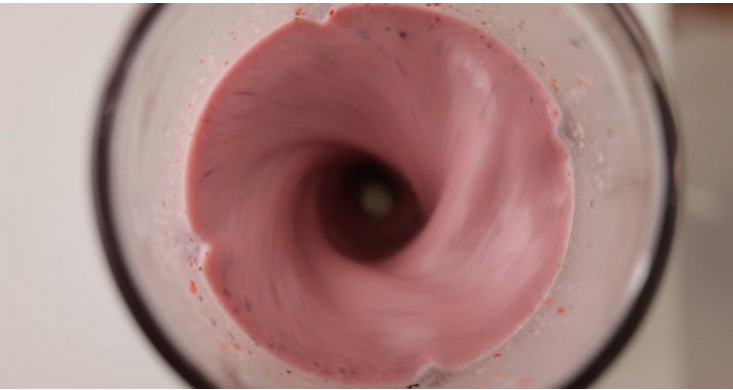


FROM
GEOSPATIAL TO
SPATIAL-OMICS
VOYAGER



Inadequate analogy

Bulk RNA-seq



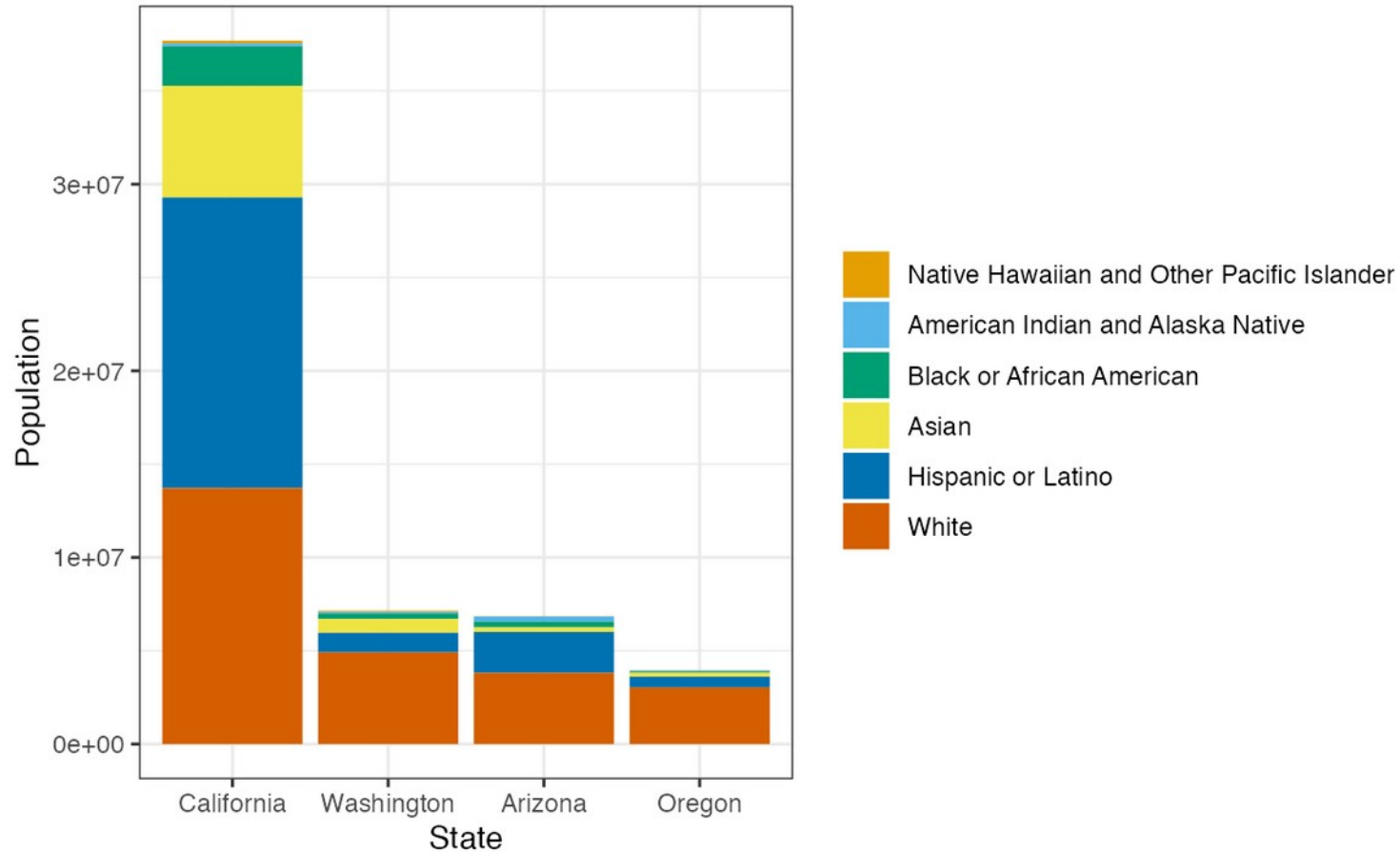
scRNA-seq



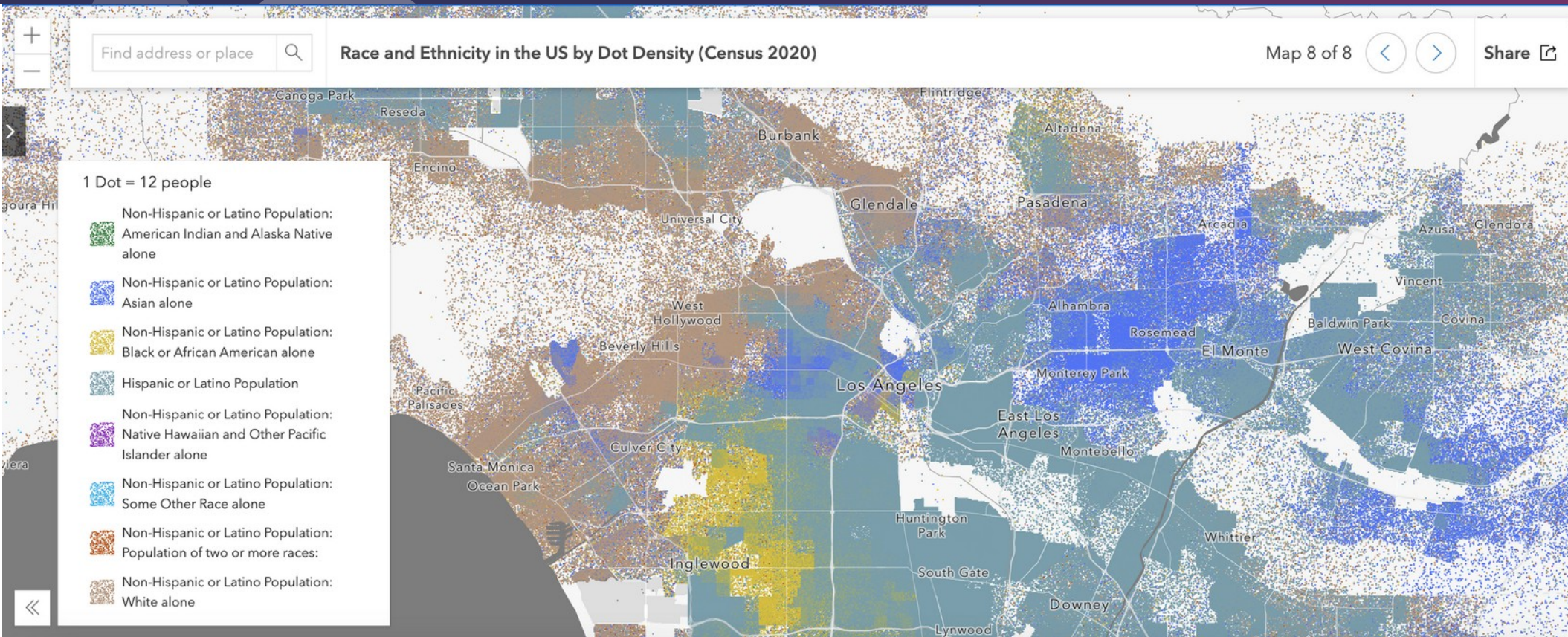
Spatial transcriptomics



