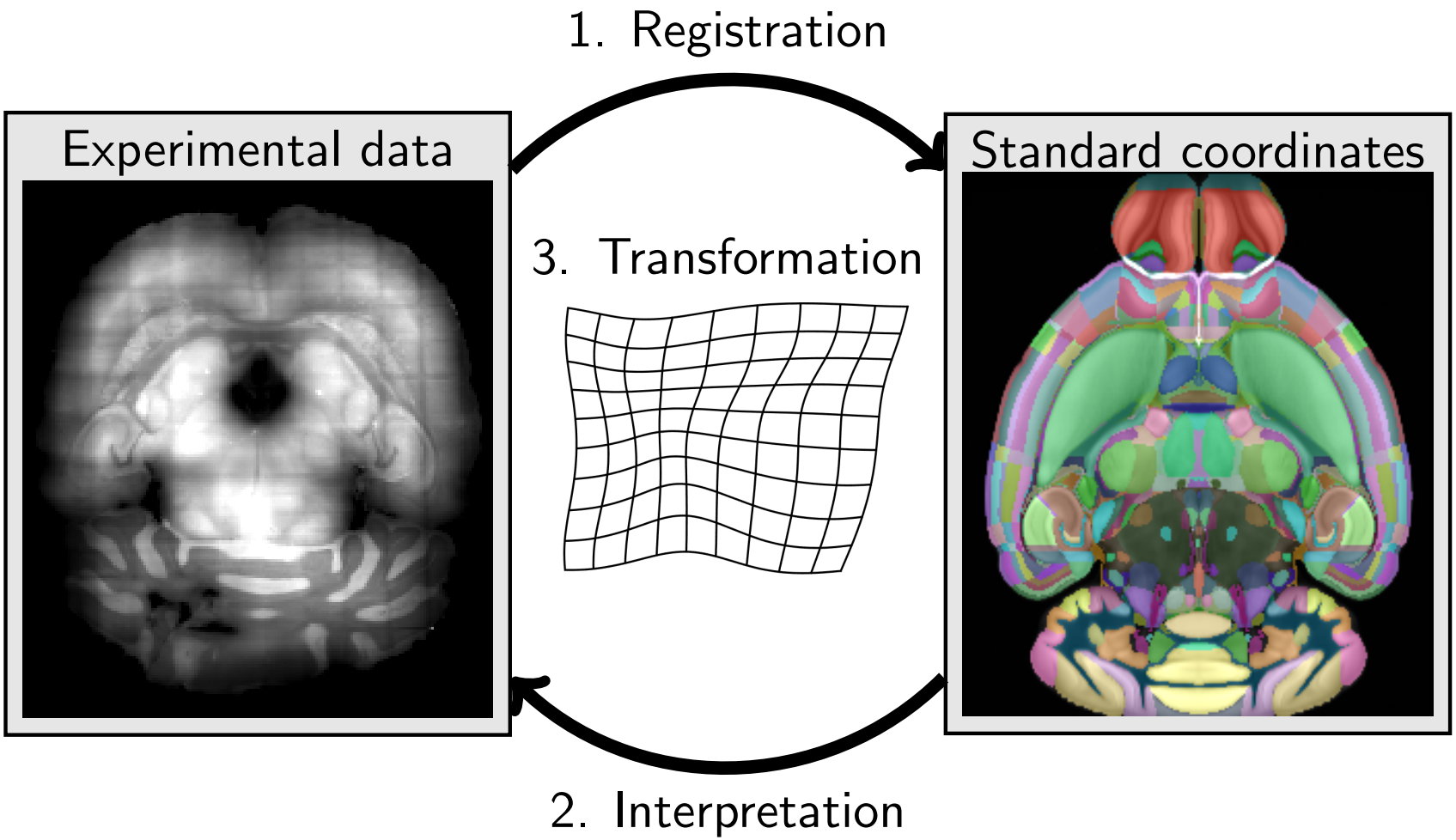
Brain mapping tools for neuroscience research

Daniel Tward (dtward@cis.jhu.edu)

