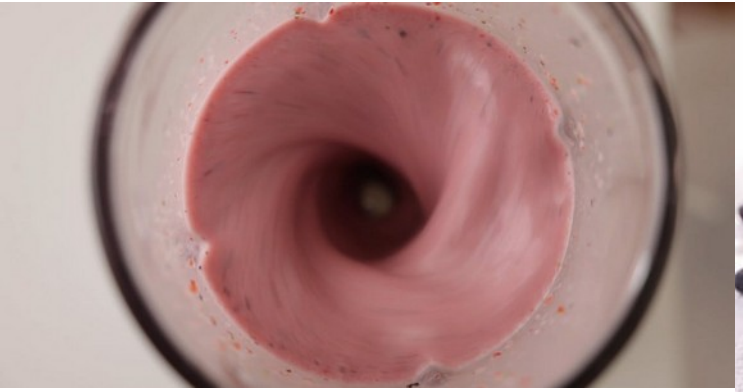
Preprint

SCAN ME

Inadequate analogy

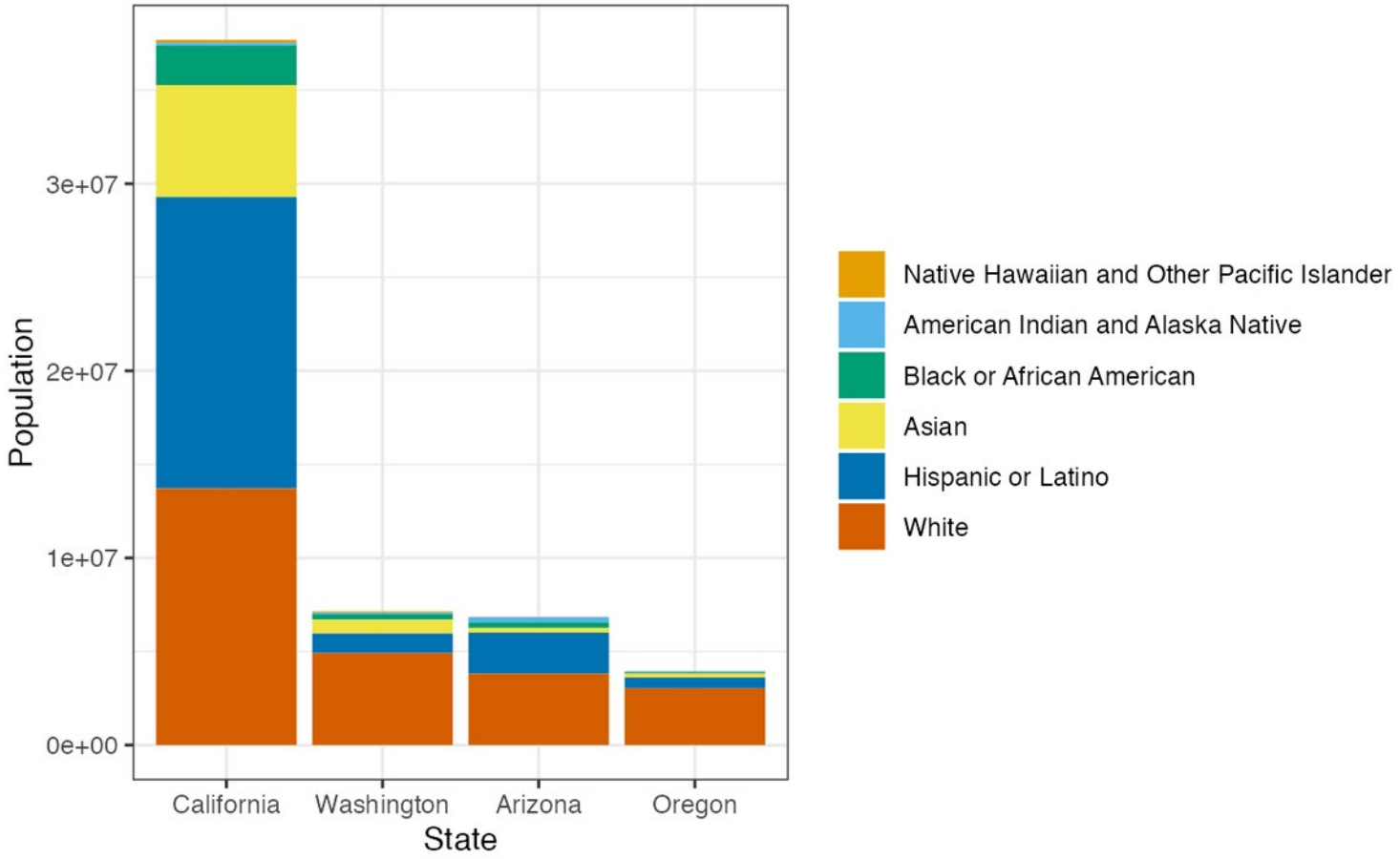
Bulk RNA-seq



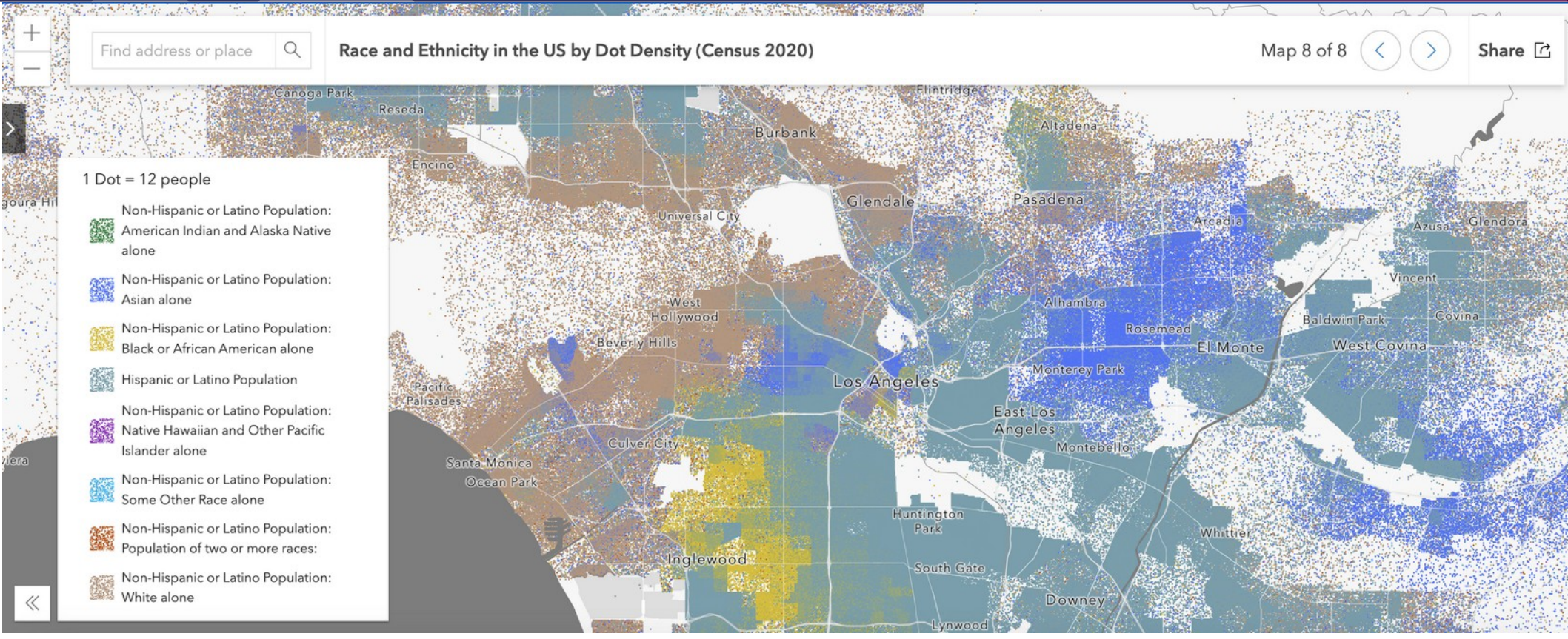
scRNA-seq

Spatial transcriptomics

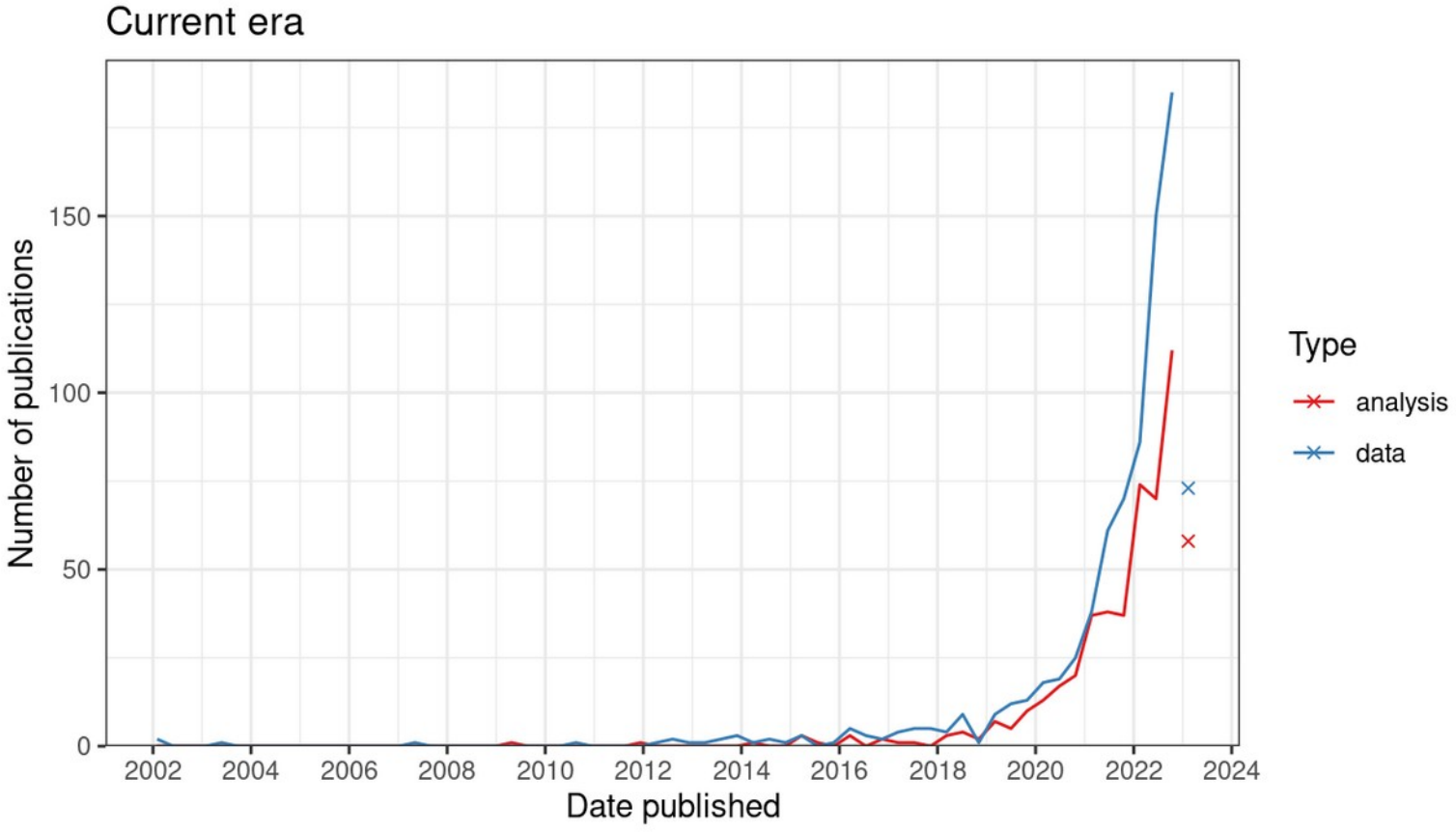
A geospatial analogy: bulk RNA-seq



