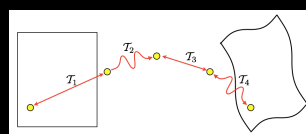
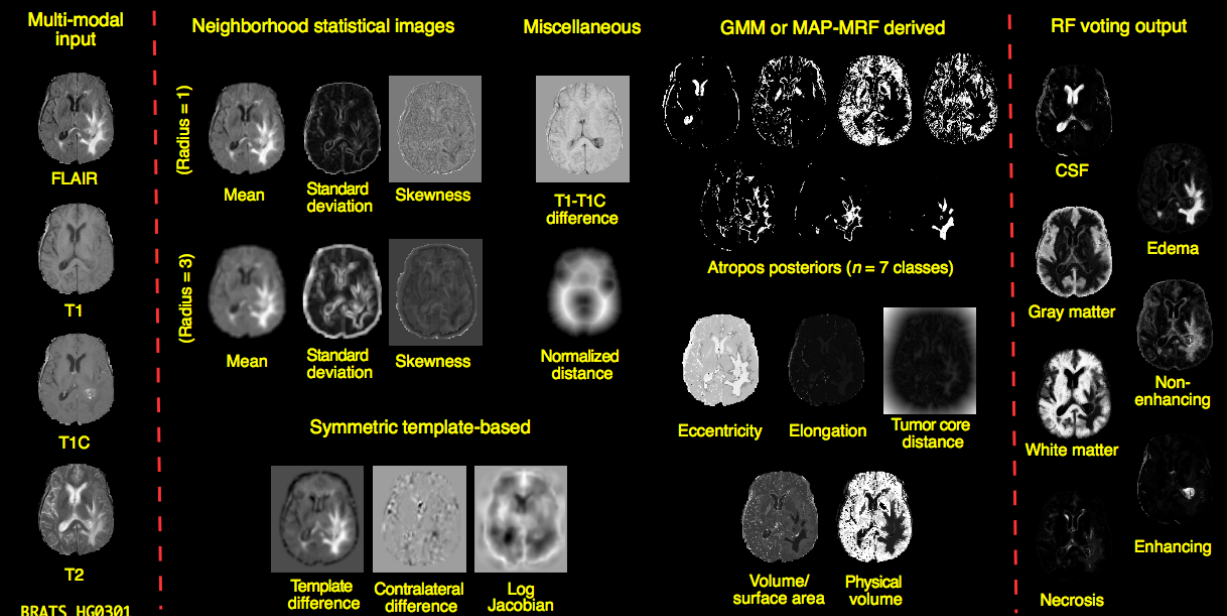
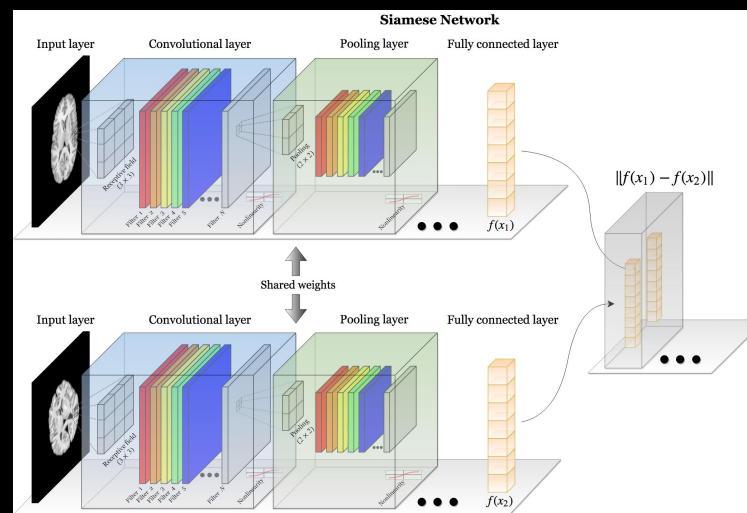
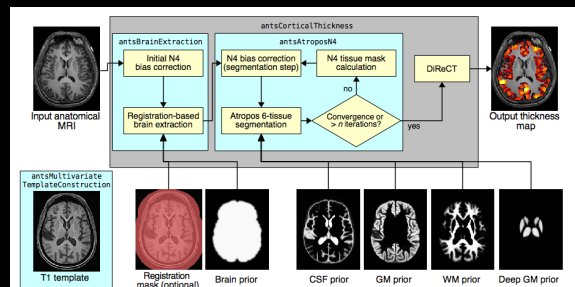
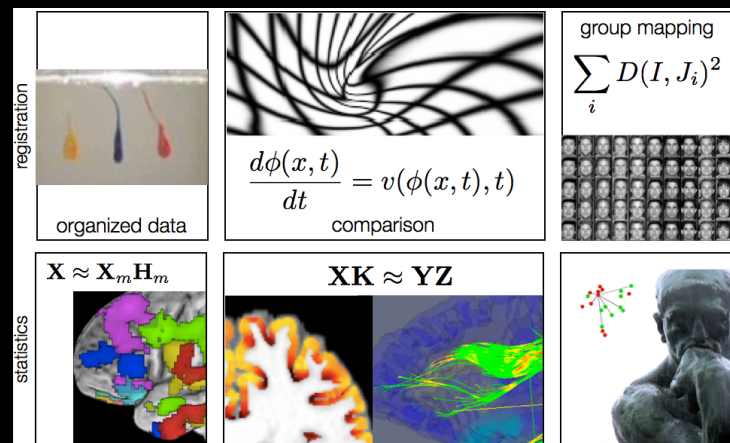
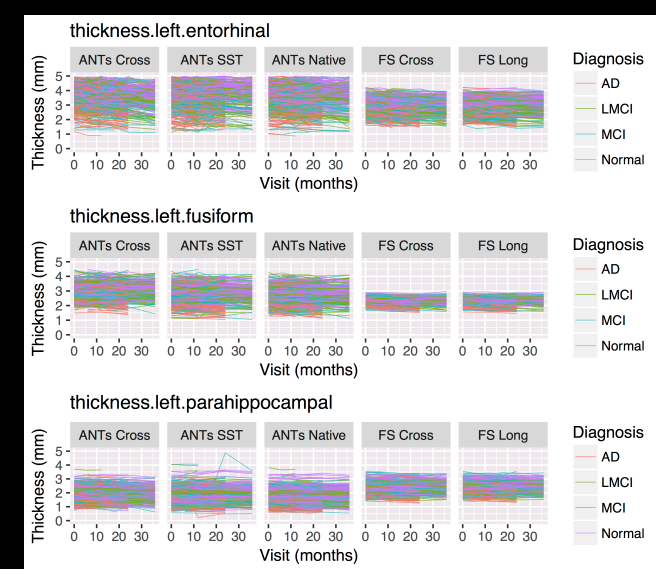
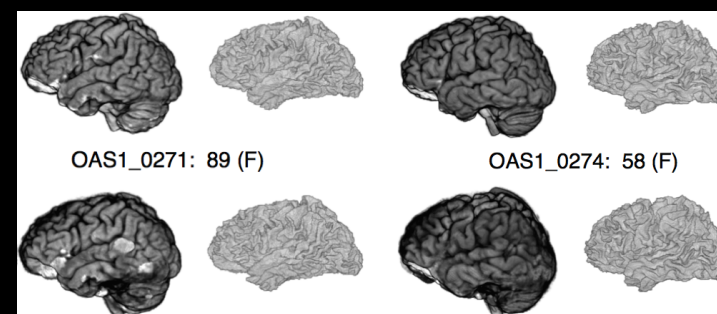
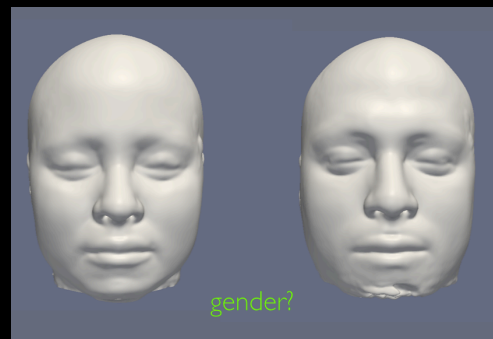
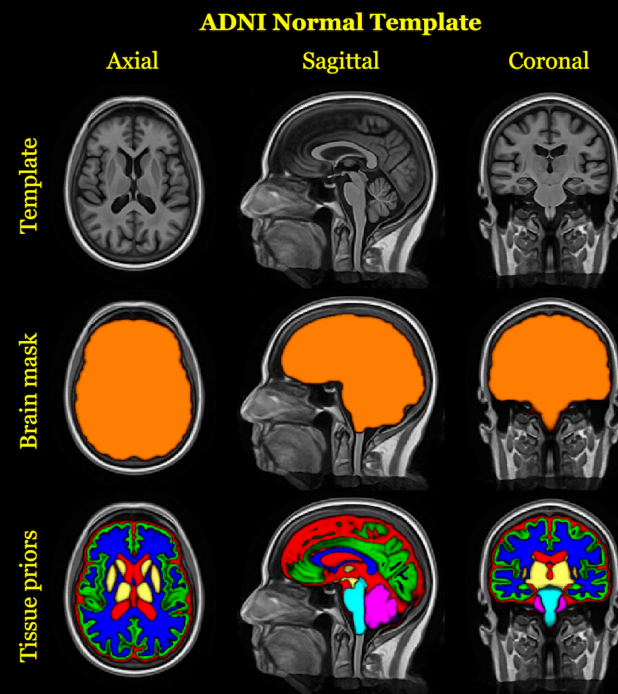