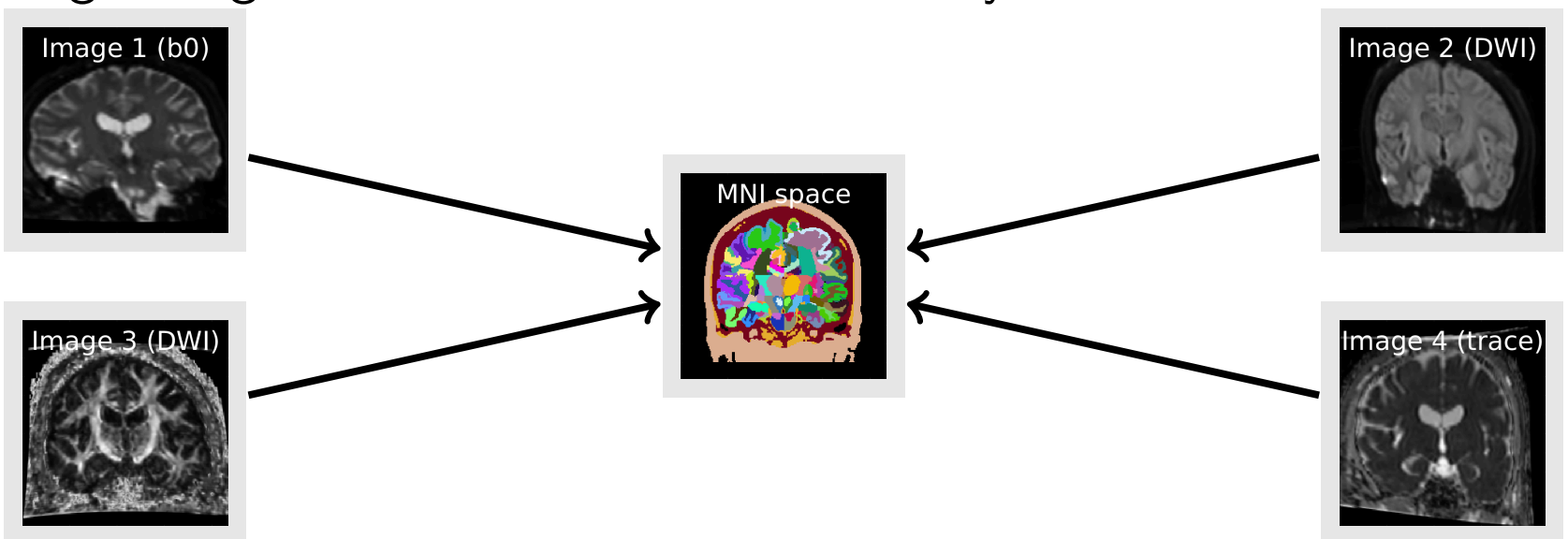
NeuroData and Center for Imaging Science
Department of Biomedical Engineering
Johns Hopkins University

The goal of brain mapping



1. Registration

Align images into a standard coordinate system



- Enrich information by fusing modalities
- Analyze different specimens statistically
- Build databases of information indexed to spatial coordinates

