicular Dendritic cell
- Granulocytes
- Littoral cell
- Lymphatic endothelium
- macrophage
- Monocytes
- Myofibroblast
- neurons
- NK cell
- Plasma cell
- Plasmablasts
- Platelets

Bimodal network describing which B characterize what CT

BG - Genes
BP - Proteins

- CD10
- CD11b
- CD11c
- CD138
- CD14
- CD141
- CD15
- CD163
- CD19
- CD20
- CD21
- CD22
- CD23+
- CD235a
- CD27
- CD27-
- CD271
- CD271-
- CD3
- CD3-
- CD31
- CD34
- CD4
- CD4 (helper)
- CD41

CCF ASCT+B Reporter UI



<https://hubmapconsortium.github.io/ccf-asct-reporter/>

ASCT+B Tables

Anatomical Structures (AS), Cell Types (CT), and Biomarkers (B) or ASCT+B tables aim to capture the partonomy of anatomical structures, cell types, and major biomarkers (e.g., gene, protein, lipid or metabolic markers).

ASCT Table

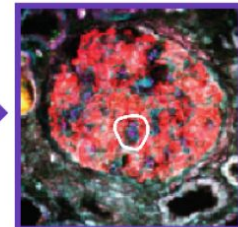
Structure/Region	Sub structure/Sub region	Cell Type
Renal Corpuscle	Bowman's (glomerular) Capsule/parietal layer	Parietal epithelial Cell
	Bowman's (glomerular) Capsule/visceral layer	Podocyte
	Glomerular Tuft	Capillary Endothelial Cell Mesangial Cell
Tubules	Proximal Tubule	Proximal Tubule Epithelial 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
	Distal Convolution	Medulla-TAL Cell
		TAL-Macula Densa Cell
		Distal Convoluted Tubule Cell (general)
	Connecting Tubule	DCT Type 1 Cell
DCT Type 2 Cell		
Connecting Tubule Cell (general)		
		CNT-Principal Cell

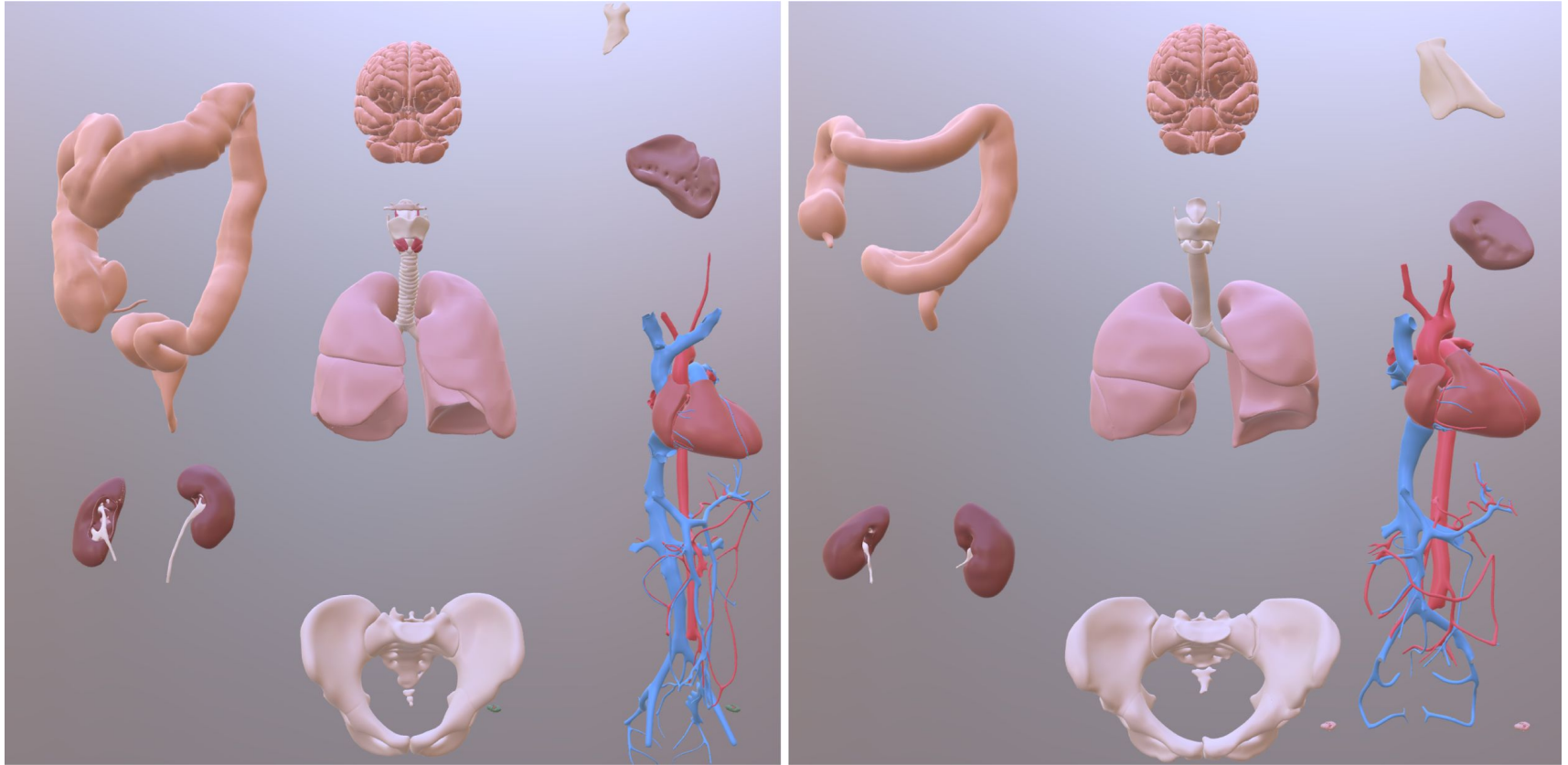
Ontology

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





Overview of CCF 3D Reference Models

ASCT+B Table Working Group

Lead by Katy Börner and Jim Gee; Ellen M Quardokus serves as Knowledge Manager

Meetings take place monthly to review and approve tables, formalize and unify table design language, discuss and expand table usage, see [WG Charter](#).

Upcoming meetings in **2021**: May 5, June 2, 11a-noon ET.

