DSCI 554 LECTURE 8

DEPTH PERCEPTION AND DESIGN, MAPS

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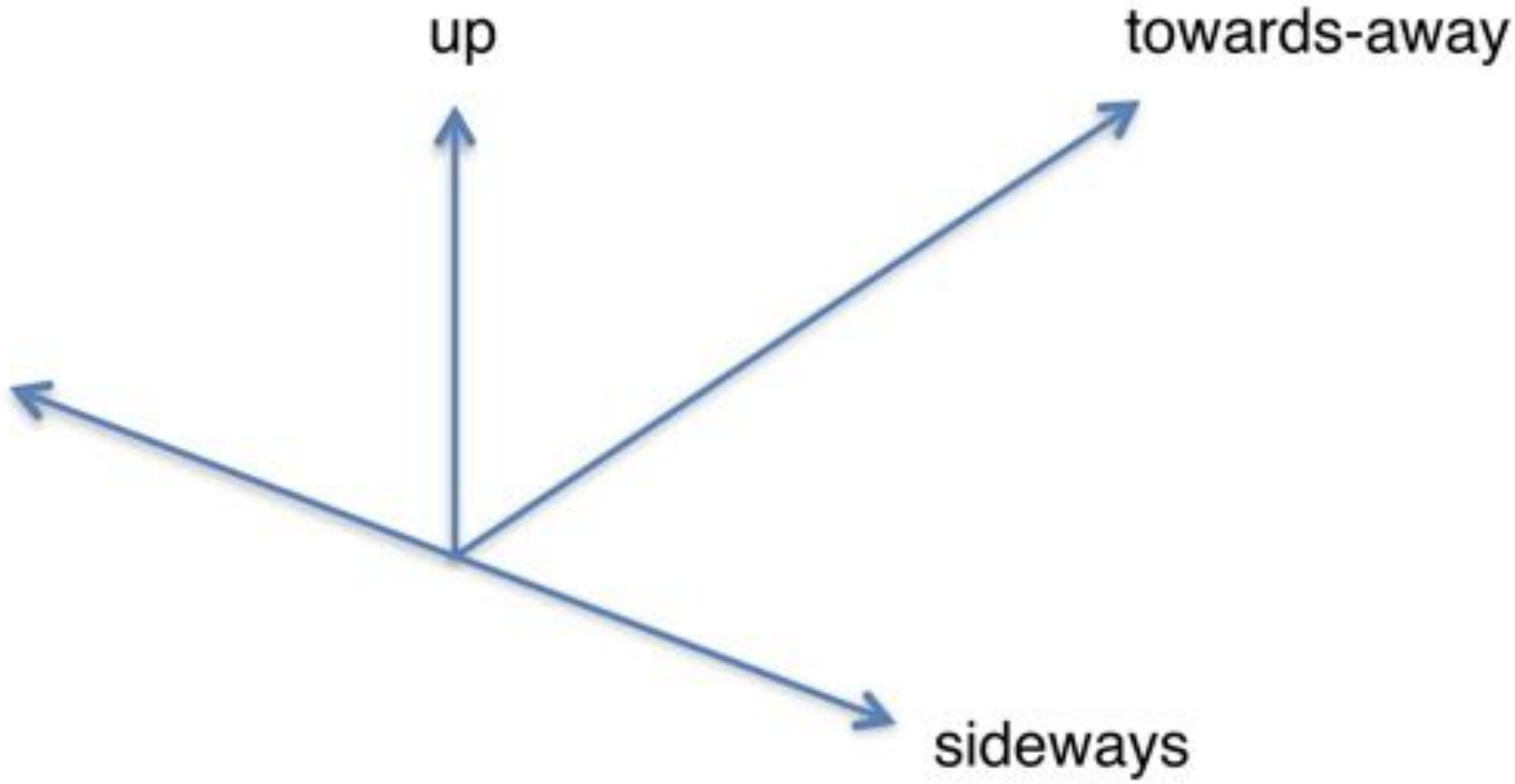
OUTLINE

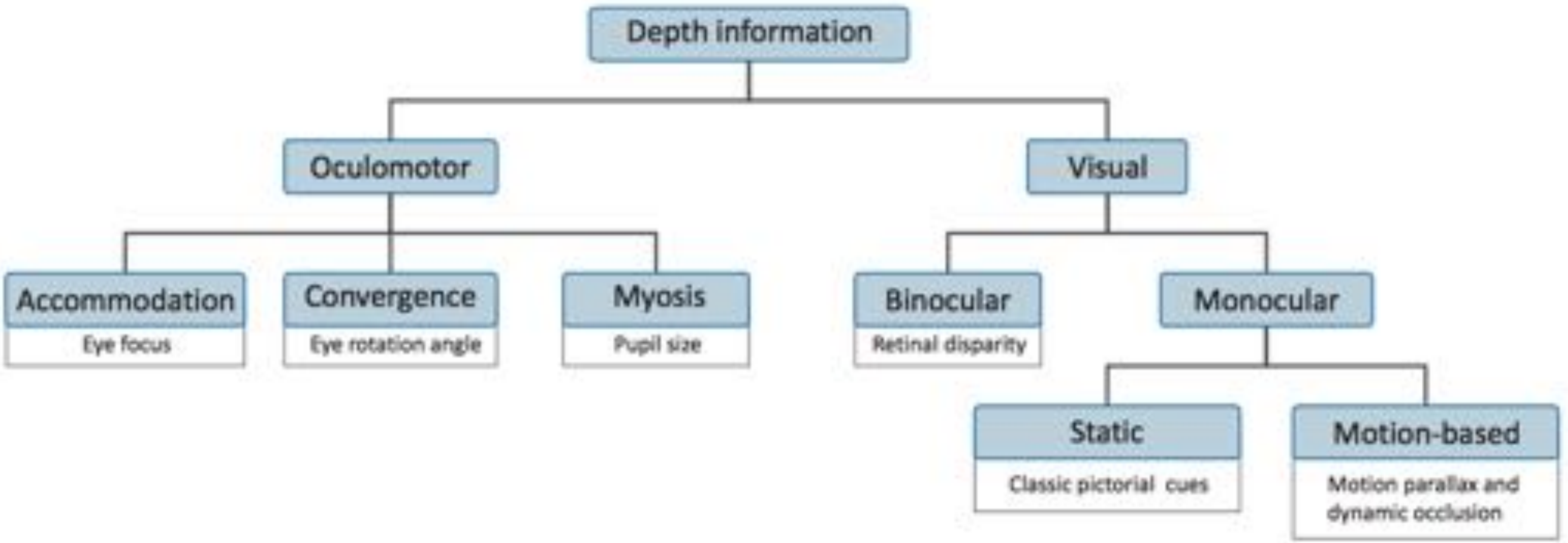
- Depth perception and design considerations
- Introduction to maps
- How maps are built?
- Maps projections and their uses
- Working with maps

PERCEPTUAL EGOCENTRIC SPACE



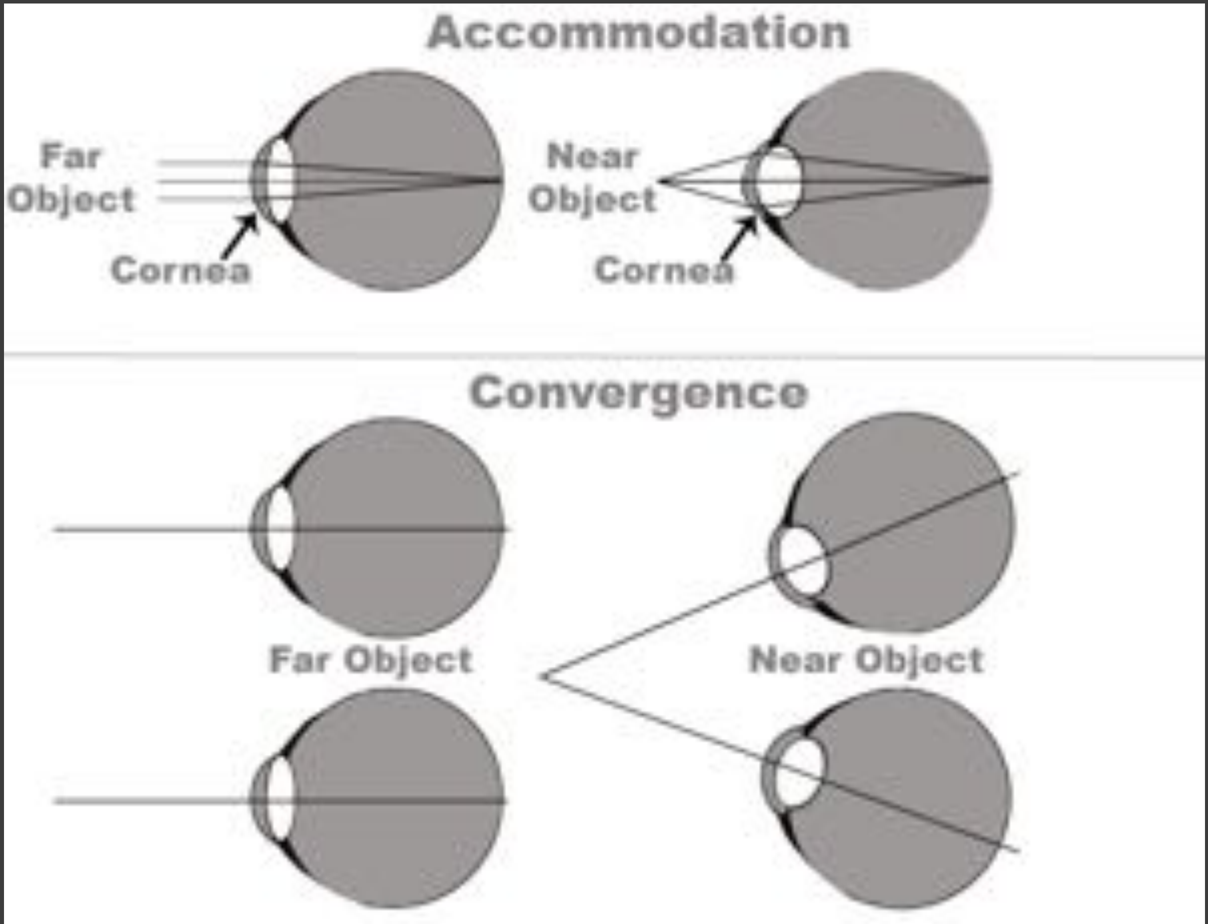
Decreased depth information in towards-away because of object occlusions

DEPTH INFORMATION AND DEPTH CUES



M. J. Tovee, An introduction to the visual system, Cambridge Univ. Press, 1996

OCULOMOTOR



- Accommodation: coordinated changes in vergence, lens shape and pupil size
- Convergence: movement of both eyes to center image is in the retina
- Myosis: constriction (squeezing) of the pupil

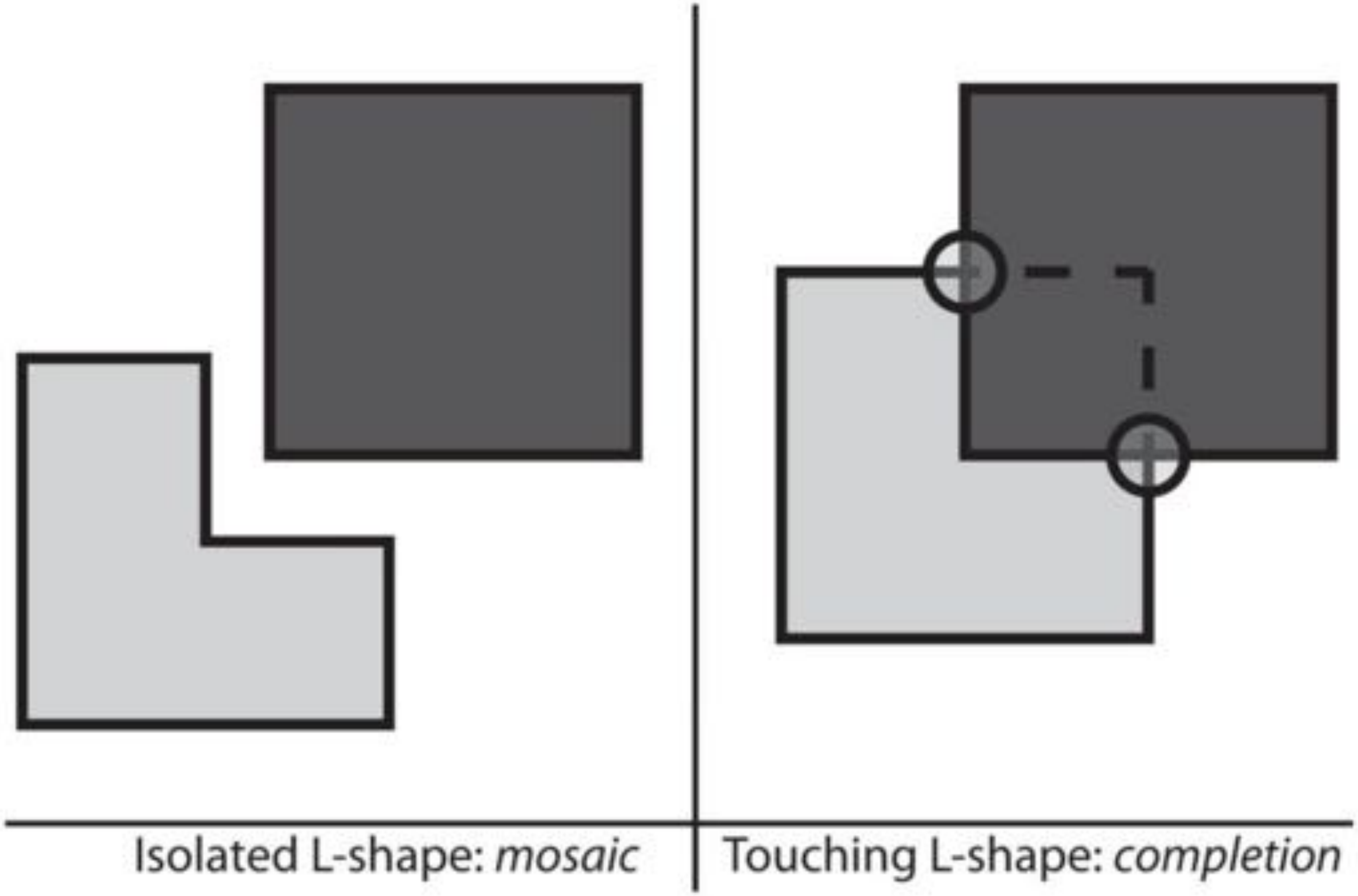
VISUAL > MONOCULAR > STATIC

<u>CLASSIC PICTORIAL</u> (I.E., IN STATIC IMAGE) CUES

- OCCLUSIONS
- LINEAR PERSPECTIVE CONVERGENCE
- RELATIVE SIZE, FAMILIAR SIZE
- TEXTURE GRADIENT
- SHADOWS
- SHADING
- DEFOCUS BLUR
- ATMOSPHERIC PERSPECTIVE

