

Martin Lindquist

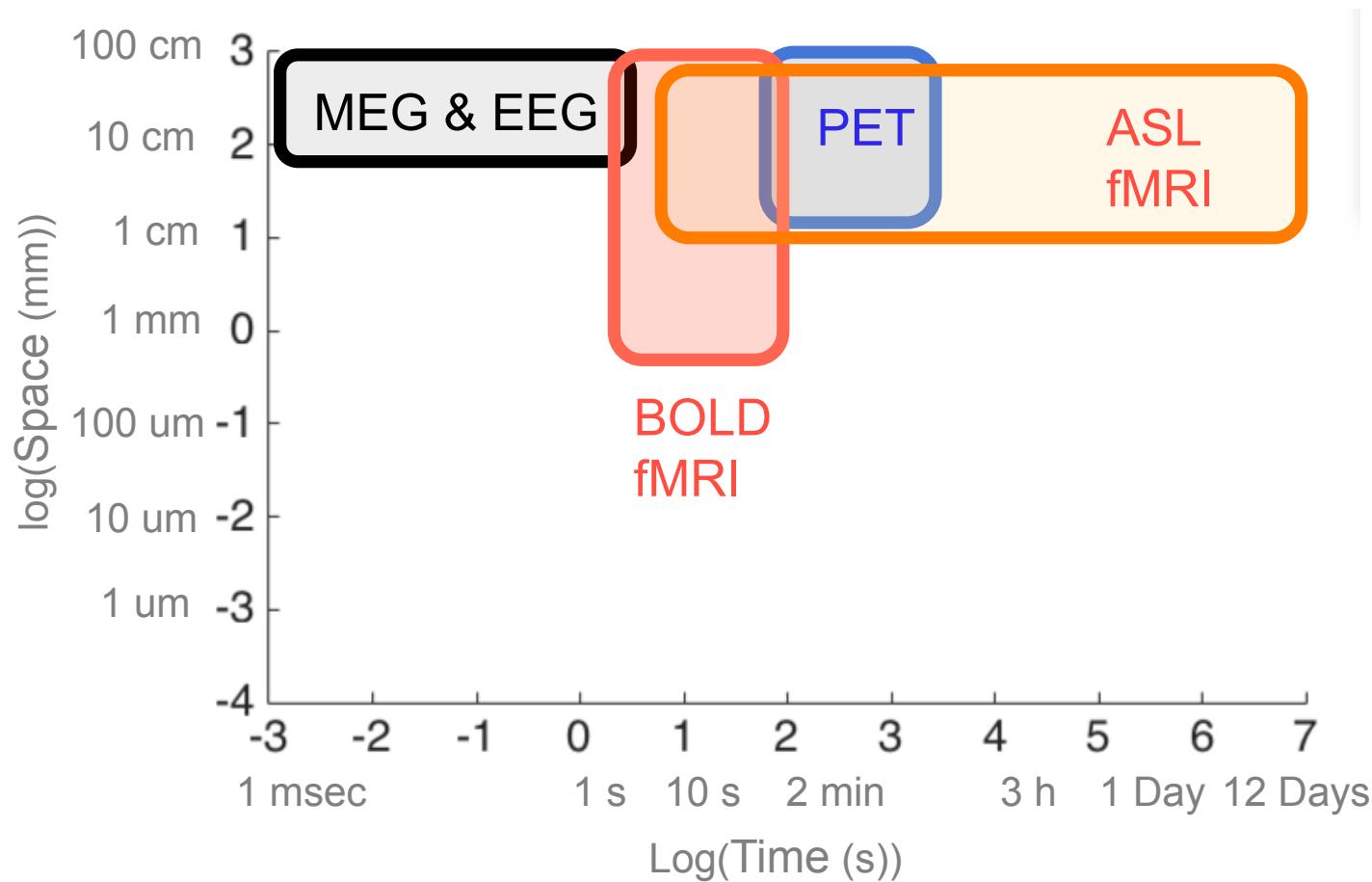
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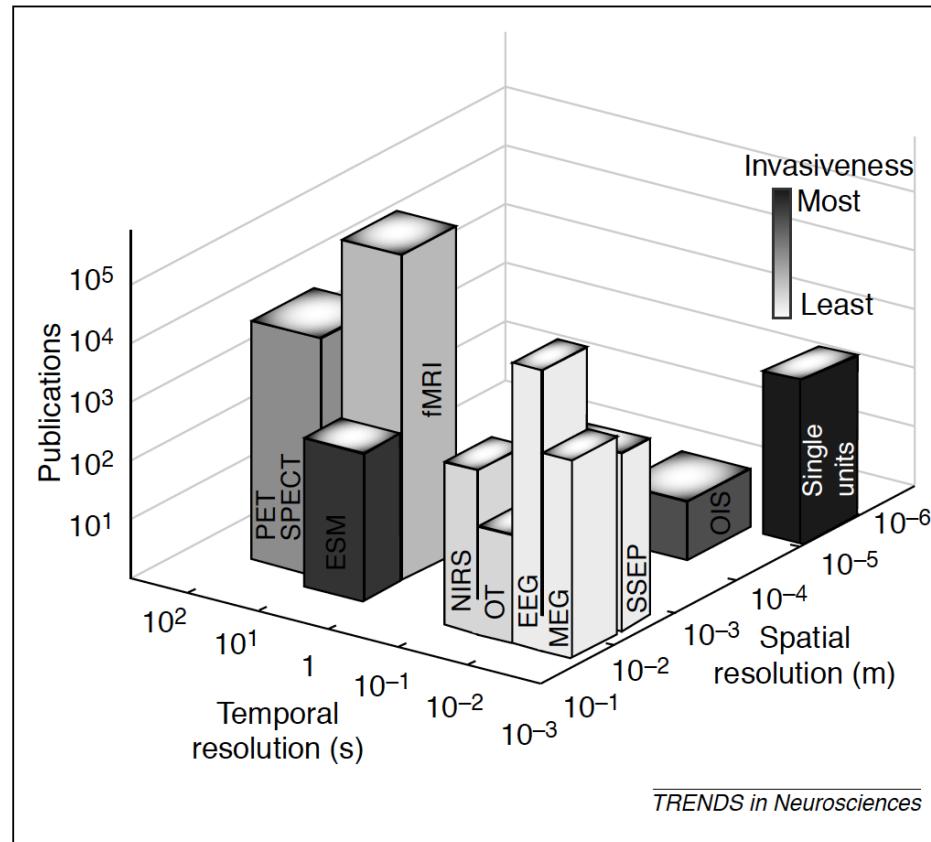
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Spatial and Temporal Resolution of BOLD fMRI