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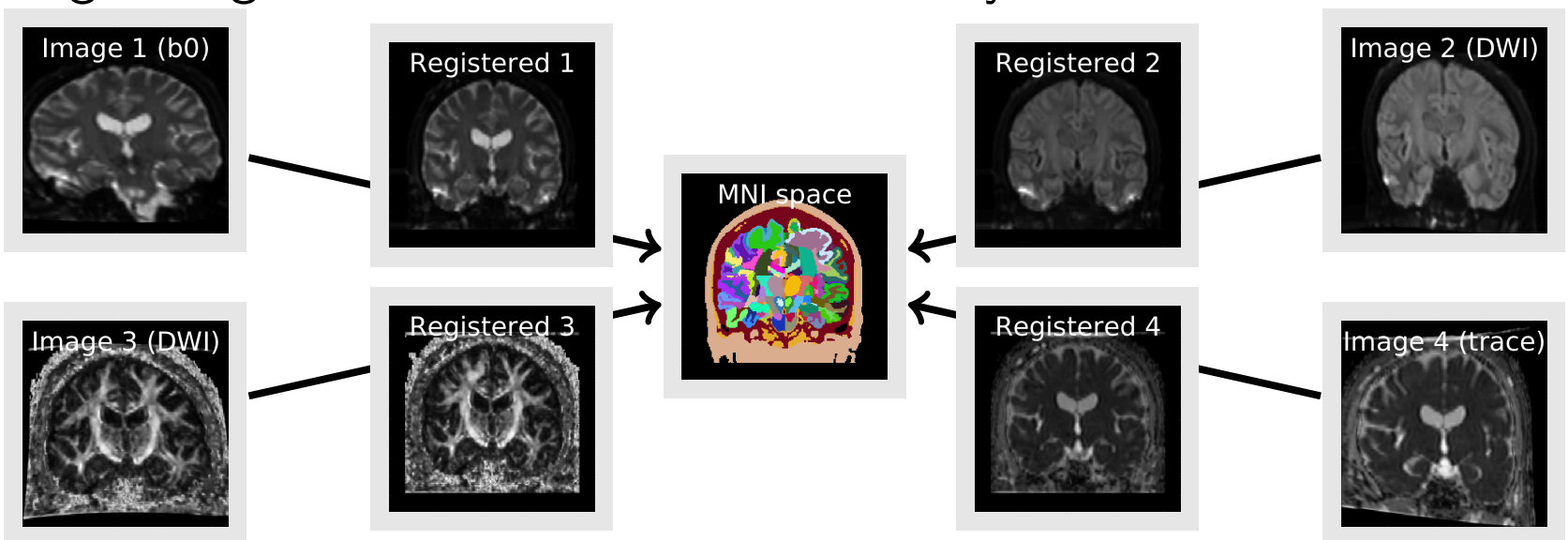

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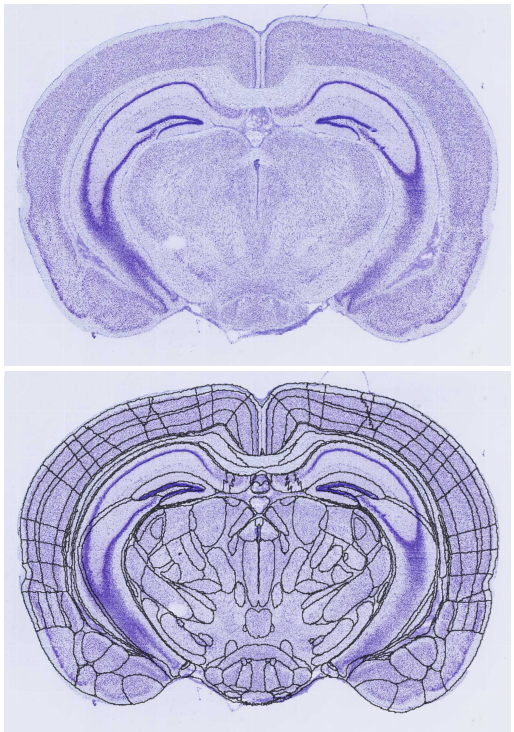
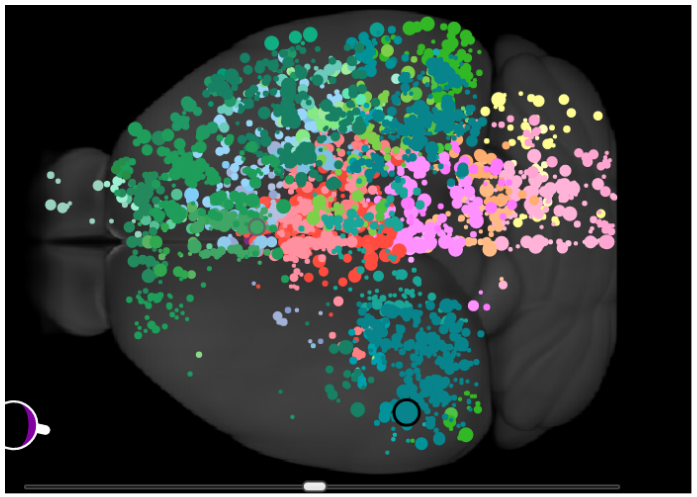
2. Interpretation