PICTORIAL > OCCLUSIONS

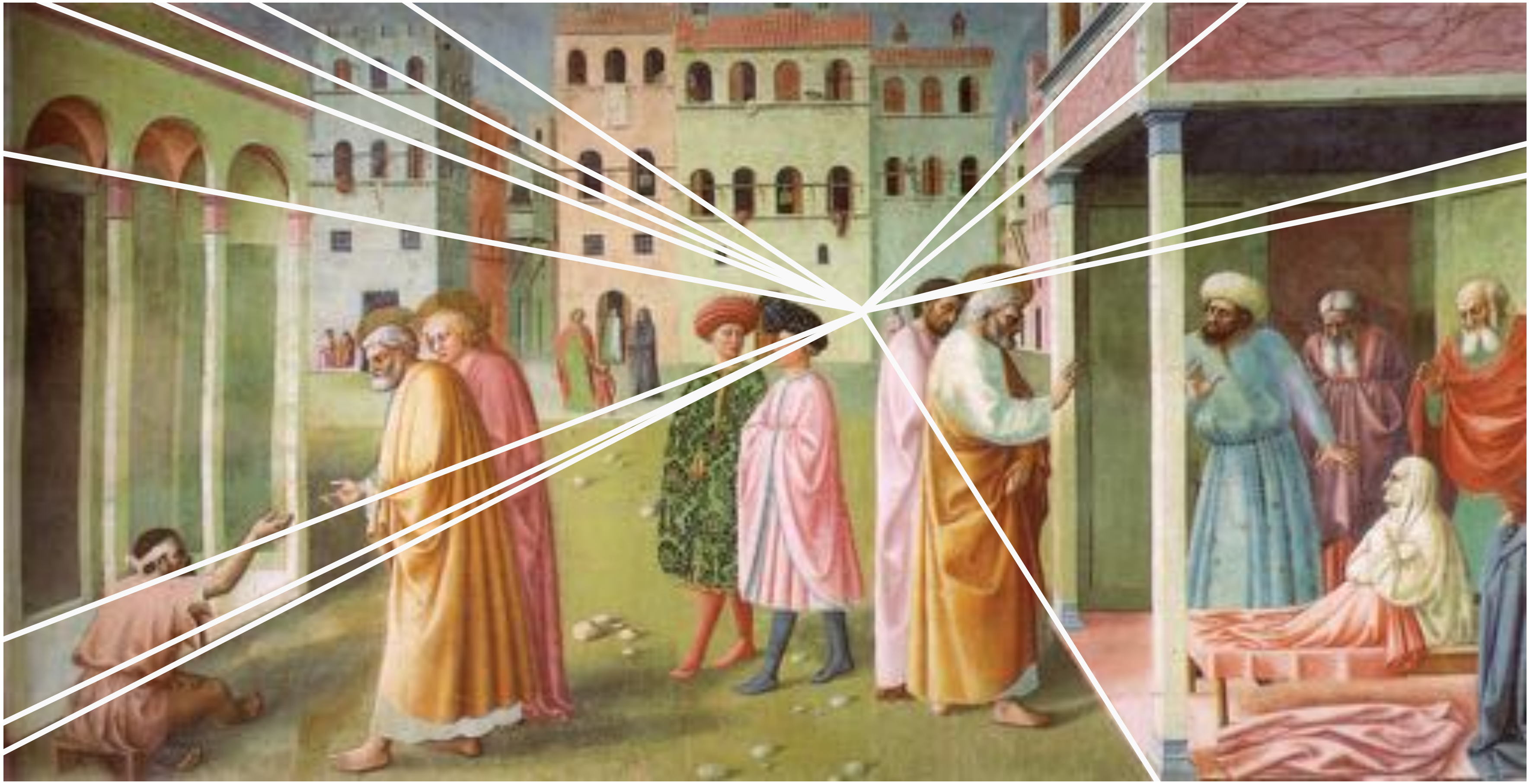
An object blocks another



Perdreau F, Cavanagh P. Do artists see their retinas?. Frontiers in human neuroscience. 2011

PICTORIAL > LINEAR PERSPECTIVE CONVERGENCE

Parallel lines appear to converge at some point in the distance

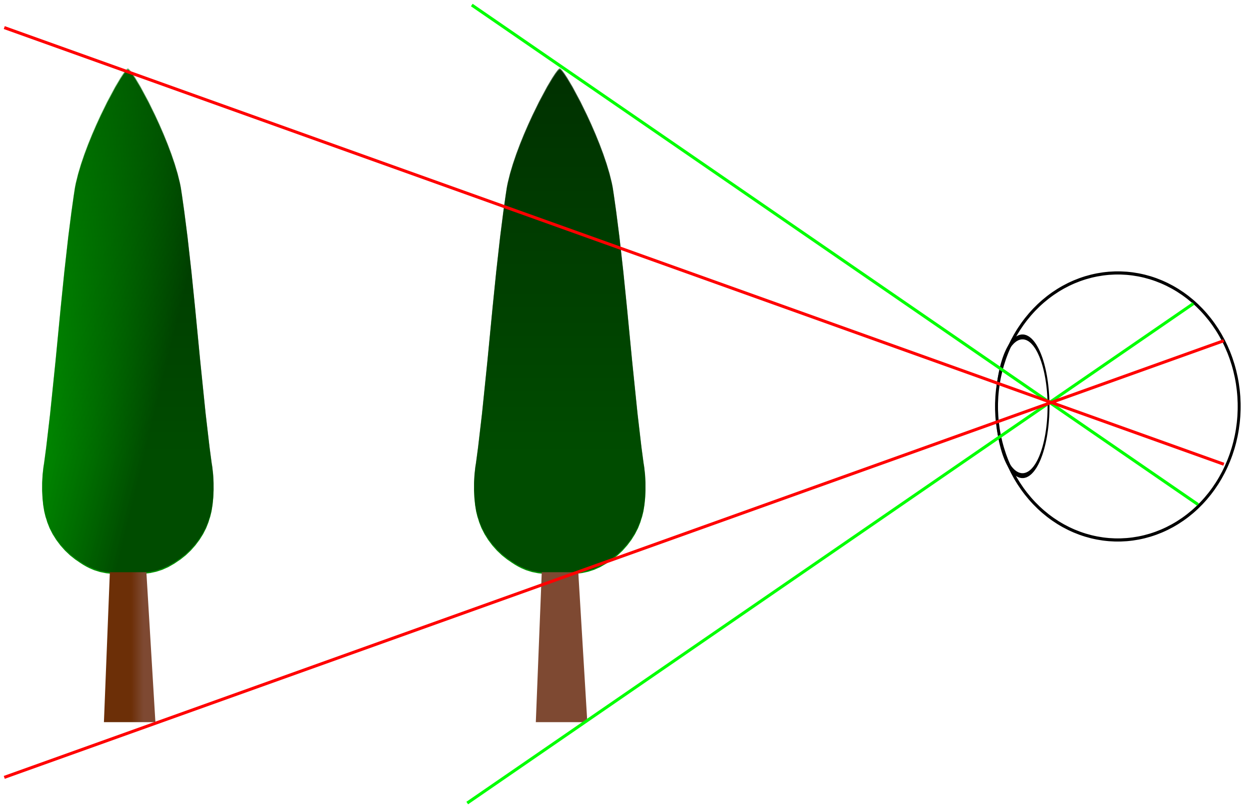


St. Peter Healing a Cripple and the Raising of Tabitha, Masolino, 1425

PICTORIAL > RELATIVE SIZE, FAMILIAR SIZE: OBJECT SIZE

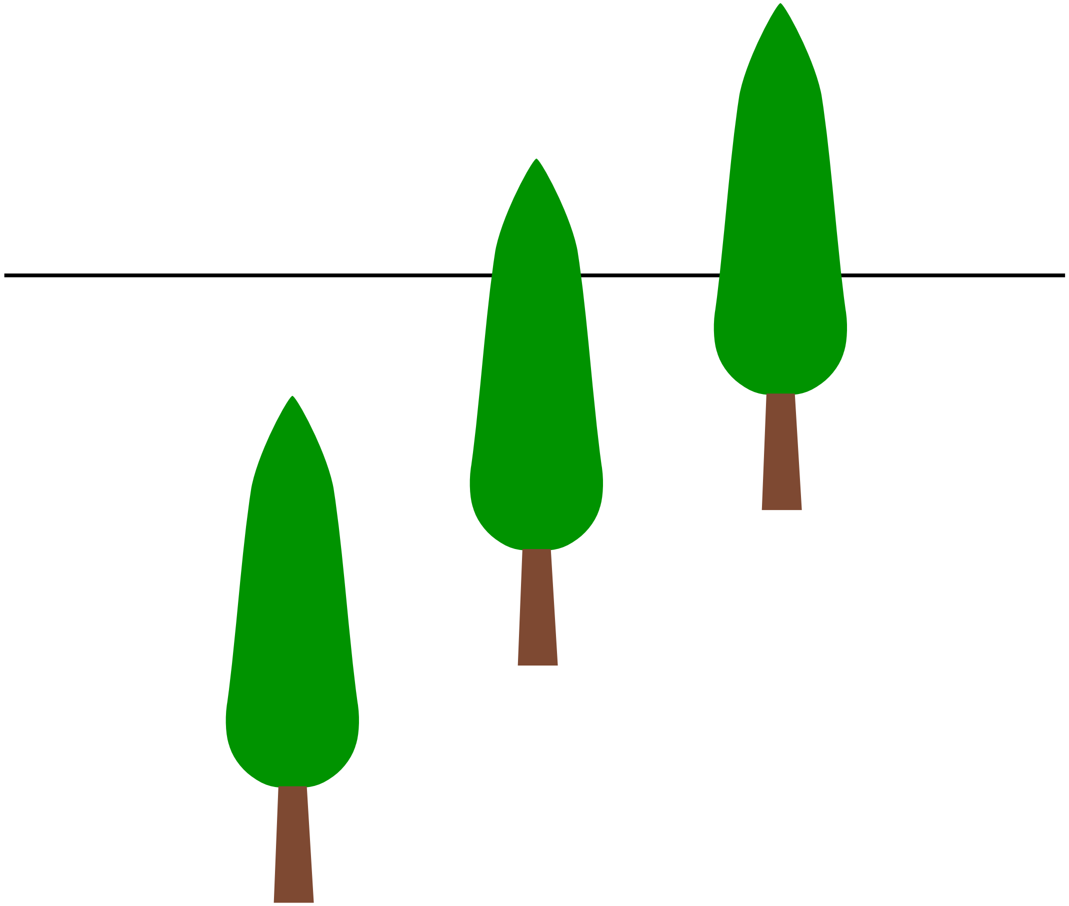
Retinal projection is:

- proportional to object size
- inversely proportional to the object distance



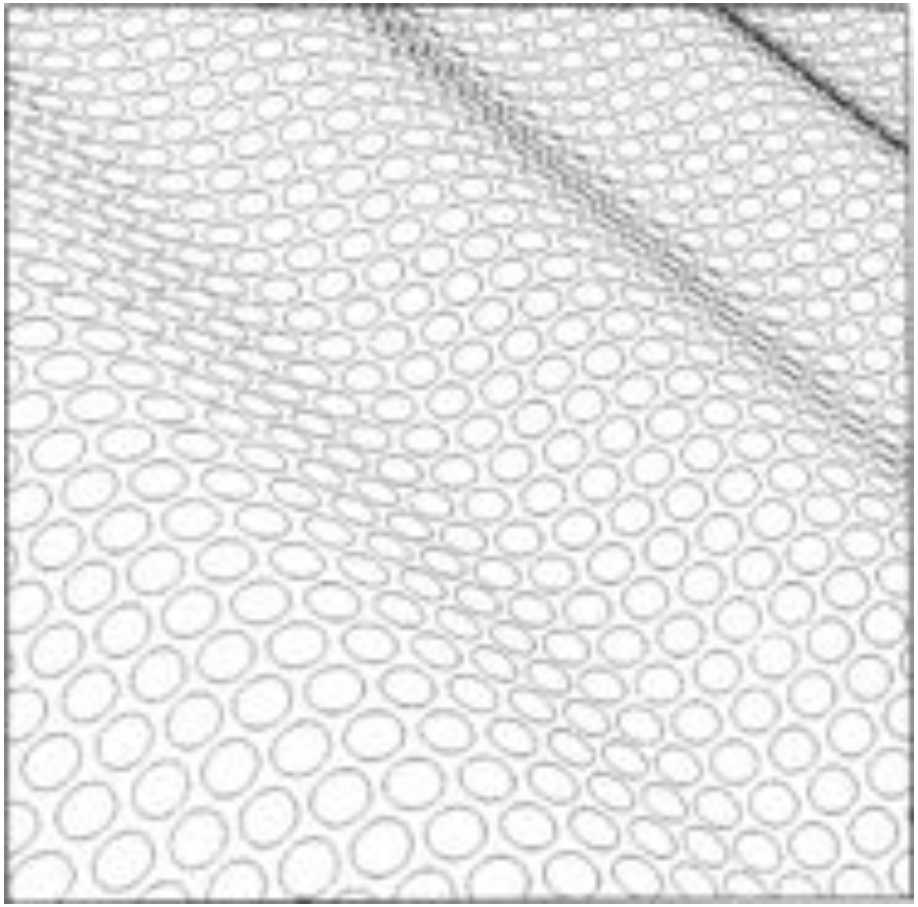
PICTORIAL > RELATIVE SIZE, FAMILIAR SIZE: RELATIVE HEIGHT

Object closer to the horizon are farther – up



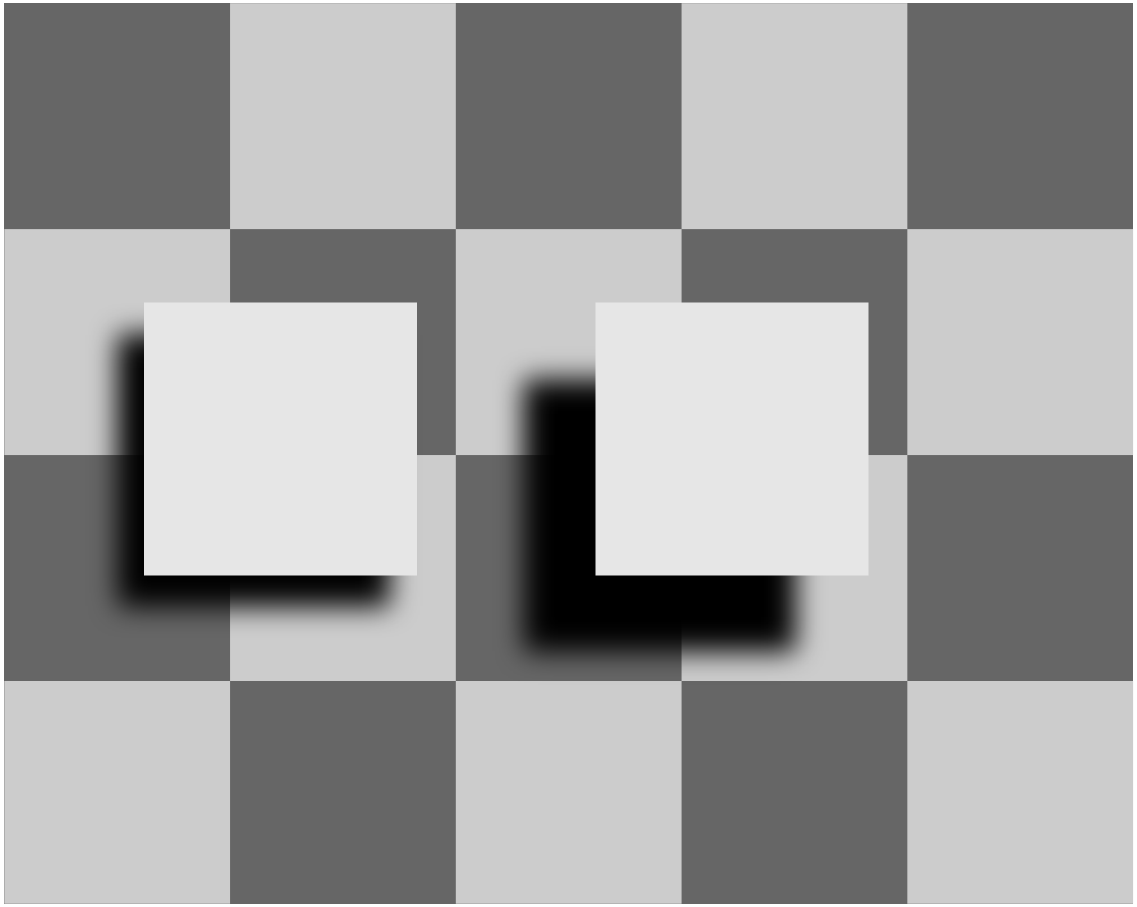
PICTORIAL > TEXTURE GRADIENTS

Density, perspective (foreshortening) and distortion of texture elements between closer and farther away objects



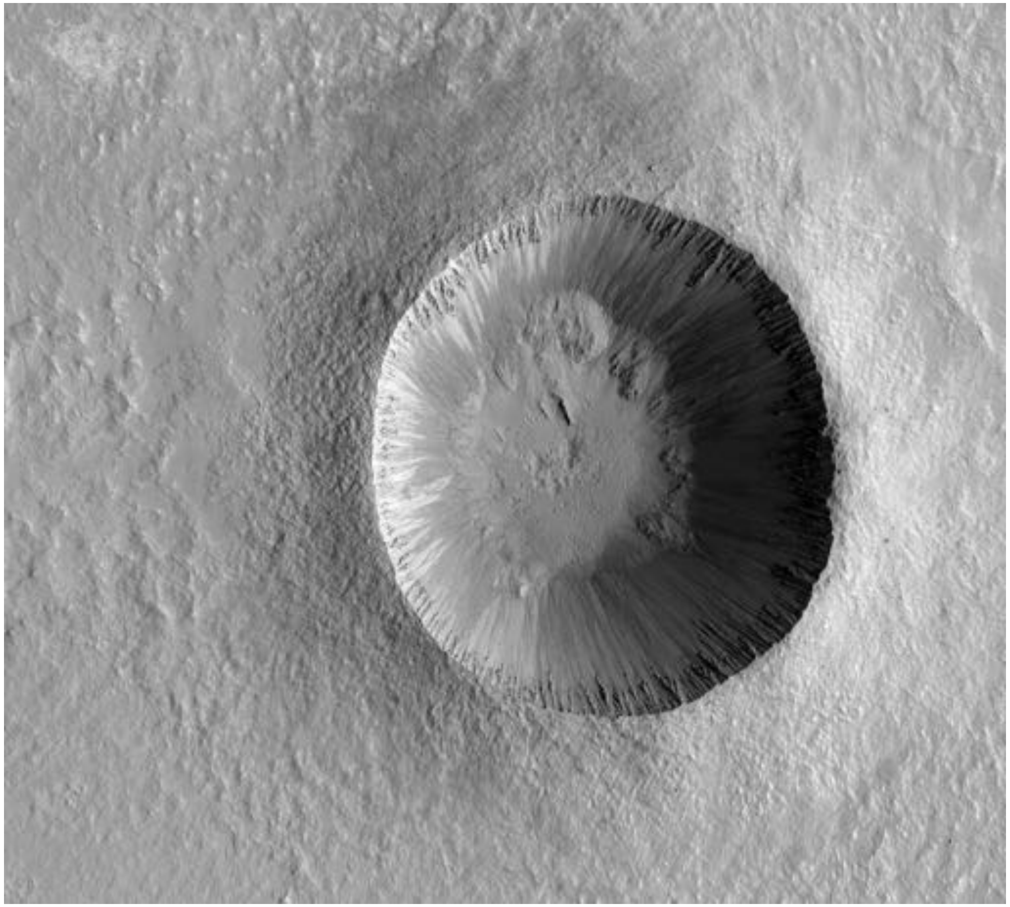
PICTORIAL > SHADOWS

Dark area where light from a light source is blocked by an opaque object



PICTORIAL > SHADING

Depicting depth in 3D models or illustrations by varying levels of darkness



Zumba Crater: Fresh 3-Km Crater, Mars. 04 May 2007, NASA/JPL University of Arizona

PICTORIAL > DEFOCUS BLUR

Aberration in which an image is out of focus

PICTORIAL > ATMOSPHERIC EFFECTS

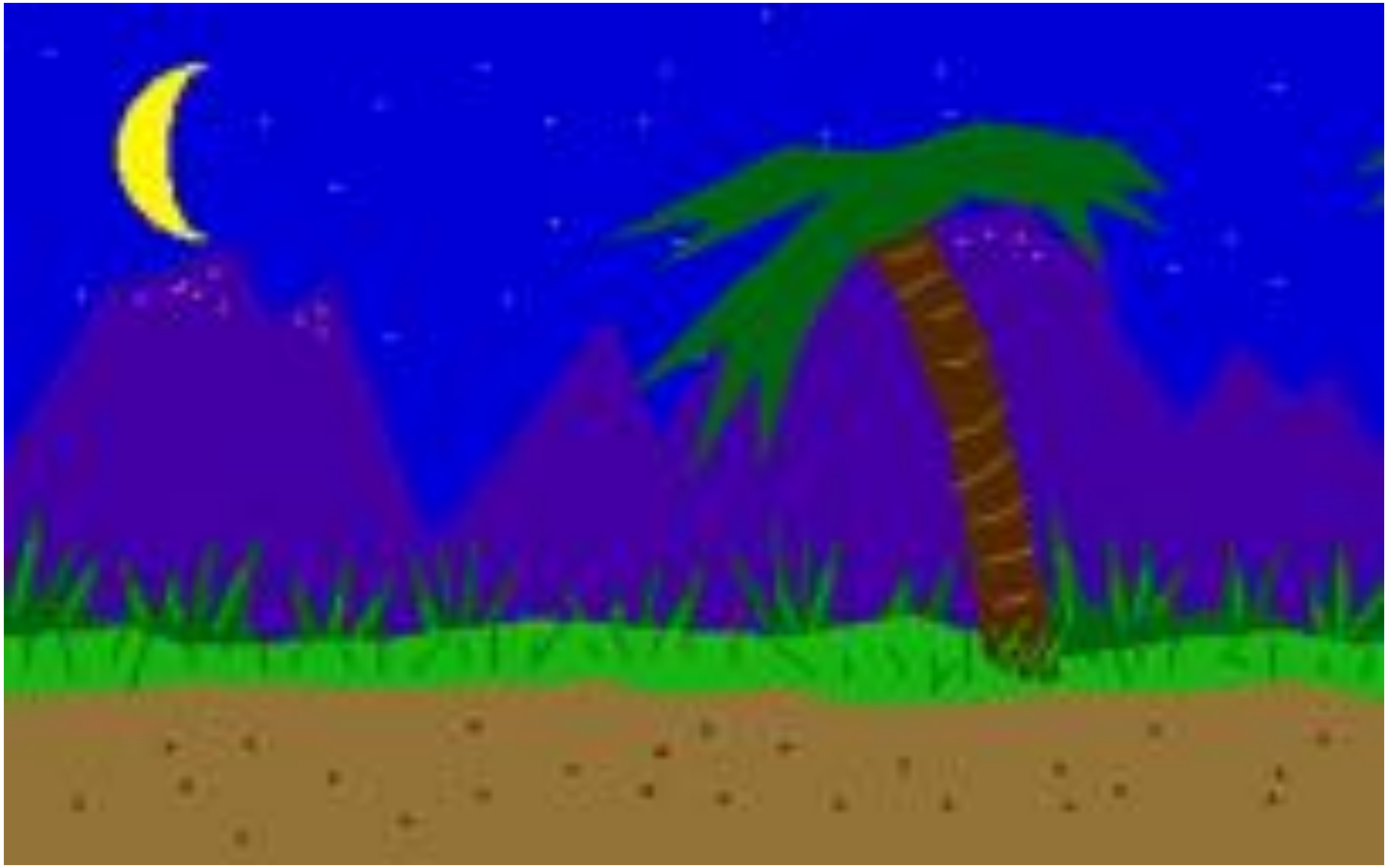
Farther objects:

- less distinct,
- colors less saturated,
- mountains in the back appear more blue

Paul Cézanne, Mont St. Victoire c. 1887

VISUAL > MONOCULAR > MOTION-BASED > MOTION PARALLAX

Closer objects move faster than farther away objects



"Parallax scrolling" uses layers of animated sprites to create the illusion of depth

With deletion and accretion a moving object appears faster than farther

Deletion

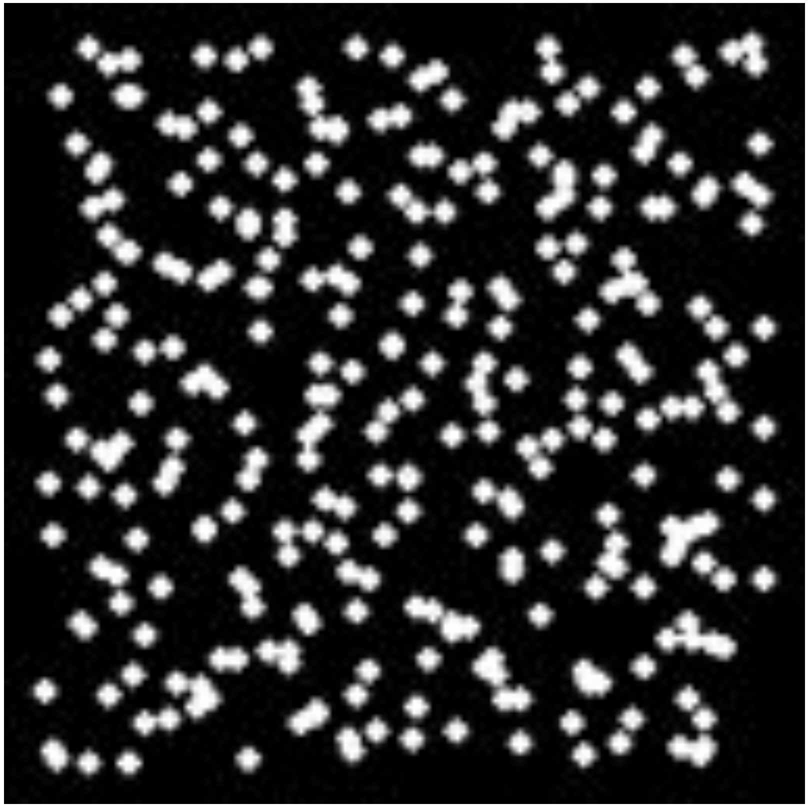
Object becomes occluded

Accretion

Object reappears

VISUAL > MONOCULAR > MOTION-BASED > STRUCTURE FROM MOTION

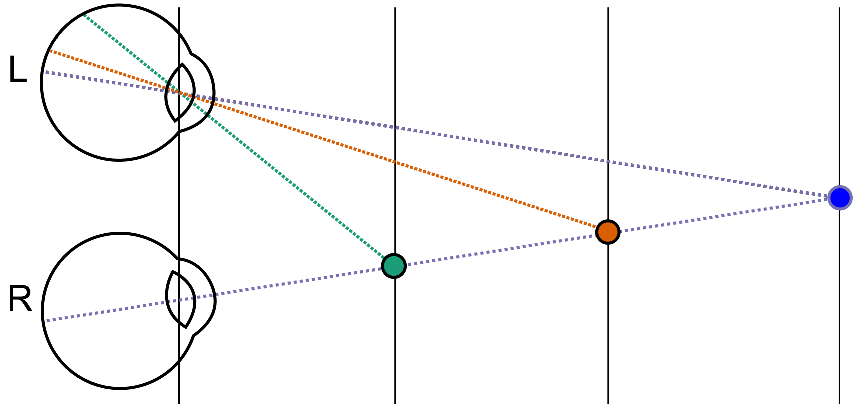
Depth cues from different points of view or moving object



This is an animation of a 3-d shape rocking back and forth, thus cued by relative motion. The dots that carry the motion flicker occasionally so as to eliminate the possible cue of changing local dot density. Despite the elimination of that cue and the flicker, it is relatively easy to perceive (and to judge) the 3-d shape. [M. Landy]

VISUAL > BINOCULAR > STEREOPSIS

Depth cues from both eyes



Biological evidence: *"binocular cells"* [Hubel & Wiesel 1952, 1969], *"disparity detectors"* [Pettigrew 1967]