Human neuroimaging: Spatial and temporal resolution

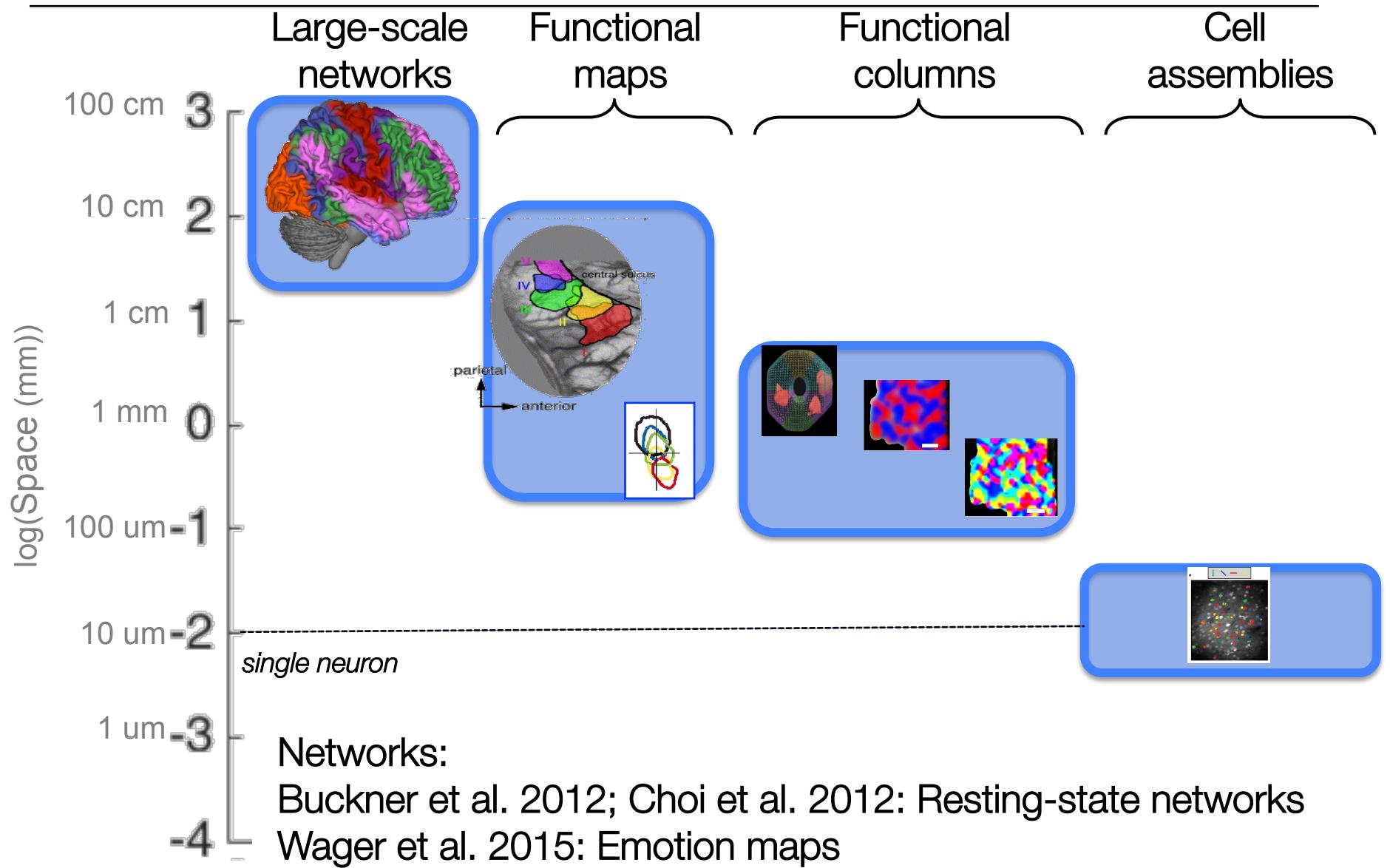


Human neuroimaging: Spatial and temporal resolution

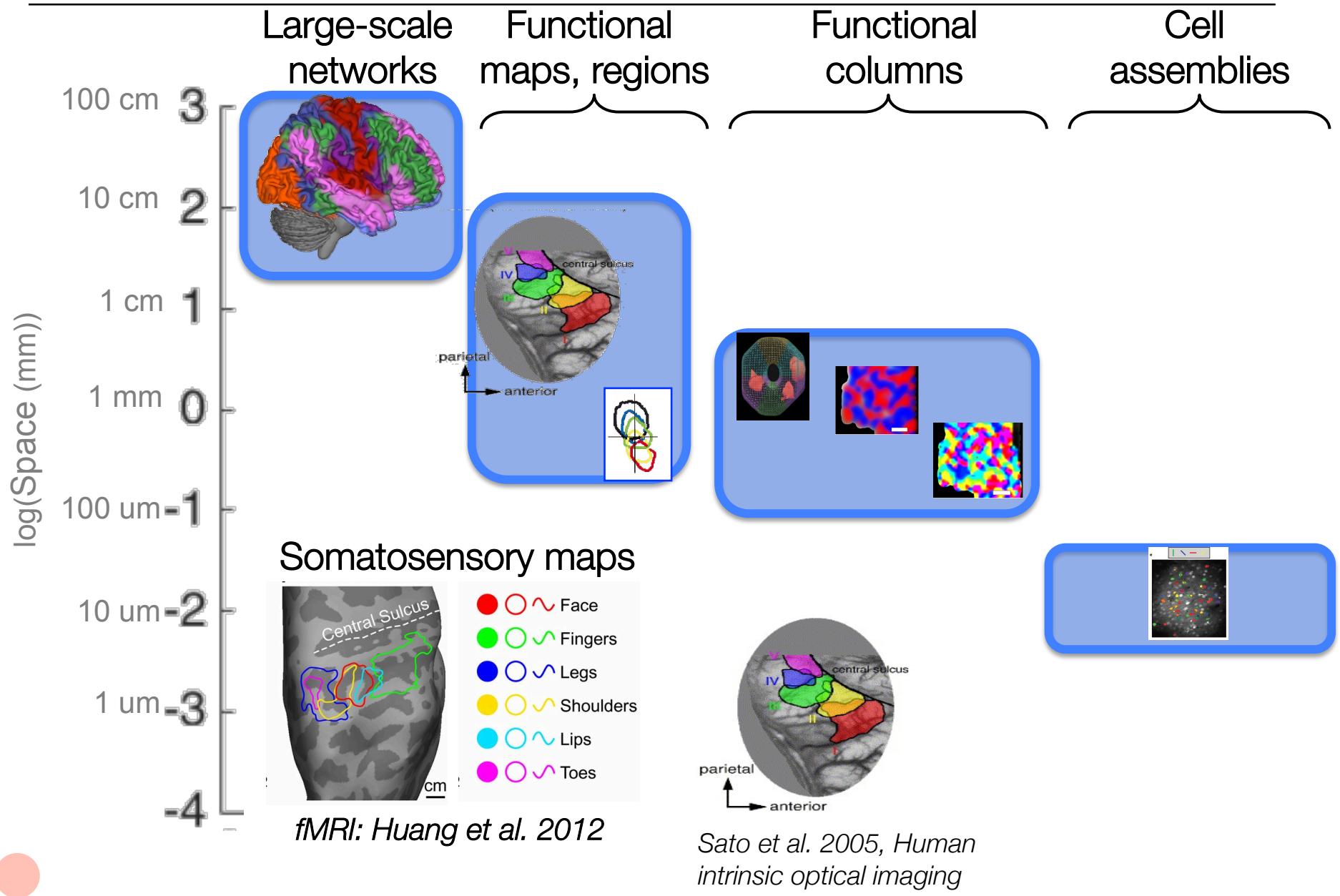


Optical imaging of intrinsic signals (OIS), voltage-sensitive dye (VSD), EEG, electroencephalography; ESM, electrical stimulation mapping; fMRI, functional magnetic resonance imaging; MEG, magnetoencephalography; NIRS, near-infrared spectroscopy; OT, optical tomography; PET, positron emission tomography; SPECT, single photon emission computed tomography; SSEPs, somatosensory evoked potentials.