Please [register](#) to receive invites and updates.



	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

Table compiled for, during, and after the NIH-HCA Joint Meeting in March 2020, <https://hubmapconsortium.org/nihhca2020>

Consortium

Allen Brain Atlas

BICCN

CZI

EU H2020

GTE_x 19

GUDMAP

Gut Cell Atlas

HTAN

HuBMAP 17

KPMP

LungMAP

MRC

RBK

SPARC

TCGA 19

Wellcome

Size
#Links



Color



Organ

Adrenal Gland

Bladder

Bone Marrow & Blood

6 Brain

6 Breast

Cervix

Decidua

Eye

Gonads

Heart

6 Intestine, Large

Intestine, Small

9 Kidney

Liver

10 Lung

Lymph Node

Ovaries

Pancreas

Placenta

Prostate

Skin

Spinal Cord

Spleen

Stomach

Testes

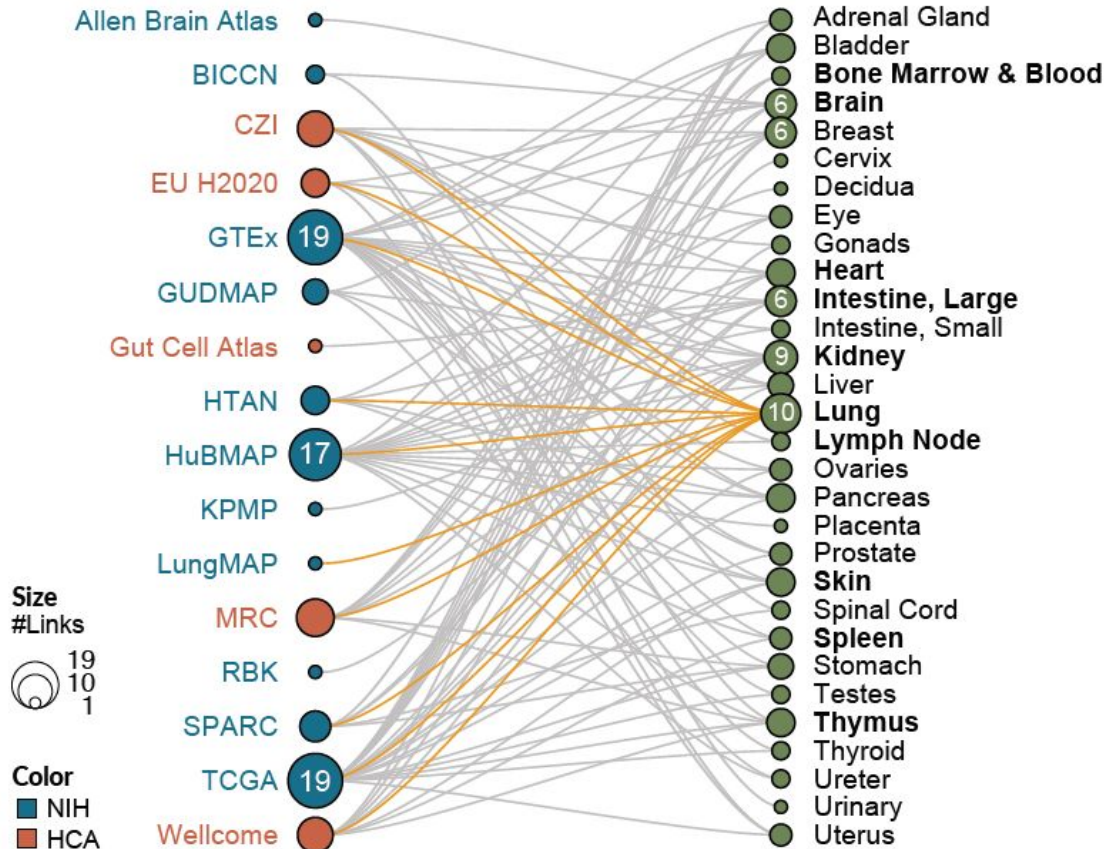
Thymus

Thyroid

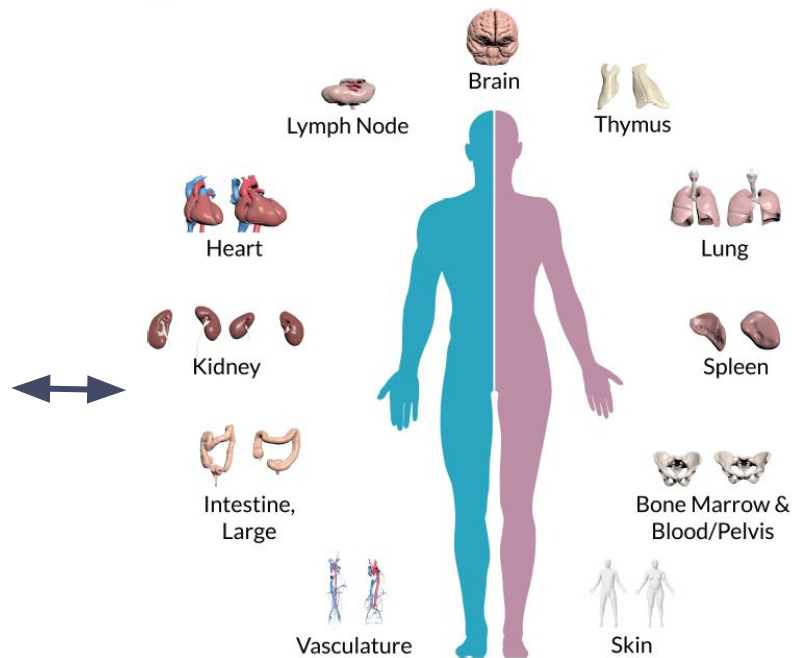
Ureter

Urinary

Uterus



Organ	#AS	#CT	#B Total	#BG	#BP	#AS-AS	#AS-CT	#CT-B
Bone Marrow & Blood/Pelvis	3	46	327	201	126	2	70	710
Brain	187	127	254	254	0	187	127	330
Heart	52	25	48	48	0	61	164	78
Intestine, Large	65	69	94	88	6	389	1,361	197
Kidney	68	63	152	152	0	67	59	257
Lung	161	92	176	172	4	1,633	12,094	286
Lymph Node	41	49	266	108	158	62	135	544
Skin	16	42	70	0	70	17	19	105
Spleen	46	66	255	80	145	68	172	414
Thymus	25	41	511	388	123	38	180	657
Vasculature	870	2	1	1	0	869	606	2
Totals:	1,534	622	2,154	1,492	632	3,393	14,987	3,580