Leverage information stored in atlas coordinates.[1]

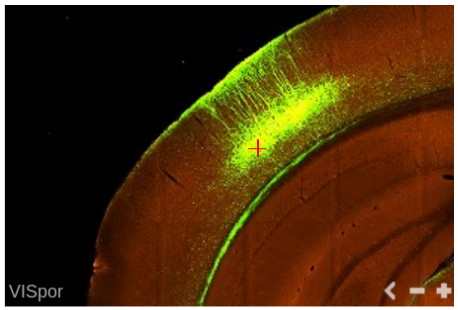
MBA

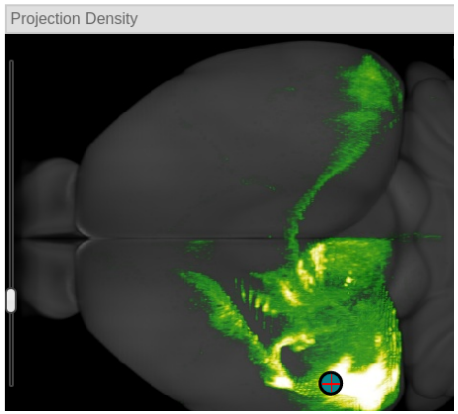


ARA



ction Structure(s)	Mouse Line	Tracer	Inj Site Vol
VISpor - VISal, VISl, VISp, VISpl, VISli, TEa	Rbp4-Cre_KL100	SypEGFP	0.400
VISpor - TEa, ECT, ENTl, ENTm, SUB	Cux2-IRES-Cre	EGFP	0.355
VISpor - VISl, VISpl	Tlx3-Cre_PL56	EGFP	0.012
VISpor - VISli, ENTl, ENTm, SUB	Syt6-Cre_KI148	EGFP	0.007
VISpor - VISl, VISli, TEa, ECT, ENTl, ENTm, SUB	A930038C07Ri…	EGFP	0.103
ACAd - ACAv	Chrna2-Cre_O…	EGFP	0.052