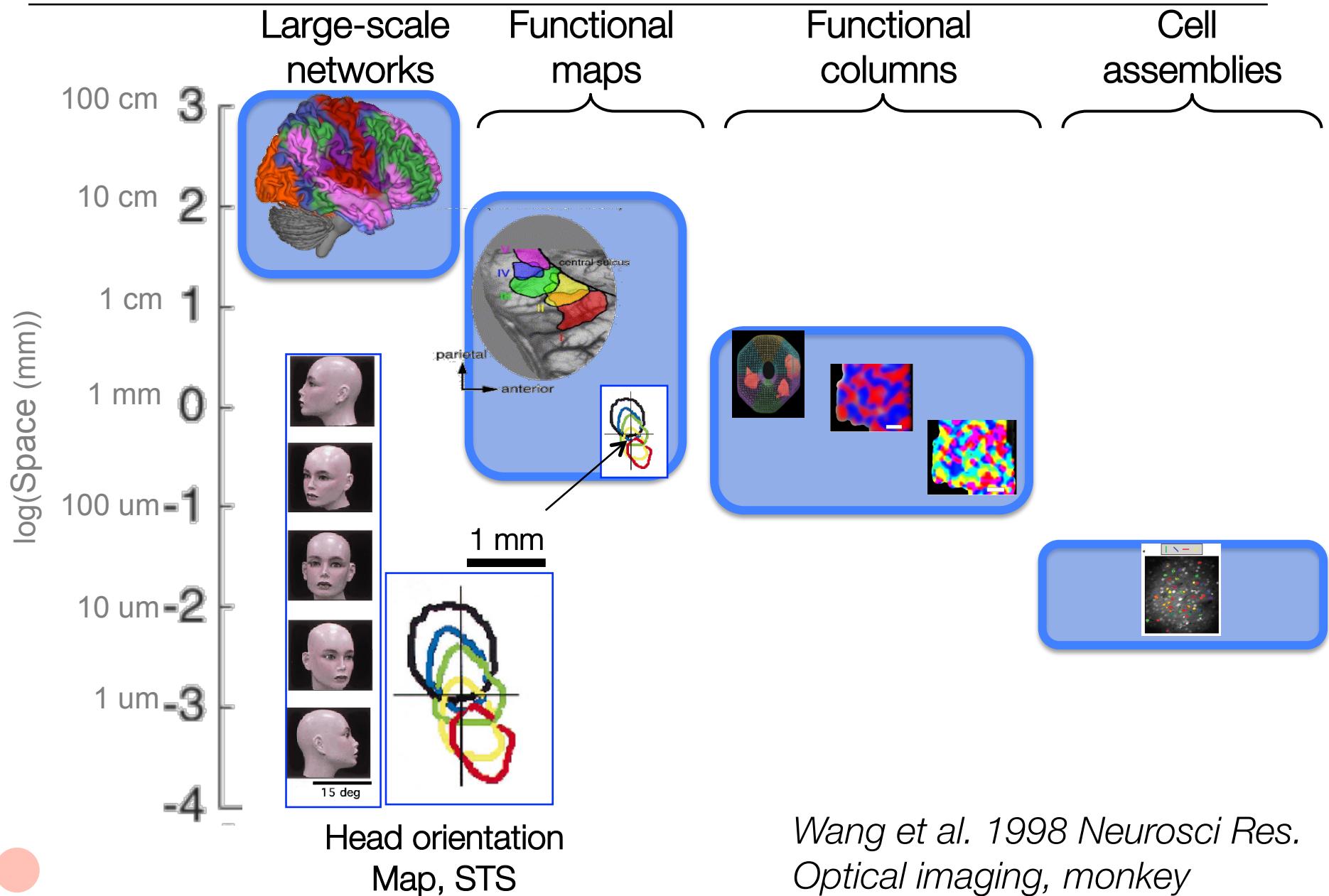
Information at multiple spatial scales



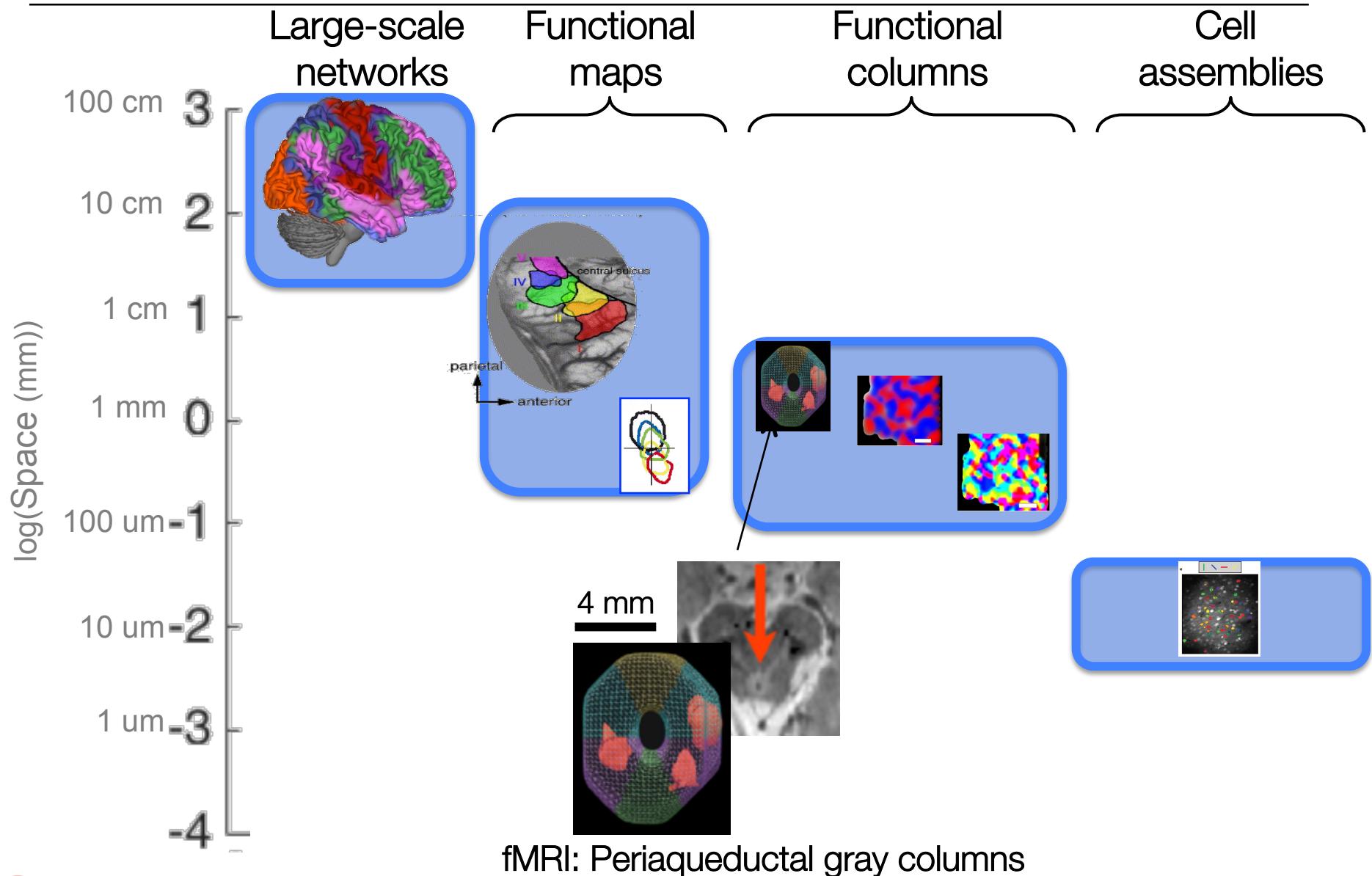
Information at multiple spatial scales



Information at multiple spatial scales

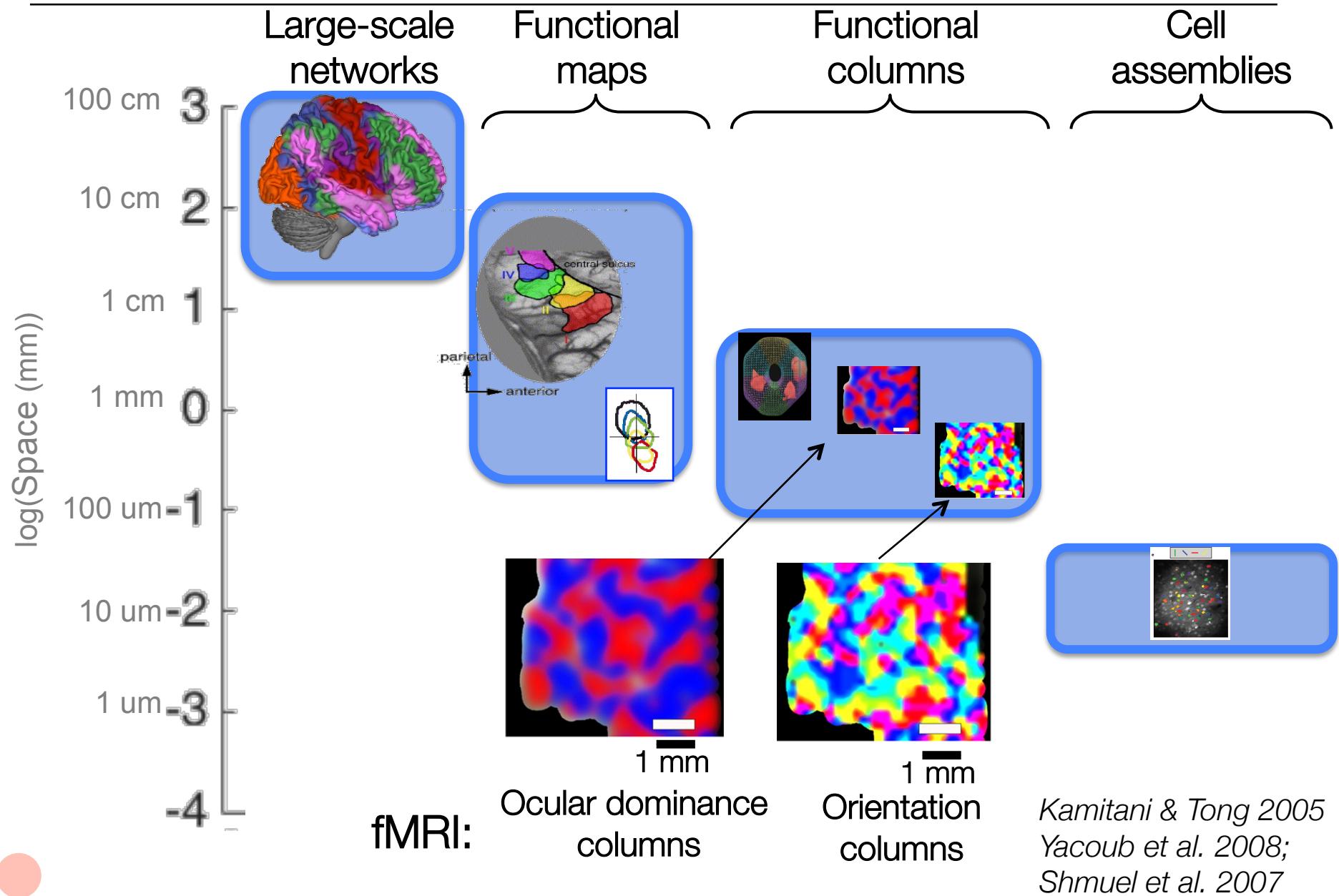


Information at multiple spatial scales