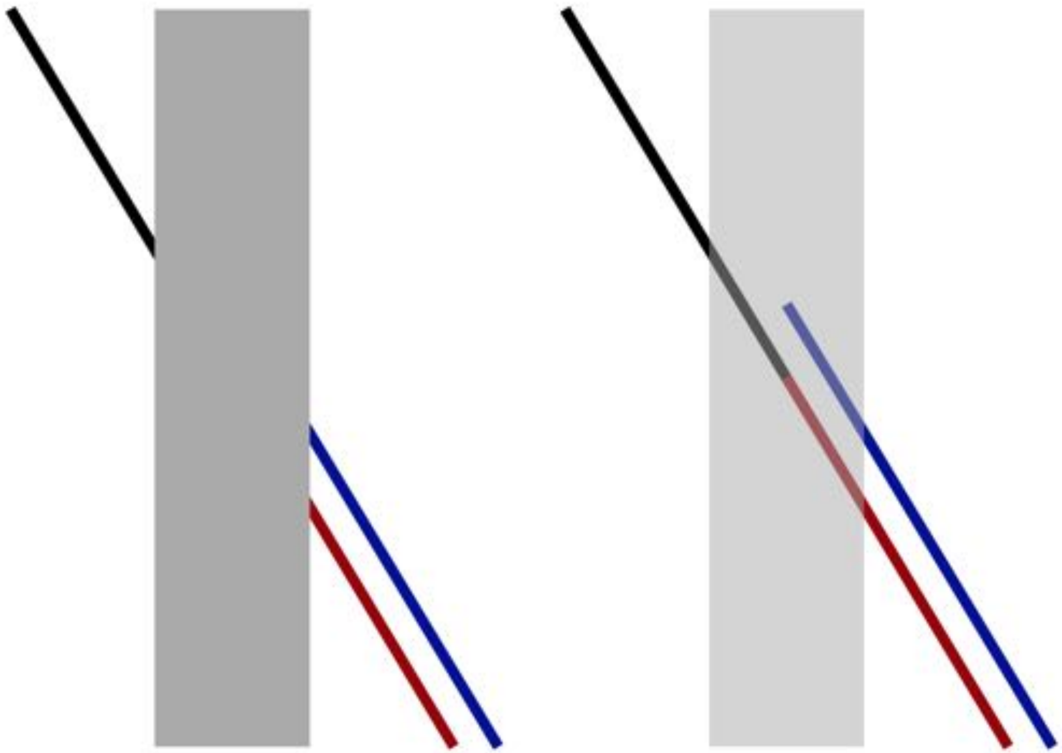
SOME (MORE) *ILLUSIONS*

SIZE CONSTANCY (PONZO) ILLUSION

Psychologist Mario Ponzo suggested that the human mind judges an object's size based on its background

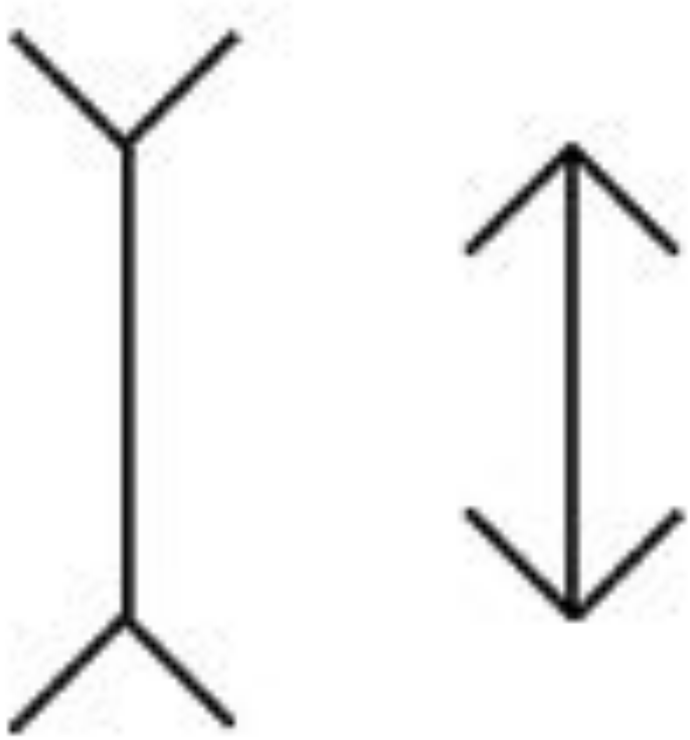
Ponzo Illusion 1911

POGGENDORFF ILLUSION

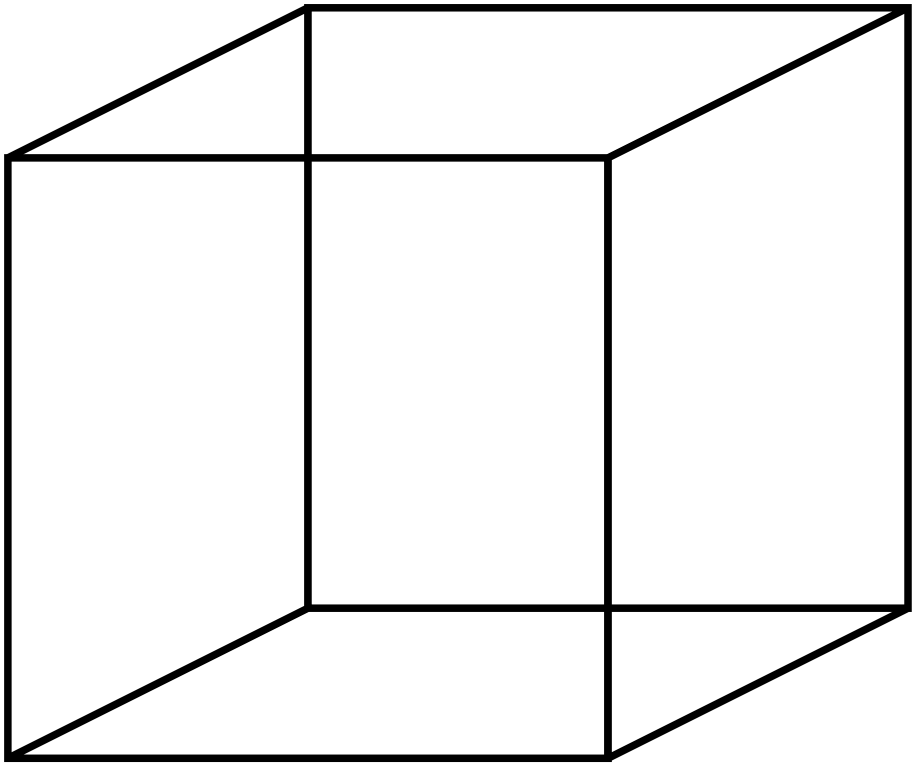


MULLER-LYER ILLUSION

Created by German psychiatrist Franz Muller-Lyer in 1889
One explanation is that opened arrows are perceived as farther away.

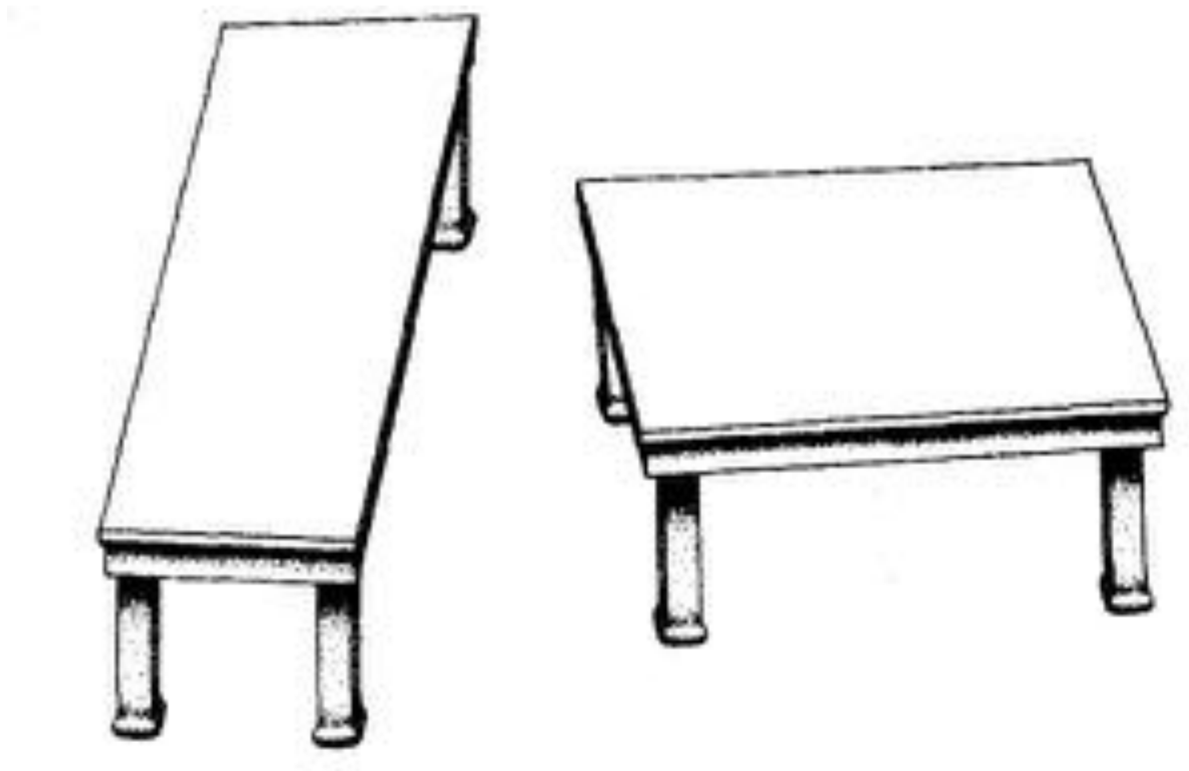


NECKER CUBE ILLUSION



SHEPARD TURNING TABLES ILLUSION [SHEPARD 90]

The visual system interprets 2D shape information in 3D



This illusion is based on a drawing of two parallelograms, identical aside from a rotation of 90 degrees. When the parallelograms are presented as tabletops, however, we see them as objects in three-dimensional space. Note that real tables have different geometry.
Open with Inkscape: shepard_table.svg

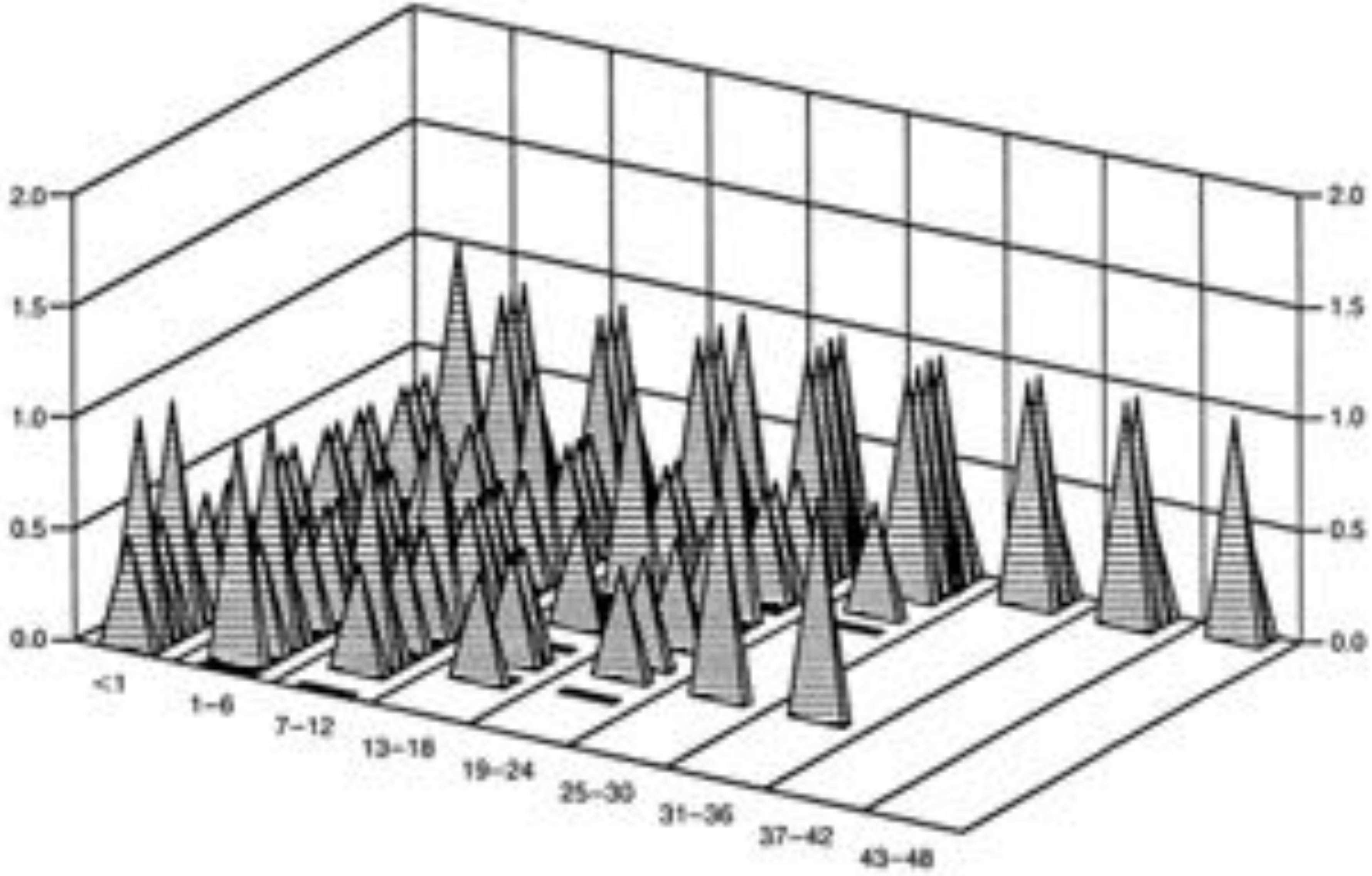
Ames room: what cues are at play?

Ames room: what cues are at play?