A geospatial analogy: spatial transcriptomics

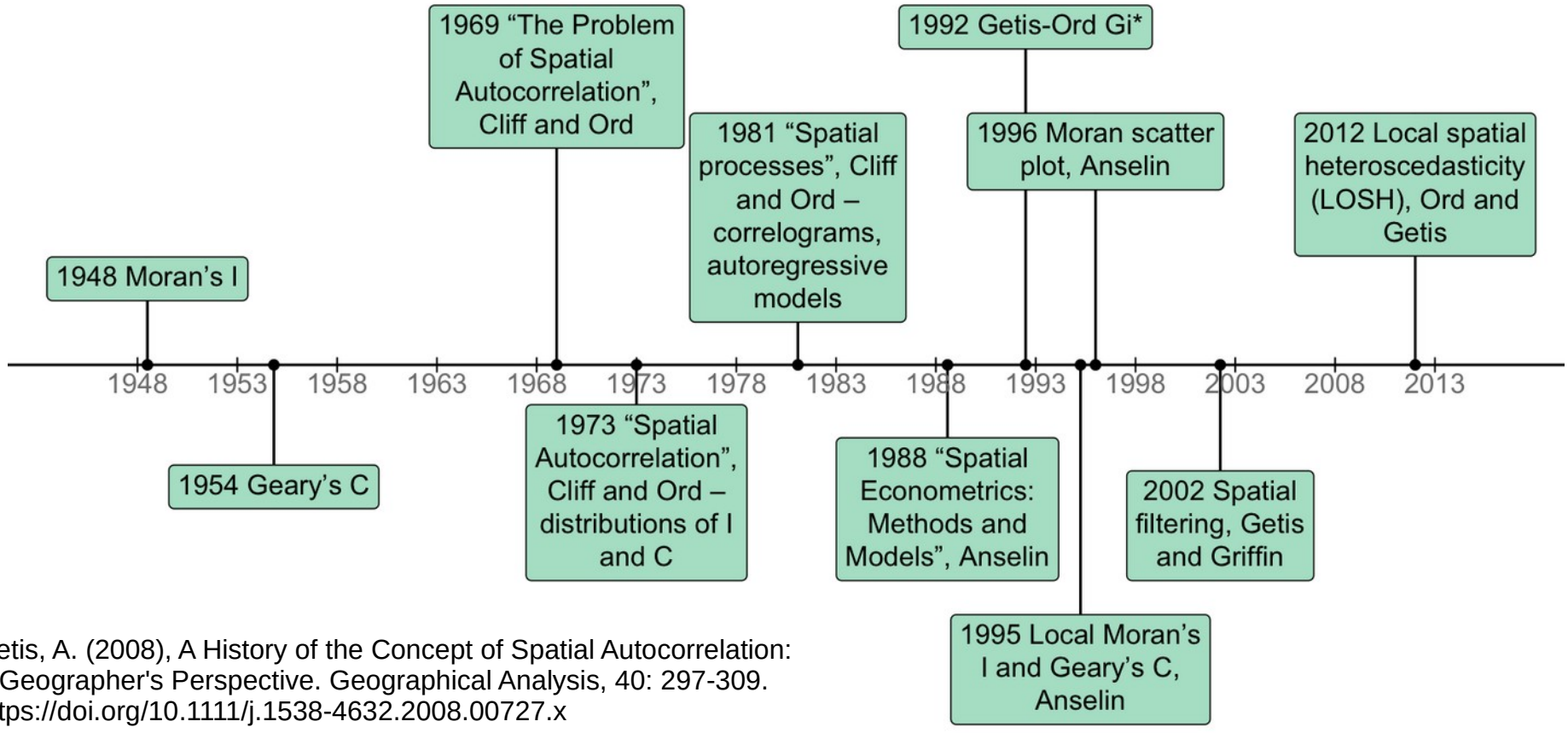


Number of new publications in spatial transcriptomics over time



Reproduced from Museum of Spatial Transcriptomics, Moses and Pachter 2022

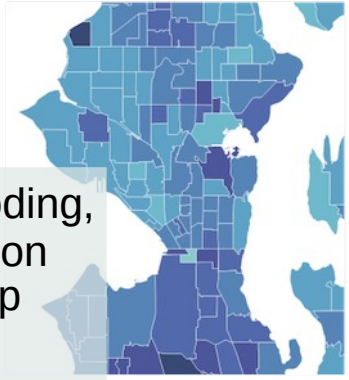