<https://hubmapconsortium.github.io/ccf/pages/ccf-anatomical-structures.html>

<https://hubmapconsortium.github.io/ccf/pages/ccf-3d-reference-library.html> (NLM VH organs)
<https://community.brain-map.org/t/allen-human-reference-atlas-3d-2020-new/> (brain)
<https://www3.cs.stonybrook.edu/~ari/> (male colon)

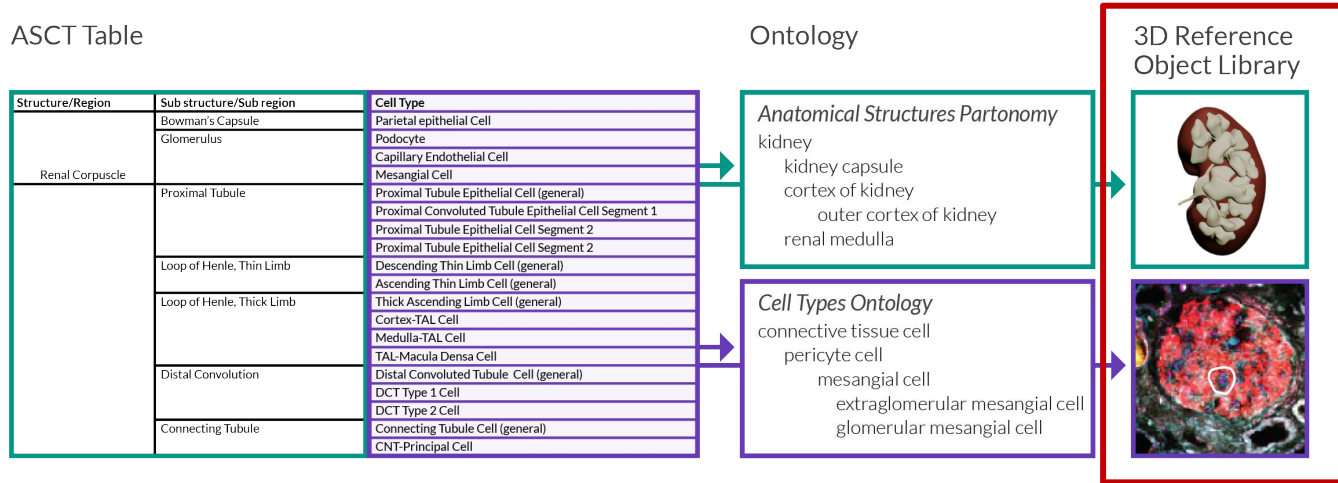


CCF Registration User Interface (RUI)



ASCT+B Table Usage

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



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

Document the tissue extraction site by registering tissue blocks within a 3D reference organ.

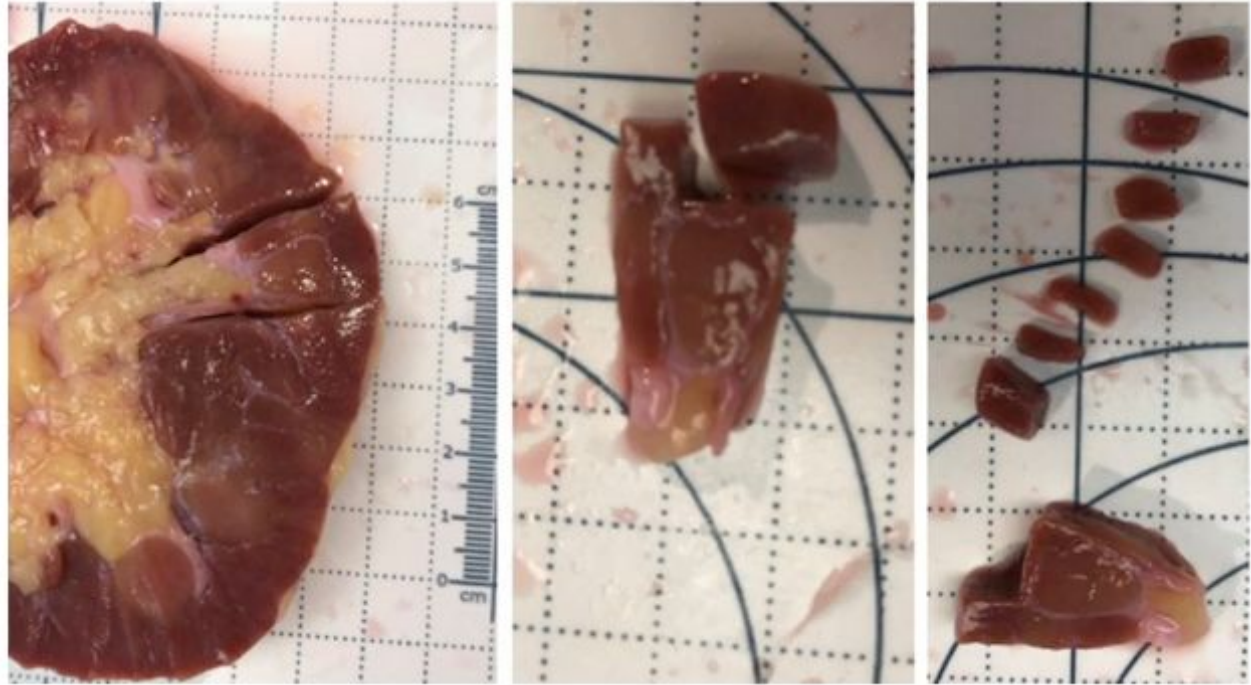
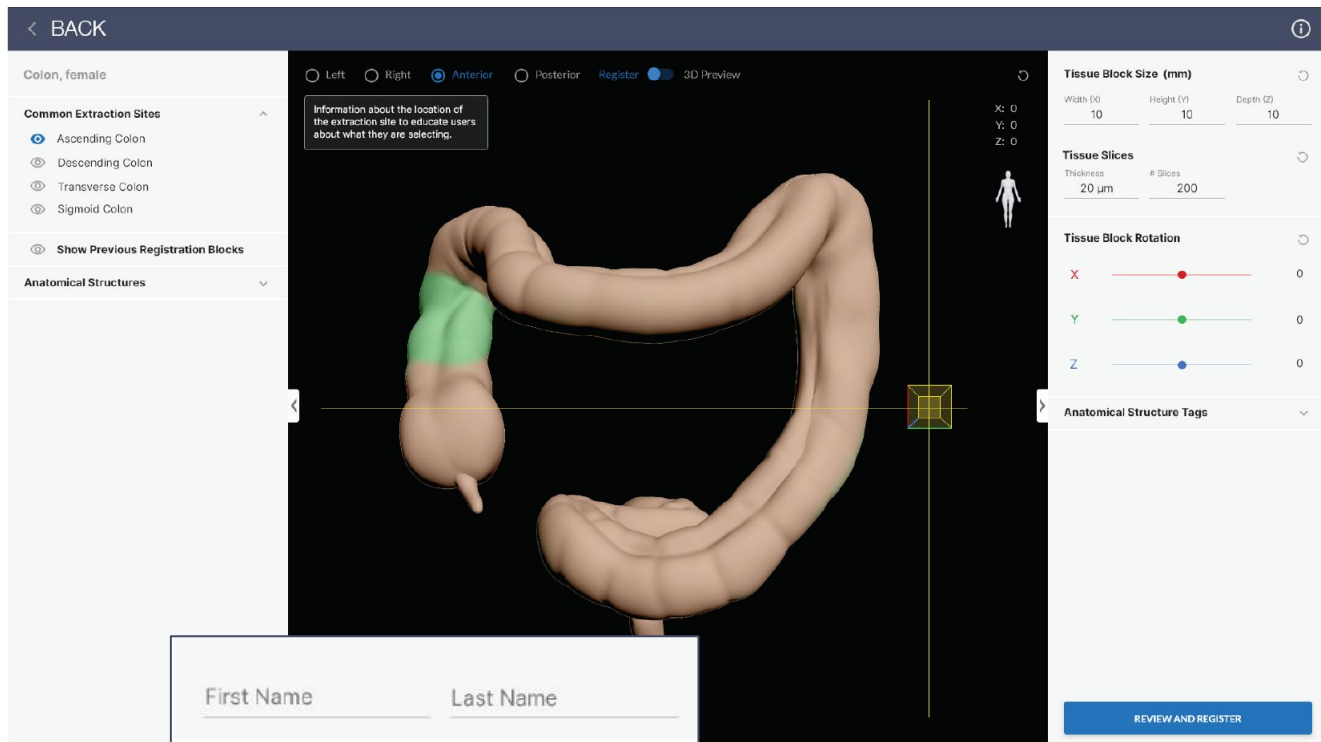


