

Diffusion Tensor Imaging (DTI)

for the study of disorders of consciousness



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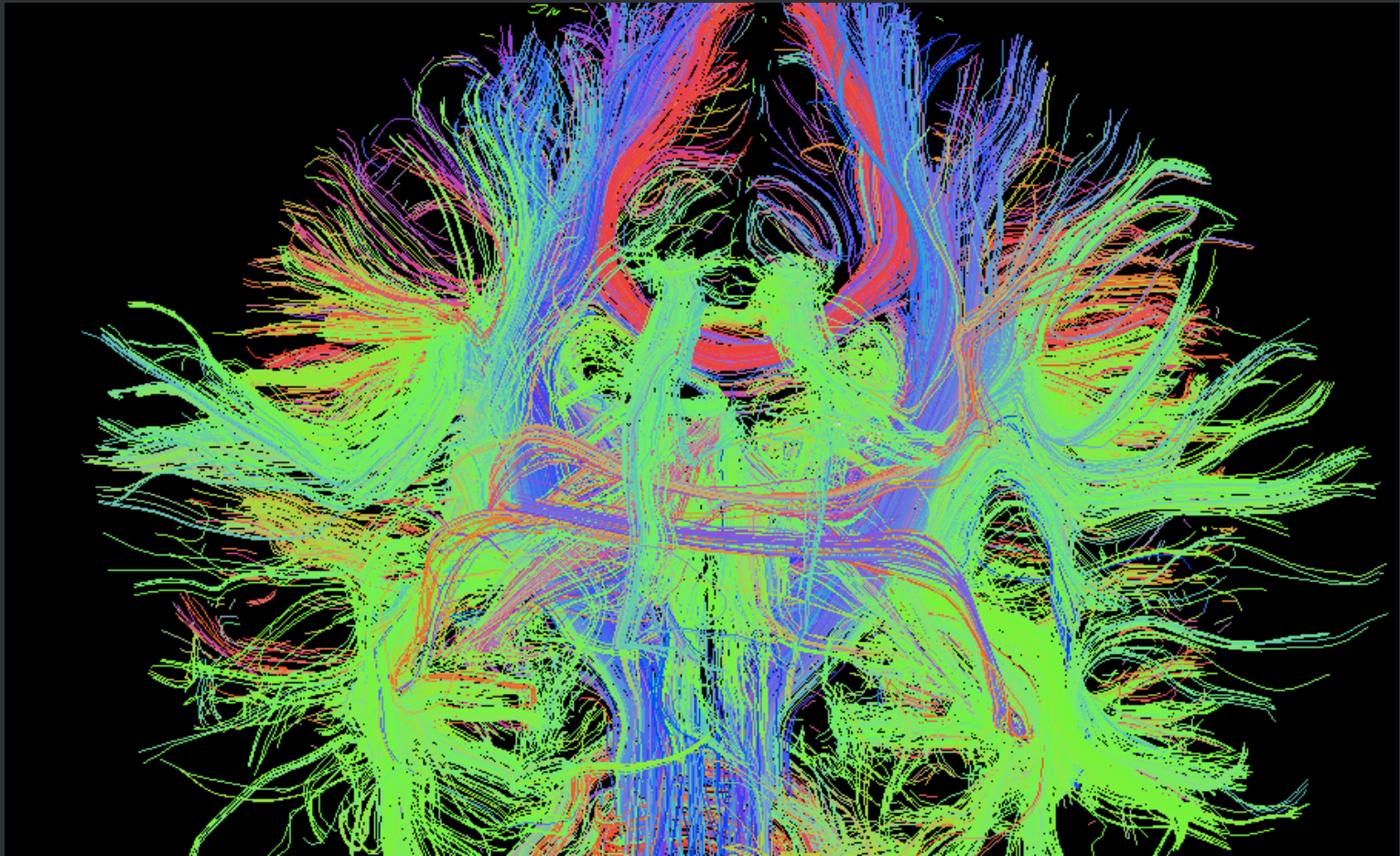
24/03/2017



Motivation

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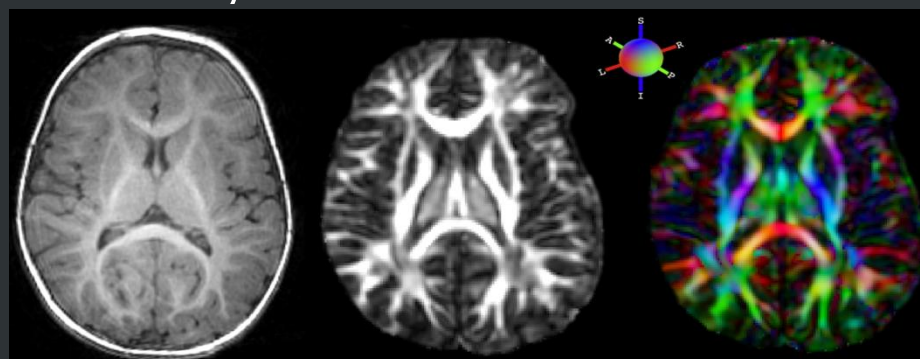
- Connectivity is of paramount importance for consciousness
- Study **connectivity structure** (micro and macro) from **white matter**



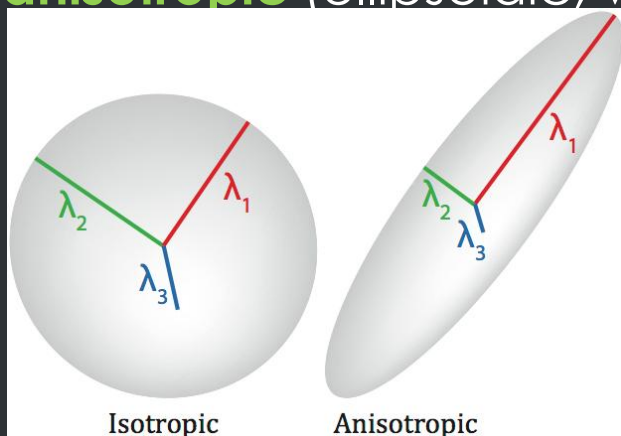
DTI preproc in 3 easy steps! (sort of...)

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1. Using diffusion magnetic resonance imagery, **acquire water** molecules (brownian) **motion**.