Timeline of spatial statistics in Voyager



Getis, A. (2008), A History of the Concept of Spatial Autocorrelation: A Geographer's Perspective. Geographical Analysis, 40: 297-309. https://doi.org/10.1111/j.1538-4632.2008.00727.x

Geospatial data types

Areal

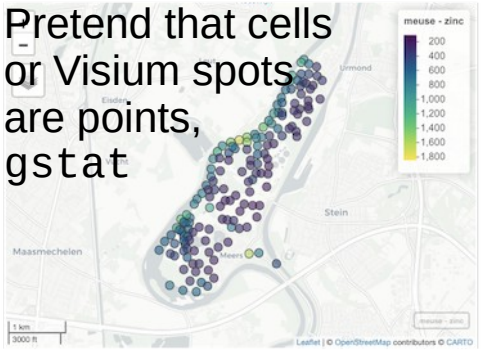


NGS barcoding,
ROI selection
`sf, spdep`

↓

SFE
Voyager

Geostatistical

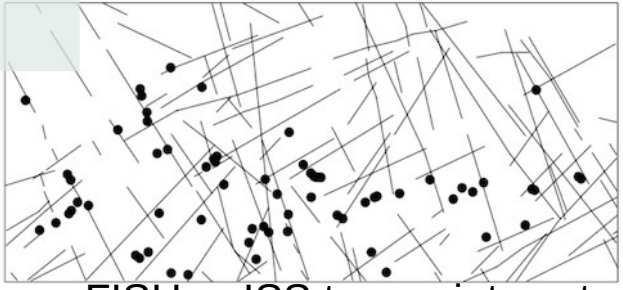


Pretend that cells or Visium spots are points,
`gstat`

Network

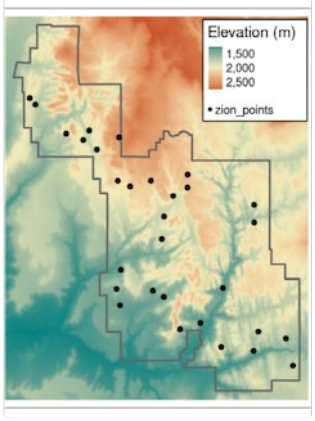
Blood vessels, axons, but 3D structure usually lost,
`sfnetwork, spatstat`