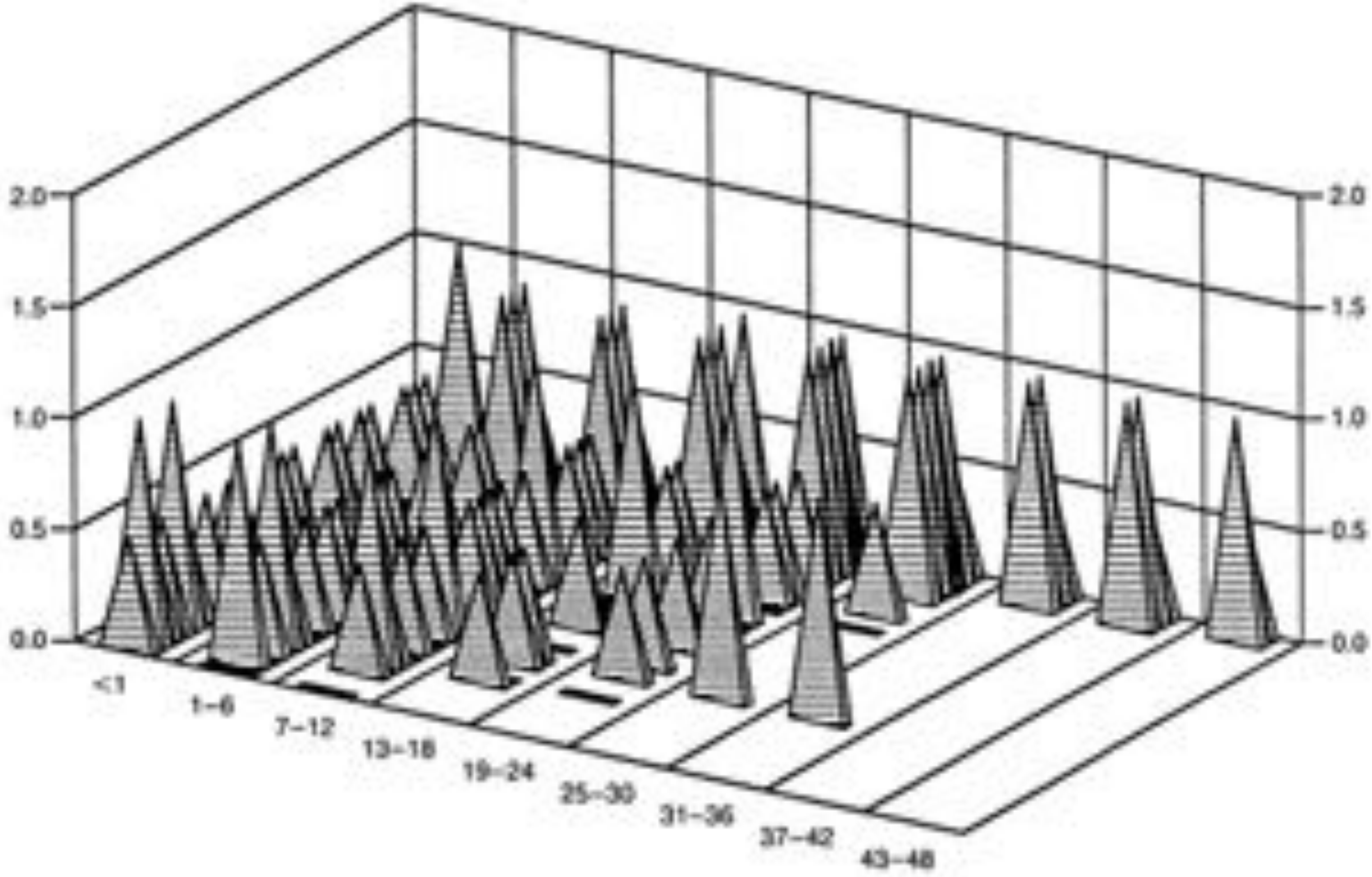
Relative size, familiar size, perspective convergence

DESIGN CONSIDERATIONS

What is wrong with this chart?

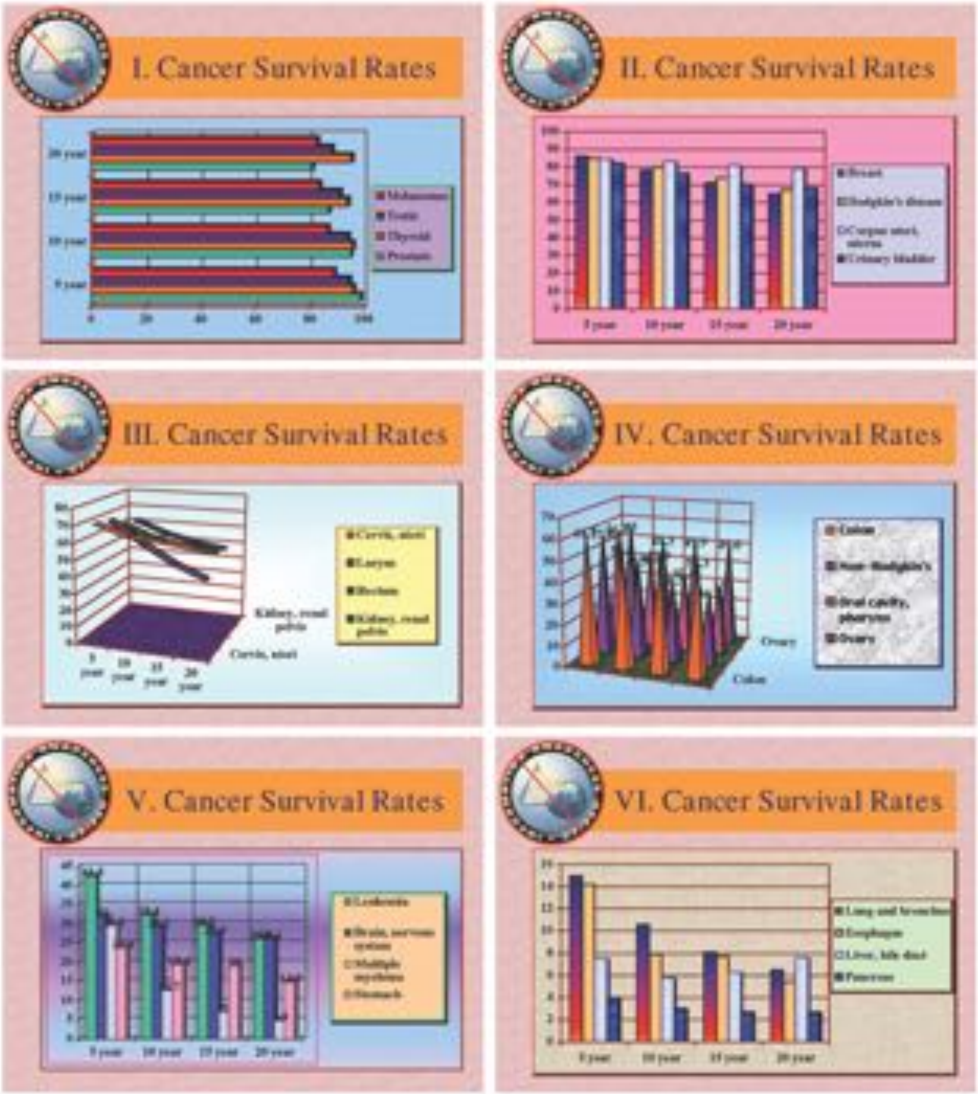


What is wrong with this chart?



Occlusions, confusing texture, confusing shapes, Necker illusion, projection

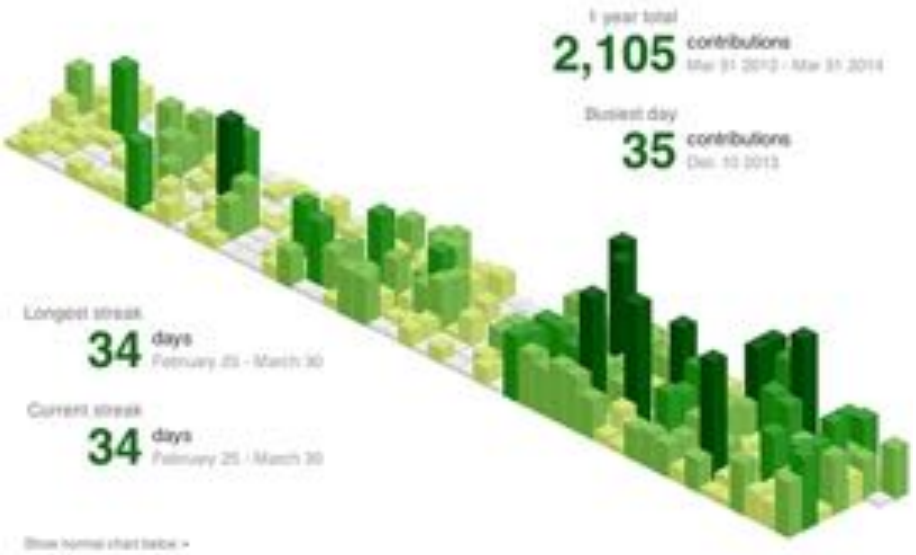
What is wrong with these charts?



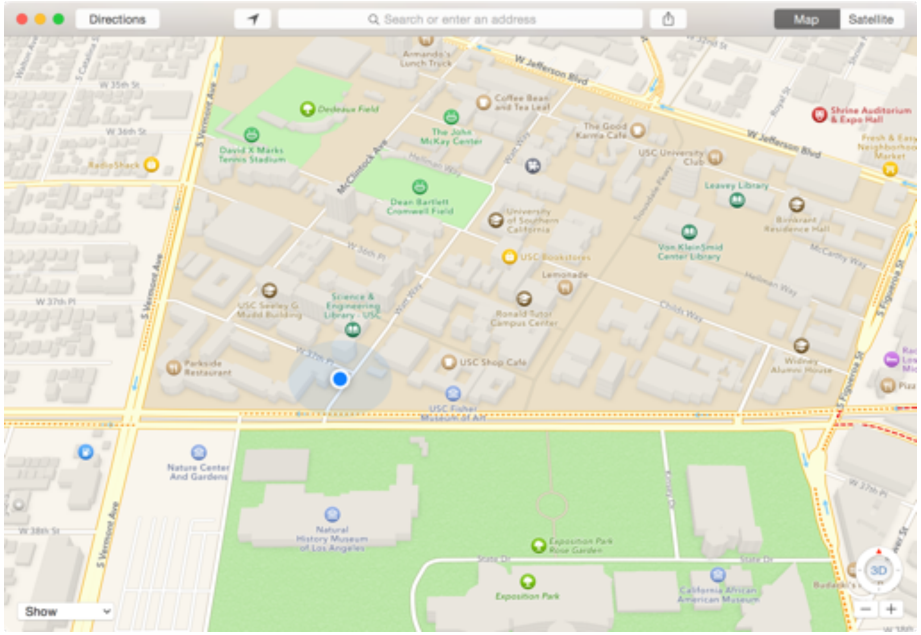
Cancer survival rates: tables, slopegraphs, barcharts, E. Tufte

POPULAR 3D DESIGN TECHNIQUES

2.5D DESIGN



2.5D DESIGN + CONSTRAINED NAVIGATION



Isometric projection: orthographic projection with coordinate axes appearing equally foreshortened and at 120 degrees from each other

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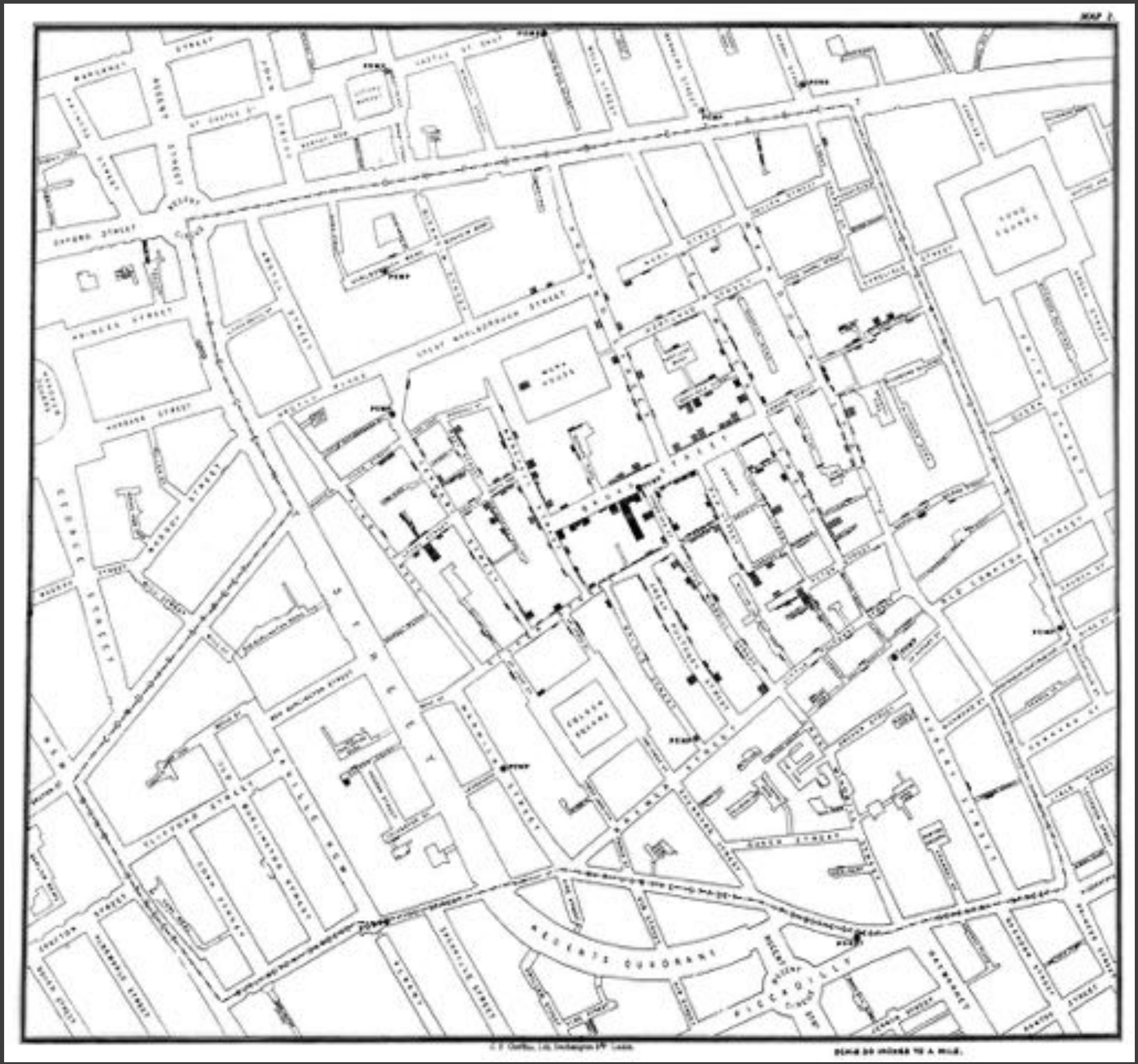
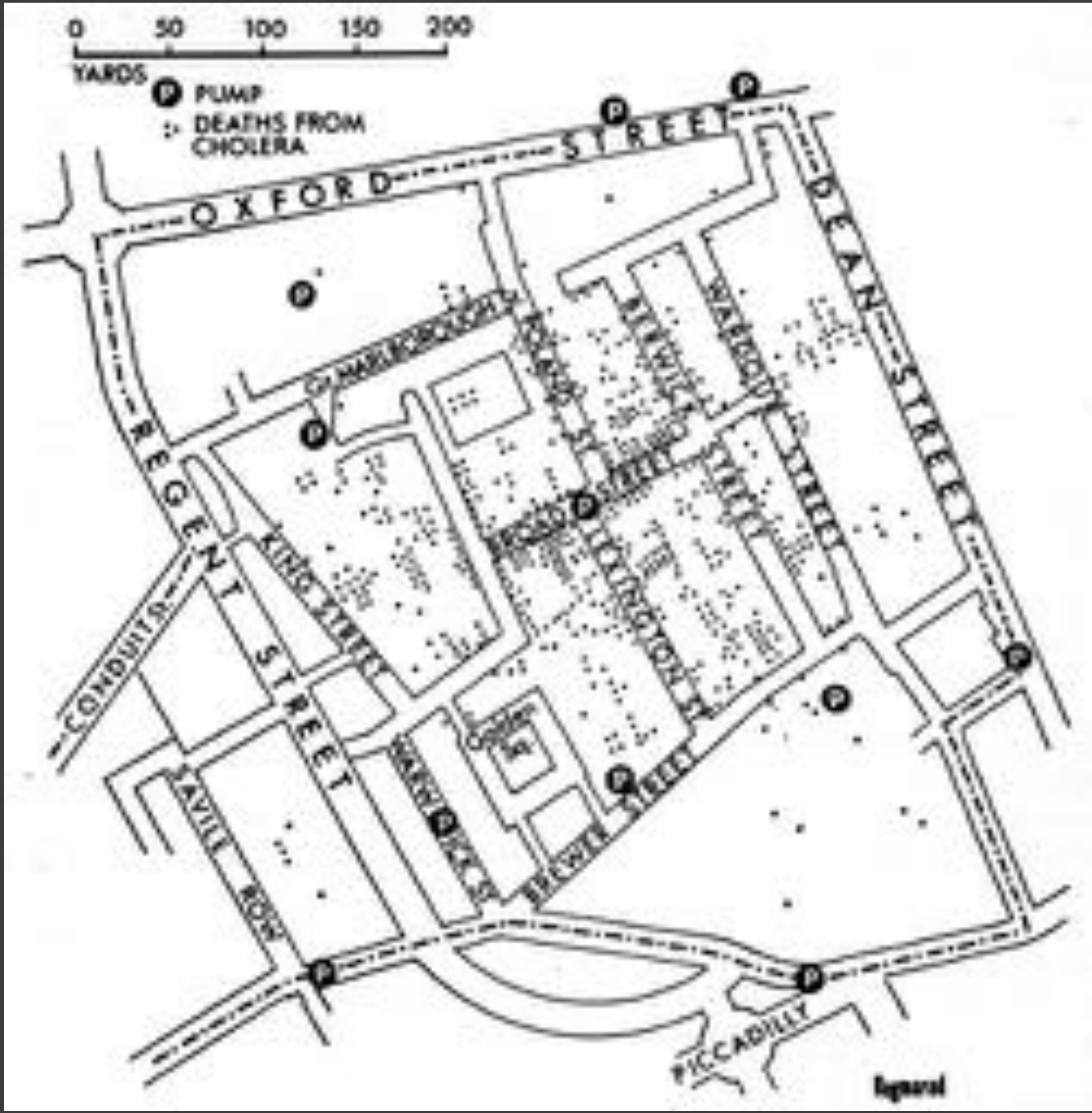