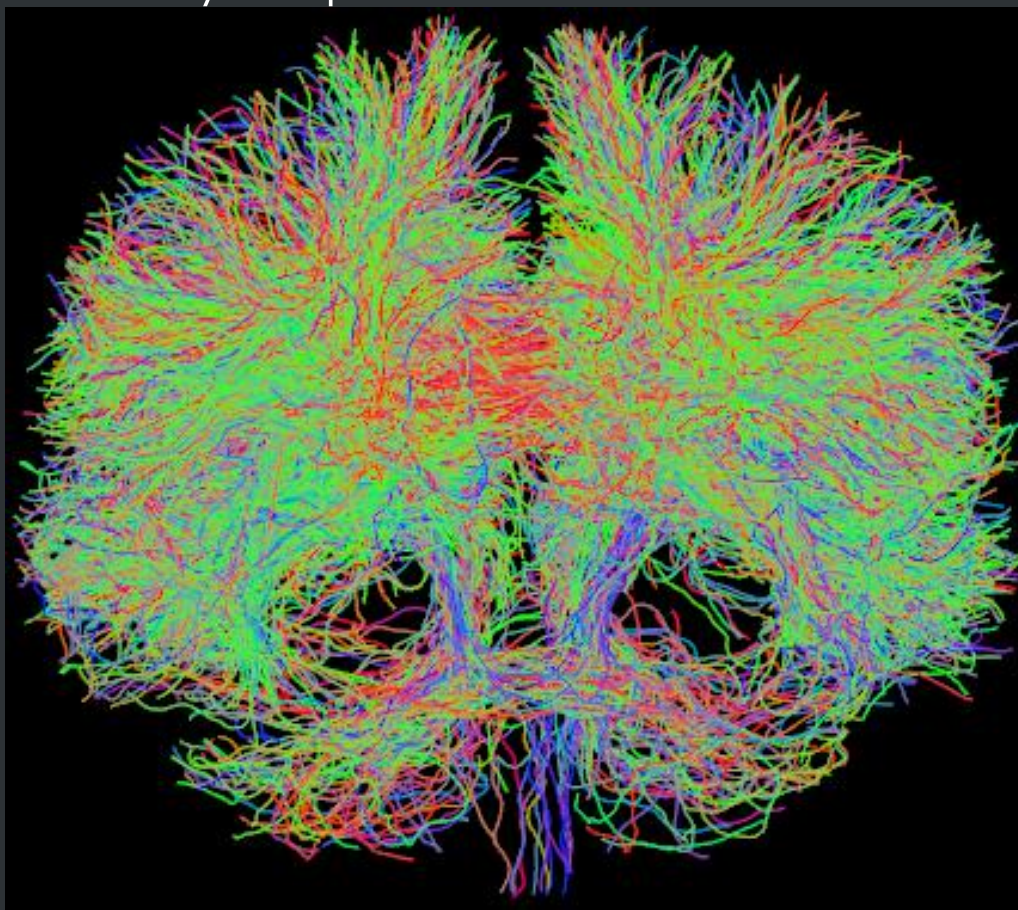


2. Estimate **tensors** \approx **mean motion** of water molecules for each brain's voxel. We get isotropic (round, grey matter) and **anisotropic** (ellipsoidal, white matter) shapes.



DTI preproc in 3 easy steps! (sort of...)

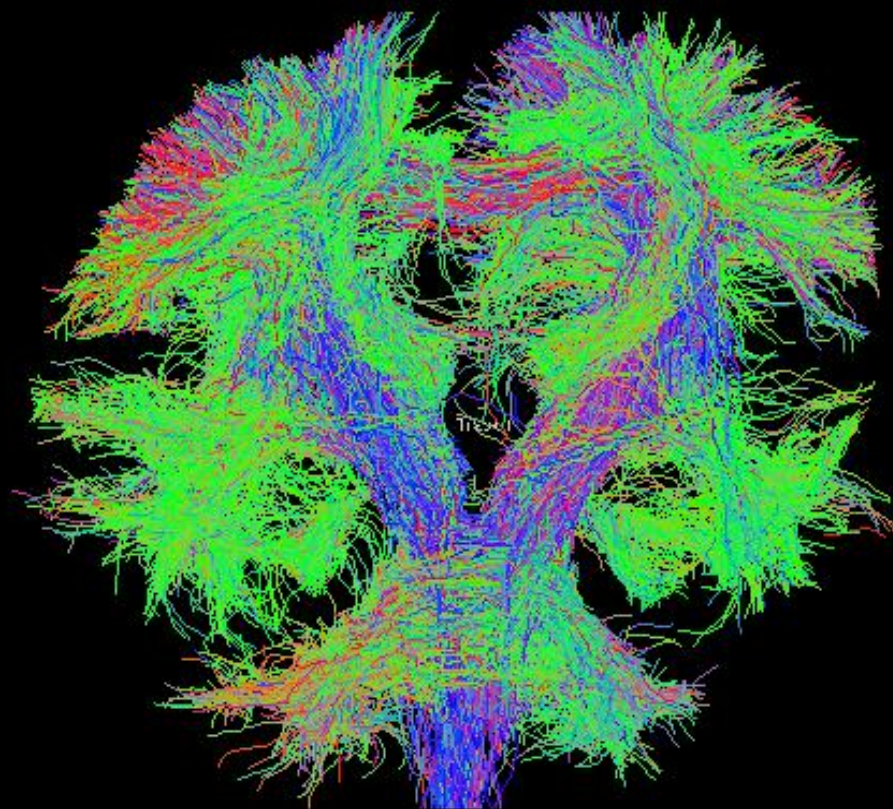
3. Estimate **tractography** (=connectivity map): use a **probabilistic** algorithm (Viterbi) to walk through the tensors and reconstruct a brain connectivity map.



CONTROL



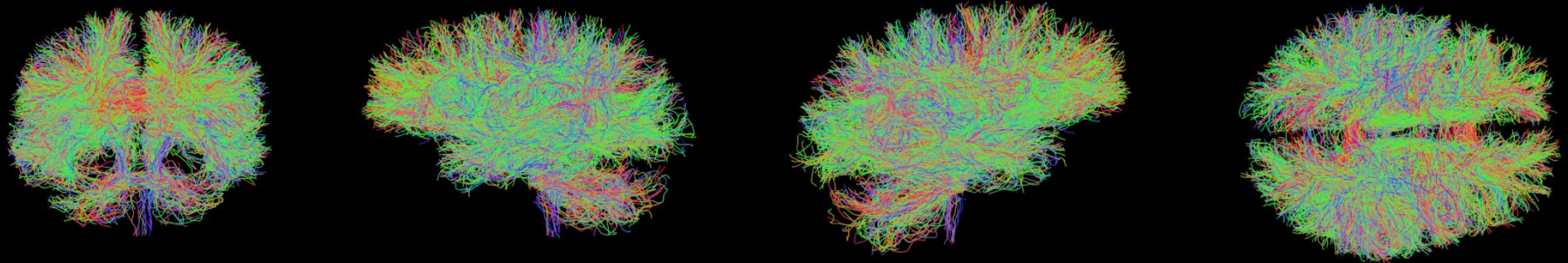
PATIENT



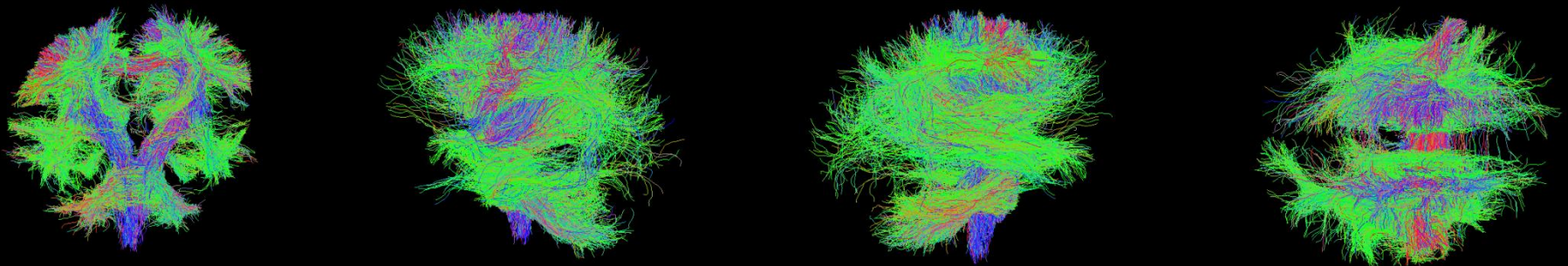
Result

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CONTROL



PATIENT



DTI preprocessing theory vs reality

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DTI preprocessing summary **in theory**:

1. Acquire DTI images (= hydrogen particles motion)
2. Estimate tensors (= mean particles motion)
3. Tractography (= reconstruct tracts and disambiguate cross-sections)

DTI preprocessing theory vs reality

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DTI preprocessing summary **in practice**:

1. Acquire DTI images + T1
2. Reorient both
3. Extract gradients (bvecs and bvals)
4. Brain Extraction (BET) mask on DWI and T1
5. Correct eddy currents
6. Estimate tensors & FA metrics
7. Segment T1
8. Coregister DWI on T1
9. Downsample T1
10. Estimate DWI response function
11. Tractography
12. And more steps depending on your objectives...

→DTI is still in the process of standardization... but not there yet!

2nd-level analysis (group comparison)

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□ **Fixel-based (local metrics) approach:**

1. Normalize all subjects on a (tracts) template
2. Compare **locally** difference of tracts metrics (eg, AFD for density)

Advantage: compare directly the whole structure, but at the expense of losing info at normalization.

□ **Connectivity approach:**

1. **Parcellation** (Freesurfer) to get regions
2. Connectivity matrix
3. Graph theory measures and comparison

Advantage: respects each subject's structure and global brain approach, but lose info at parcellation (your analysis is as good as your parcellation)

□ **Average/global measures approach:**

1. Compute a global measure for each subject (eg, average FA)
2. T-test on the values of one group with the other group

Take home message

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- Enables research of **connectivity** fibers' **micro-** and **macro-structure**
- **In vivo** (and the first one!)
- By measuring the magnitude and orientation of water diffusion
- > **non-invasive**
- Useful pre-clinical **diagnosis** tool
- Limitation: only ~30% of DTI fibers actually exist in the brain, keep in mind it's a model!

To go further

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- MRTRIX3 whole documentation
- Beginner's DTI preprocessing pipeline:
<http://community.mrtrix.org/t/beginner-connectome-pipeline-updated/373/2>
- Fixel-based analysis using MRTRIX3:
http://mrtrix.readthedocs.io/en/latest/workflows/fixel_based_analysis.html
- FSL eddy
- Subparcellation
- Do Tromp DTI tutorials, <http://www.diffusion-imaging.com/>, 2016
- MRTRIX3 community forum!

Thank you for your attention

References:

- **Posterior cingulate cortex-related co-activation patterns: a resting state FMRI study in propofol-induced loss of consciousness**, Amico, Enrico, et al, *PLoS One* 9.6 (2014): e100012.
- **Multimodal neuroimaging in patients with disorders of consciousness showing “functional hemispherectomy”**, Van Someren, E. J. W. (2011), *Slow Brain Oscillations of Sleep, Resting State and Vigilance: Proceedings of the 26th International Summer School of Brain Research, Held at the Royal Netherlands Academy of Arts and Sciences, Amsterdam, The Netherlands, 29 June-2 July, 2010*, 193, 323.
- **Neural correlates of consciousness in patients who have emerged from a minimally conscious state: a cross-sectional multimodal imaging study**, Carol Di Perri & Mohamed Ali Bahri & Enrico Amico & Aurore Thibaut & Lizette Heine et al., *The Lancet Neurology*, 2016
- Do Tromp, <http://www.diffusion-imaging.com/>, 2016
- Amico et al., *Conf Proc IEEE Eng Med Biol Soc.* 2015



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BONUS SLIDES



How DTI works – A small tale

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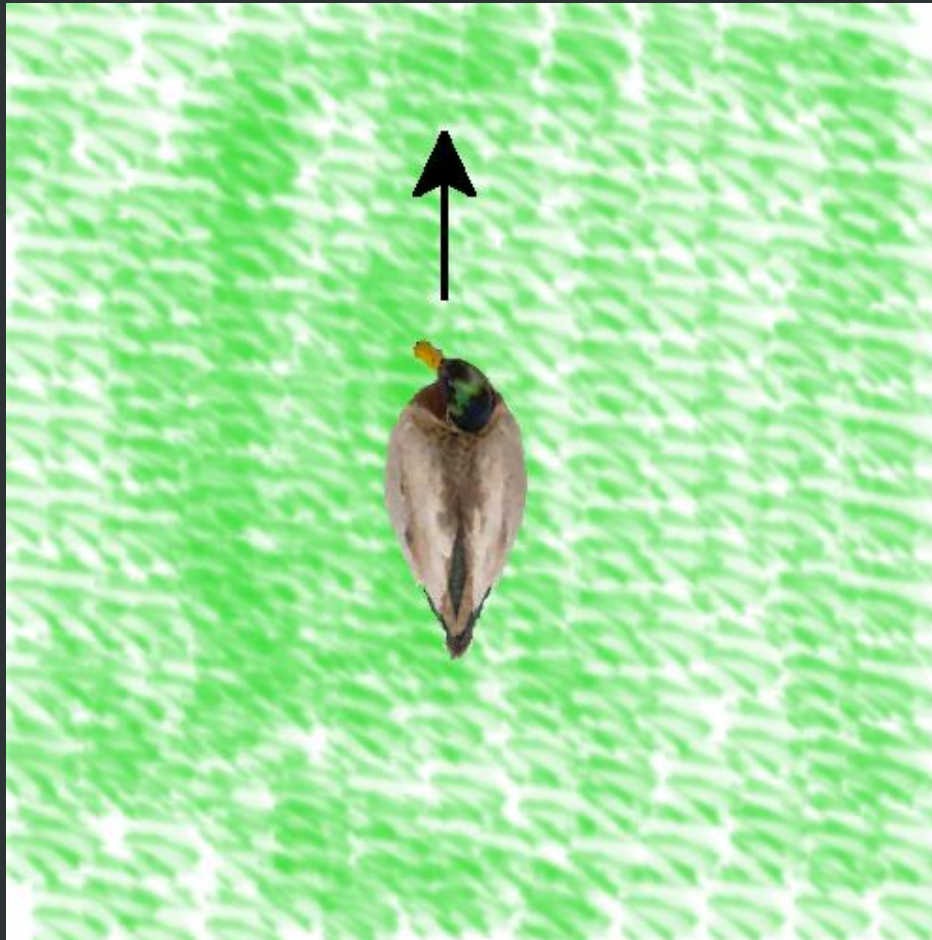
How DTI works – A small tale