Point process



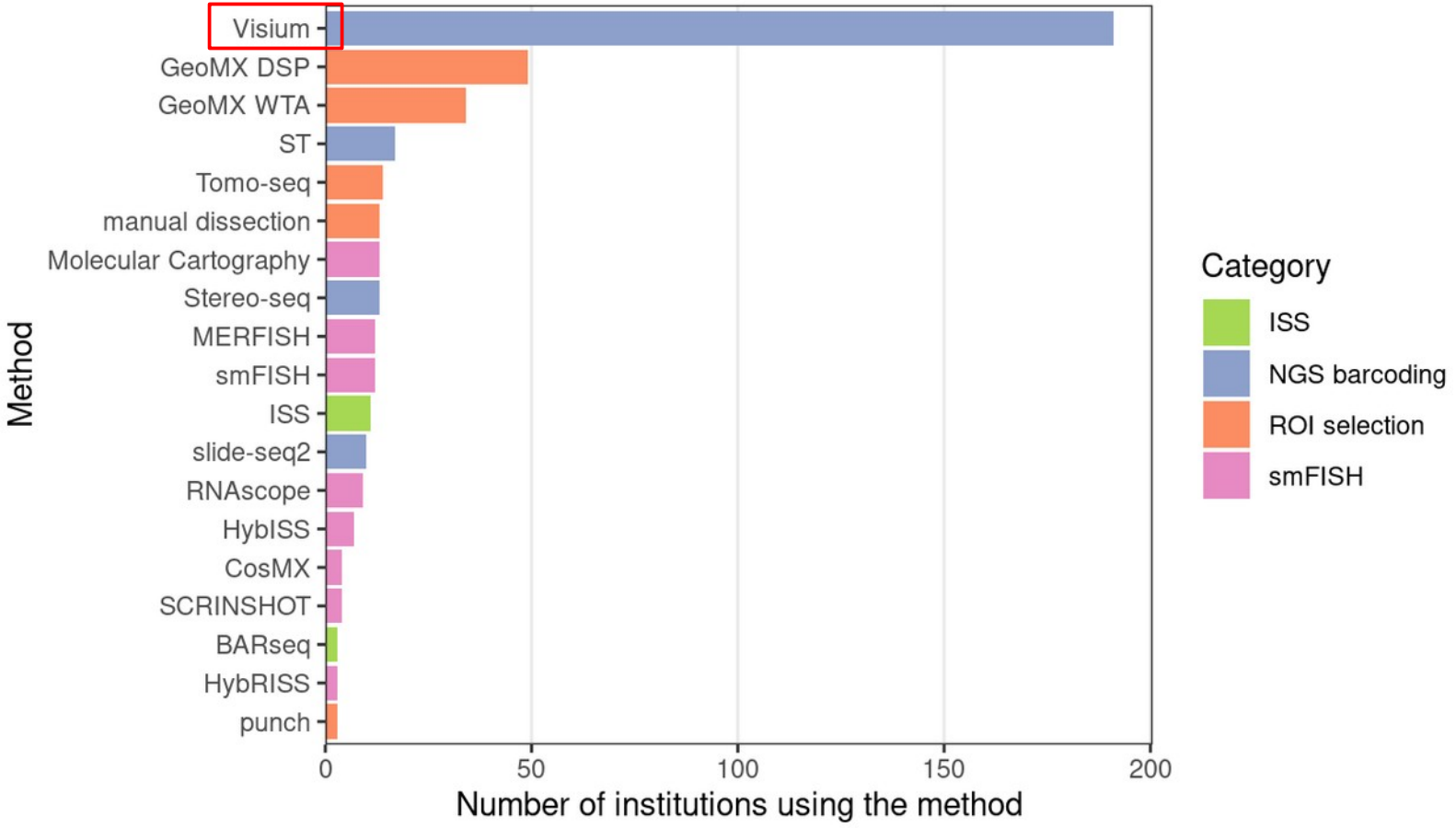
smFISH or ISS transcript spot and cell localization,
`spatstat`

Raster



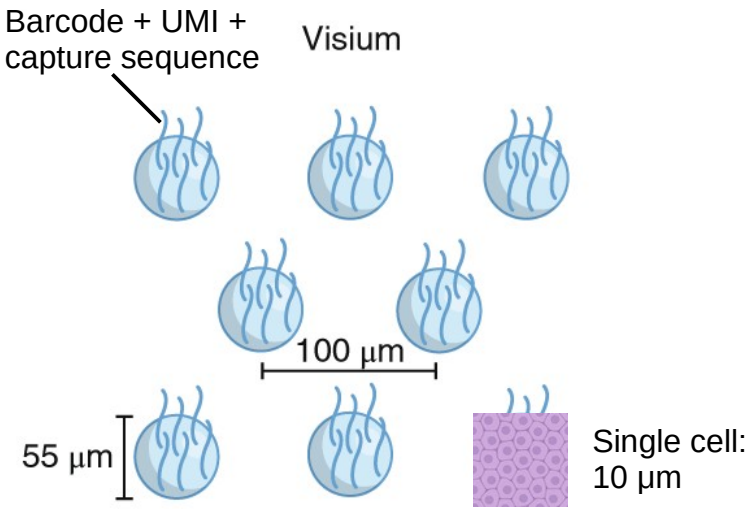
Histology images, regular grid,
`terra`

Number of institutions using each current era technology



Visium: the most popular NGS barcoding technology

10X website

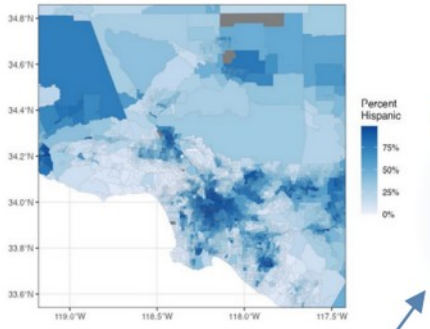


Museum of Spatial Transcriptomics

VOYAGER

From geospatial

to spatial -omics



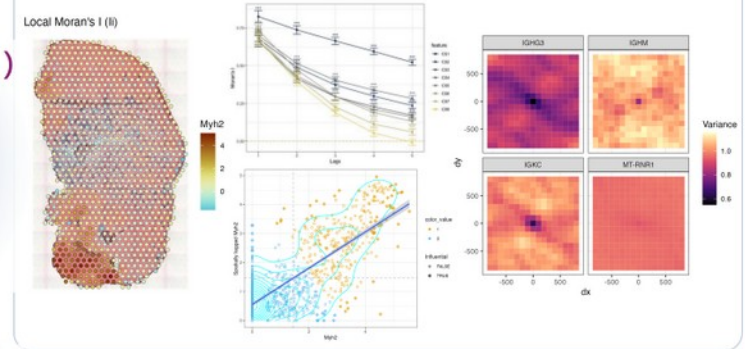
`runUnivariate()`
Moran's I,
Geary's C,
local Moran,
Getis-Ord Gi*,
correlogram,
variogram...