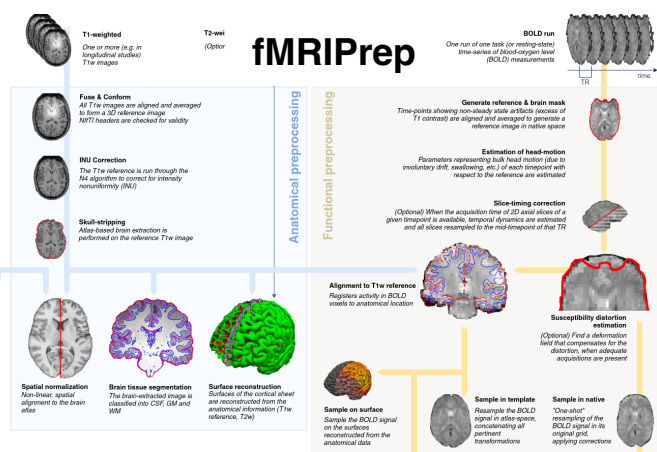
# Toward large-scale image science with ANTsX

(large scale processing/evaluation, open science, and current trends)

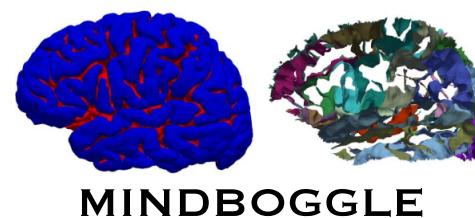
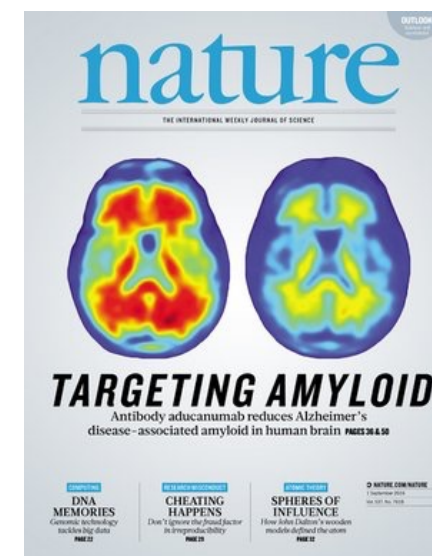




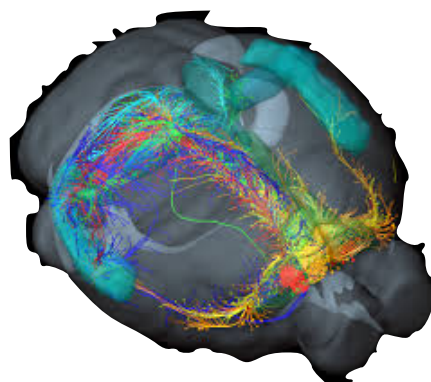
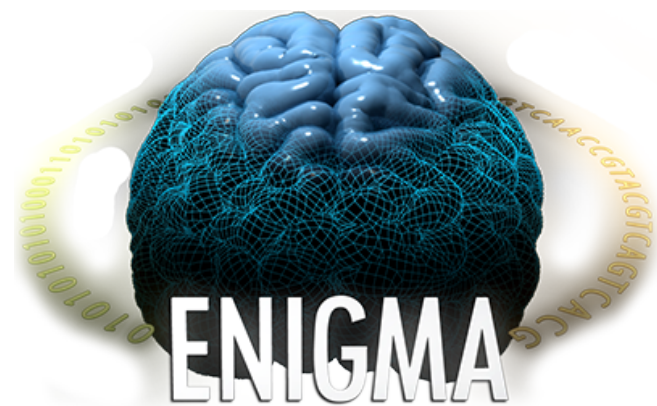
# The user base spans academia and industry