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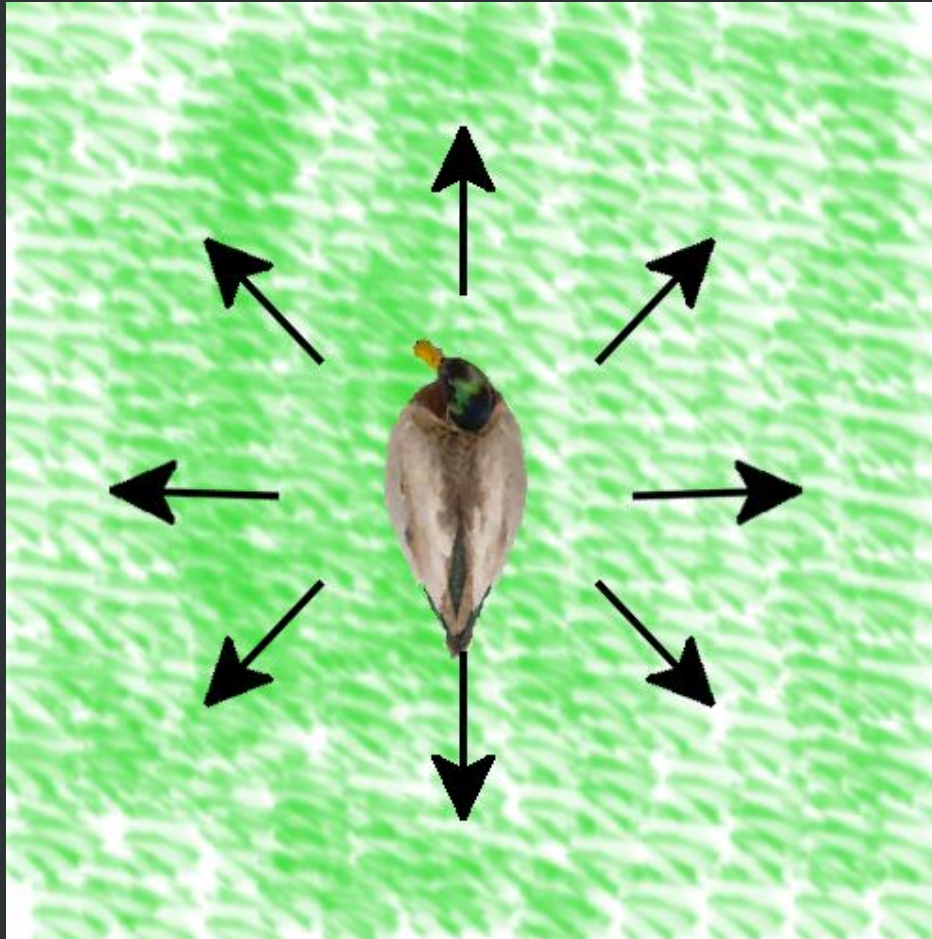
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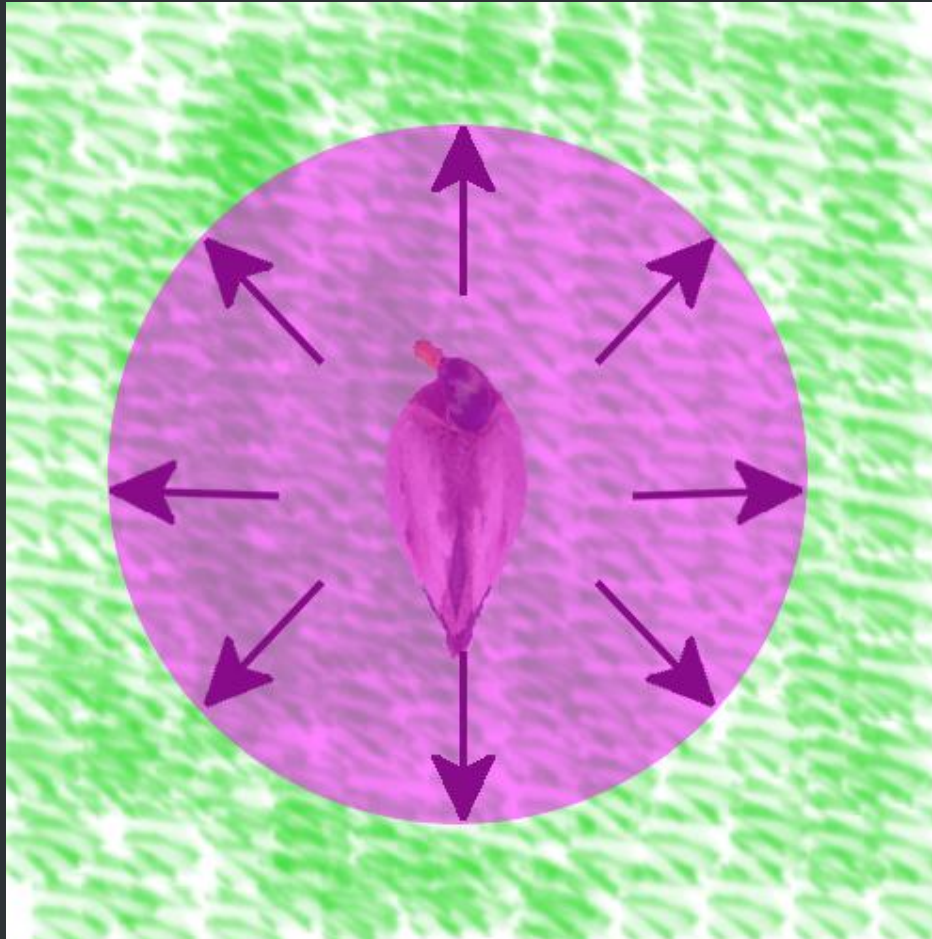