Image provided by Sanjay Jain, TMC-UCSD






CCF Registration User Interface (RUI) v1.0.0

New Features:

- Organ carousel with 4 reference organs
- Support for tissue extraction sites
- Expanded ontology
- Semantic annotation via collision detection & manual annotation
- Support for non-HuBMAP usage



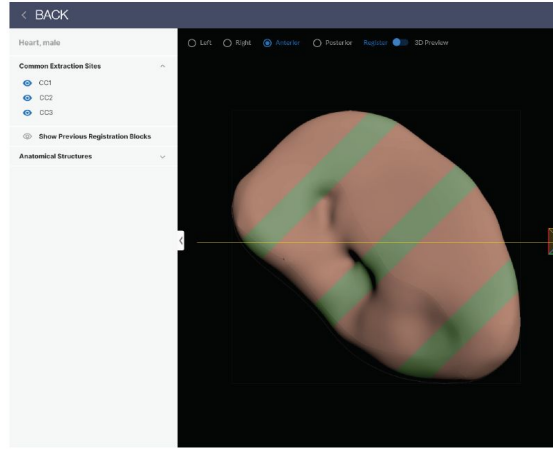
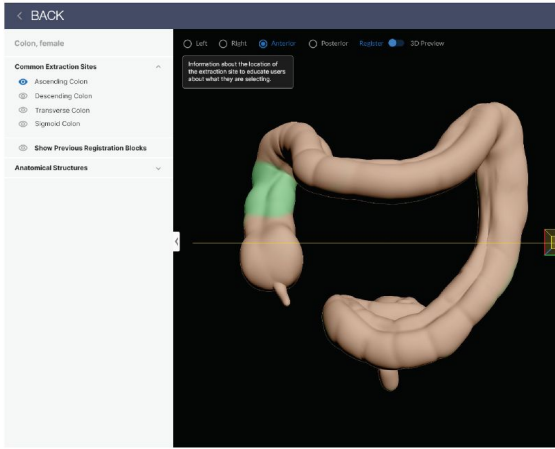
First Name _____ Last Name _____