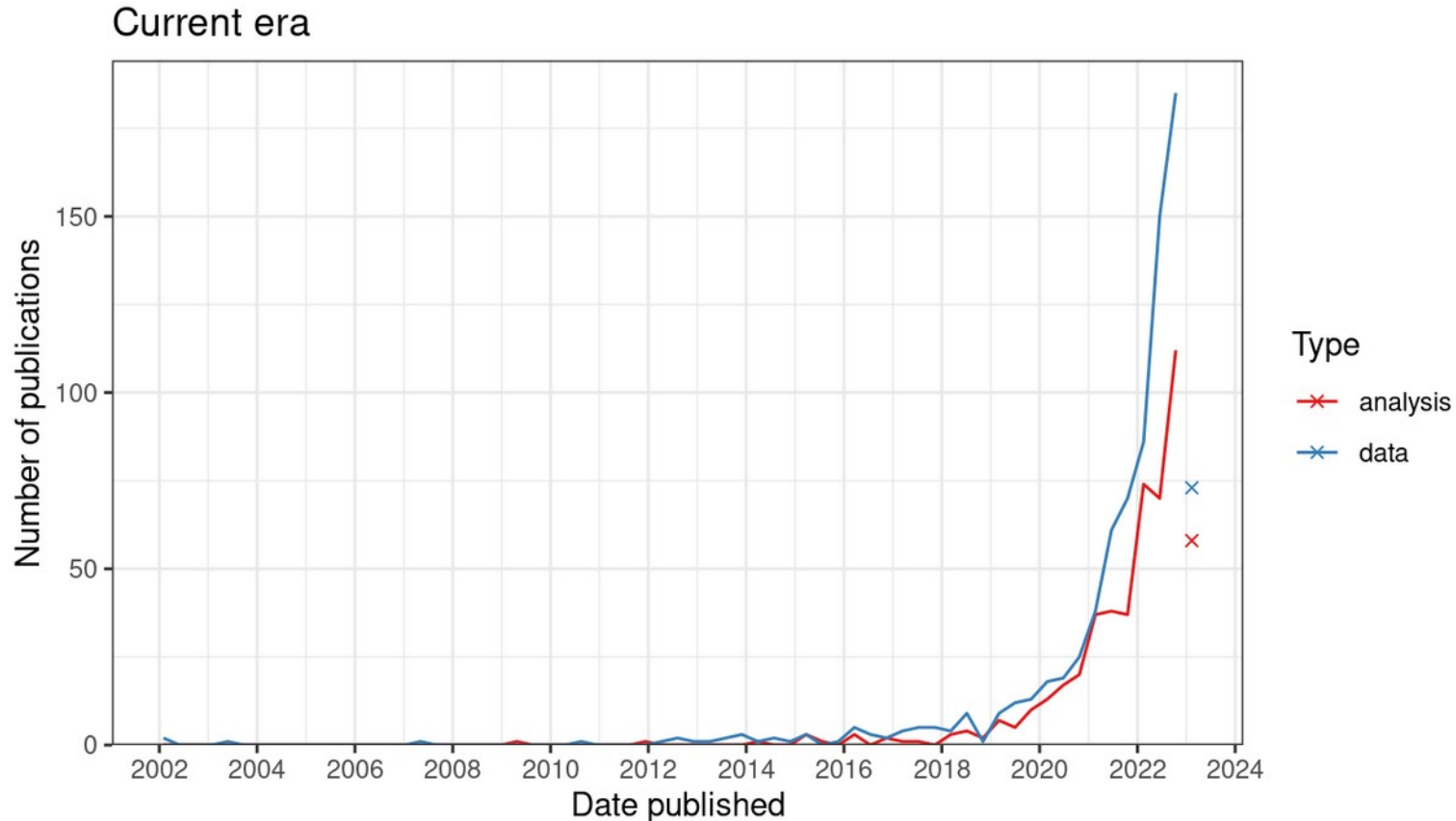
A geospatial analogy: bulk RNA-seq



A geospatial analogy: spatial transcriptomics

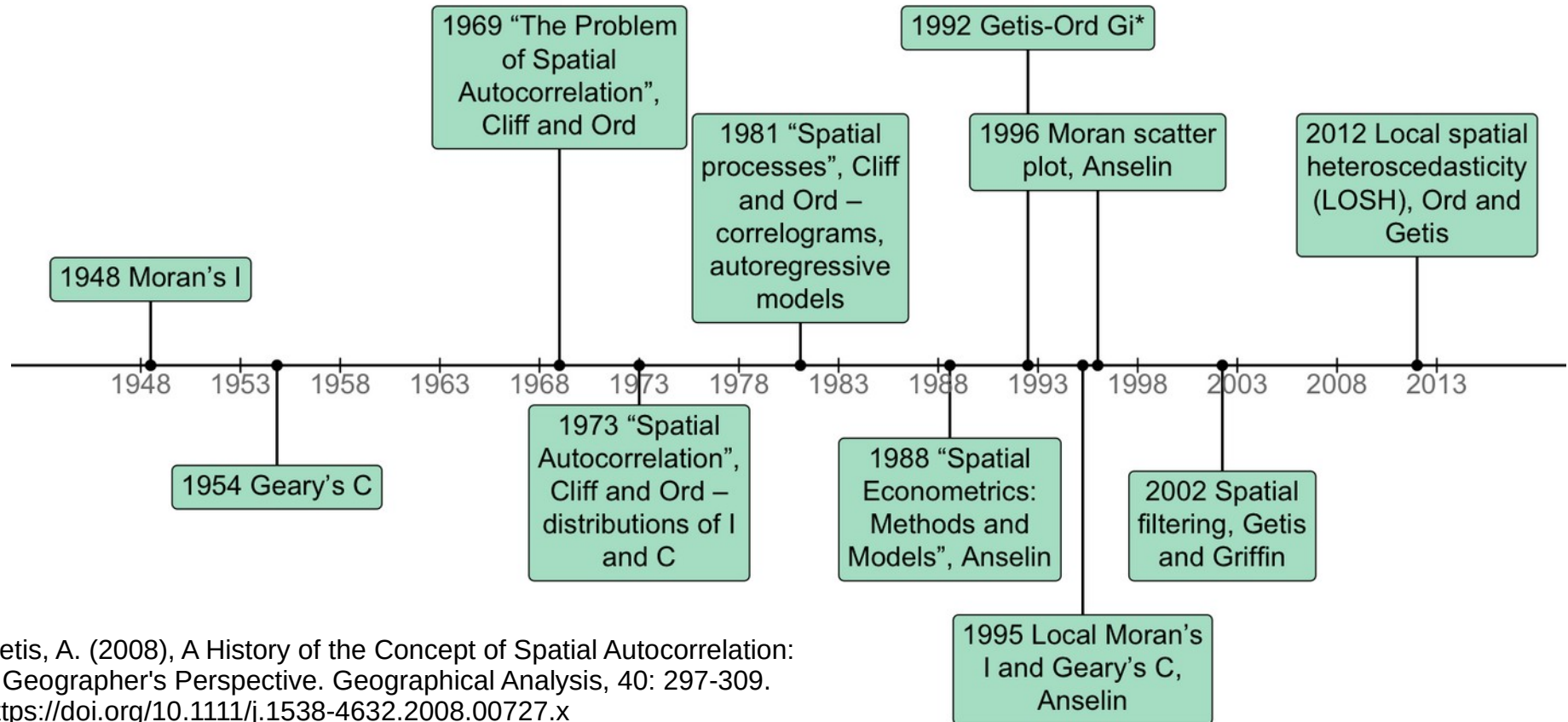


Number of new publications in spatial transcriptomics over time