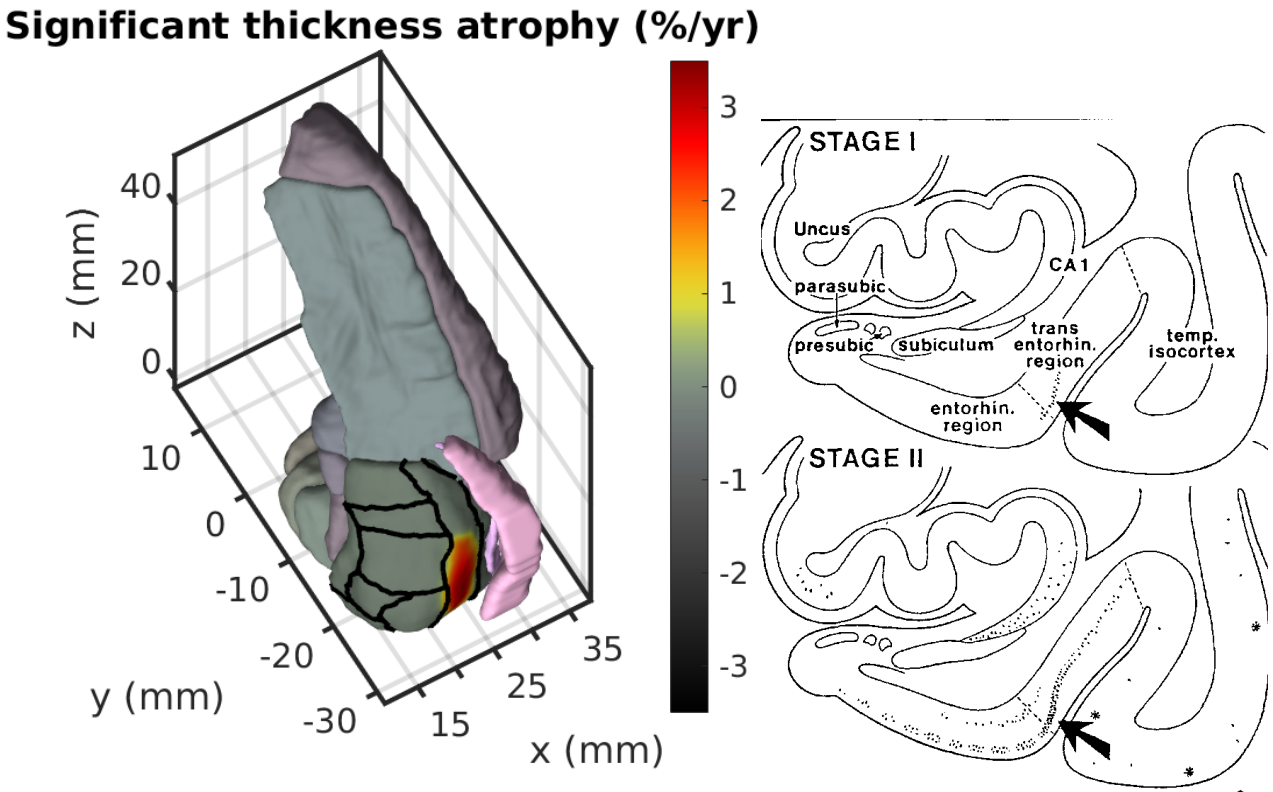


- Label images with standard ontologies
- Index to gene expression, cell types, tractography, etc.

[1] MBA: Mouse brain architecture `brainarchitecture.org`, ARA: Allen reference atlas `connectivity.brain-map.org/`

3. Transformation

Studying transformations quantifies growth or atrophy



- Here thickness change in transentorhinal region measured from longitudinal MRI[2]
- Previously only observed at autopsy

[2] Tward, Daniel J., et al. "Entorhinal and transentorhinal atrophy in mild cognitive impairment using longitudinal diffeomorphometry." Alzheimer's & Dementia: Diagnosis, Assessment & Disease Monitoring 9 (2017): 41-50.

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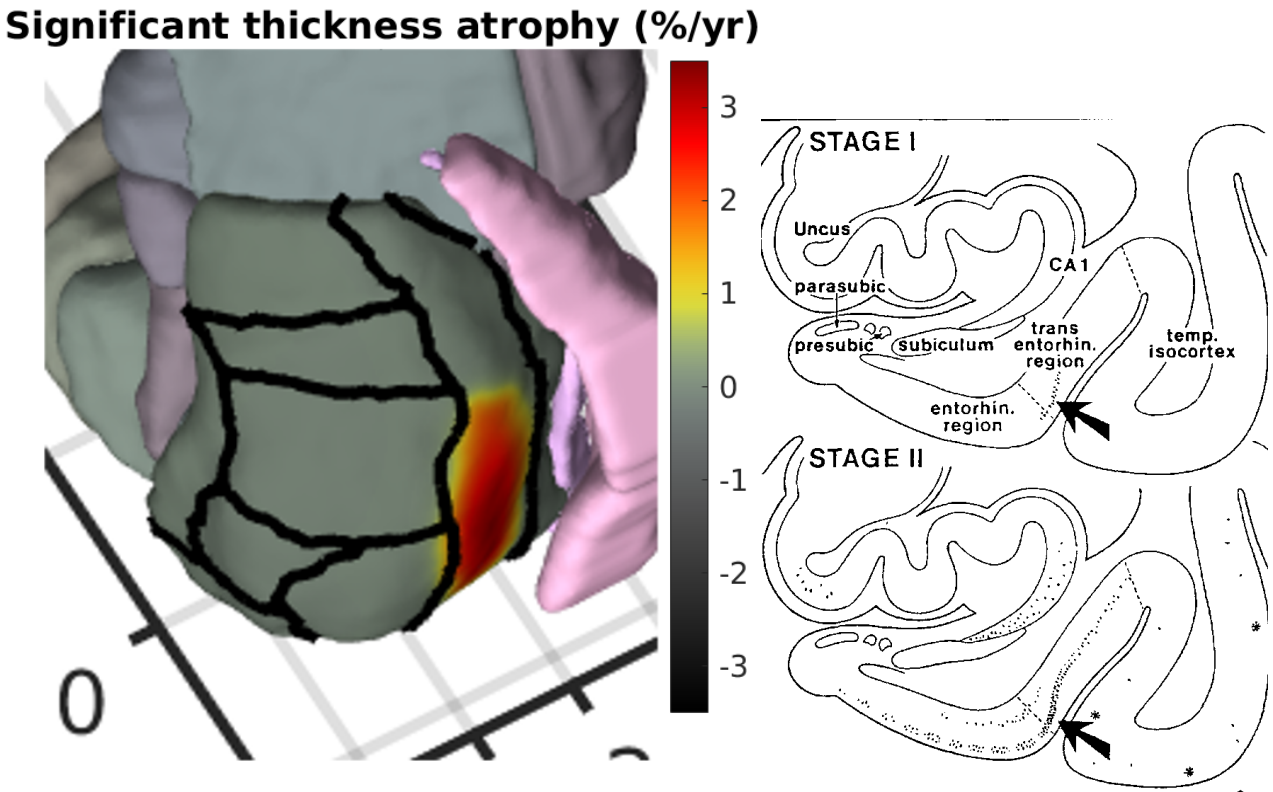