<      >

Colon Heart Lung Kidney Spleen

Male Female

<https://hubmap-ccf-ui.netlify.app/rui/>



Kidney

- Bisection Line

Spleen

- CC1
- CC2
- CC3

Colon

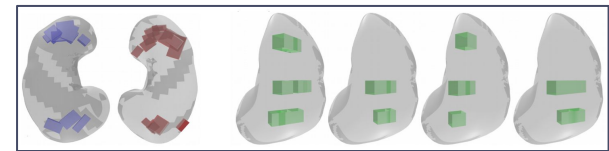
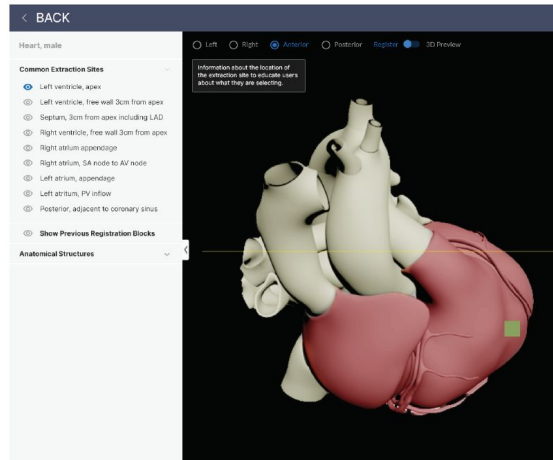
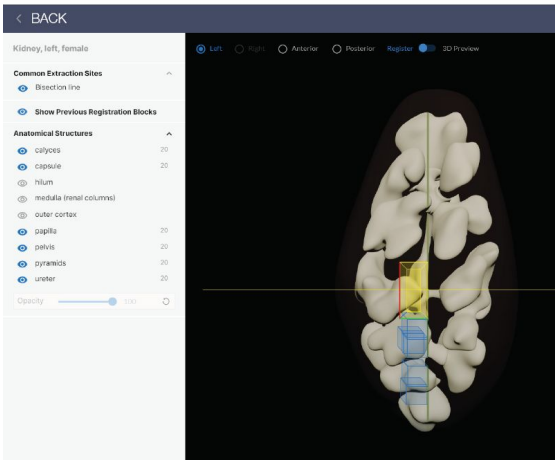
- Ascending Colon
- Descending Colon
- Transverse Colon
- Sigmoid Colon

Heart

- Left atrium, appendage
- Left atrium, PV inflow
- Left ventricle, apex
- Left ventricle, free wall 3cm from apex
- Septum, 3cm from apex including LAD
- Posterior, adjacent to coronary sinus
- Right atrium appendage
- Right atrium, AV (atrioventricular) node
- Right atrium, SA (sinoatrial) node
- Right ventricle, free wall 3cm from apex

Extraction Site Mapping

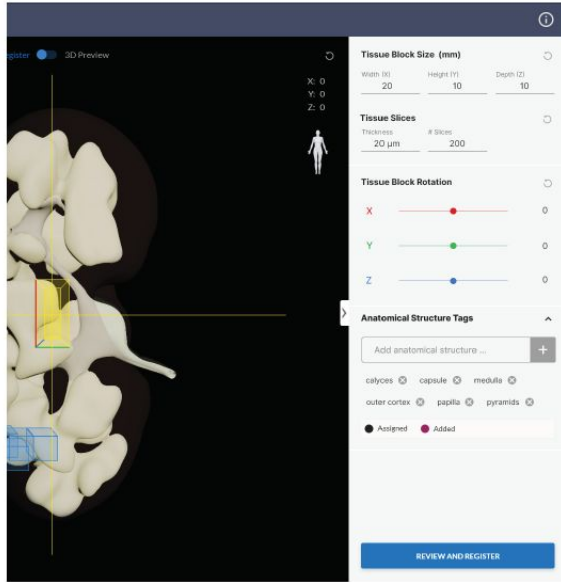
- 7
- 8
- 1
- 2
- 3
- 9
- 5
- 6a
- 6b
- 4



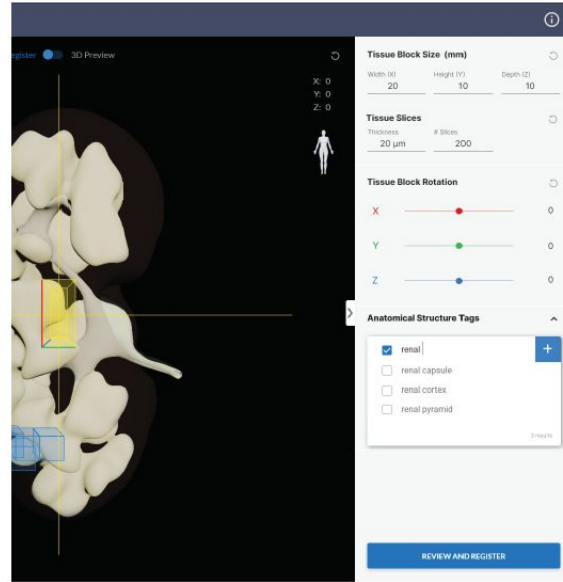
For the first HuBMAP portal release, 48 tissue blocks were registered.

CCF Registration User Interface (RUI) v1.0.0 cont.

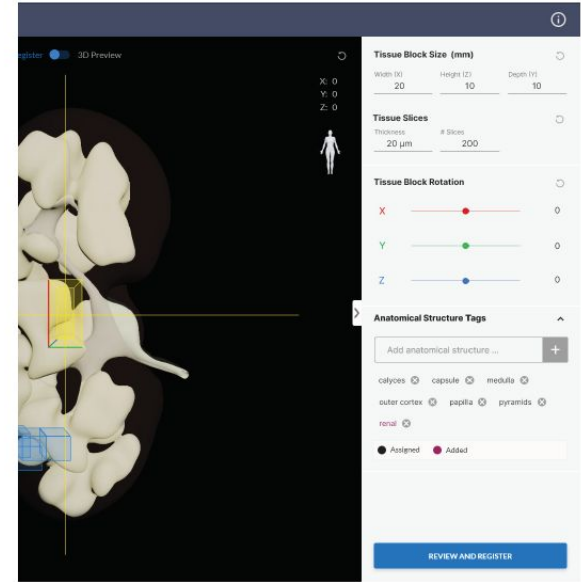
Collision when Tissue Block hits Reference Organ



Tag Search behavior



Custom tag added to list



CCF Registration User Interface (RUI)

The screenshot displays the CCF Registration User Interface (RUI) for the HuBMAP project. The interface is divided into several sections:

- Header:** "HuBMAP CCF REGISTRATION USER INTERFACE" with an information icon on the right.
- User Information:** Fields for "First Name" (Andreas) and "Last Name" (Bueckle).
- Orientation and Registration:** Radio buttons for "Left", "Right", "Anterior" (selected), and "Posterior". A "Register" button is active, and a "3D Preview" toggle is on.
- Organ Selection:** A row of icons for "Colon", "Heart", "Kidney" (selected), "Spleen", and "Bladder".
- Gender and Side:** "L" (selected) and "R" radio buttons, and "Male" (selected) and "Female" radio buttons.
- Anatomical Structures List:** A scrollable list with checkboxes for "kidney capsule", "cortex of kidney", "outer cortex of kidney", "renal column" (selected), "hilum of kidney", "renal medulla", "renal papilla", and "renal pyramid".
- 3D Model:** A central 3D rendering of a kidney with a blue rectangular box highlighting a specific region. A small human figure icon is visible to the right of the model.
- Coordinates:** "X: 80", "Y: 69", "Z: 40" displayed on the right side.
- Configuration Panels (Right Side):**
 - Tissue Block Size (mm):** Width (X) 8, Height (Y) 6, Depth (Z) 10.
 - Tissue Slices:** Fields for "Thickness" and "# Slices".
 - Tissue Block Rotation:** Sliders for X, Y, and Z axes, all set to 0.
 - Anatomical Structure Tags:** A search field "Add Anatomical Structures ..." and a legend for "Assigned" (black circle) and "Added" (pink circle).
- Footer:** A blue button labeled "REVIEW AND DOWNLOAD".