Reproduced from Museum of Spatial Transcriptomics, Moses and Pachter 2022

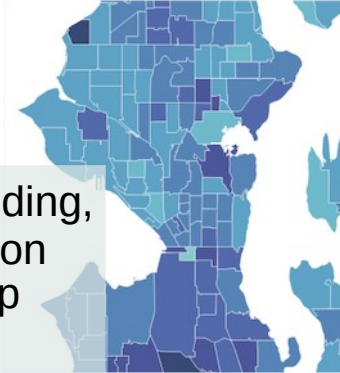
Timeline of spatial statistics in Voyager



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

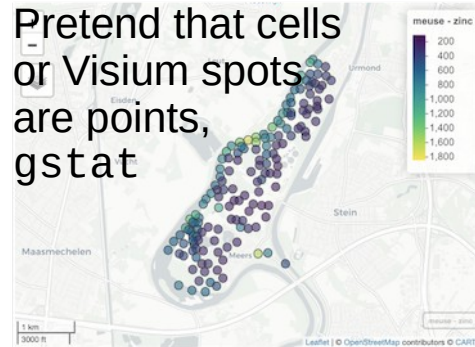


NGS barcoding,
ROI selection
sf, spdep

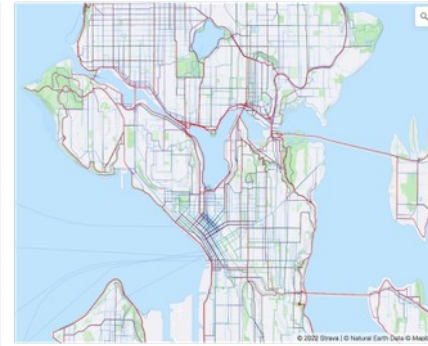


SFE
Voyager

Geostatistical

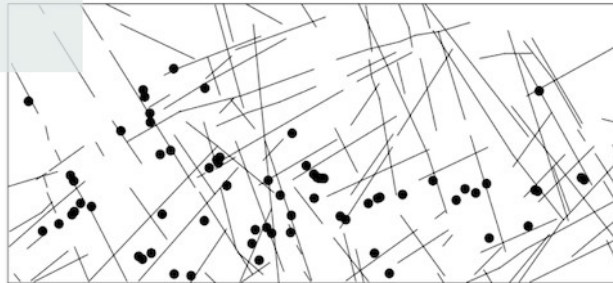


Network



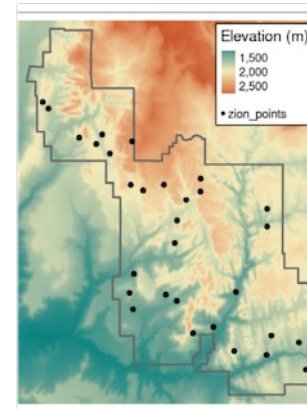
Blood vessels, axons,
but 3D structure
usually lost,
sfnetwork,
spatstat