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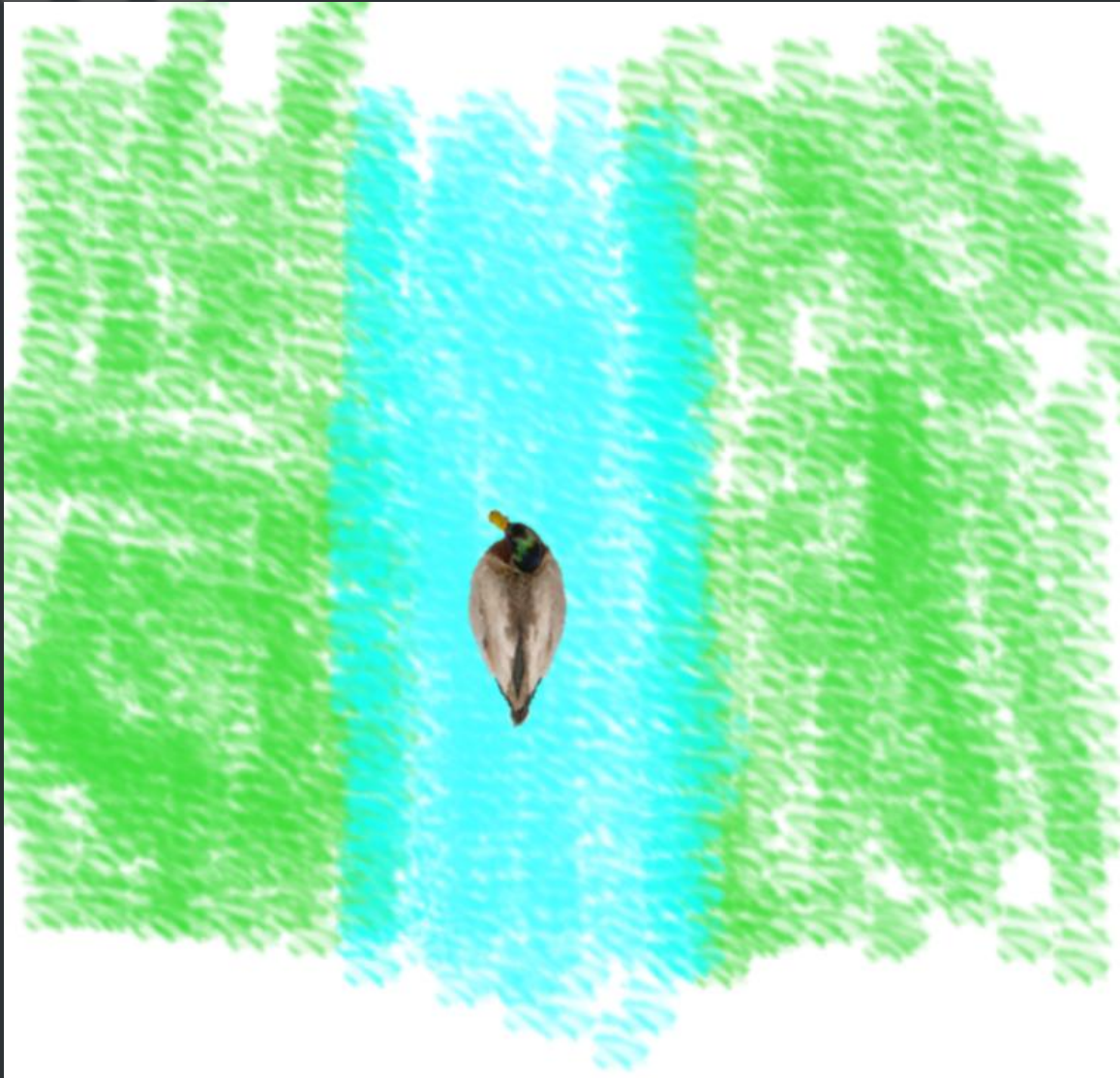
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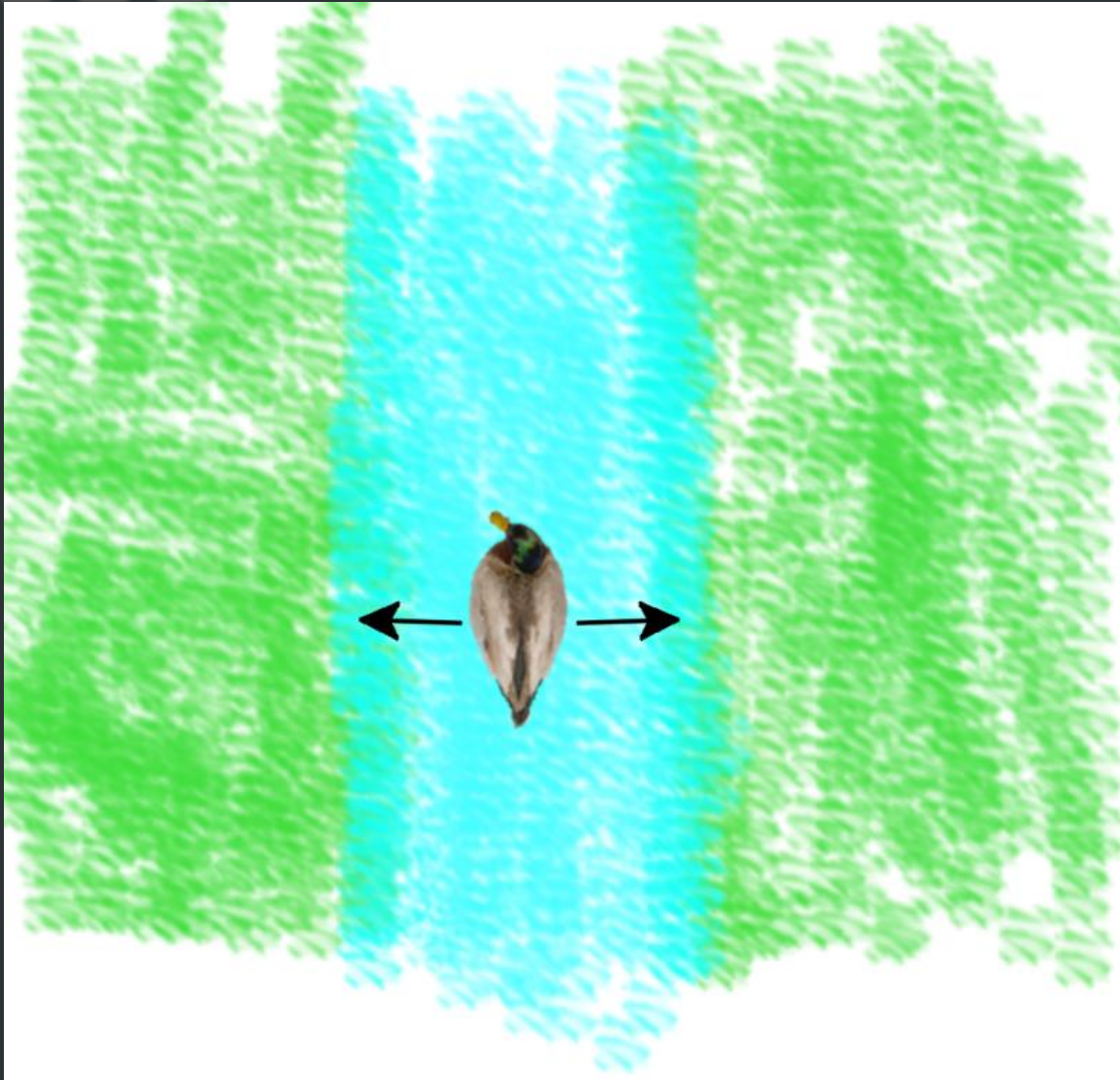
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