Stanford University

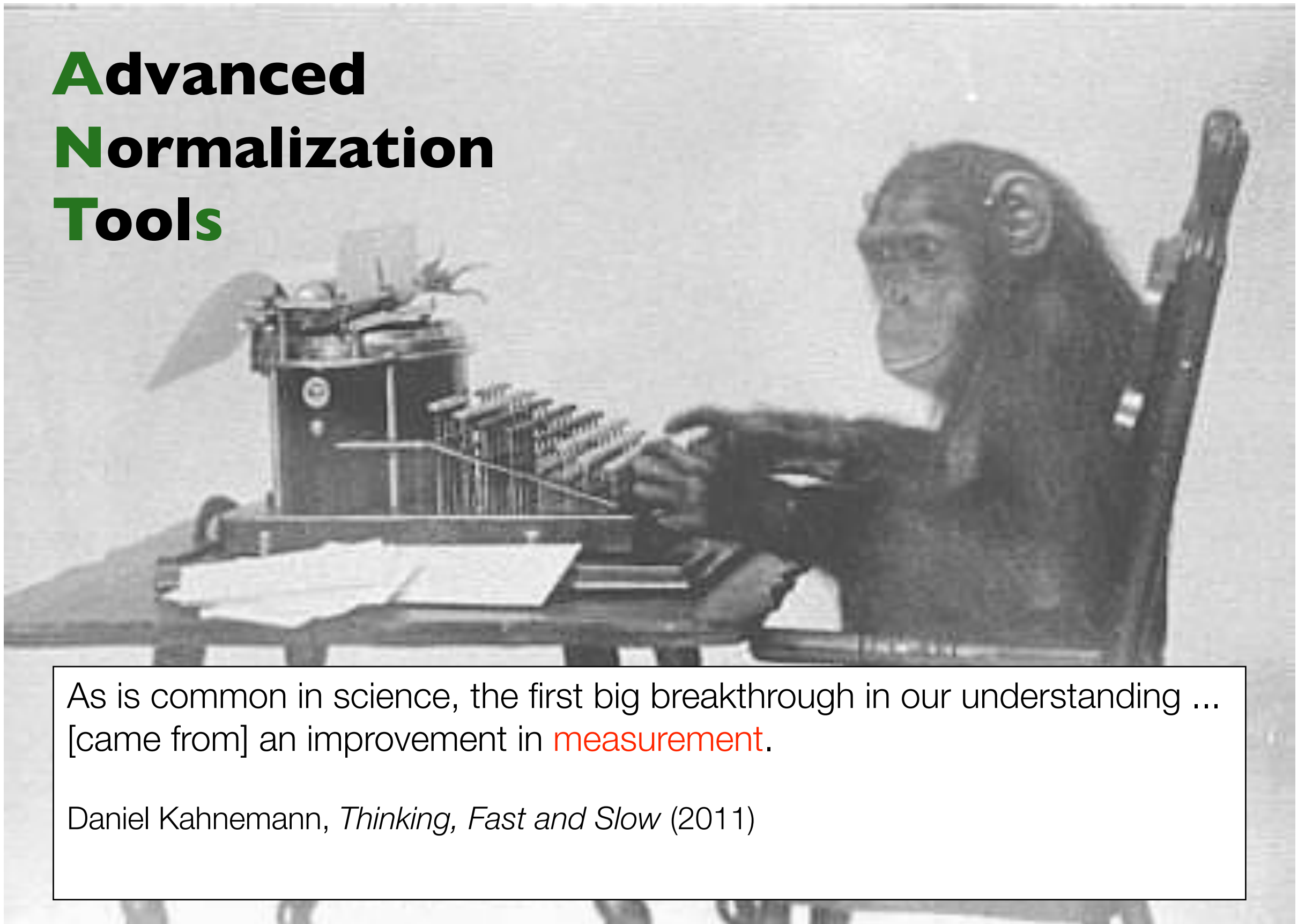


Princeton Neuroscience Institute





# Advanced Normalization Tools

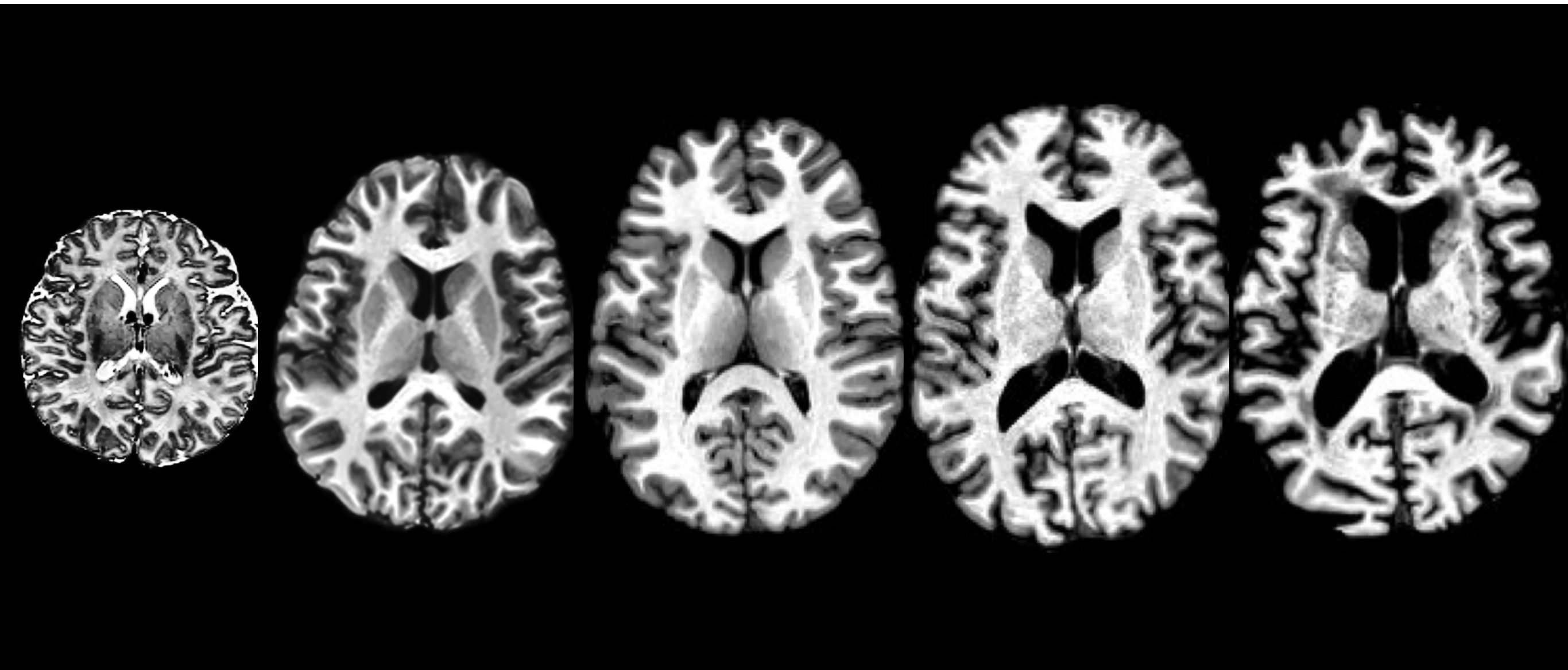


As is common in science, the first big breakthrough in our understanding ... [came from] an improvement in **measurement**.

Daniel Kahnemann, *Thinking, Fast and Slow* (2011)



# Contemporaneous state-of-the-art in image registration

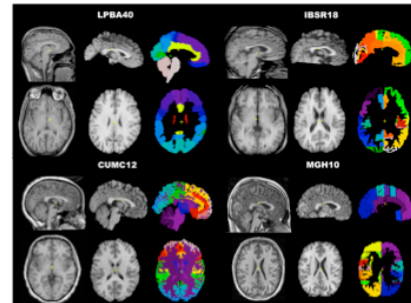




# SyN-related evaluations

## Independent Evaluation of ANTs Methods

"Would you like to participate in an unbiased evaluation of deformable registration?"  
- Arno Klein, Nov 2008



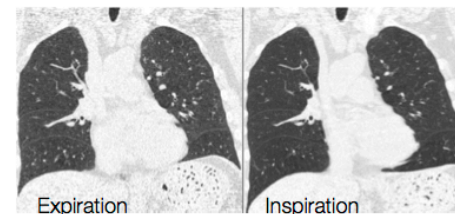
### Klein Evaluation 2009

	LPBA40 $\mu$ (SD)	IBSR18 $\mu$ (SD)	CUMC12 $\mu$ (SD)	MGH10 $\mu$ (SD)
rank 1	AIR .82 (.35)	SPM_D .83 (.27)	SPM_D .76 (.24)	SyN .77 (.37)
	SyN .60 (.38)	SyN .72 (.51)	SyN .74 (.51)	AIR .72 (.45)
	FNIRT .49 (.66)	IRT .67 (.53)	IRT .74 (.50)	IRT .61 (.51)
	JRD-Fluid .49 (.66)	AIR .60 (.70)	AIR .60 (.70)	
	IRT .43 (.63)	JRD-Fluid .30 (.82)		SPM_D .27 (.23)
	D-Demons .13 (.82)			D-Demons .27 (.69)
	SPM_US .11 (.83)			JRD-Fluid .24 (.66)
				ROMEO .06 (.63)
rank 2	ROMEO .08 (.73)	FNIRT .16 (.82)	D-Demons .20 (.84)	
	SPM_D .07 (.29)	D-Demons .05 (.84)	FNIRT .18 (.81)	
			JRD-Fluid .17 (.81)	

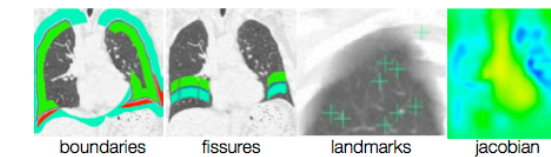
Permutation test ranking of the registration methods by label set. This table lists the methods that attained the top three ranks after conducting permutation tests between mean target overlaps (averaged across regions) for each pair of methods, then calculating the percentage of p-values less than or equal to 0.05 (of 100,000 tests for CUMC12 and MGH10 or of 10,000 tests for LPBA40 and IBSR18;  $\mu$ =mean, SD=standard deviation). Methods within ranks 1, 2, and 3 have positive mean percentages lying within one, two, and three standard deviations of the highest mean, respectively. Values are not comparable across label sets (columns). (SPM\_D=DARTEL pairwise)

2008

### Murphy Evaluation 2010/2011



"Brian, should we participate in this lung registration challenge?"  
- Gang Song

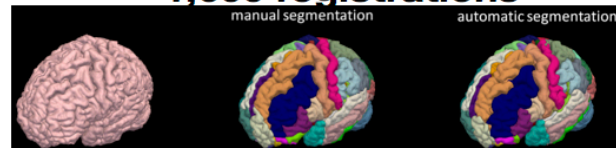


	Boundaries	Fissures	Landmarks	Folding	Overall					
Team Name	Avg Score	Avg Rank	Avg Score	Avg Rank	Avg Score	Avg Rank	Avg Score	Avg Rank	Placed	Last Update
picst gsyn	0.12	9.00	0.03	9.52	0.75	3.65	0.00	13.77	8.73	1
nifty Reggers	0.00	7.57	0.27	12.30	0.75	7.25	0.00	12.50	9.90	2
Iowa sstvd										

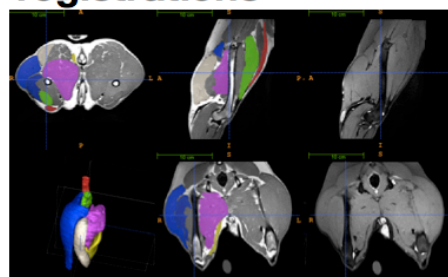
- Register pairs of thoracic CT volumes
- Part of MICCAI 2010 Grand Challenges: <http://emphire10.cs.uiowa.edu>
- First round offline competition finished on June 21, 2010
- ANTS by *picst gsyn* : 1<sup>st</sup> place among 34 teams

### SATA Challenge MICCAI 2013: Standardized Registration

1,600 registrations

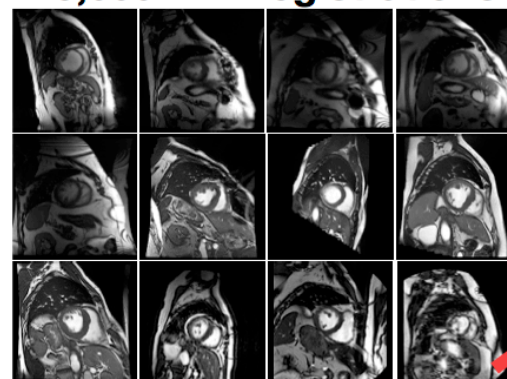


7,000+ multivariate registrations

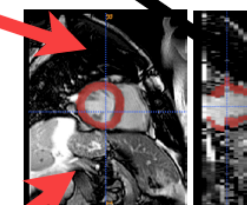


Expected Results for challenge participants ~ Dice = 0.8+

13,000+ 4D registrations



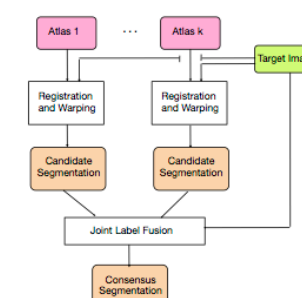
I wouldn't be surprised if getting "reasonable" & "consistent" registrations for this data is difficult or impossible.