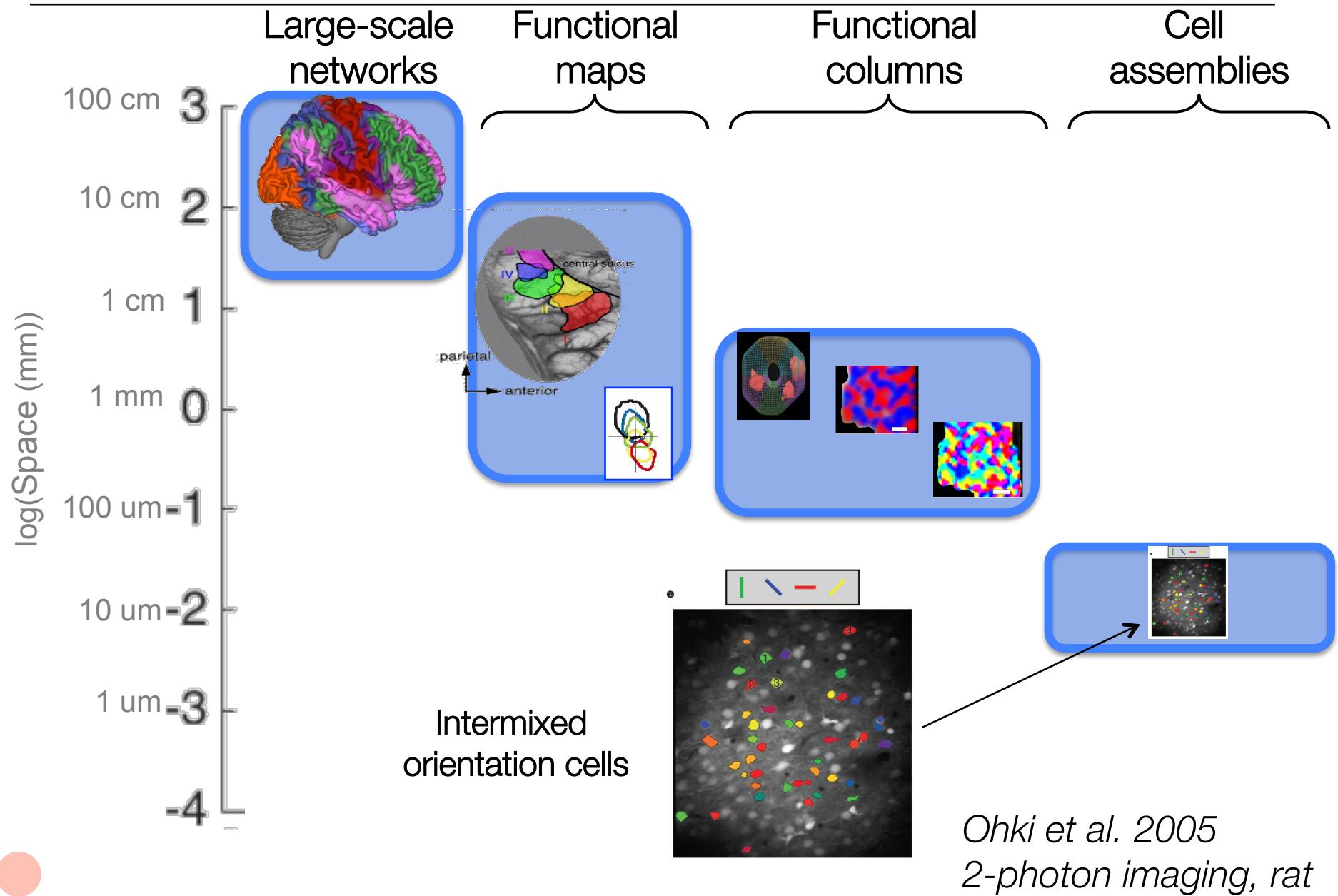


Satpute et al. 2013

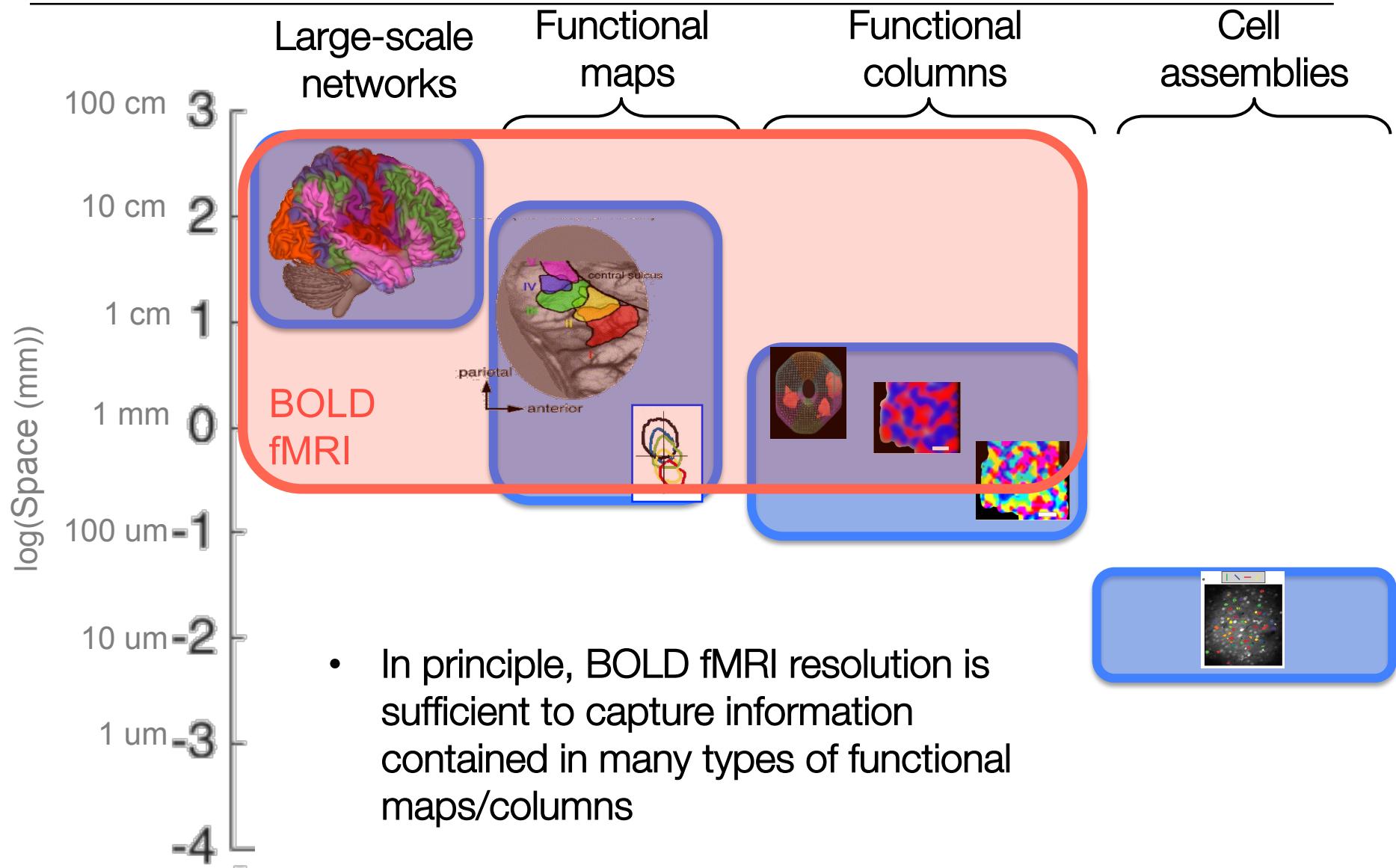
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Information at multiple spatial scales



Causes and limits of resolution

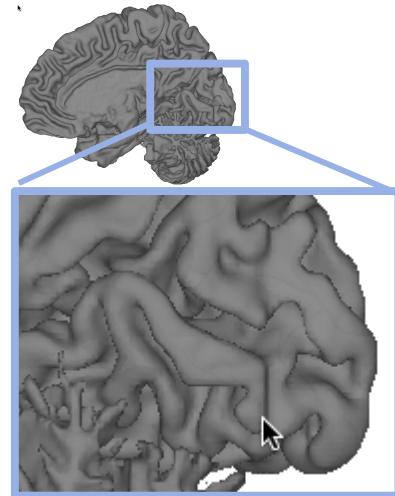