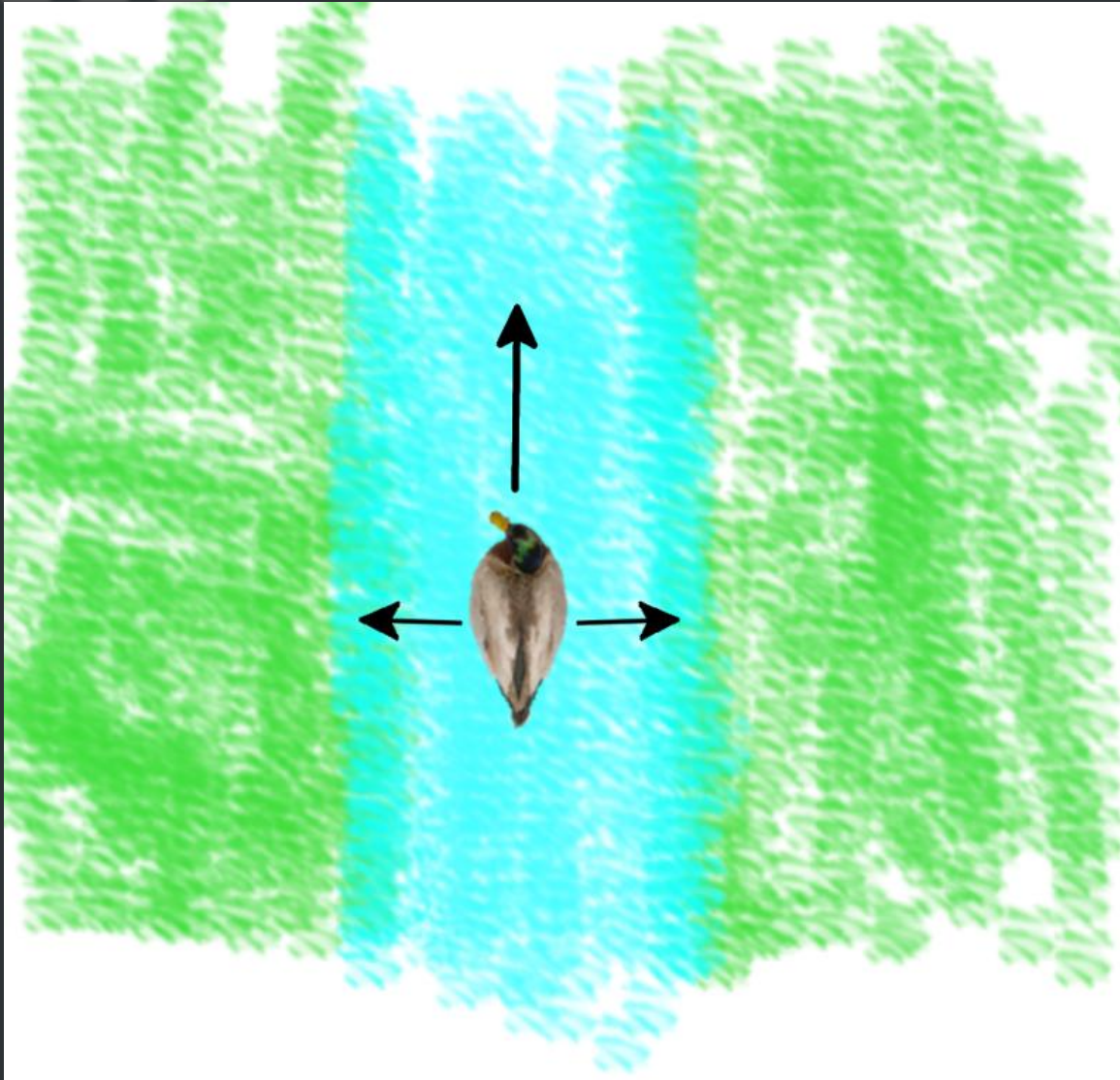
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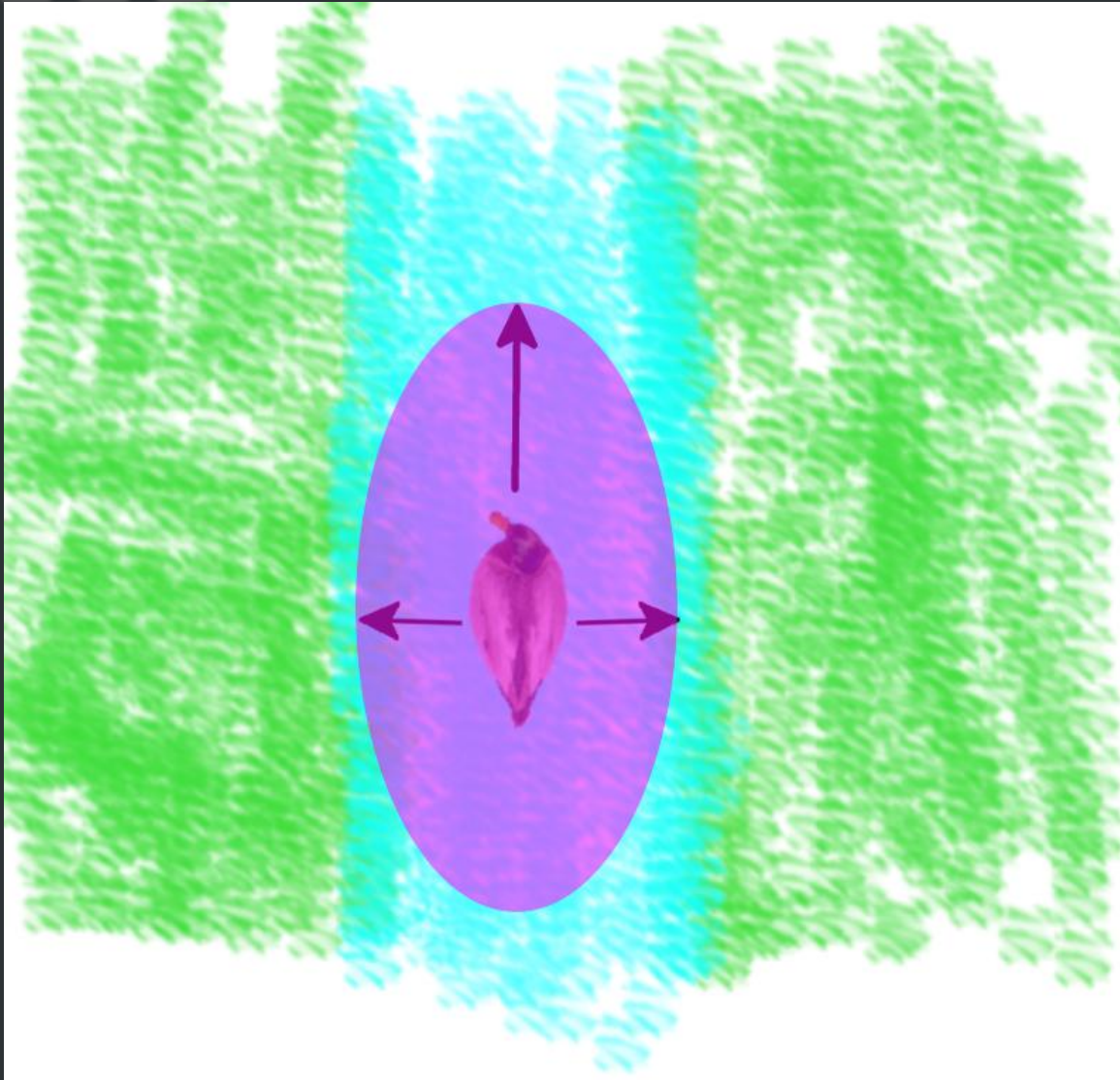
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