High-res axis Low-res axis

Expected Results for challenge participants ~ Dice = 0.7

### SATA Challenge MICCAI 2012

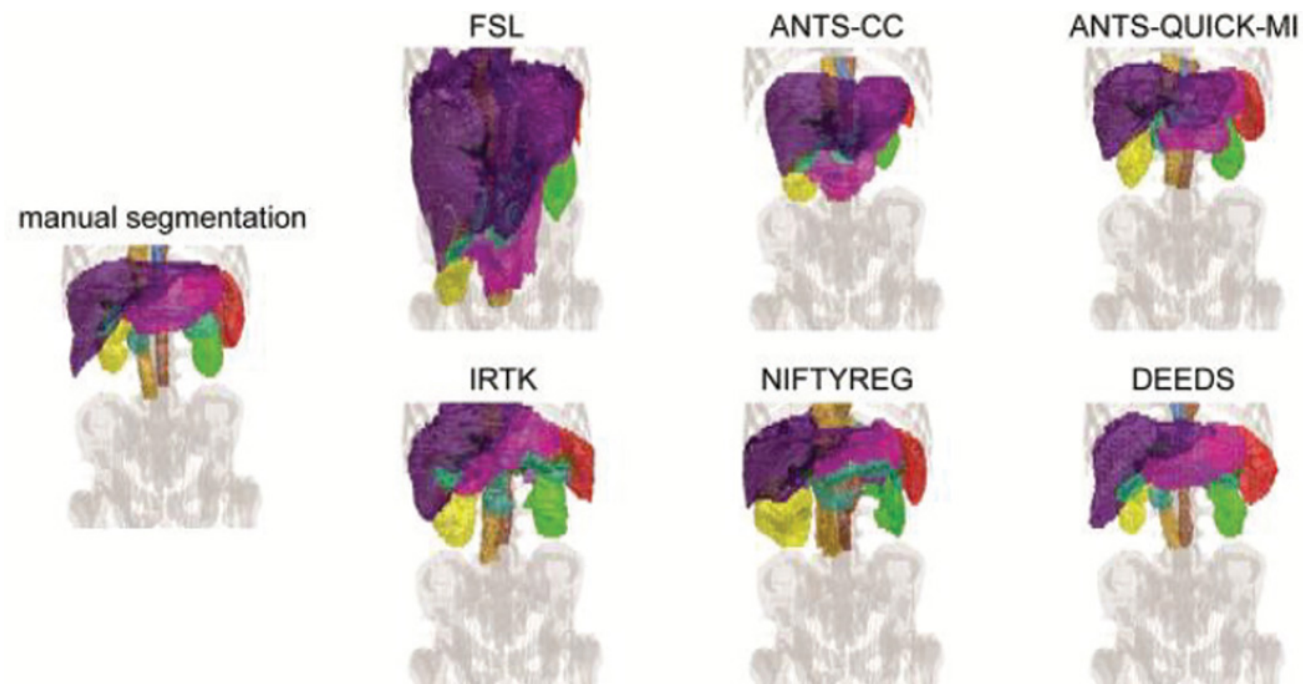


Overall Rank	Team Name	Mean DSC	Mean DSC	Mean DSC
1	picst gsyn	0.7048	0.7048	0.7048
2	NonLocalNet	0.7001	0.7001	0.7001
3	NAACP_SIN	0.7076	0.7076	0.7076
4	PRIN_SIN	0.7069	0.7069	0.7069
5	NAACP	0.7063	0.7063	0.7063
6	STAPL	0.7072	0.7072	0.7072
7	SpaGEANT	0.7072	0.7072	0.7072
8	CSL_SIN	0.7077	0.7077	0.7077
9	CSL_SIN	0.7077	0.7077	0.7077
10	CSL_SIN	0.7077	0.7077	0.7077
11	CSL_SIN	0.7077	0.7077	0.7077
12	CSL_SIN	0.7077	0.7077	0.7077
13	CSL_SIN	0.7077	0.7077	0.7077
14	CSL_SIN	0.7077	0.7077	0.7077
15	CSL_SIN	0.7077	0.7077	0.7077
16	CSL_SIN	0.7077	0.7077	0.7077
17	CSL_SIN	0.7077	0.7077	0.7077
18	CSL_SIN	0.7077	0.7077	0.7077
19	CSL_SIN	0.7077	0.7077	0.7077
20	CSL_SIN	0.7077	0.7077	0.7077
21	CSL_SIN	0.7077	0.7077	0.7077
22	CSL_SIN	0.7077	0.7077	0.7077
23	CSL_SIN	0.7077	0.7077	0.7077
24	CSL_SIN	0.7077	0.7077	0.7077

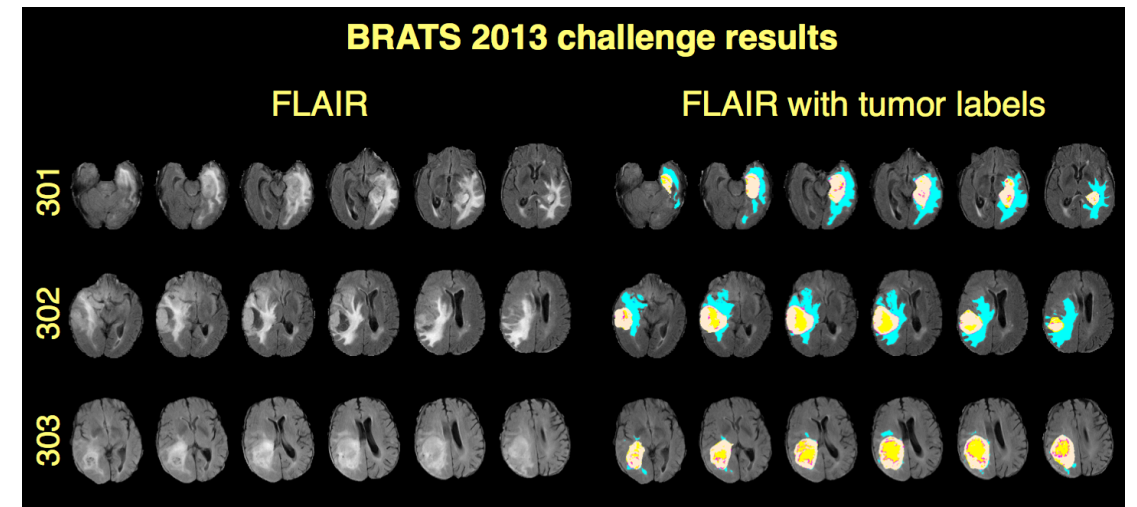


# SyN-related evaluations (part 2)

## Evaluation of Six Registration Methods for the Human Abdomen on Clinically Acquired CT



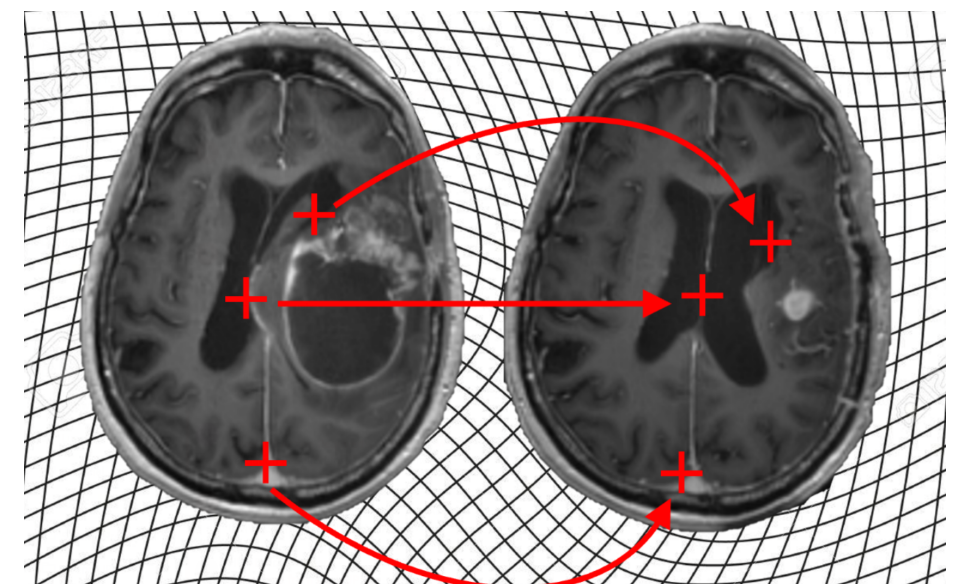
## BraTS-Seg 2013



Patient

Position	User	Dice			Positive Predictive Value			Sensitivity			Kappa	Complete tumor Rank	Tumor core Rank	Enhancing tumor Rank
		complete	core	enhancing	complete	core	enhancing	complete	core	enhancing				
1	Nick Tustison	0.87 (1)	0.78 (1)	0.74 (1)	0.85 (2)	0.74 (4)	0.69 (4)	0.89 (2)	0.88 (1)	0.83 (1)	0.99 (1)	1.67	2.00	1.89
2	Raphael Meier	0.82 (5)	0.73 (2)	0.69 (3)	0.76 (6)	0.78 (2)	0.71 (1)	0.92 (1)	0.72 (4)	0.73 (3)	0.99 (4)	4.00	2.67	3.00
3	Syed Reza	0.83 (4)	0.72 (3)	0.72 (2)	0.82 (3)	0.81 (1)	0.70 (3)	0.86 (5)	0.69 (6)	0.76 (2)	0.99 (3)	4.00	3.33	3.22
4	Hoon Zhao	0.84 (3)	0.79 (1)	0.68 (4)	0.81 (4)	0.87 (1)	0.68 (5)	0.80 (3)	0.70 (4)	0.70 (4)	0.98 (5)	3.33	4.00	4.11