- Advantage of fMRI: Large scale – can measure the whole brain every 1-2 sec
- But how fine-grained can it be?
- What information are we gaining by improving resolution (or losing by not doing so?)



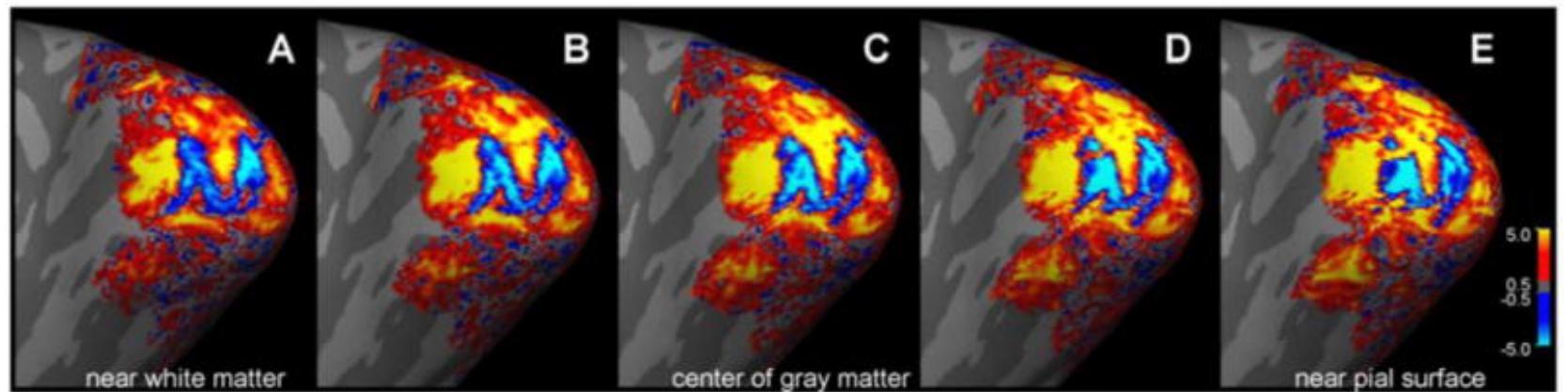
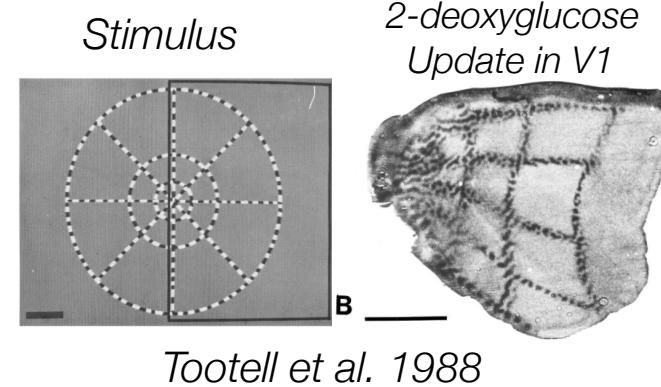
Spatial resolution