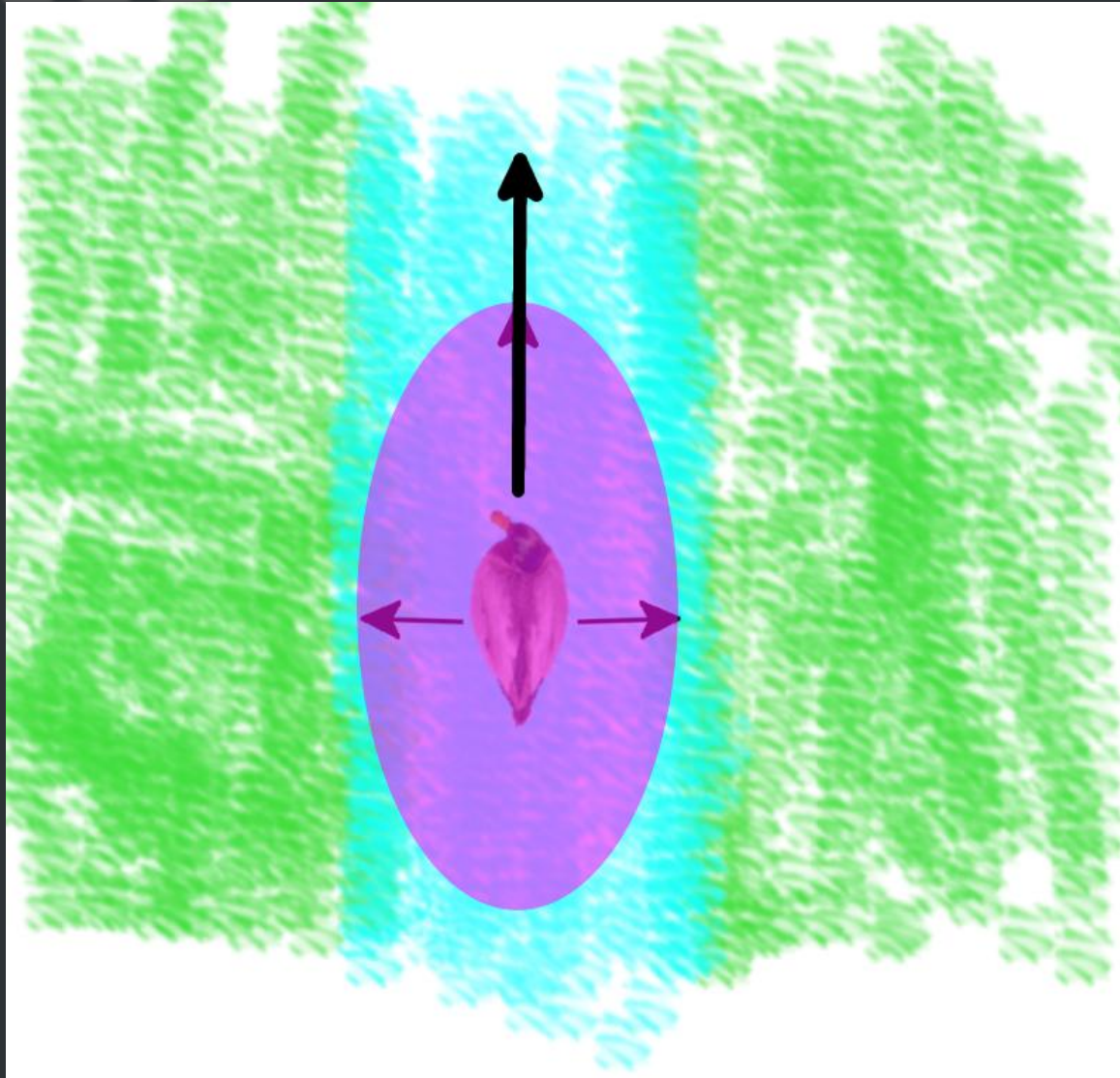
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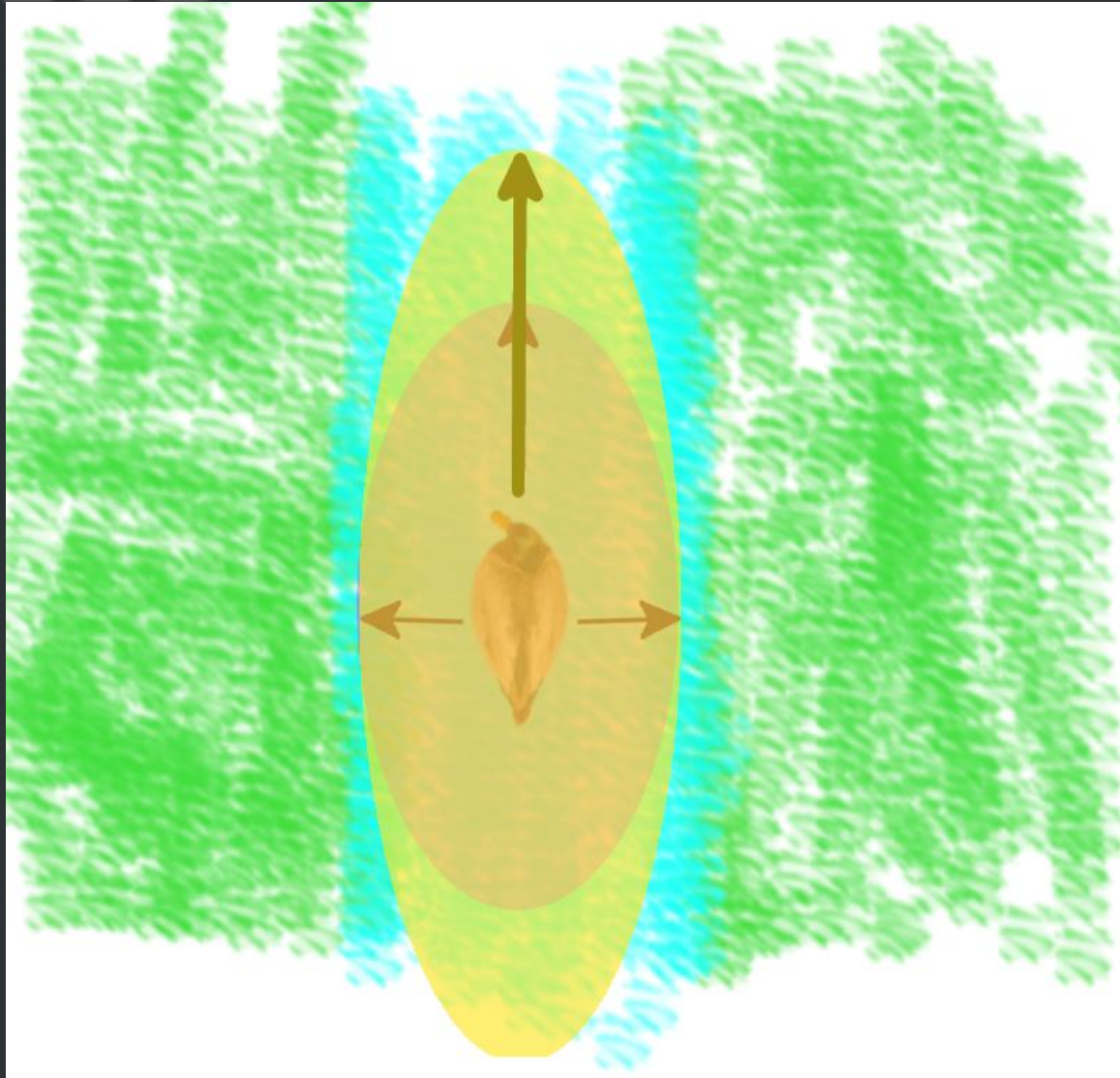
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UNKNOWN LAND