Point process



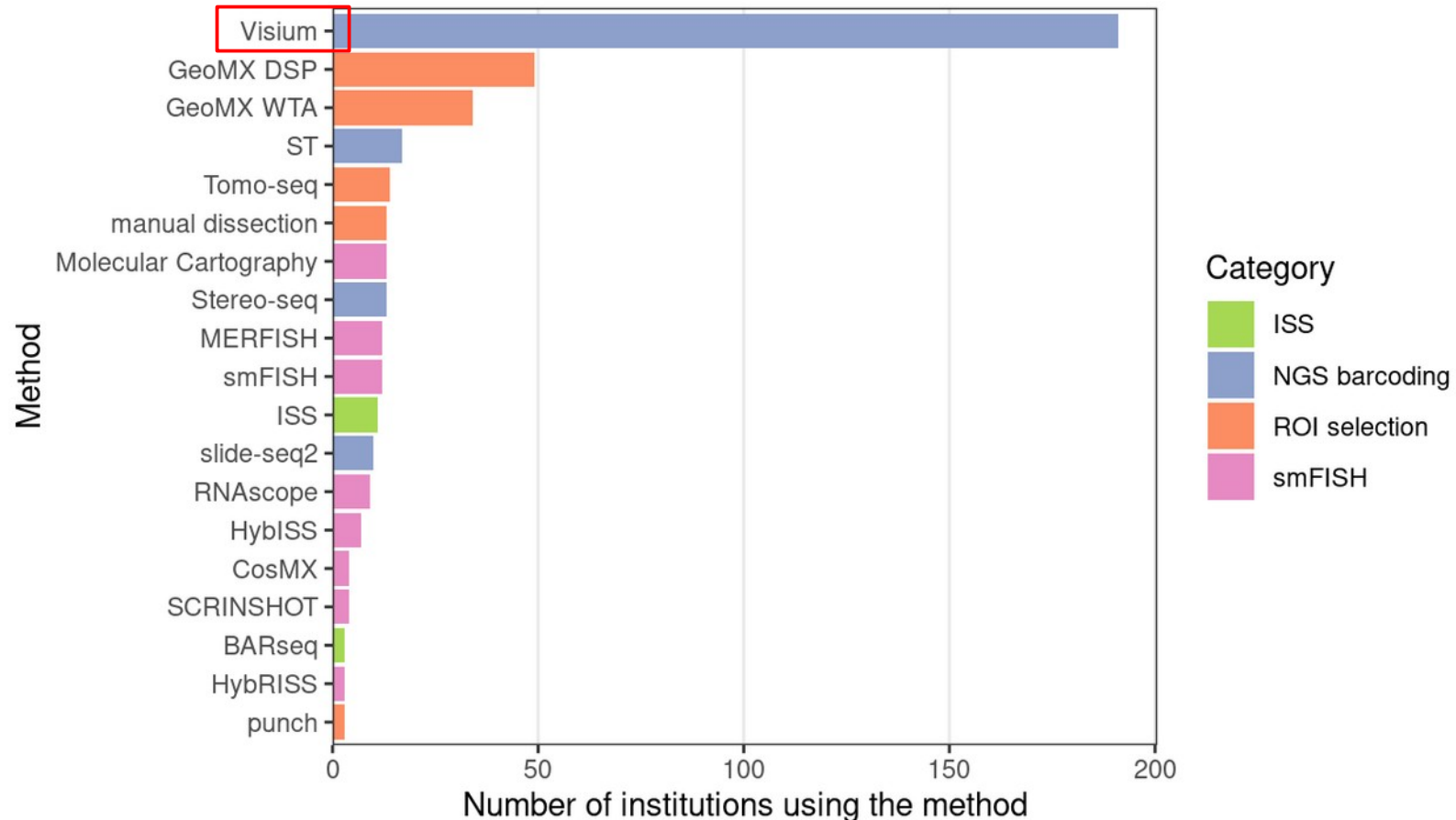
smFISH or ISS transcript spot
and cell localization,
spatstat