## BraTS-Reg 2021-22\*



*“...because ANTS was almost always at the top when we (internally) optimized it to the task...”*

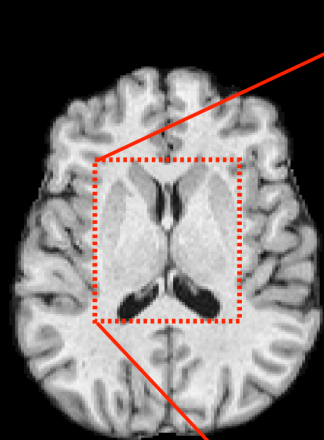


# ANTs core processing tools

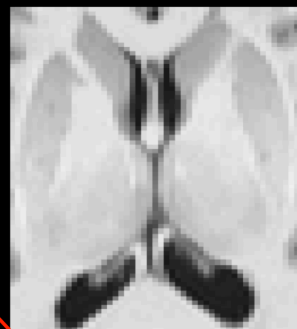
## ANTs core processing tools



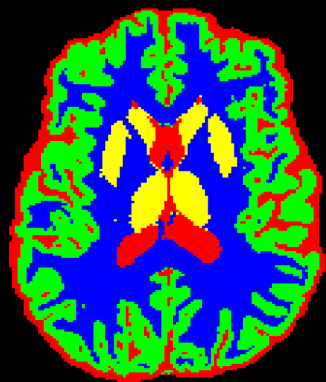
IXI 061



N4 bias correction



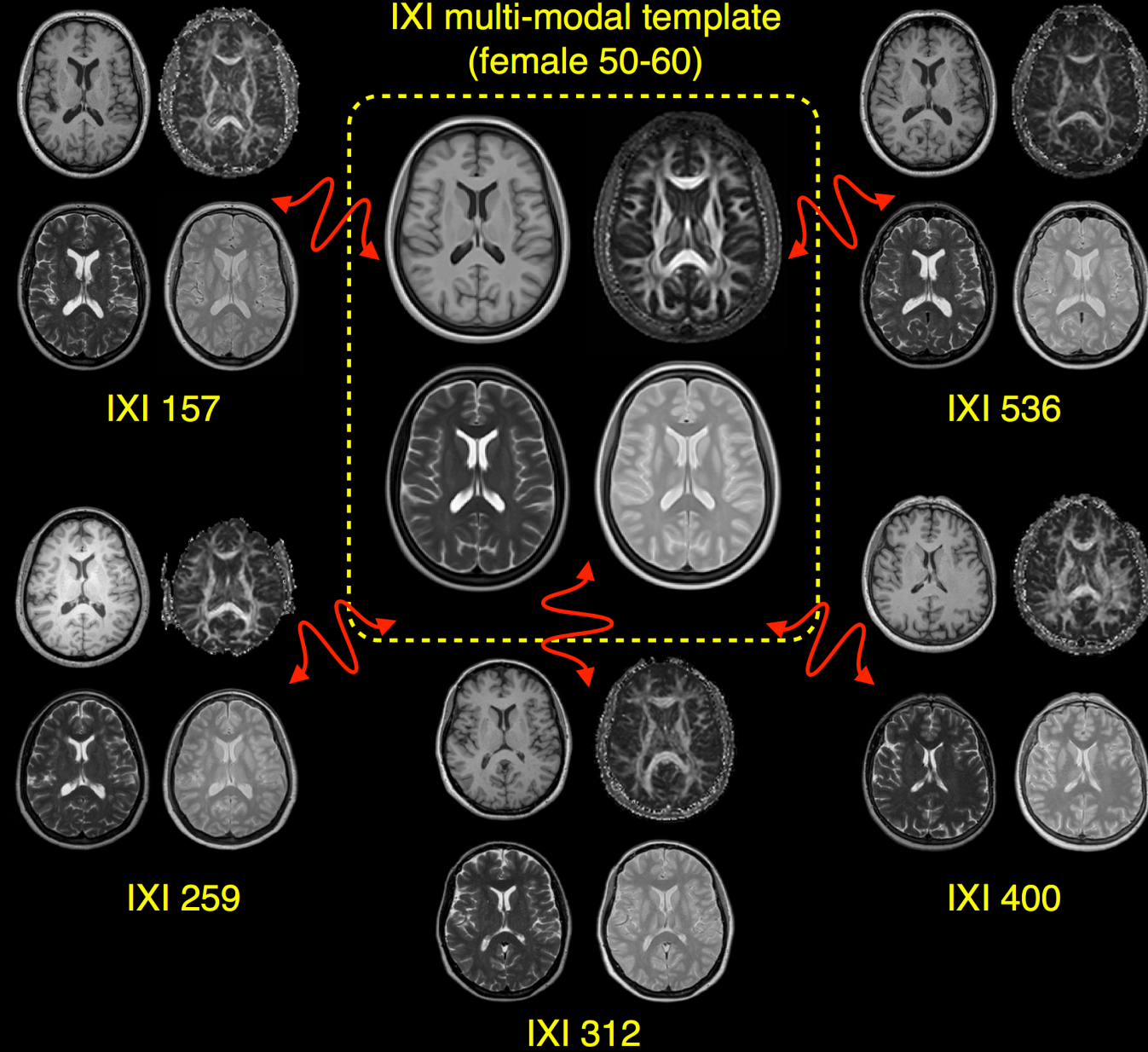
Denoising



Atropos  
segmentation

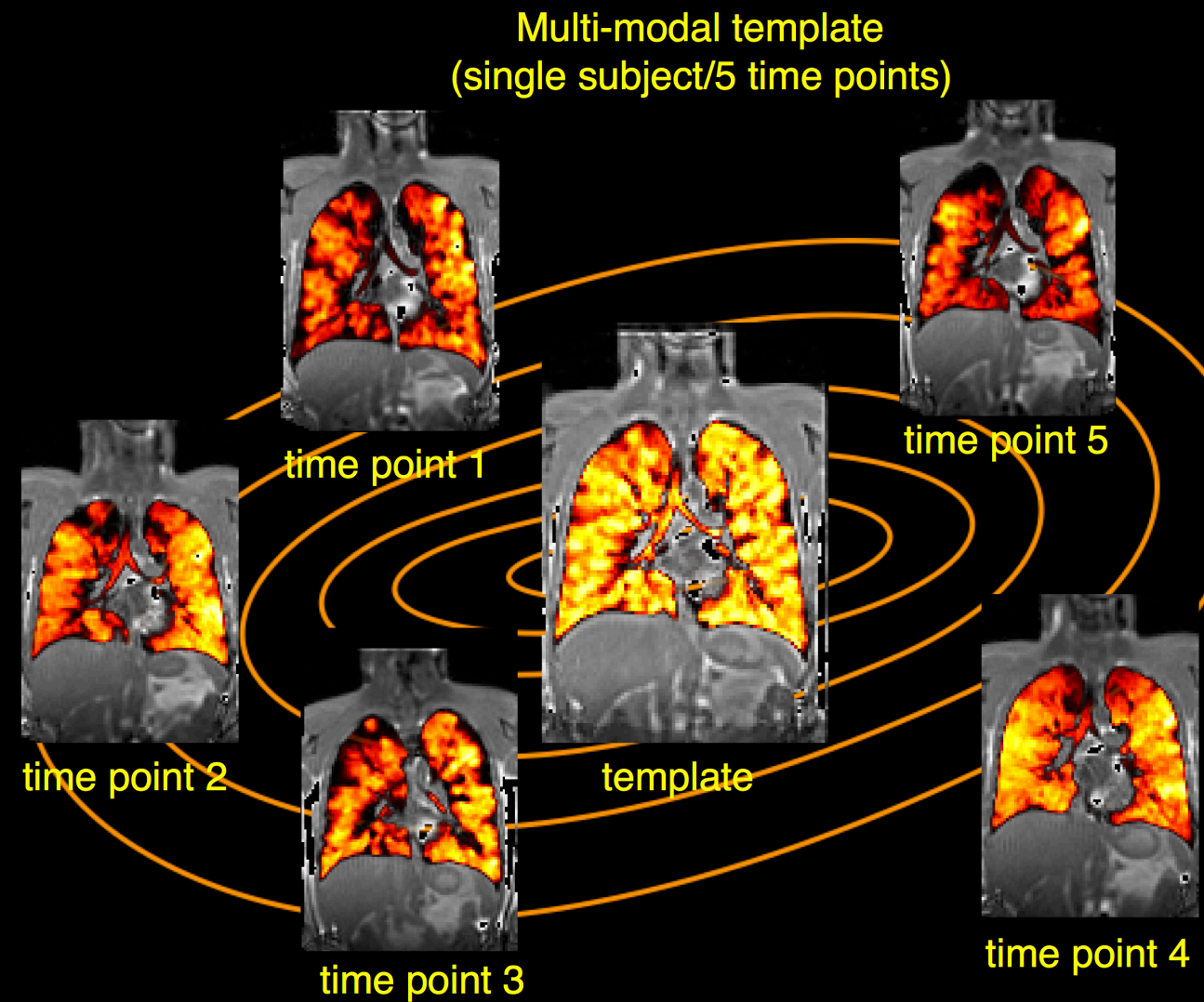