<https://hubmapconsortium.github.io/ccf-ui/rui/>



CCF Exploration User Interface (EUI)



CCF Exploration User Interface (EUI)

HuBMAP Sex: Both Age: 1-110 BMI: 13-83 Login

Search ontology terms ...

- body
 - heart
 - lung
 - kidney
 - right kidney
 - left kidney
 - kidney capsule
 - cortex of kidney
 - renal medulla
 - renal column
 - renal pyramid
 - hilum of kidney
 - kidney interstitium
 - kidney calyx
 - renal pelvis
 - ureter
 - renal papilla
 - renal fat pad
 - nephron

body

- 2 Centers
- 27 Donors
- 41 Samples

10x Female, Age 14, BMI 14.7
HBM894.MPVN.828
TMC-Florida
First case collected. Incomplete d...

CODEX Male, Age 18, BMI 27.1
HBM436.GHWX.449
TMC-Florida
section is 190um from block surface

Male, Age 56, BMI 32.5
HRM696.XTYL.498
TMC-Vanderbilt
Age 56, White Male

Male, Age 53, BMI 26.5
HRM652.VRL.D.292
TMC-Vanderbilt
Age 53, Black Male

Male, Age 58, BMI 22.0
HBM477.CJKM.899
TMC-Vanderbilt
107-111

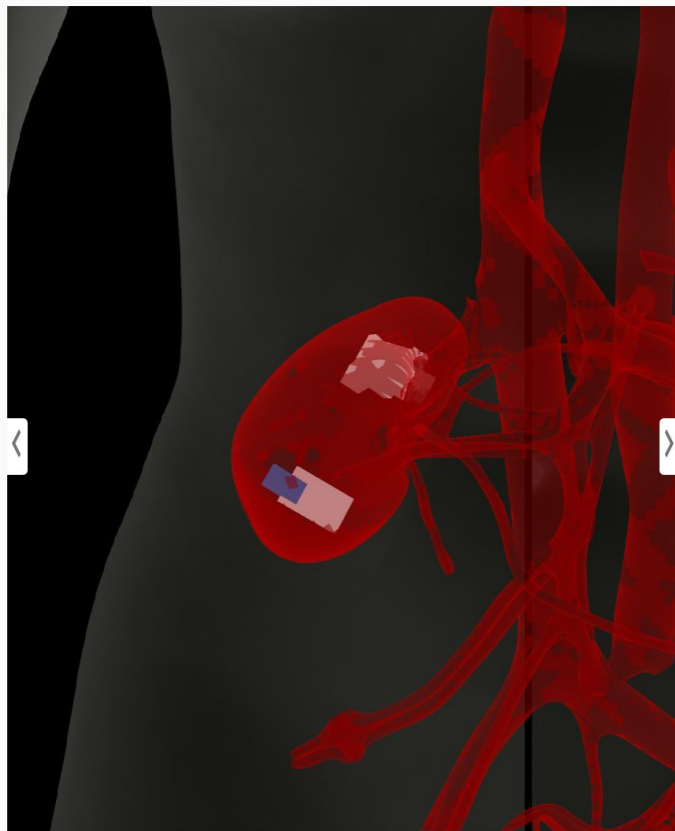
CODEX Male, Age 18, BMI 25.5
HBM473.VKCM.878
TMC-Florida
section is 255um from block surface

LC Male, Age 55, BMI 25.4
HBM824.BLXF.883
TMC-Vanderbilt
13-16

Search ontology terms ...



- body
 - heart
 - lung
 - kidney
 - right kidney
 - left kidney
 - kidney capsule
 - cortex of kidney
 - renal medulla
 - renal column
 - renal pyramid
 - hilum of kidney
 - kidney interstitium
 - kidney calyx
 - major calyx
 - minor calyx
 - renal pelvis
 - ureter
 - renal papilla
 - renal fat pad
 - nephron
 - spleen
 - colon



body

1 Centers
 9 Donors
 40 Samples



Male, Age 55, BMI 25.4
 HBM695.RTLJ.484
 TMC-Vanderbilt
 13-16



Male, Age 21, BMI 21.8
 HBM634.MMGK.572
 TMC-Vanderbilt
 Age 21, White Male, Trauma Patient



Female, Age 44, BMI 28.0
 HBM457.NNQN.252
 TMC-Vanderbilt
 Age 44, white female.



Female, Age 44, BMI 28.0
 HBM465.VKHL.532
 TMC-Vanderbilt
 Age 44, white female.



Male, Age 21, BMI 21.8
 HBM693.HFFJ.752
 TMC-Vanderbilt
 Age 21, White Male, Trauma Patient