- Spatial resolution can in principle be relatively fine
 - Limited by BOLD point-spread and signal to noise
 - These depend on field strength, distance of coil from tissue, and vasculature
 - Upper limit: High-field, high-res imaging with implanted coils (~400 μM – e.g., Logothetis)

An example: Visual cortical imaging at 7T



Area 17: Primary visual cortex



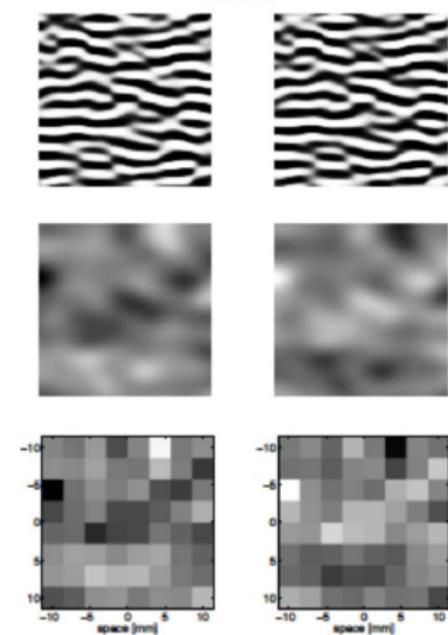
Deep layers

Superficial layers

Polimeni et al. 2010

Bold point-spread function

- Related to microvasculature bed area affected by local neuronal activity and venous/arterial flow contributions
- Varies with field strength



Engel et al., 1997; Parkes et al., 2005; Shmuel et al., 2007; Chaimow et al. 2011

Effective resolution in group analyses

- Typical effective spatial resolution in group analyses is much lower: 10 – 15 mm
- Why?
 - Artifacts
 - Inter-subject normalization
 - Individual differences in functional anatomy (e.g., Truet Allison)
 - Diffuse modulatory effects (e.g., Woo cluster extent)



Additional issues: Spatial alignment

- Many sources of mismatch:
 - Match between functionals and structural images is not exact!
Distortion of functional (e.g., EPI) images.
 - Spatial misalignment between structurals and template (reference) image
 - Spatial misalignment between results and atlases used for localization
 - Atlases can be approximate (e.g., Talairach)

- What this means:
 - Create mean anatomical image and use that as underlay for functional results
 - Also an easy way to see some problems with inter-subject alignment
 - Interpret anatomical locations with caution

New solutions

- Hyperacuity

- Pattern of activity across voxels may contain more information than any one voxel (e.g., Kamitani & Tong 2005; Chaimow et al. 2011)
- Can sometimes detect functional topography even if voxels are not small enough to fit within one functional area

- Hyperalignment

- Direct inter-subject alignment of brains in a functional space (e.g., defined by activity during movie-watching; e.g., Haxby et al. 2011)
- Circumvent need to normalize brains to an atlas or define individualized ROIs, but still permit group analysis



Hyperacuity:

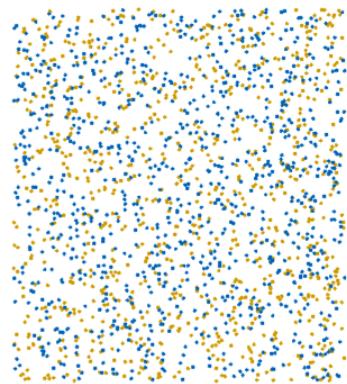
Classification when neurons are randomly intermixed?



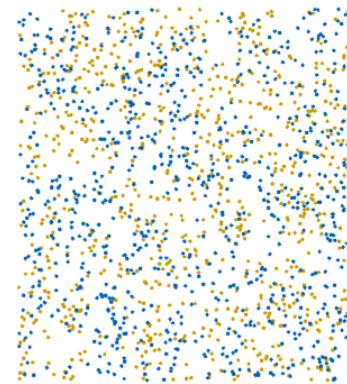
- In the brain, neurons are often not randomly intermixed
- Organization at multiple spatial scales
- Even if they are random, there can be information!

Three types of simulated random neuronal distributions

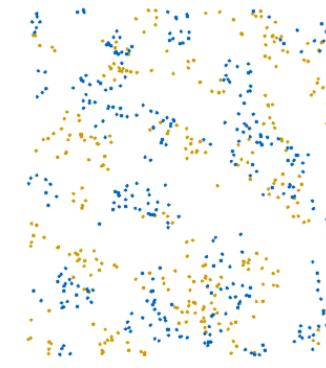
- Event type 1
- Event type 2



Homogeneous
Poisson process



Independent Poisson
random fields
(low variance)



Independent Poisson
random fields
(high variance)

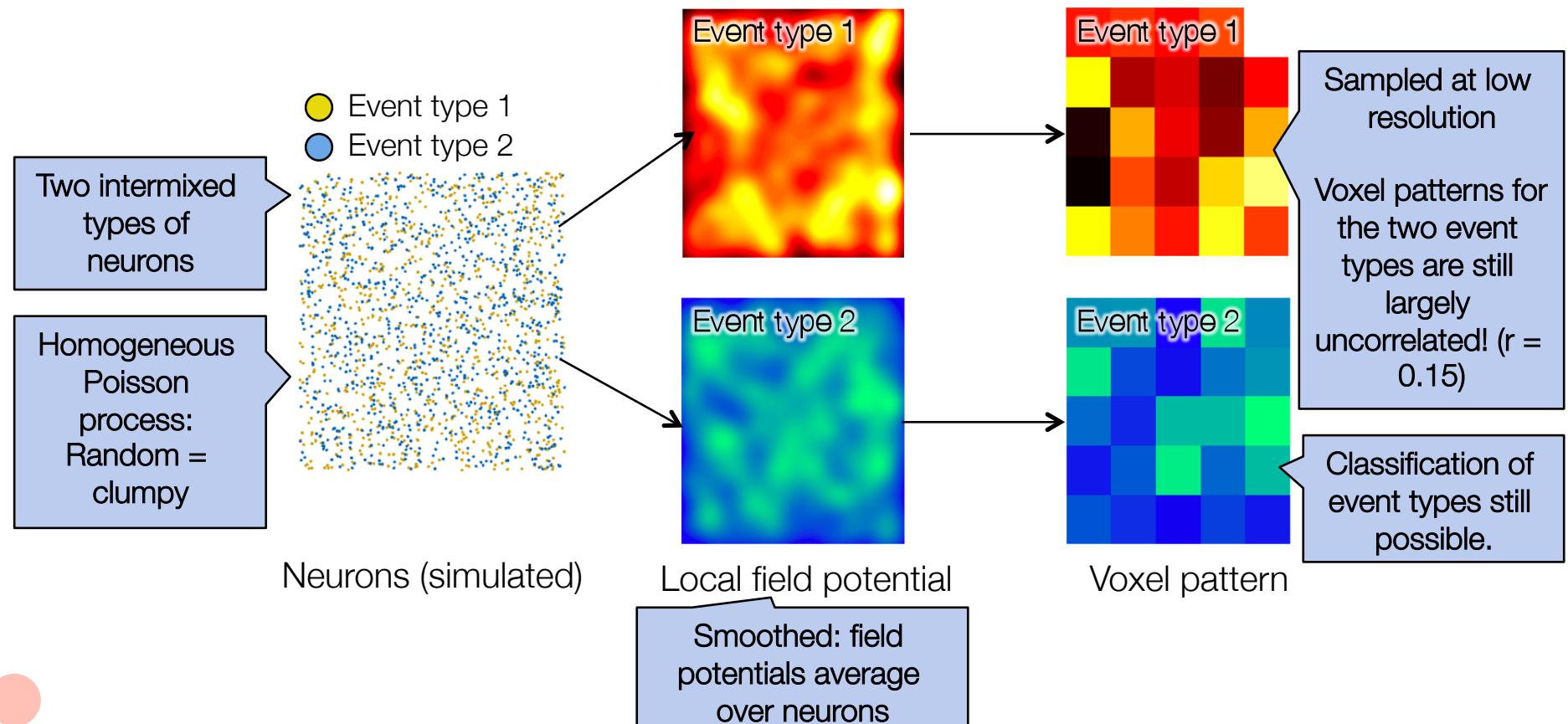
- Random does not mean uniform!
- Differences in neural activity at the fMRI voxel pattern level can be detected for all 3 types