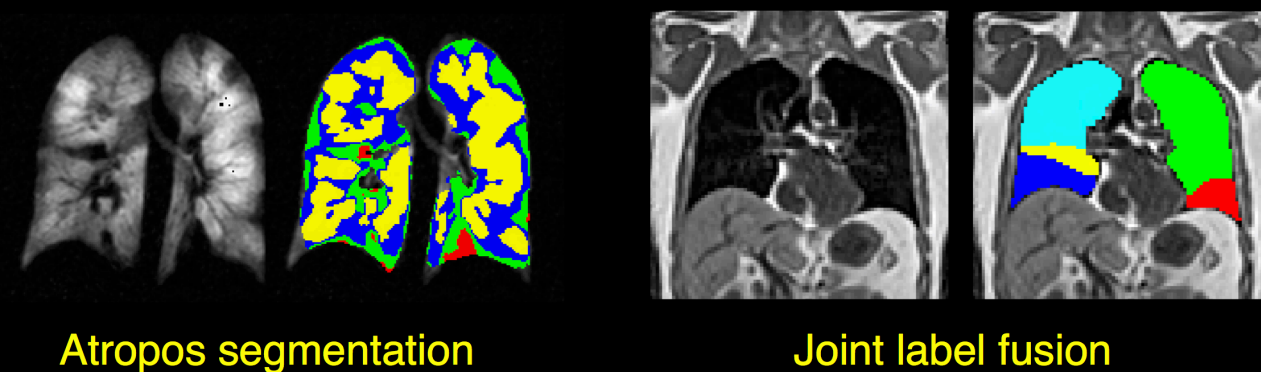
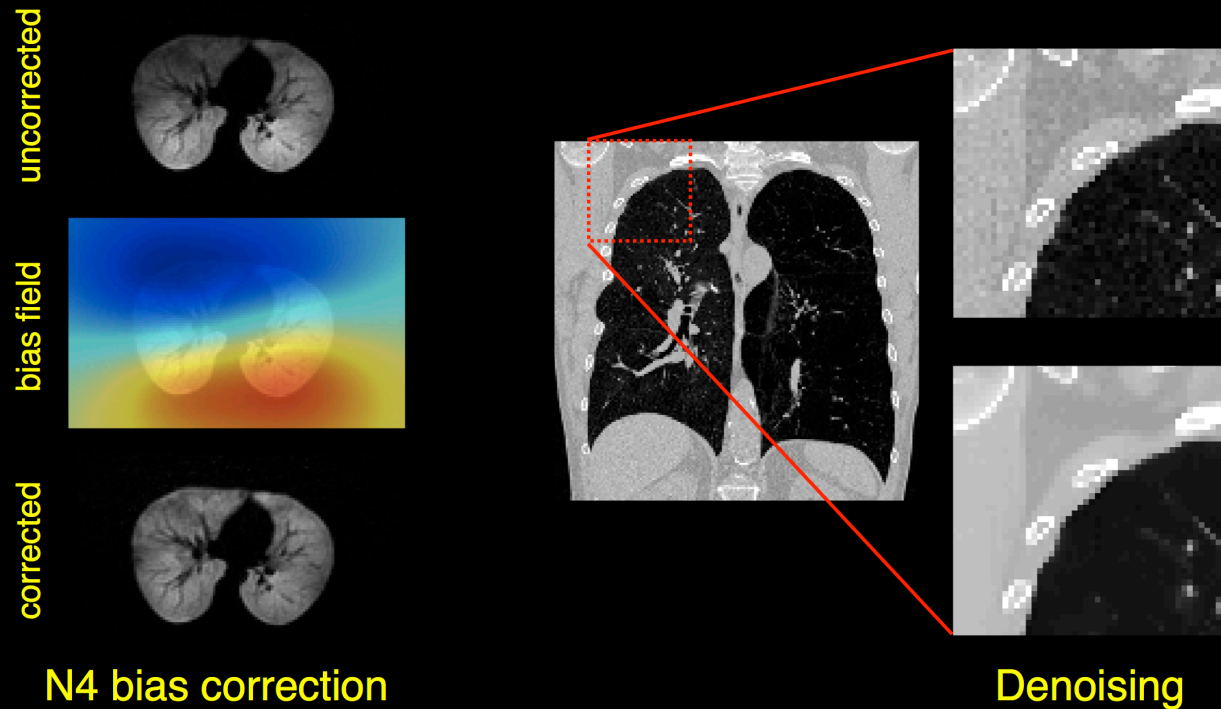


Joint label fusion



# ANTs core processing tools (adapted)

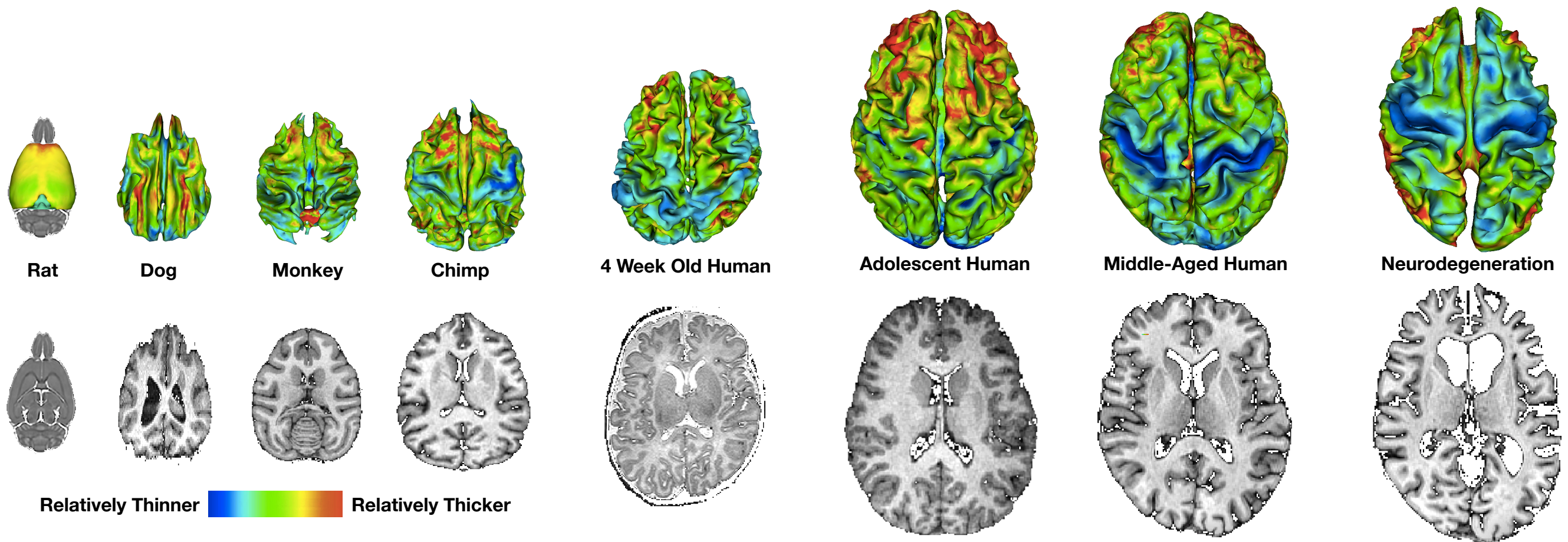
## ANTs core processing tools for multi-modal lung imaging studies





# ANTs cortical thickness (other species)

DiReCT  
cortical thickness



Mean Thickness: rat=1.7mm dog=2.0mm, monkey=3.0mm, chimp=3.5mm, adol=3.4mm, mid-age=3.0mm, ndgen=2.6mm

Badea, et al.

Shamy, et al.