Raster

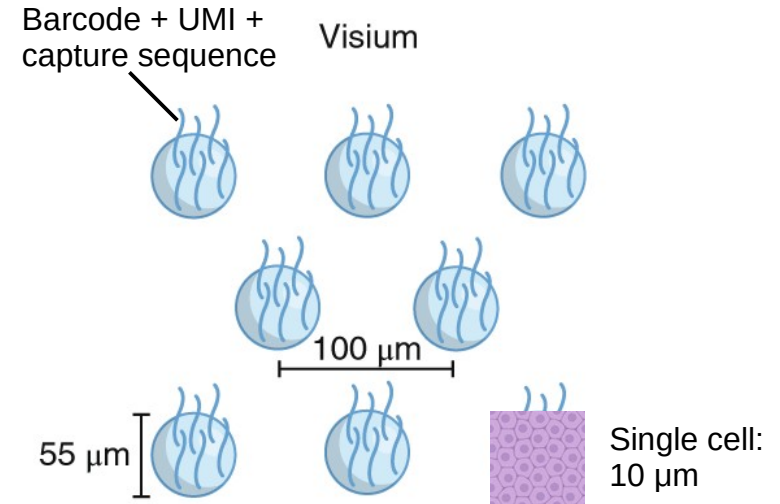


Histology
images,
regular grid,
terra

Number of institutions using each current era technology

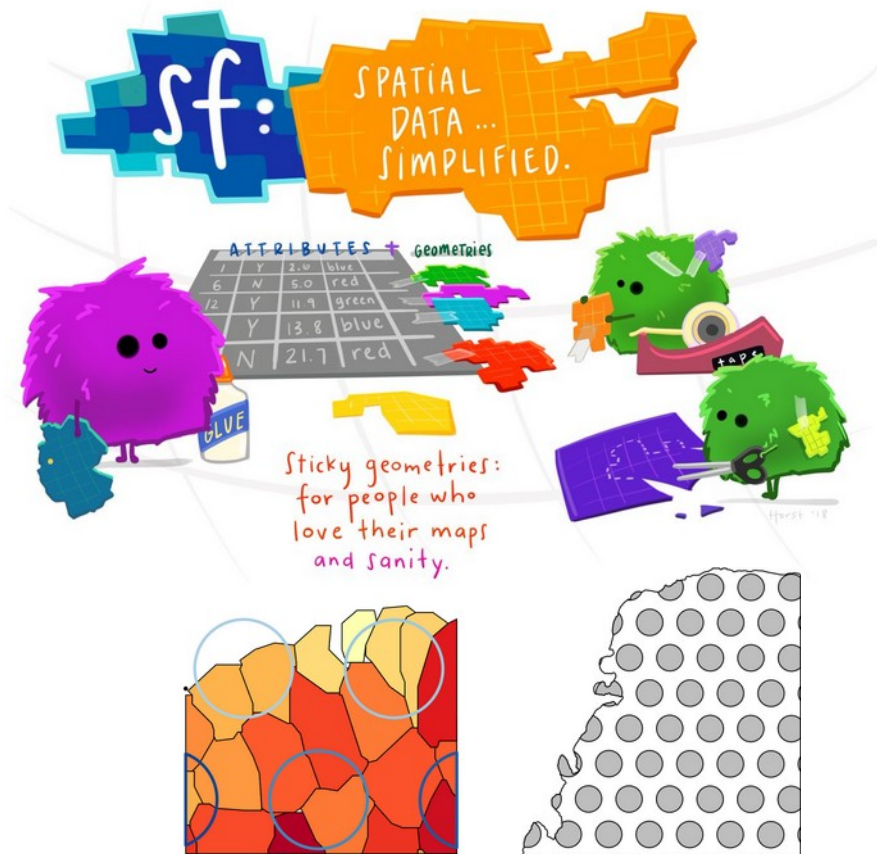


Visium: the most popular NGS barcoding technology



Museum of Spatial Transcriptomics

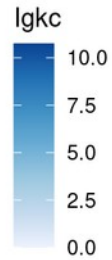
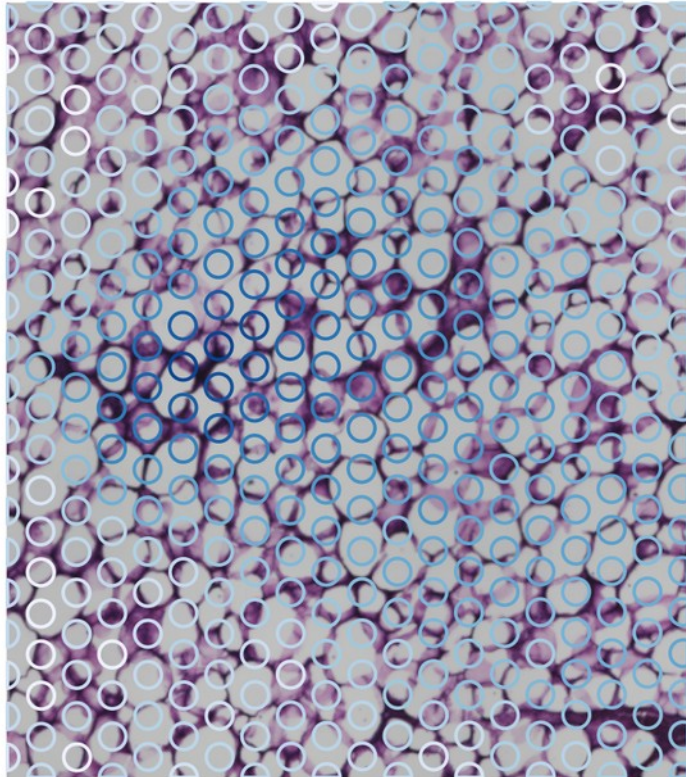
Simple Features: sf R package



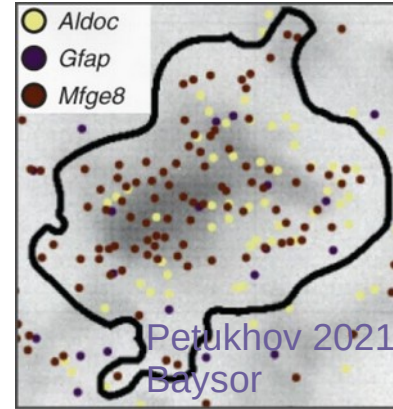
- Data frame with special column for spatial geometries
- GEOS C++ library for fast geometric operations
- Whether two geometries intersect
- Find the geometry of the intersections
- Find cells in each Visium spot
- Find cells or spots in each pathologist annotated region
- Crop SFE object by polygon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