`spdep`, `PySAL`:
spatial autocorrelation
`gstat`: geostatistical variograms

`runBivariate()`
Lee's L,
cross variogram

`runMultivariate()`
MULTISPATI PCA,
multivariate local C

Visualize data and spatial analysis results



Comprehensive and reproducible documentation

Tutorials with data from:

Visium	MERFISH
Slide-seq	seqFISH
Xenium	CODEX
CosMX	Chromium

Automated website build

GitHub Actions

`SFEData` package: example datasets

Terra

sf

Raster image operations

Vector geometry operations

GeoPandas

SingleCellExperiment

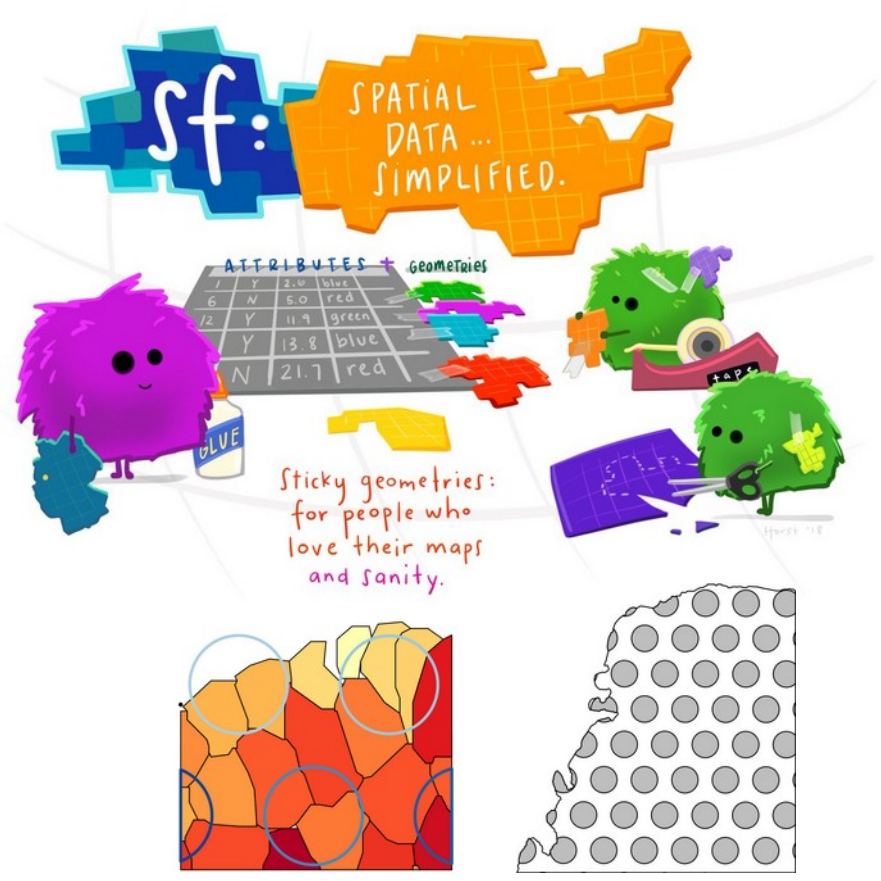
SpatialExperiment

`SpatialFeatureExperiment`

Compatibility tests

SCAN ME

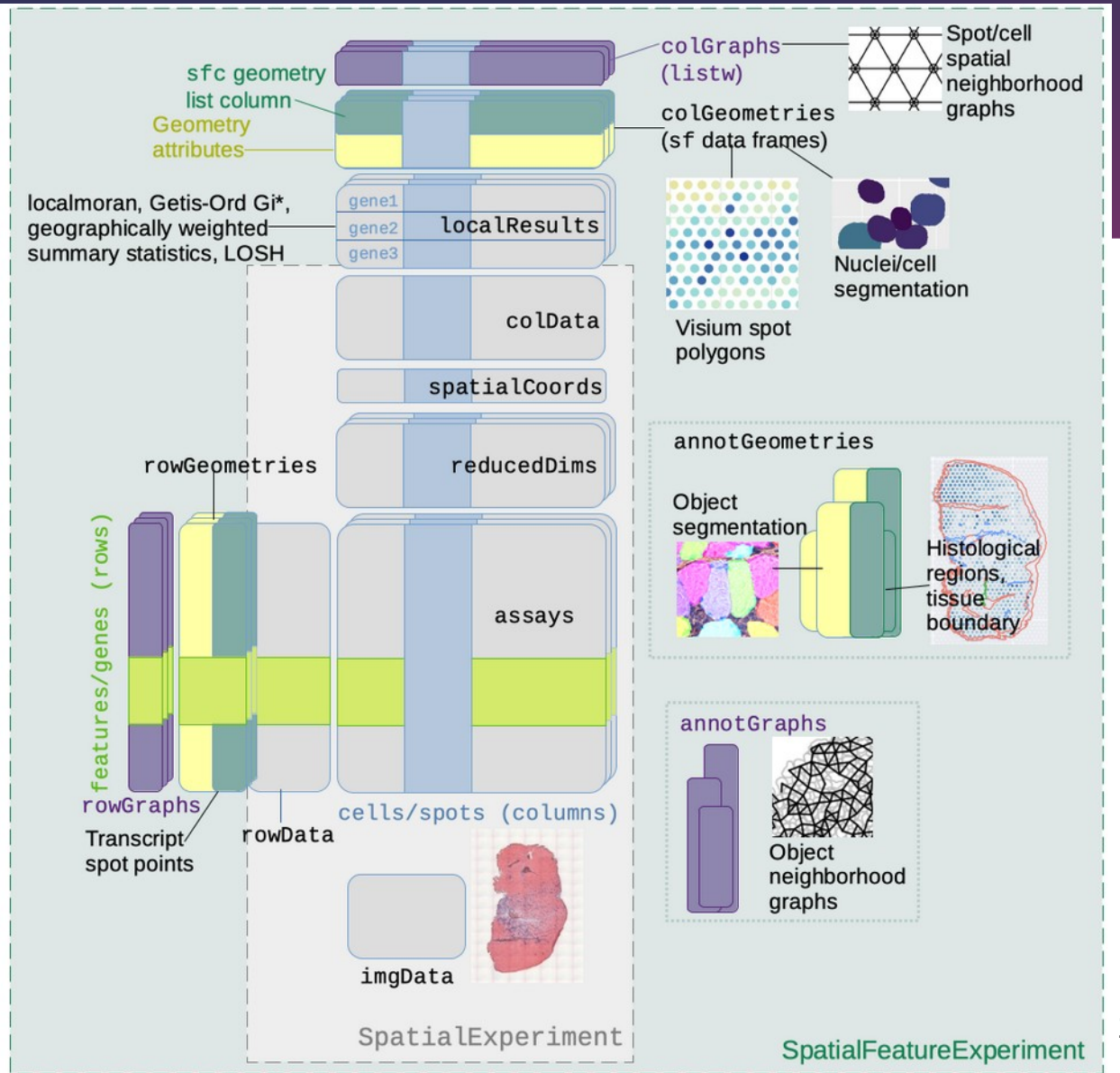
Simple Features: `sf` R package