Original map by John Snow showing the clusters of cholera cases in the London epidemic of 1854 [Snow 1854]

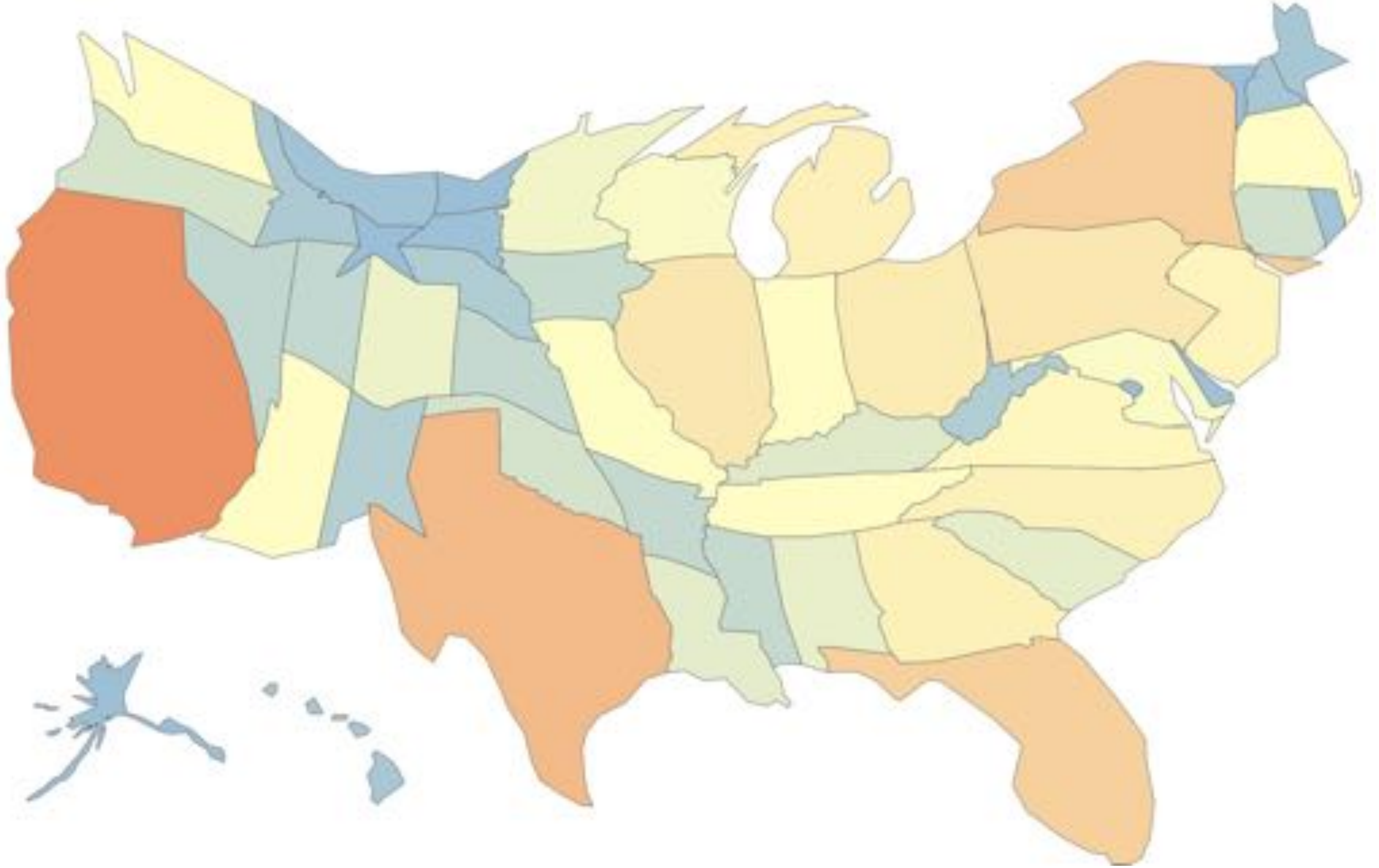


Update of John Snow's London cholera epidemic [Regmarad 1960]

THEMATIC MAPS

Dot Map	Can be used to locate each occurrence of a phenomenon. One-to-one or one-to-many.
Cartogram	Area used to display value. Distortion used to show continuous variables
Choropleth	Areas are shaded or patterned in proportion to variable.
Proportional Symbol Map	Scaled symbols show data for areas/locations. Also called Graduated Symbol Map.
Isopleth	Use contours to show continuous variables. Also called Isarithmic.

Continuous area cartograms with D3 and TopoJSON repository and example.



DASYMETRIC MAP (CHOROPLETH MAP) [SEMENOV-TYAN-SHANSKY 1911]

Refined choropleth map where ancillary information is used to model a phenomena

	+		+		=	
tract data		population density		land cover (ancillary data)		dasymetric map

Mennis, J. Generating surface models of population using dasymetric mapping. The Professional Geographer, 2003.

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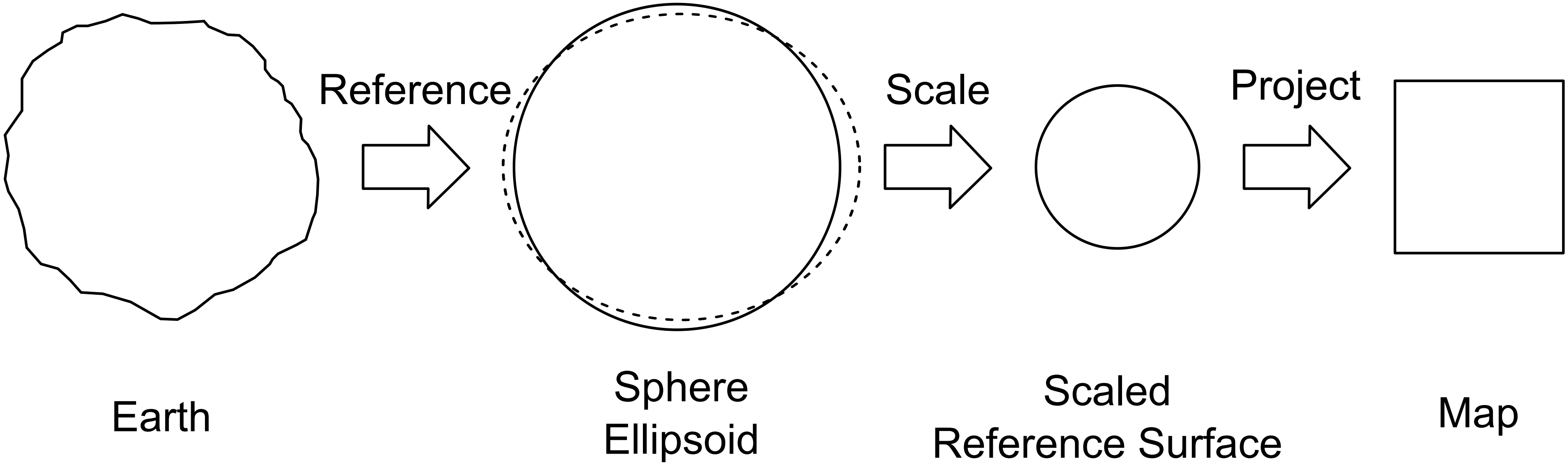
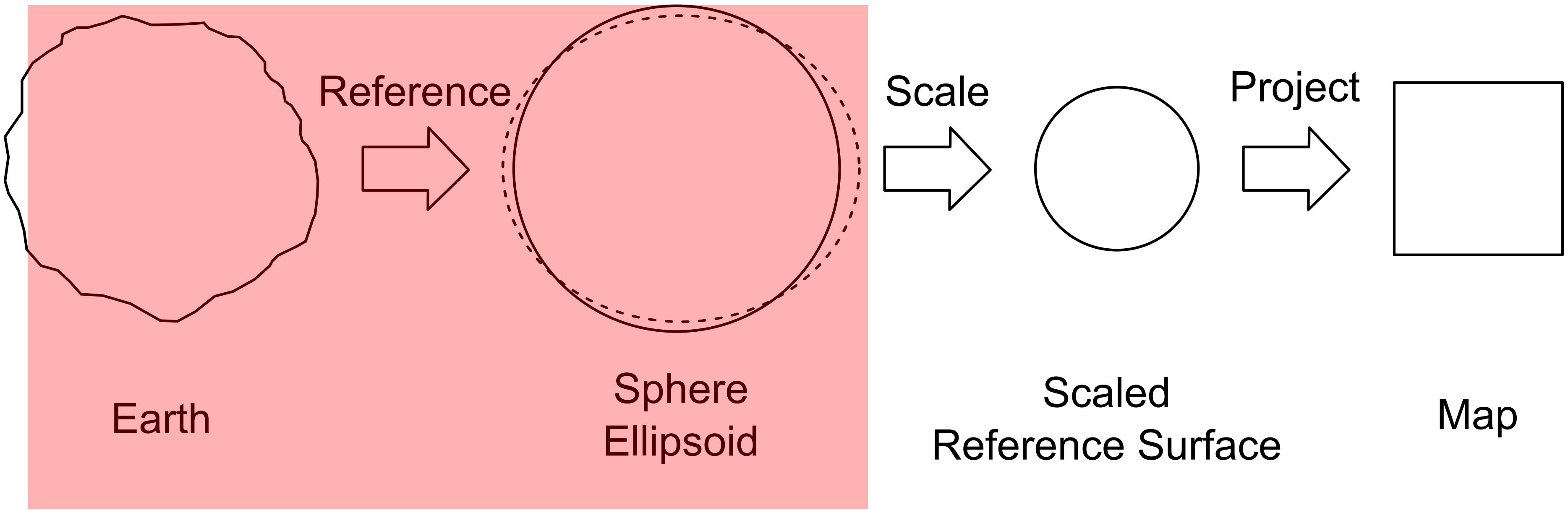
HOW MAPS ARE BUILT?

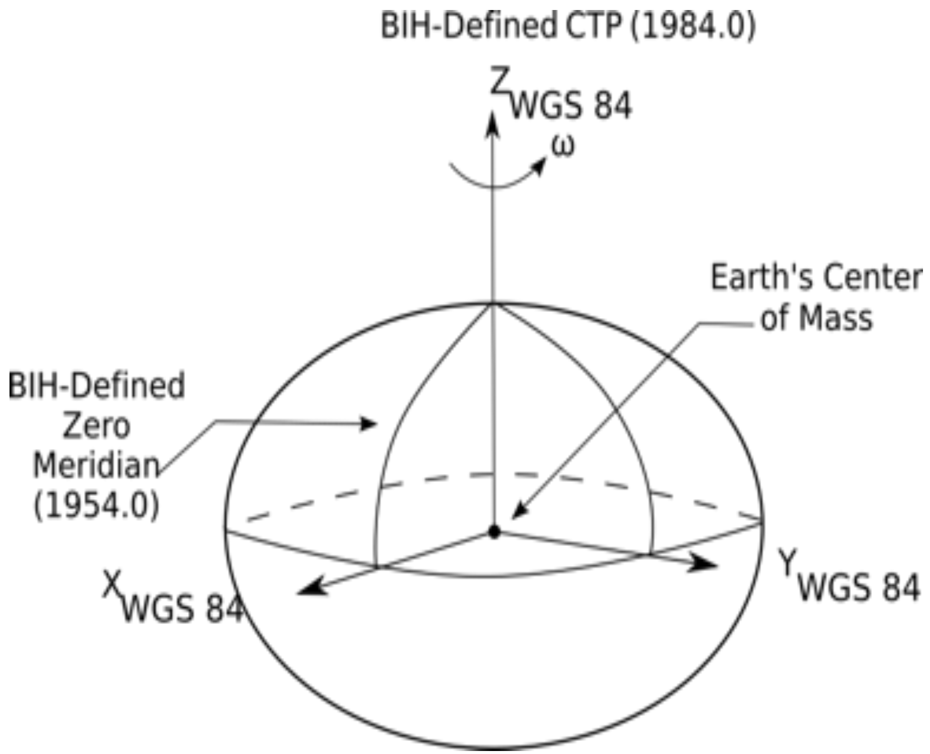

Reference
Scale
Project
Earth
Sphere
Ellipsoid
Scaled
Reference Surface
Map

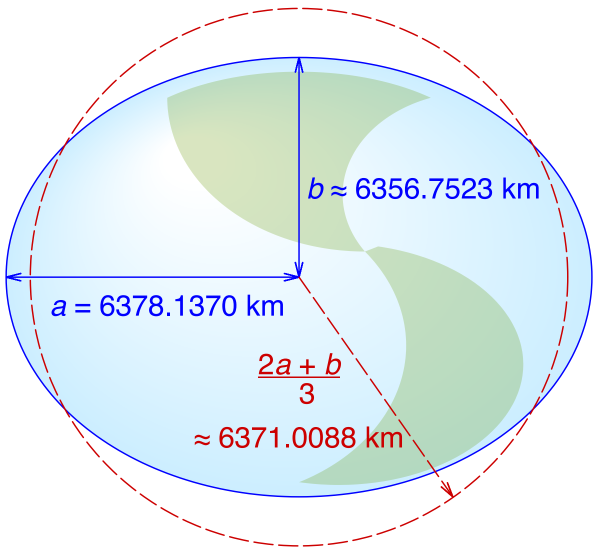
HOW MAPS ARE BUILT?