Geometries in biology

Visium spots

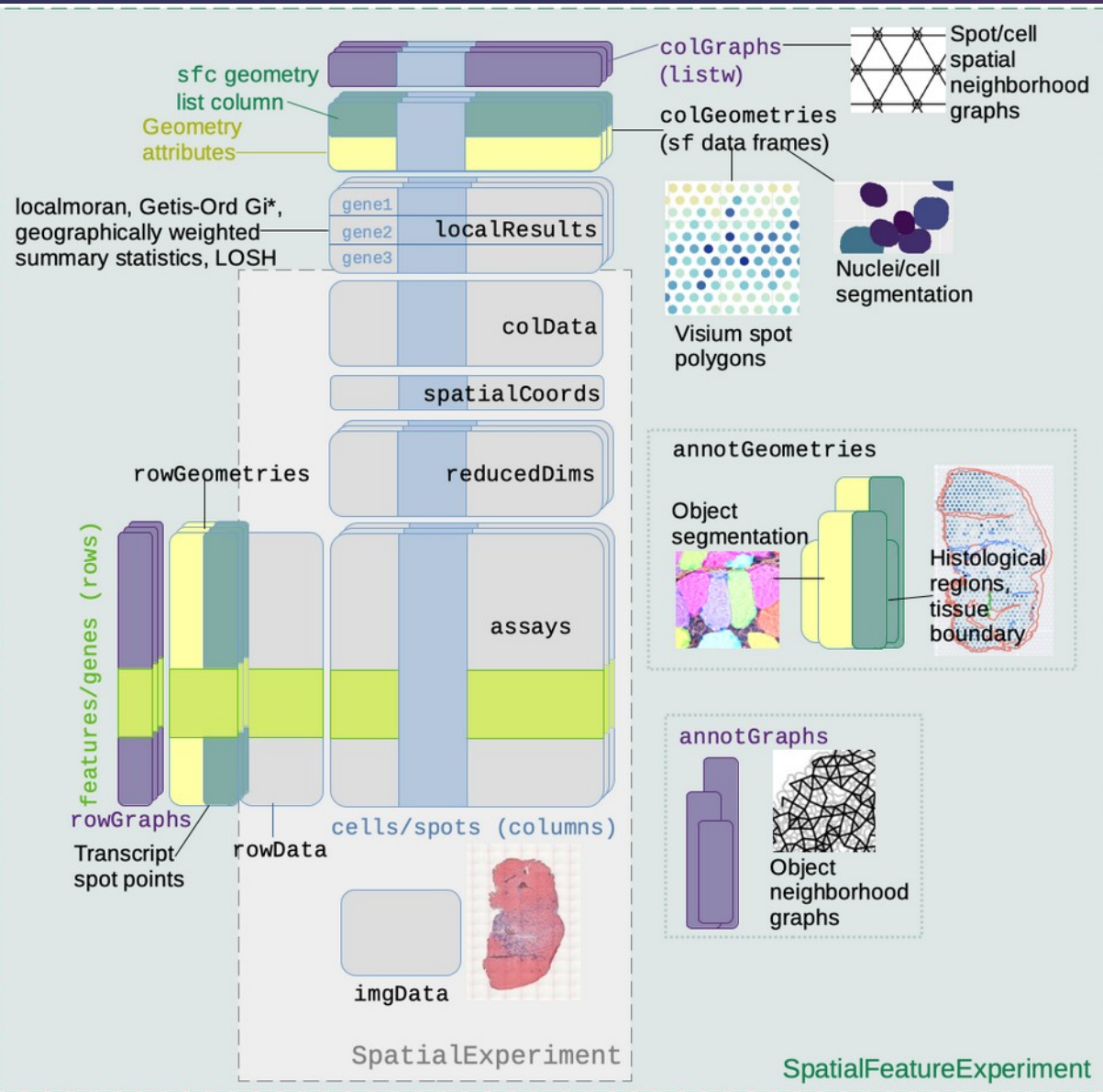


Cell boundaries and mRNA molecule spots



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



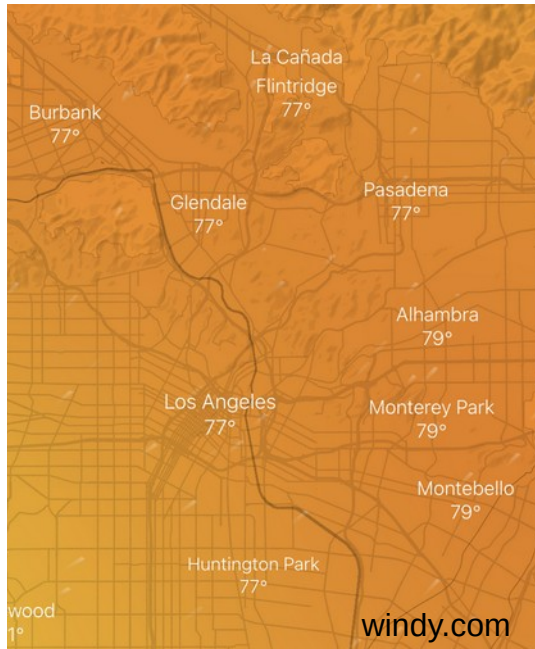
Exploratory data analysis (EDA)