Hyperacuity:

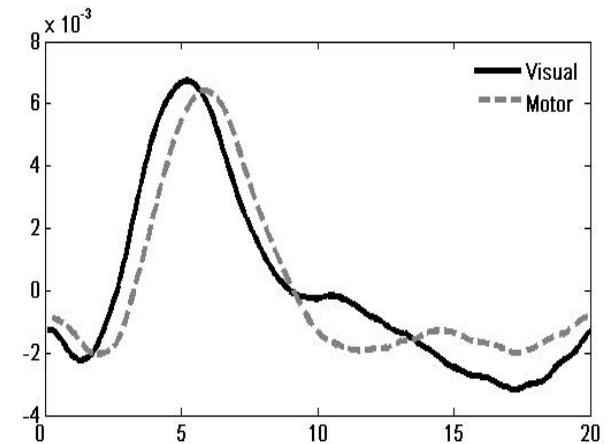
Classification when neurons are randomly intermixed?

- Even if neurons are intermixed randomly, MVPA may still identify patterns differentially associated with each



Temporal resolution

- EEG, MEG, optical methods have much greater temporal resolution
- fMRI resolution is limited by slow hemodynamic response function (HRF)
 - Onset of response detectable in 2-3 sec
 - Peaks at 5-6 sec
- Temporal ‘hyperacuity’
 - If events are averaged, can detect differences in response latency of ~100-200 msec
 - New rapid sampling methods help!! Whole brain in 100-200 msec