(YES I WAS TOO LAZY TO DRAW)

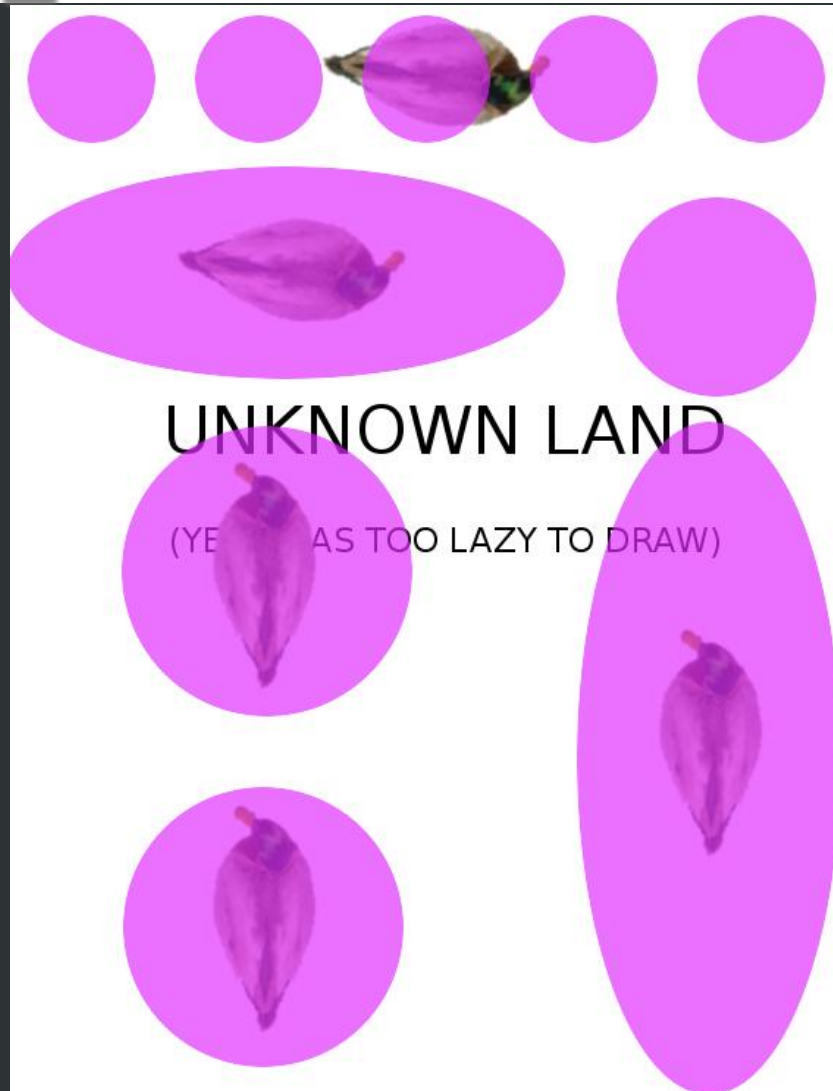
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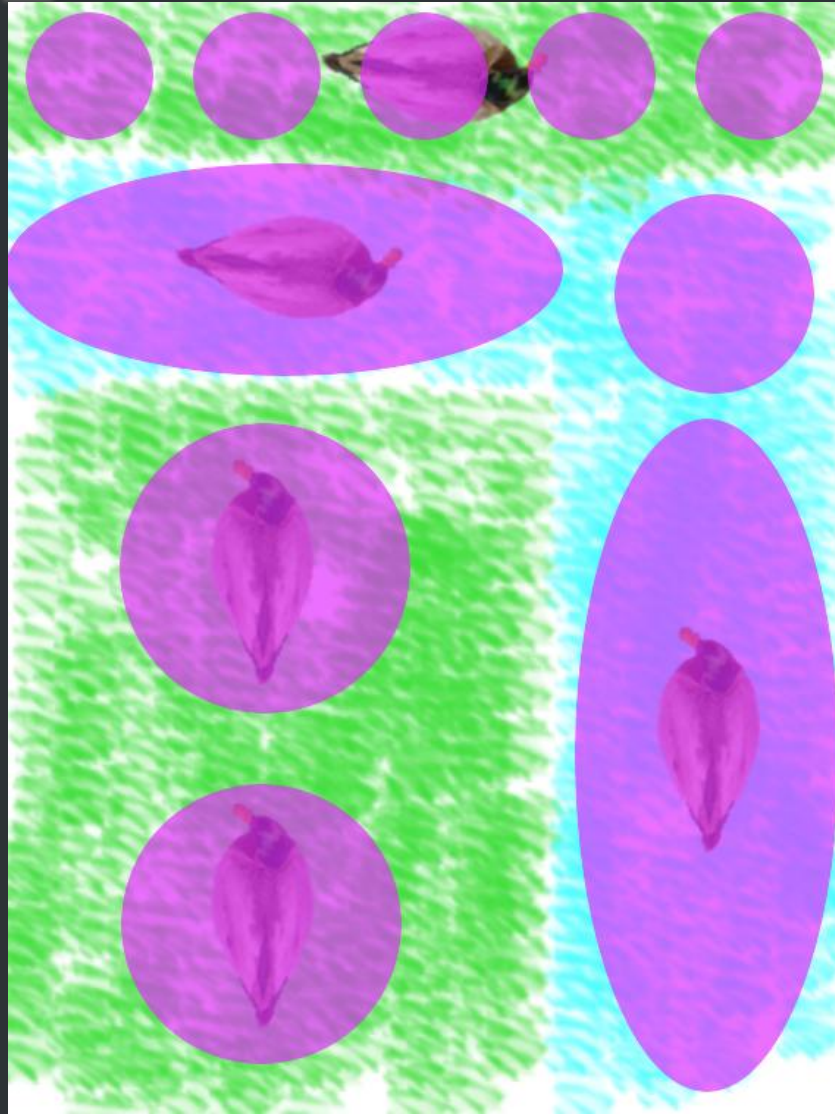
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TRACTOGRAPHY FTW!!!



Duck's tale imagery to DTI

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- Ducks with GPS = **hydrogen** particles (in water molecules)
- Ducks motion = **Brownian** motion (influenced by environment)
- Ellipsoid of average travel distance = **FA tensors** (Fraction Anisotropy)
- Rivers = white matter **fibers tracts**
- Solving river cross-sections = **tractography**