- 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

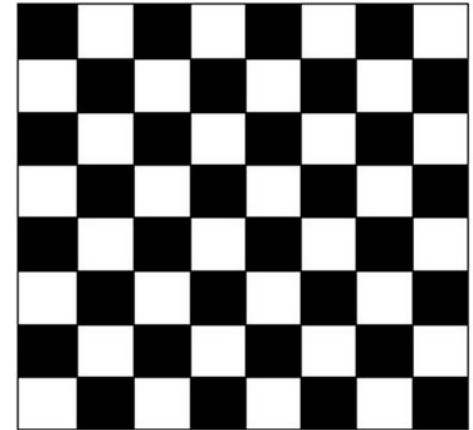
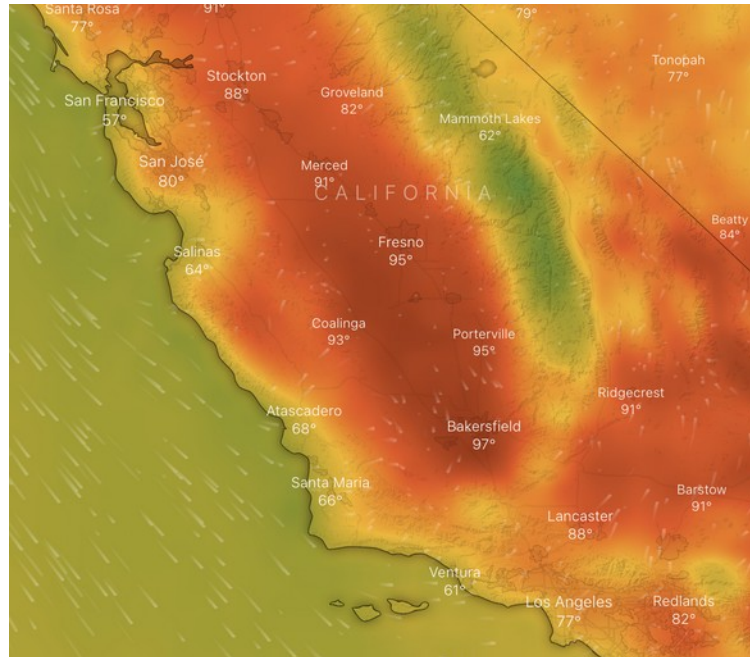
Spatial autocorrelation

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

Positive



Negative



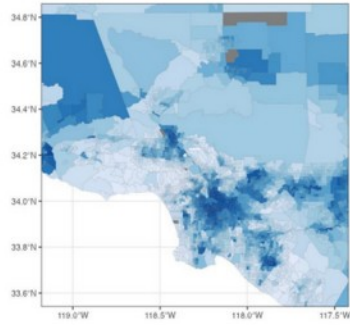
From geospatial to spatial transcriptomics

- 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: smfishhmr (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



`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



Raster image
operations



Vector geometry
operations



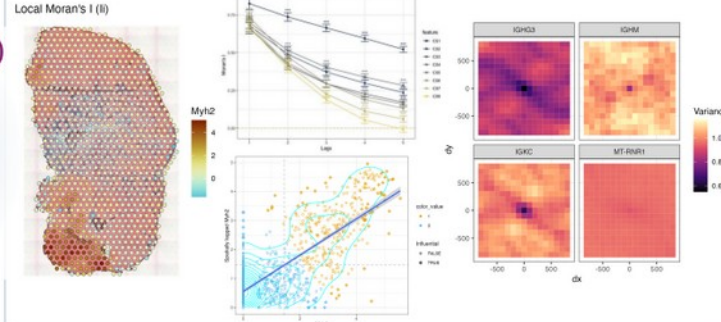
GeoPandas

`runMultivariate()`
MULTISPATI PCA,
multivariate local C



`SpatialFeatureExperiment`

Visualize data and spatial analysis results



Comprehensive and reproducible documentation

Tutorials with data from:

Visium
Slide-seq
Xenium
CosMX

MERFISH
seqFISH
CODEX
Chromium

Automated website build



`SFData` package: example datasets



Compatibility
tests



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
- Funding: National Institute of Mental Health (NIMH), NIH, Icelandic Research Fund Project