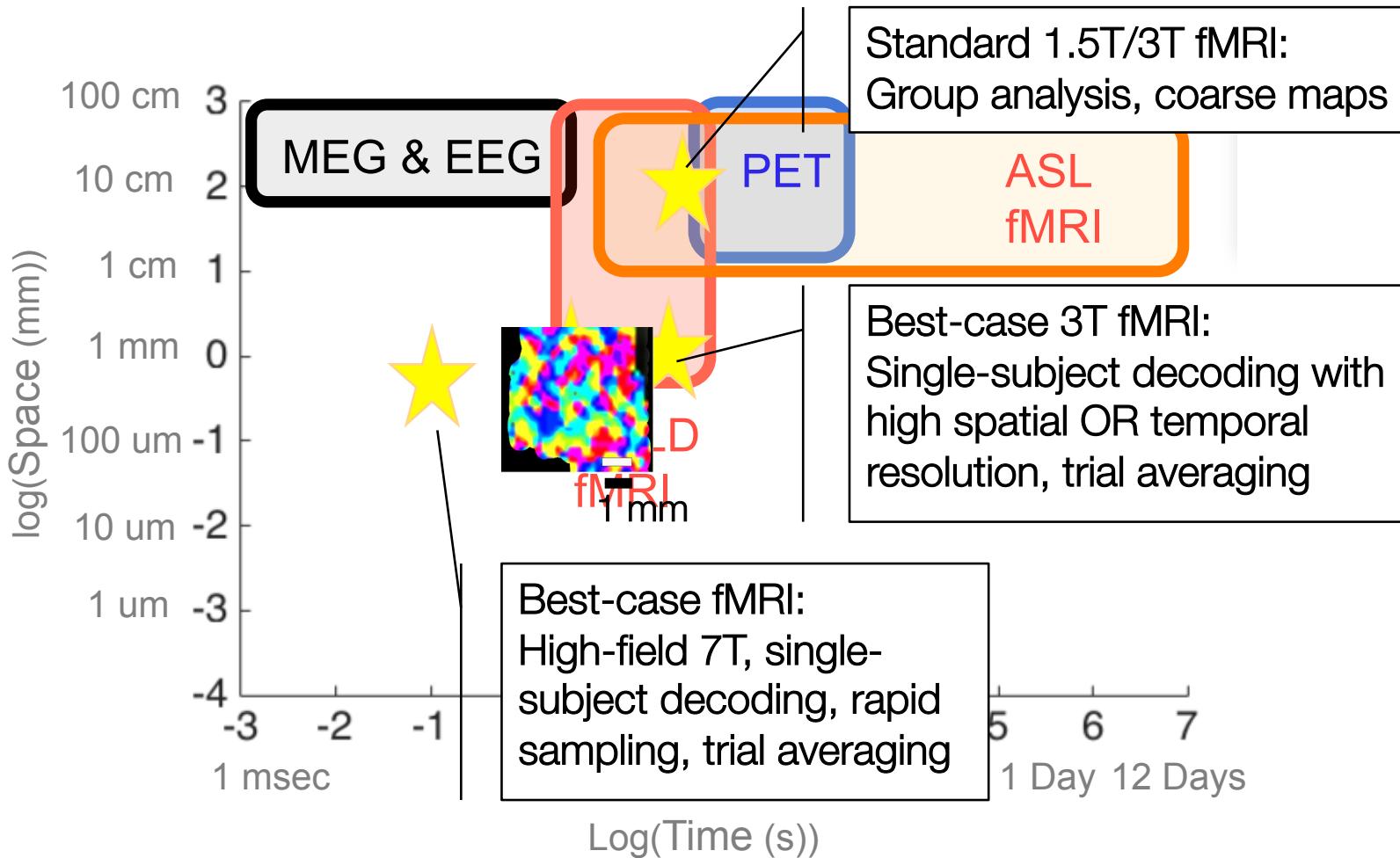
Lindquist et al., 2008



Reliable difference in latency of visual & motor responses 100 msec apart

See also: Menon et al., 1998

Human neuroimaging: Pushing the boundaries

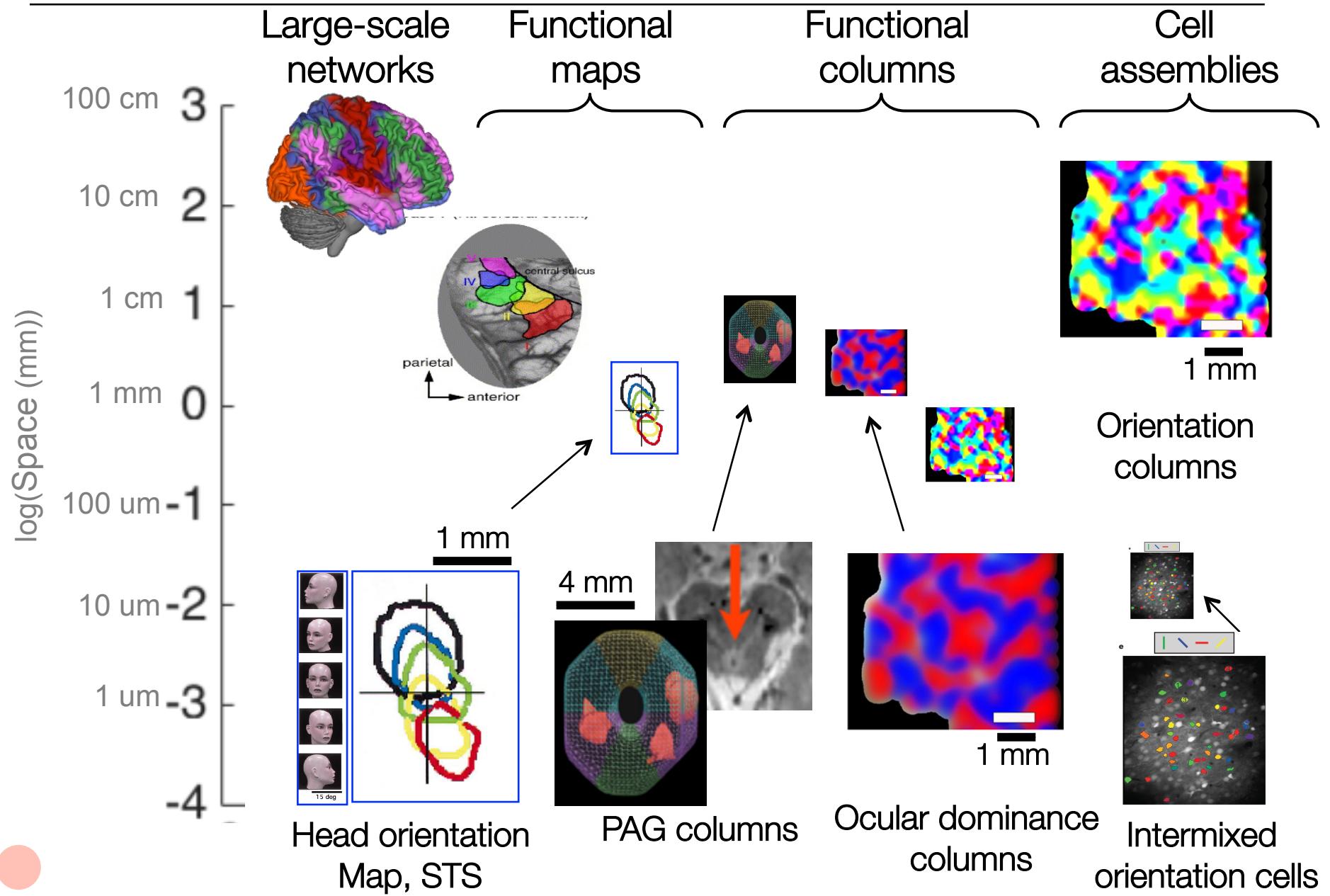


End of Module

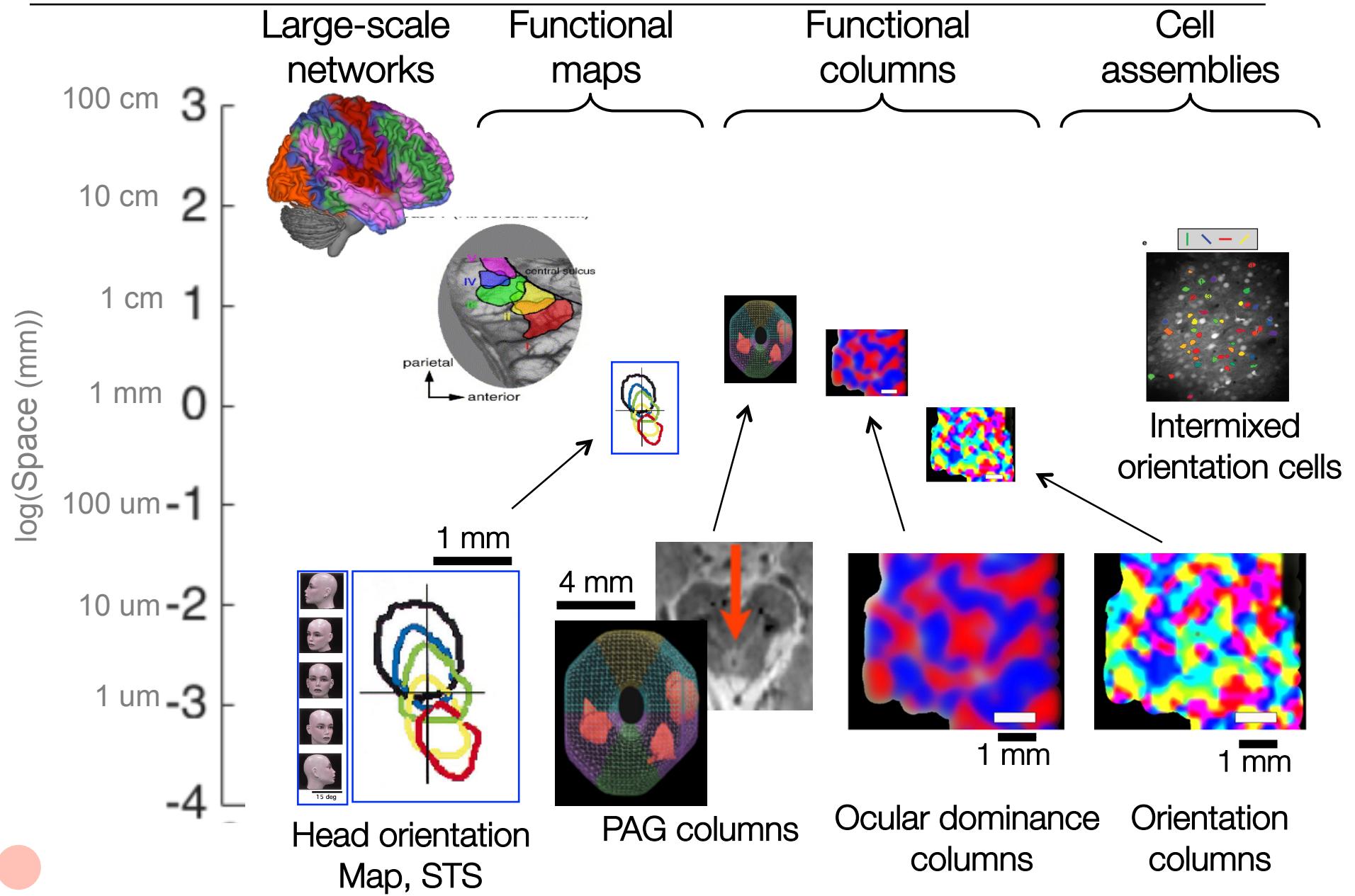


@fMRIstats

Information at multiple spatial scales



Information at multiple spatial scales



fMRI and PET in context