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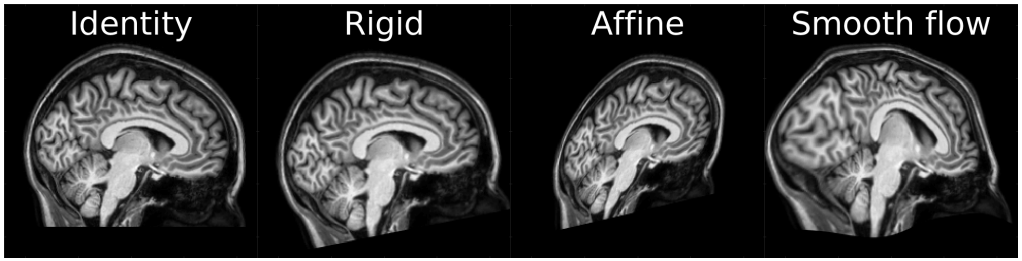
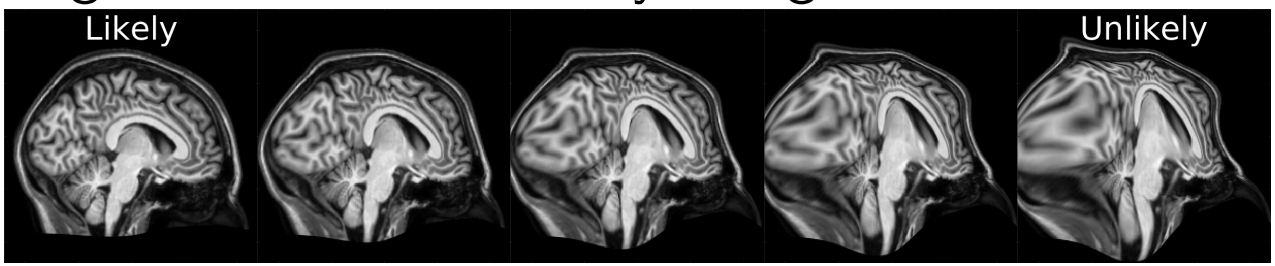
The ingredients of a brain mapping tool

Transformation model: What types of mappings do we consider?



Similarity: How good is an alignment?