- Data frame with special column for spatial geometries
- GEOS C++ library for fast geometric operations
- Whether two geometries intersect
- Find the geometry of the intersections
- Find cells in each Visium spot
- Find cells or spots in each pathologist annotated region
- Crop SFE object by polygon
- Visualize cell morphology

SpatialFeatureExperiment

- `SpatialExperiment` (SPE): Existing package extending SCE for spatial -omics data
- SFE: data structure extending SPE with `sf`
- Brings spatial geometries and geometric operations to -omics data for the first time
- Voyager: spatial analysis methods (`spdep`) populating and plotting SFE fields



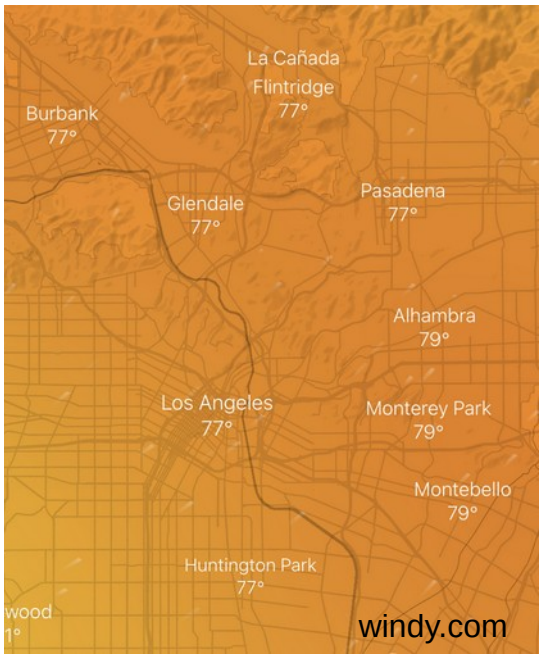
Exploratory data analysis (EDA)