Female, Age 58, BMI 23.0
 HBM536.LDTZ.757
 TMC-Vanderbilt
 Age 58, White Female



Male, Age 48, BMI 35.3
 HBM334.GCCX.874
 TMC-Vanderbilt
 Age 48, White Male



Male, Age 31, BMI 32.6
 HBM776.PKJF.786
 TMC-Vanderbilt
 Age 21, White Male

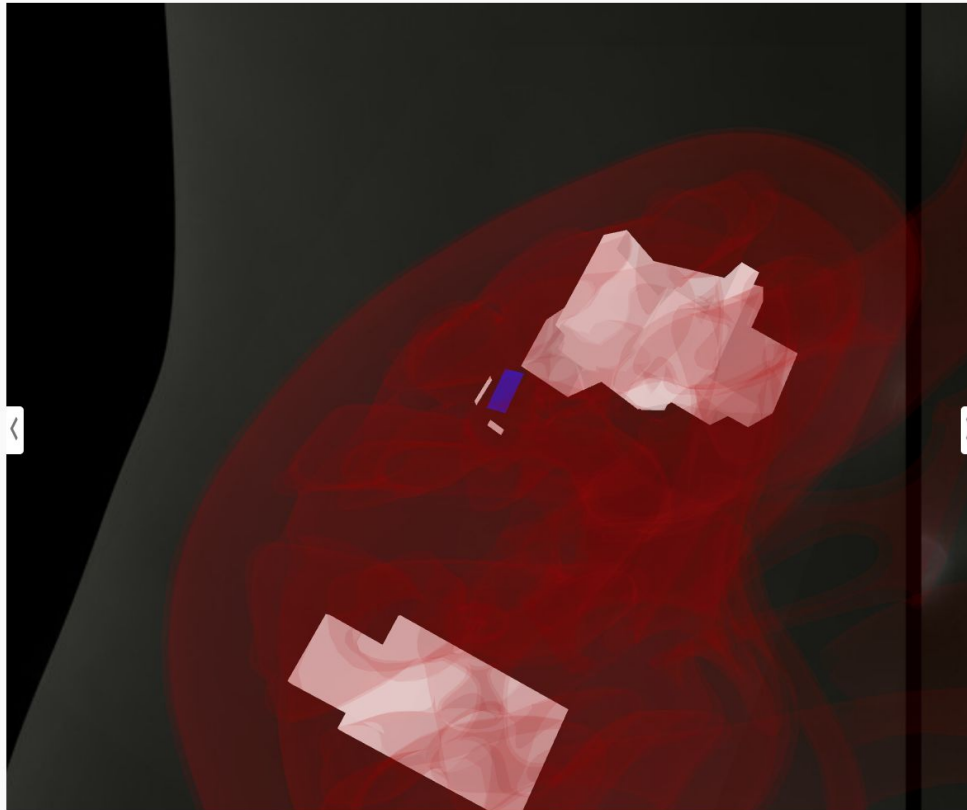


Female, Age 66, BMI 31.3
 HBM284.TRCV.726














Search ontology terms ... 🔍

- body
 - heart
 - lung
 - kidney
 - right kidney
 - left kidney
 - kidney capsule
 - cortex of kidney
 - outer cortex of kidney
 - renal medulla
 - outer medulla
 - inner medulla
 - renal column
 - renal pyramid
 - hilum of kidney
 - kidney interstitium
 - kidney calyx
 - major calyx
 - minor calyx
 - renal pelvis
 - ureter
 - renal papilla
 - renal fat pad
 - nephron
 - spleen
 - colon
 - small intestine