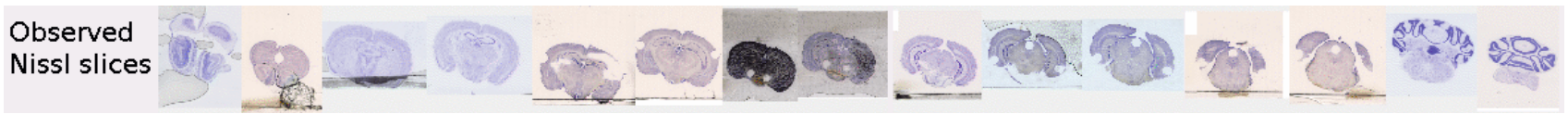
Regularization: How likely is a given transformation?



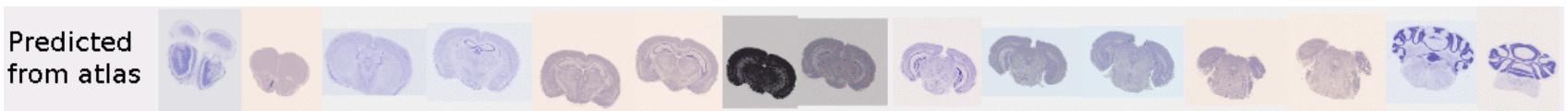
Challenges and solutions

Most brain mapping techniques were developed for medical imaging, but neuroscience data faces unique challenges:

- Incomplete or sliced data
- Artifacts or damaged tissue
- Multiple different modalities or appearance



We use machine learning techniques to predict one image from another, while jointly performing registration[3]

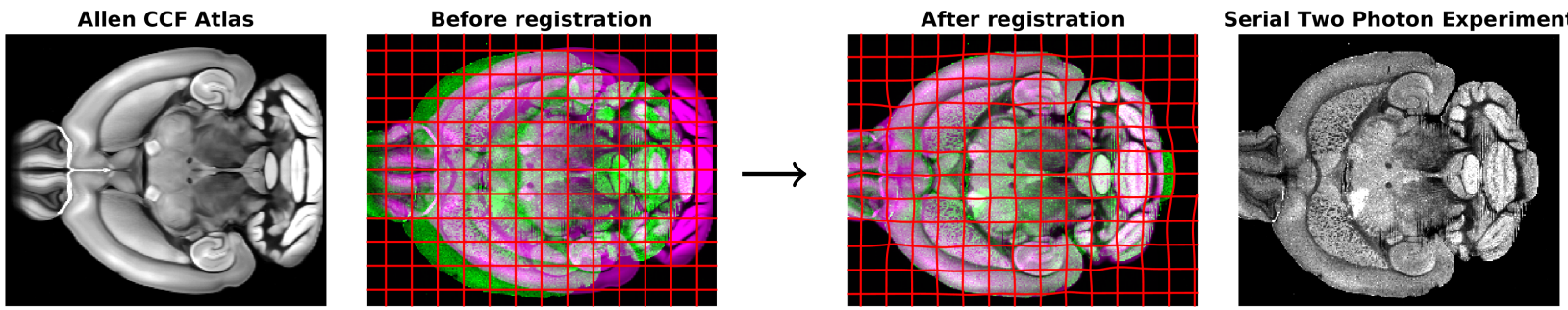


[3] Tward, Daniel Jacob, et al. "Diffeomorphic registration with intensity transformation and missing data: Application to 3D digital pathology of Alzheimer's disease." BioRxiv (2019): 494005.

ARDENT[4]: NeuroData's open source brain mapping tool

Publications and code available online from `neurodata.io/reg`

Ingredient	Choice	Benefit
Transform	Diffeomorphism	Smooth invertible fluid transform
Similarity	Log likelihood	Enables statistical approaches to artifacts and multi-modality
Regularization	Kinetic energy	Enables sparse representations effective in high dimensional bias variance tradeoff[5,6]



[4]Affine and Regularized Diffeomorphic Numeric Transform. [5]Tward, Daniel, et al. "Parametric surface diffeomorphometry for low dimensional embeddings of dense segmentations and imagery. IEEE transactions on pattern analysis and machine intelligence (2016) [6]Tward, Daniel, et al. "Estimating diffeomorphic mappings between templates and noisy data: Variance bounds on the estimated canonical volume form. Quarterly of Applied Mathematics (2019).

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