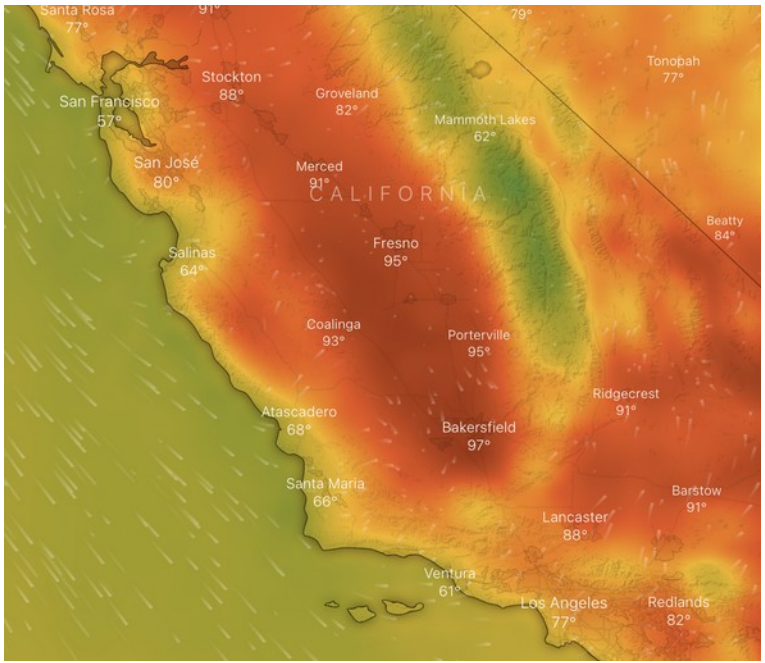
- Voyager to SFE is like scater to SCE and Seurat to SeuratObject
- It is important to understand what you CAN DO before you learn to measure how WELL you have seem to DONE it (Exploratory Data Analysis, Tukey 1977)
- Exploratory *spatial* data analysis (ESDA): EDA for spatial aspects of the data, especially spatial autocorrelation

Spatial autocorrelation

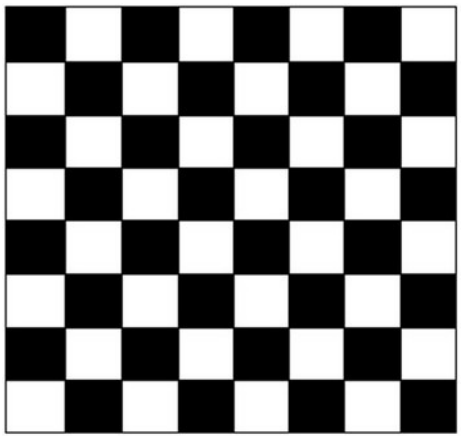
Tobler’s first law of geography: Everything is related to everything else.
But near things are more related than distant things.

Positive





Negative



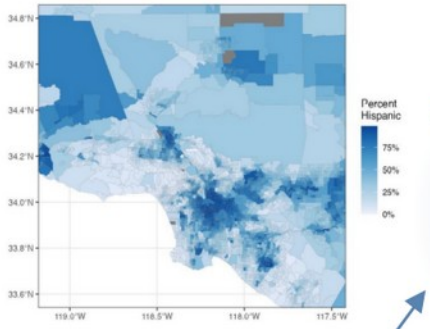
From geospatial to spatial transcriptomics

- Spatial point process: trendsceek, pciSeq, Bento, squidpy, spicyR
- Geostatistical (Gaussian process): SpatialDE, SPARK, GPcounts, BOOST-GP, spatialGE
- Moran's I: MERINGUE, Seurat, benchmarking SVG methods
- Local Moran's I: MERINGUE
- Lee's L: MERINGUE, Giotto
- Potts model spatial clustering: smfishhmrf (Giotto), BayesSpace
- GeoTIFF: samui browser
- Existing packages tend to focus on "how WELL you have seem to DONE it"
- Voyager: general ESDA ("what you CAN DO"), systematic uniform user interface, more efficient implementations

VOYAGER

From geospatial

to spatial -omics



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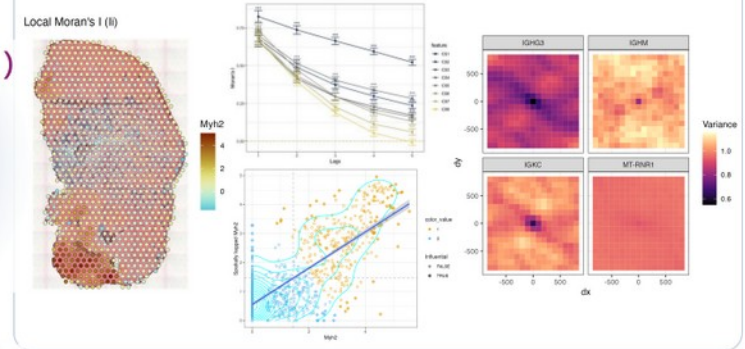

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Acknowledgement

- Voyager website: Kayla Jackson, Laura Luebbert, Lior Pachter
- Python implementation: Sina Booeshaghi, Pétur Helgi Einarsson, Pall Melsted, Sindri Antonsson
- Maria Carilli, Delaney Sullivan, Nikhila Swarna, Anne Kil, Charlene Kim, Taleen Dilanyan, and everyone in the lab
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