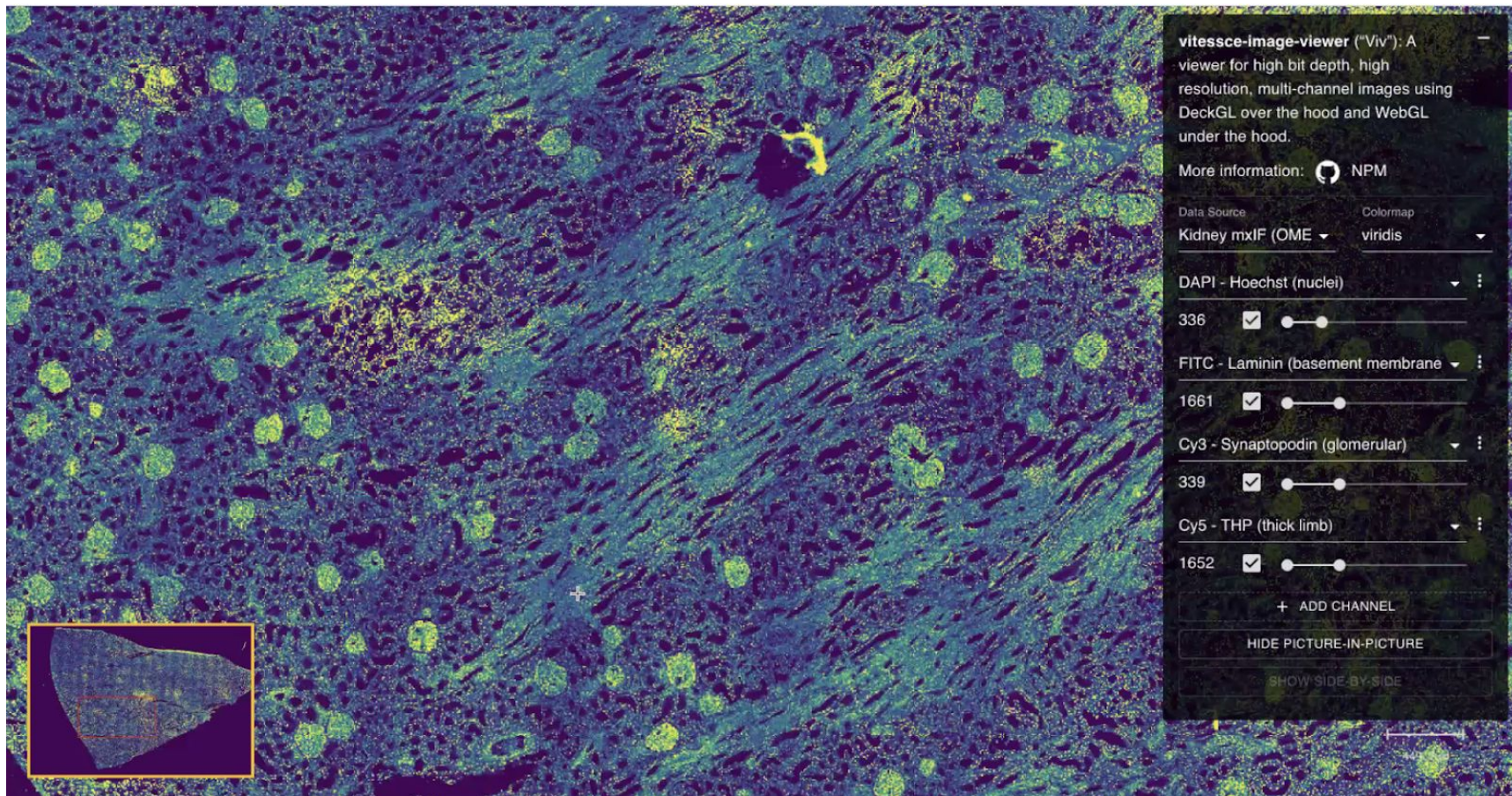


body

2 Centers
9 Donors
14 Samples

- 
CoverNephrectomy
 10.1016/j.trsl.2017.07.006
 KPMP-IUCSU
 Isolated as a part of a kidney st...
- 
Patient B Cortical biopsy
 10.1681/ASN.2016091027
 KPMP-IUCSU
 Biopsy from Nephrology bioban...
- 
Patient A Cortical biopsy
 10.1681/ASN.2016091027
 KPMP-IUCSU
 Biopsy from Nephrology bioban...
- 
Male, Age 55, BMI 25.4
 HBM824.BLXF.883
 TMC-Vanderbilt
 13-16
- 
Female, Age 66, BMI 31.3
 HBM554.ZRCG.496
 TMC-Vanderbilt
 21-24
- 
Female, Age 58, BMI 23.0
 HBM926.VBJV.597
 TMC-Vanderbilt
 Age 58, White Female
- 
Male, Age 62, BMI 34.9
 HBM947.VLDP.894
 TMC-Vanderbilt
 Kidneys 153-156
- 
Female, Age 44, BMI 28.0
 HBM457.NNQN.252
 TMC-Vanderbilt
 Age 44, white female.
- 
Male, Age 21, BMI 21.8
 HBM693.HFFJ.752
 TMC-Vanderbilt
 Age 21, White Male, Trauma Pat...
- 
Female, Age 58, BMI 23.0
 HBM536.LDTZ.757
 TMC-Vanderbilt
 Age 58, White Female
- 
Male, Age 48, BMI 35.3

Register your data via <https://hubmap-ccf-ui.netlify.app/rui/> so it can be spatially/semantically explored in EUI.



<http://gehlenborglab.org/research/projects/vitessce/>

DAY TWO: 15 APRIL 2021

Interactive Session: Demo of HuBMAP Tools

Presentation 1: Cellar: Interactive Single Cell Data Annotation Tool

JUN DING, Assistant Professor, Department of Medicine, **McGill University**

16:00

-

16:30

Presentation 2: Vitesse: A Framework For Integrative Visualization Of Multi-Modal Single-Cell Data

MARK S. KELLER, PhD Program in Bioinformatics and Integrative Genomics, Division of Medical Sciences, **Harvard Medical School**

Presentation 3: CCF Tissue Registration User Interface (RUI)

ANDREAS BUECKLE, PhD Program in Information Science, Luddy School of Informatics, Computing, and Engineering, **Indiana University**



Visible Human MOOC (VHMOOC)



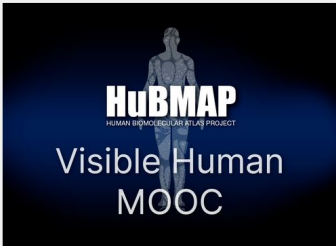
VH Massive Open Online Course (VHMOOC)

Goals

- Communicate tissue data acquisition and analysis,
- Demonstrate single-cell analysis and CCF mapping techniques, and
- Introduce major features of the HuBMAP portal.

Learning modules come with

- Videos (incl. interviews, tool demos)
- Hands-on exercises
- Self-quizzes



HuBMAP
HUMAN BIOMOLECULAR ATLAS PROJECT

Visible Human
MOOC

HuBMAP Visible Human MOOC (VHMOOC)

Started Aug 4, 2020

[GO TO CANVAS COURSE](#)

You are enrolled.



Course Introduction

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. If you have questions or experience issues during registration, please email cnsctr@indiana.edu.

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. Yingre 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

<https://expand.iu.edu/browse/sice/cns/courses/hubmap-visible-human-mooc>

Acknowledgements

HuBMAP Consortium (<https://hubmapconsortium.org>)



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



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



Kristen Browne
Medical Imaging and
3D Modeling Specialist
NIAID

3D Models

MC-IU HIVE Team



Katy Börner
MC-IU PI
CHS Director



Griffin Weber
Assoc. Professor of Medicine
Harvard Medical School



Lisel Record
MC-IU PI
CHS Associate Director



Bruce Herr II
Sr. Systems Architect/PI



Ellen Quandokus
Sr. Research Analyst



Yingnan Ju
PhD Candidate



Andreas Bueckle
PhD Candidate



Leonard Cross
Sr. UX/UI Designer



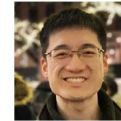
Matthew Martindale
Center Assistant



Daniel Bolin
Software Developer



Adam Phillips
Software Developer



Edward Lu
Software Developer



Paul Hrishikesh
Research Assistant



Leah Scherschel
Research Assistant



Avinash Boggana
Research Consultant



Yashvardhan Jain
Research Assistant



Kasturi Nikharge
Software Developer

Spatial Biology Europe: **ONLINE**

LIVE & INTERACTIVE CONTENT SCHEDULE

Please see the full programme for the conference below. Where possible, sessions will be made available OnDemand after the scheduled time slot.

Please note: Access to OnDemand sessions will only be available to delegates who purchase a full access pass

DAY TWO: 15 APRIL 2021

Panel Discussion: Human Reference Atlas

PROFILING &
IMAGING

Moderator: KATY BÖRNER, Victor H. Yngve Distinguished Professor of Engineering and Information Science, **Indiana University**

Panellists:

JAMES GEE, Associate Professor of Radiologic Science in Radiology. Director, Penn Image Computing and Science Laboratory, Department of Radiology, Perelman School of Medicine, **University of Pennsylvania**

XUEGONG ZHANG, Professor of Pattern Recognition and Bioinformatics, Director, Bioinformatics Division, TNLIST (Tsinghua National Laboratory for Information Science & Technology), Department of Automation, **Tsinghua University**

AMY BERNARD, Director, Science & Technology Strategy, **Allen Institute**

BERNARD DE BONO, Principal Investigator, Associate Professor, **University of Auckland**

15:30
-
16:00



Q&A