Hallam Hurt

Martha Farah

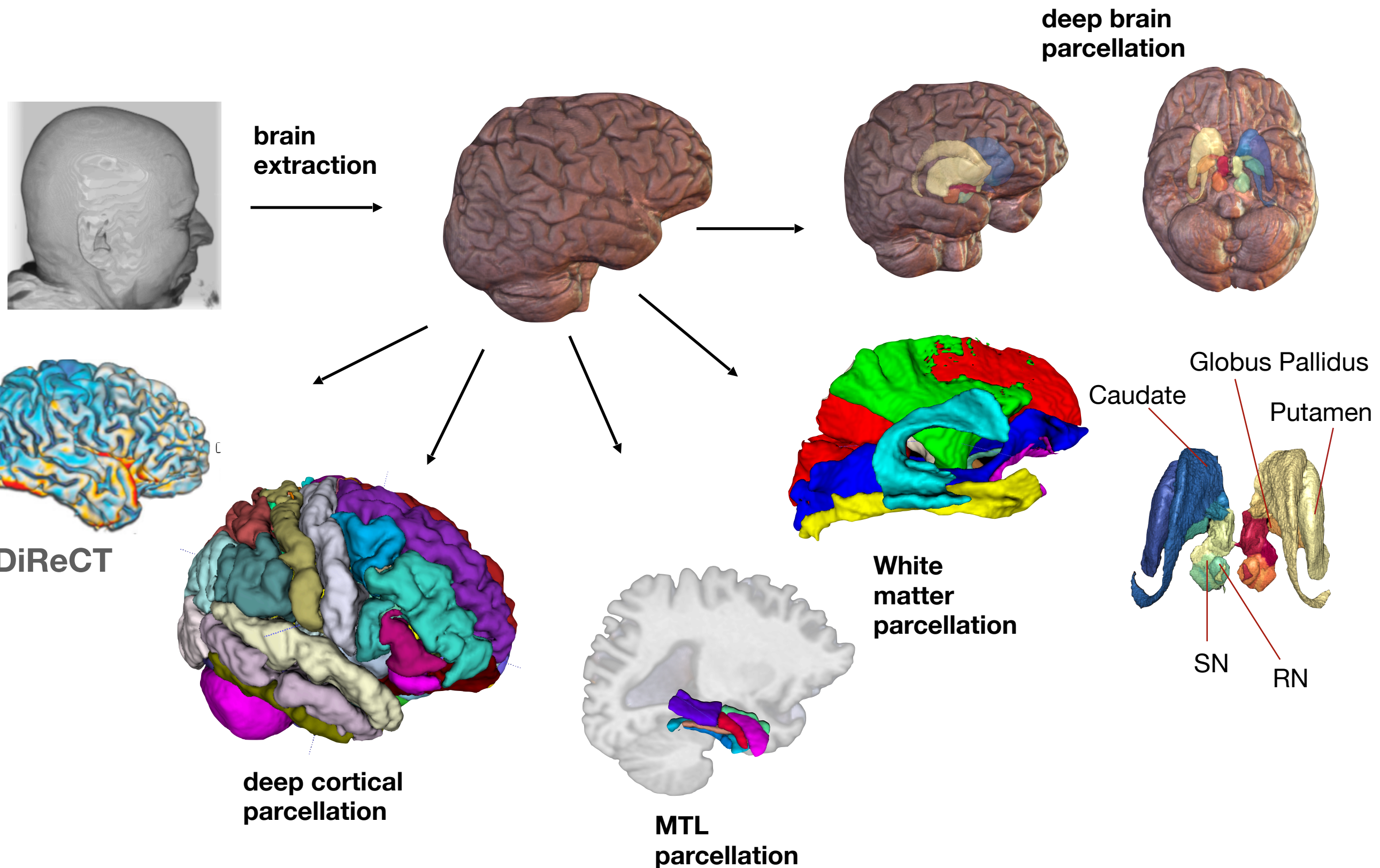
Avants, Tustison

Grossman, et al.

Datta, et al.