Reference
Scale
Project
Earth
Sphere
Ellipsoid
Scaled
Reference Surface
Map

REFERENCE ELLIPSOID

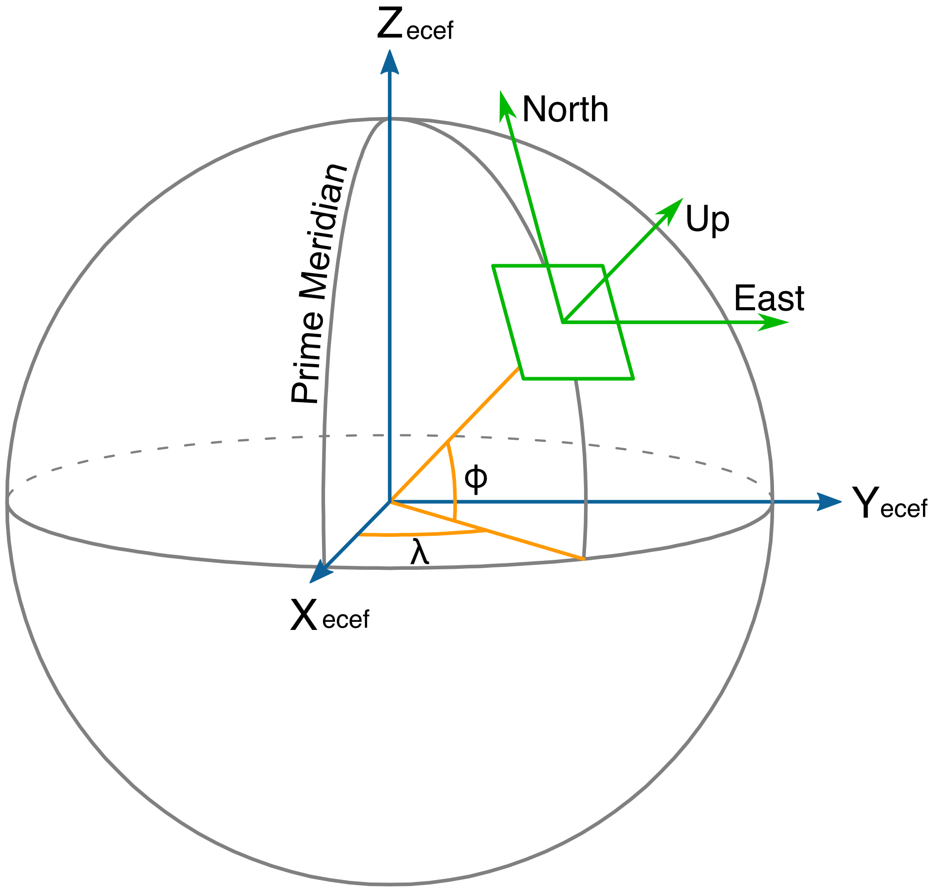
World Geodetic System 1984 (WGS 84), used for GPS





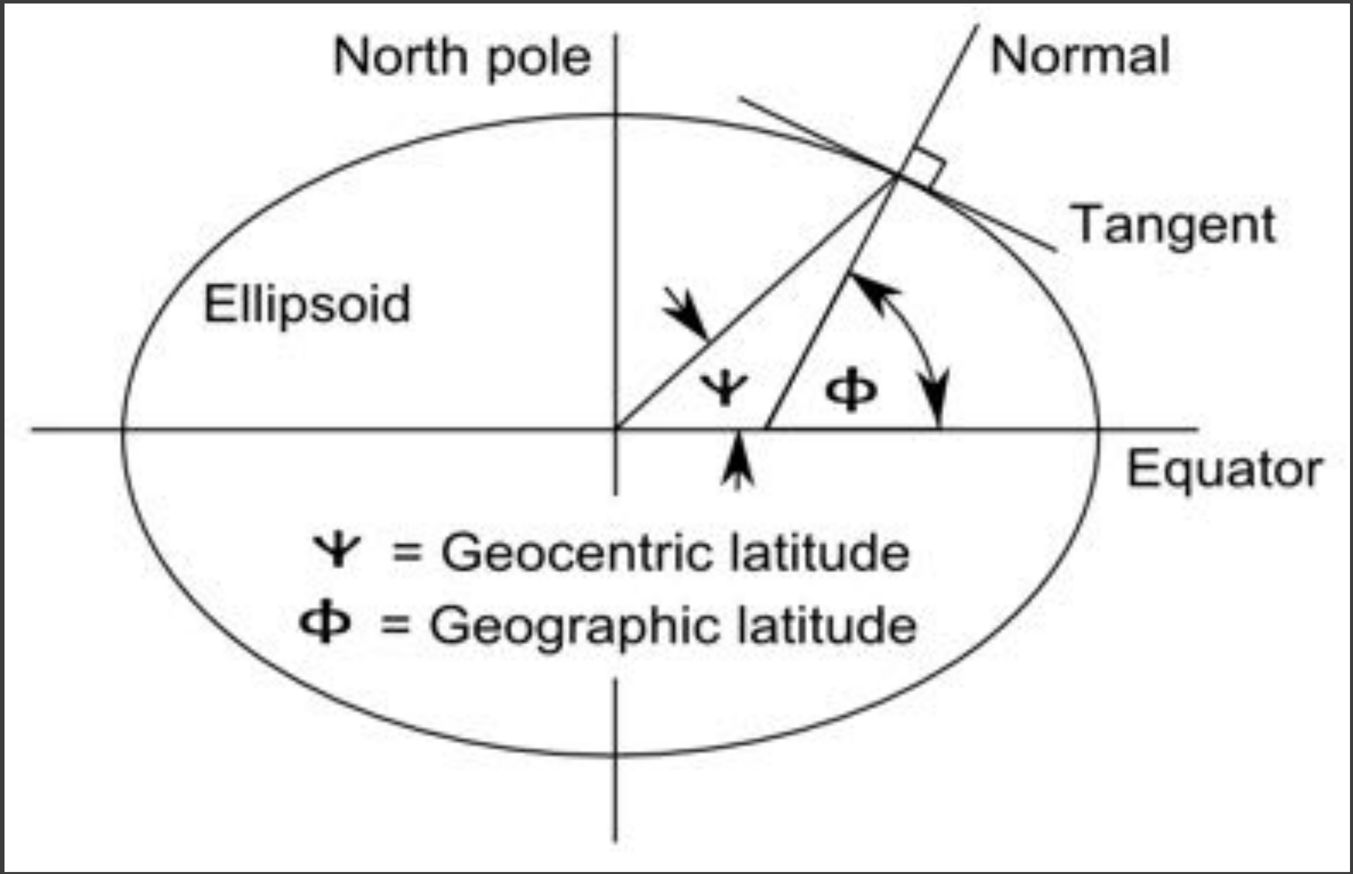
GEOGRAPHIC COORDINATES

$(\lambda, \phi) = (\text{longitude, latitude})$ angles (degrees)



GEOGRAPHIC VS. GEOCENTRIC LATITUDE

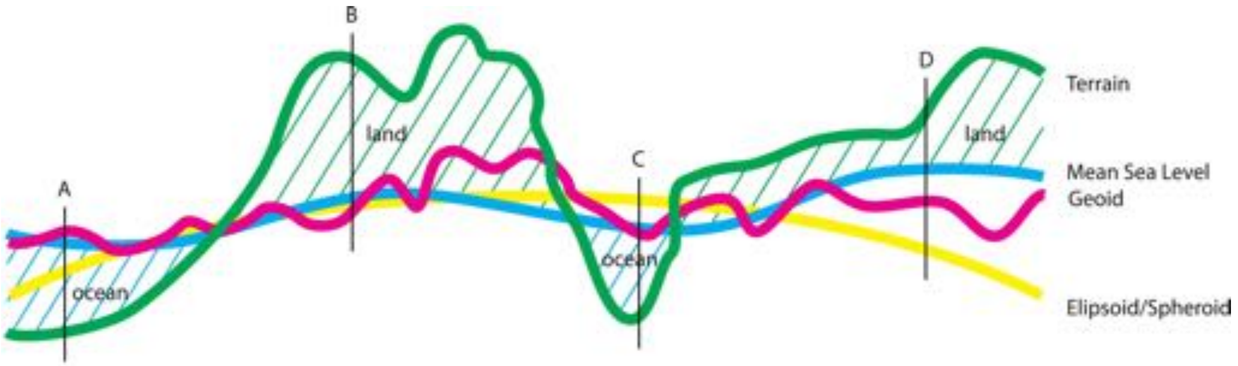
If not specified → geographic ϕ



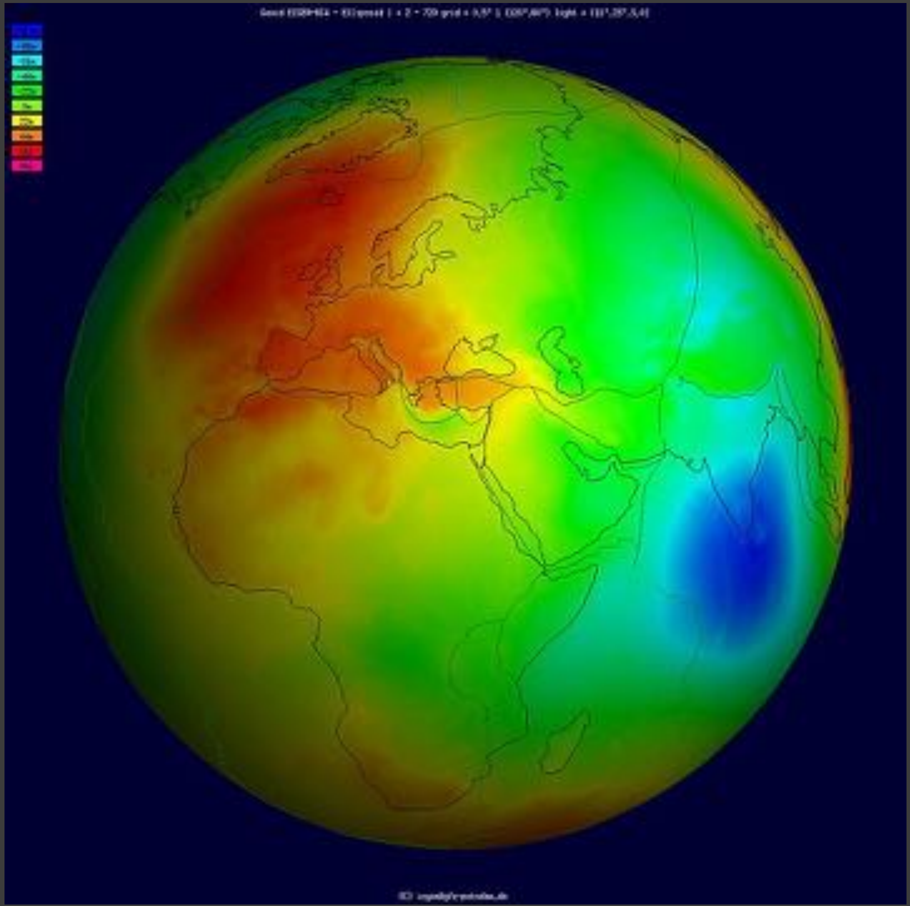
GEODETIC DATUM

A <u>coordinate system</u> and <u>reference</u> to locate places defined by a <u>horizontal</u> and a <u>vertical</u> datum

- **Horizontal datum:** defined by a reference ellipsoid
- **Vertical datum:** defined by the way we measure elevation:
  - *"Geodetic"* if based on ellipsoid of horizontal datum
  - *"Tidal"* if based on sea levels
  - *"Gravimetric"* if based on a geoid



GEOID



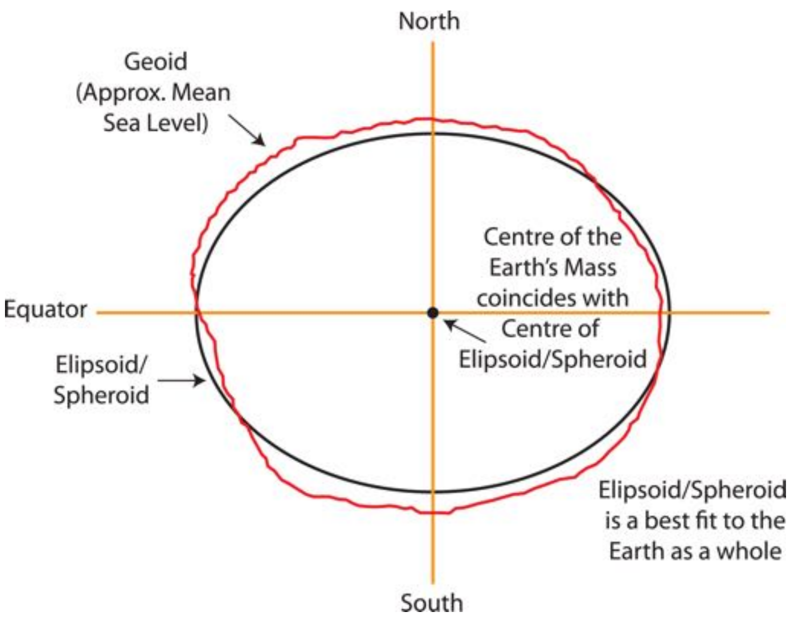
Geoid undulation in false color, to scale.
By International Centre for Global Earth Models (ICGEM)