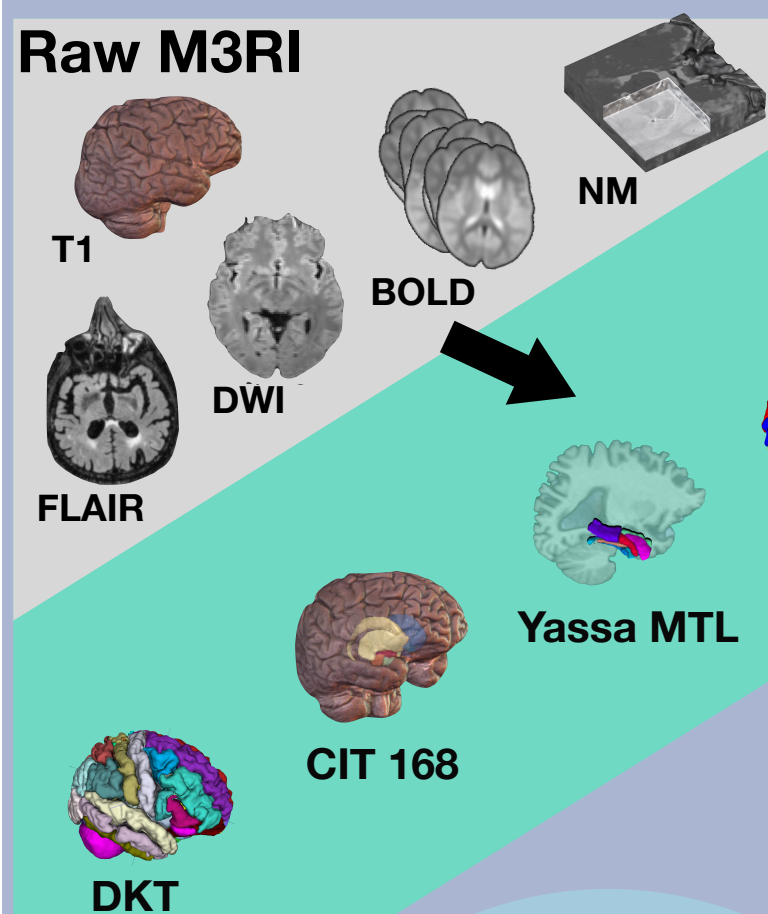
Avants, Hoffman

# Structural IDPs from T1w using ANTsPyT1w

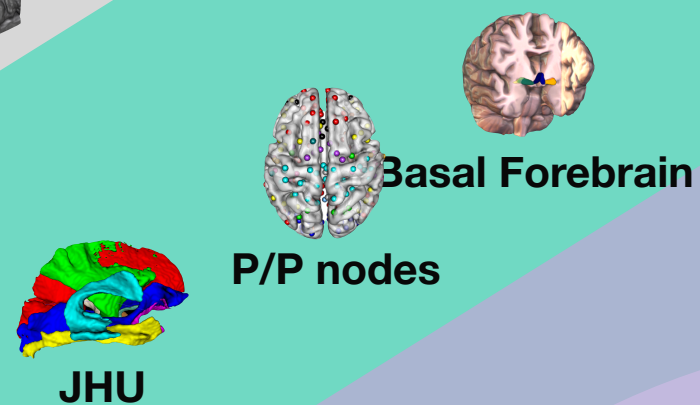




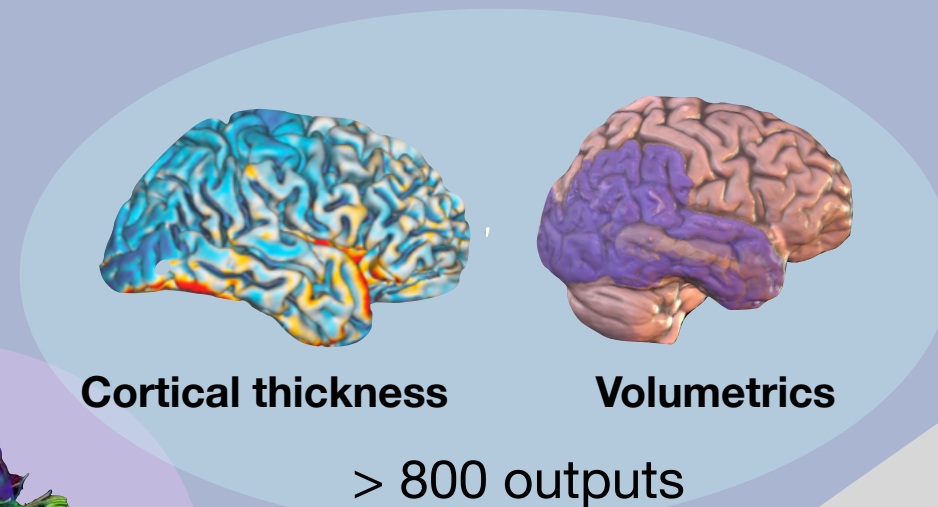
## Raw M3RI



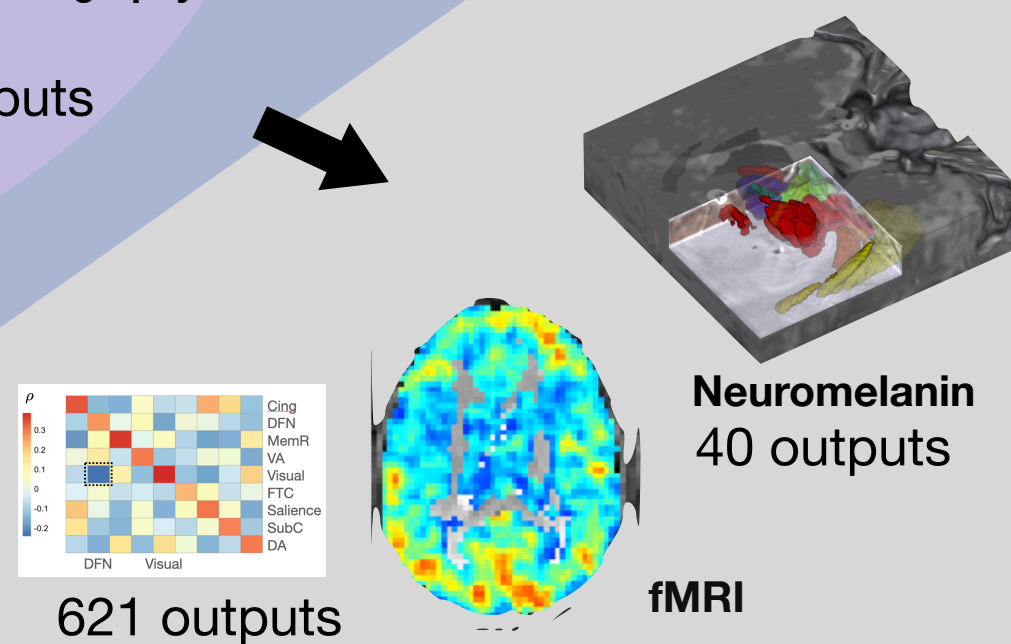
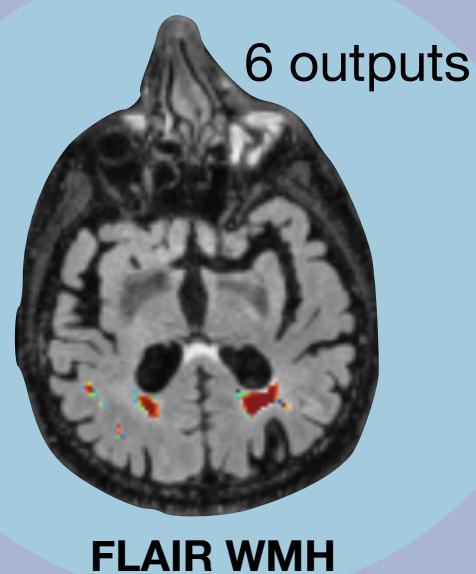
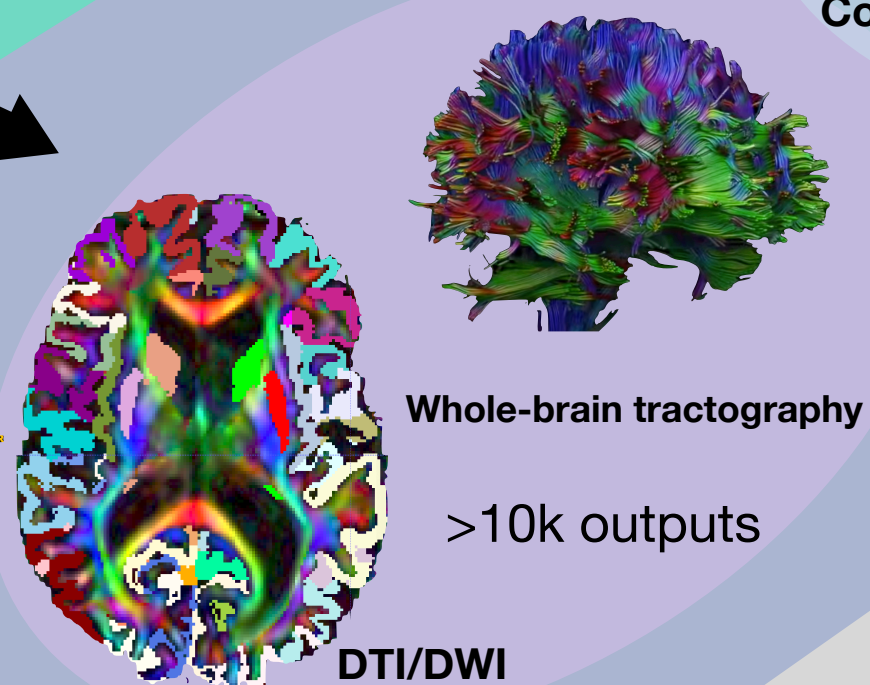
## Anatomical priors



## Structural Quantification

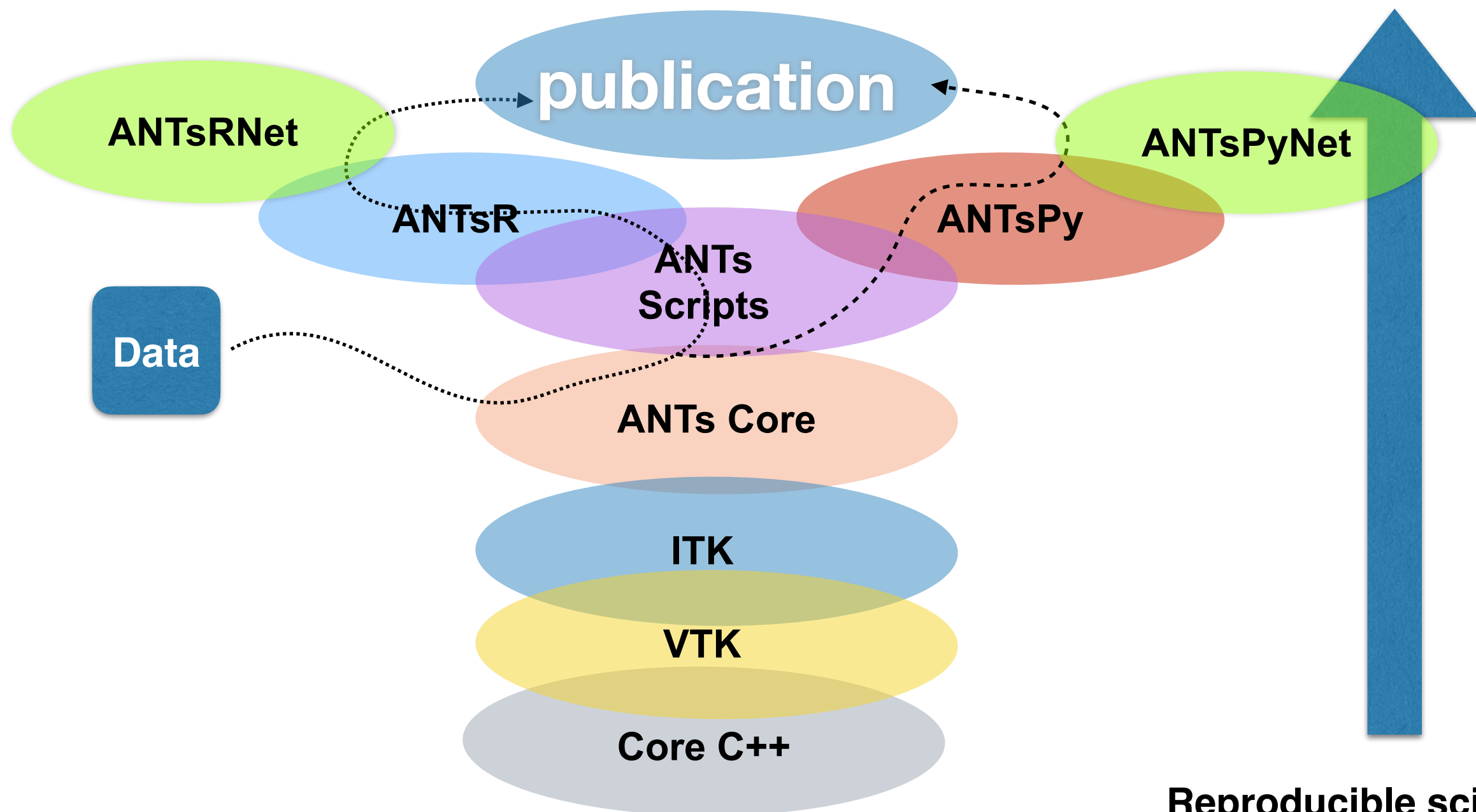


## Functional Quantification



# Full integration of “hard-core” C++ with R, Python and Keras (deep learning)

ANTs<sup>R</sup> & ANTsPython



Reproducible science stack