GEOCENTRIC VS. LOCAL GEODETIC DATUM

Defined by the type of horizontal datum used

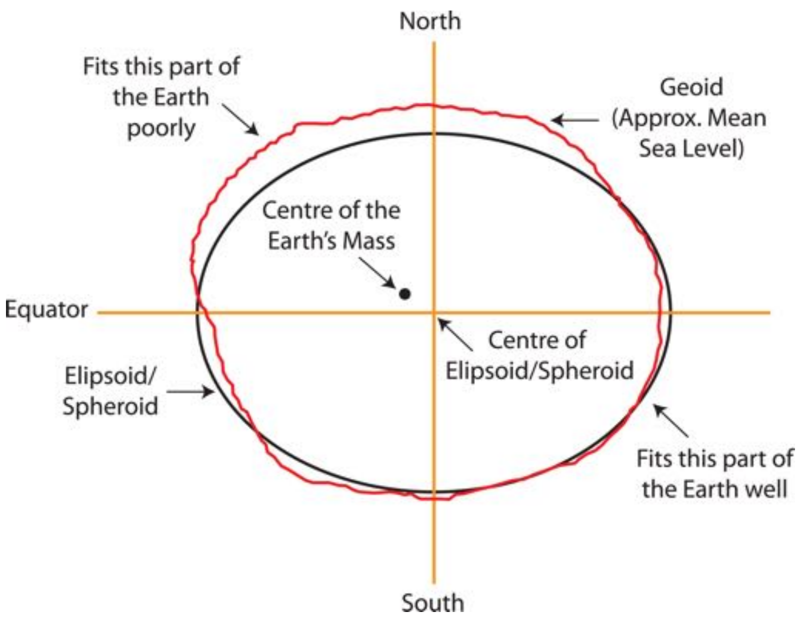
Geocentric datum

Good for global applications

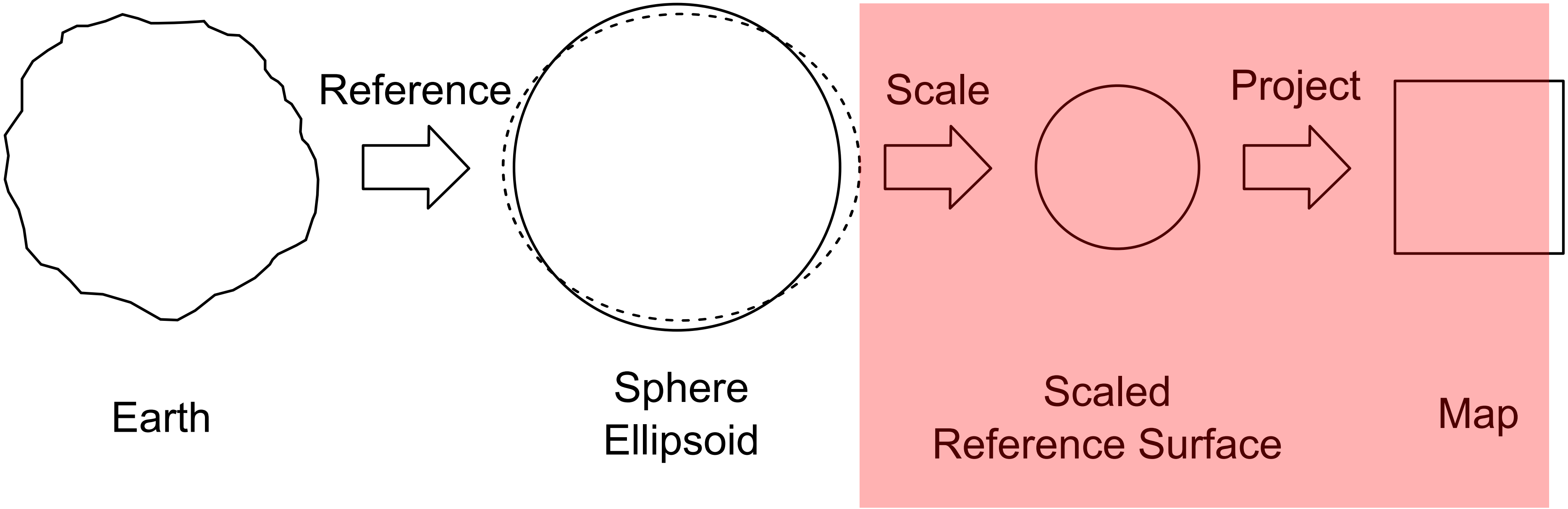


Local datum

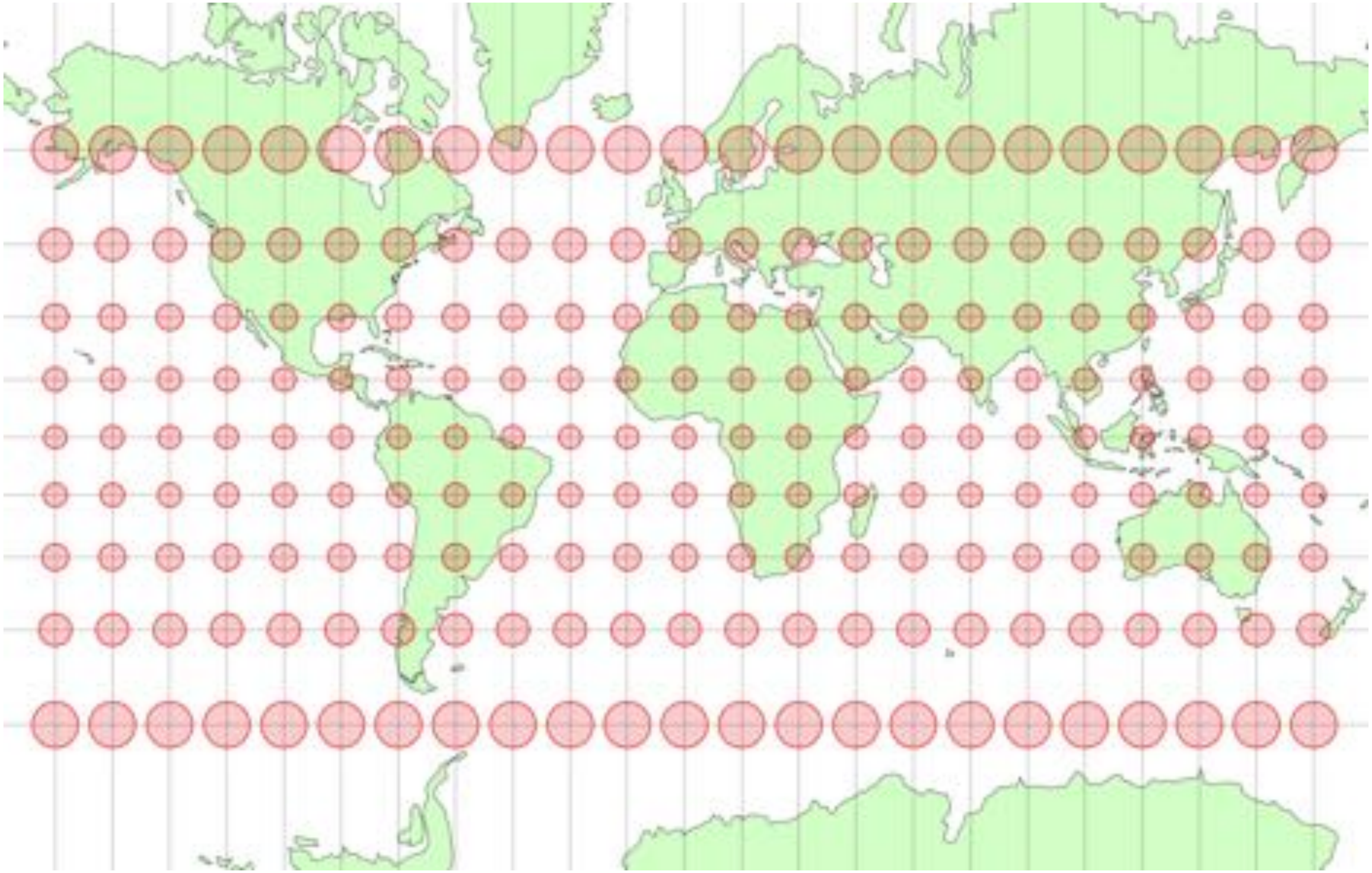
Good for regional applications



HOW MAPS ARE BUILT?


Reference
Scale
Project
Earth
Sphere
Ellipsoid
Scaled
Reference Surface
Map

MAP PROJECTION

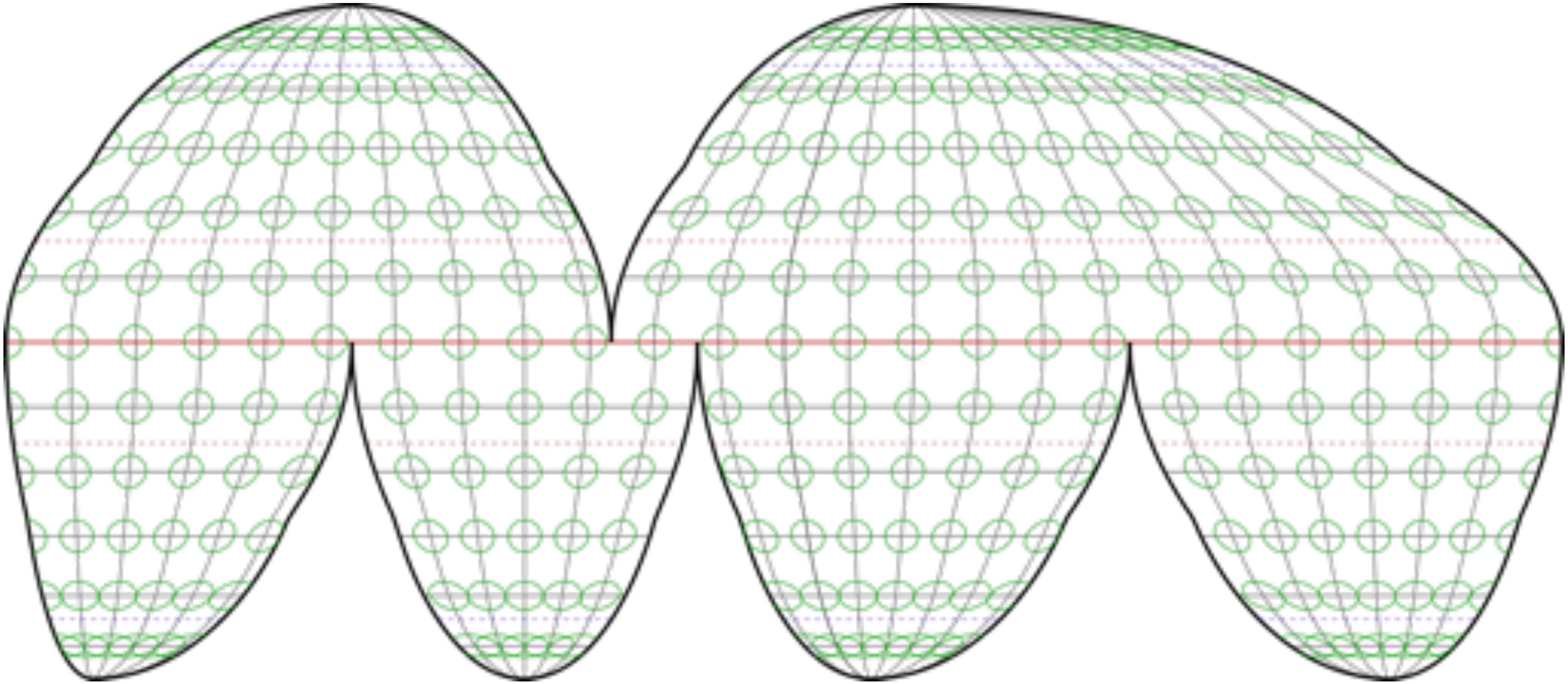


All projections introduce some distortion
Tissot’s indicatrix by Jason Davies

PROPERTIES PRESERVED IN MAPS

Name	Property preserved
Conformal	Shape of small regions. At any point same scale in all directions, 90^o between parallels and meridians, angles preserved at each point.
Equal-area	Areas proportional to areas on Earth
Equidistant	Scale along one or more lines, or from one or two points to all other points
Azimuthal (true direction)	Directions from a central point: great circles through the central point are straight lines

CAN YOU HAVE A MAP THAT IS BOTH CONFORMAL AND EQUAL-AREA?



Cannot flatten an orange peal without tearing!

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NAMED PROJECTIONS TYPES

Named after the developable surface* used

Cylindrical
Conical
Azimuthal

* Developable surface: surface that can be unfolded or unrolled into a plane or sheet without stretching, tearing or shrinking

NAMED PROJECTIONS SUB-TYPES

Based on intersection and orientation

	Name	Example
Intersection	**Tangent or Secant**	

	Name	Example
Orientation	**Normal**	
	Transverse	
	Oblique	

LAMBERT AZIMUTHAL EQUAL AREA

PROJECTION: AZIMUTHAL, EQUAL-AREA

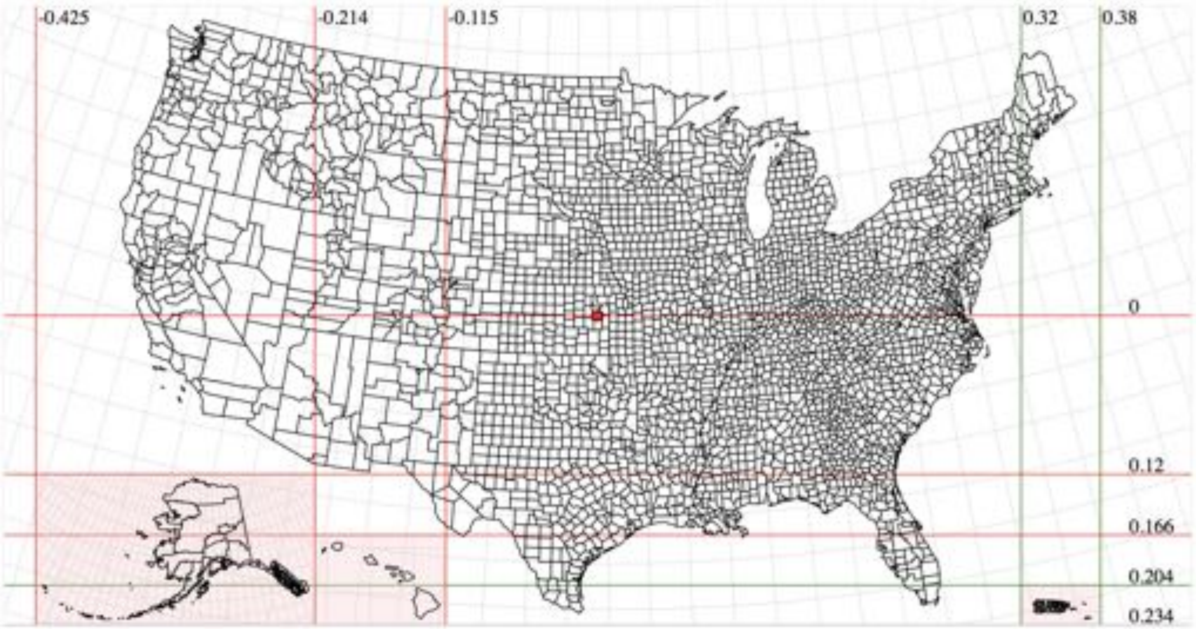
- Named after Johann H. Lambert
- **Useful for choropleth maps**

National Atlas of the United States, United States Department of the Interior (2002)

ALBERS CONIC

PROJECTION: CONIC, EQUAL AREA

- Named after Heinrich C. Albers
- Used by the United States Geological Survey and Census Bureau
- **Useful for choropleth maps**

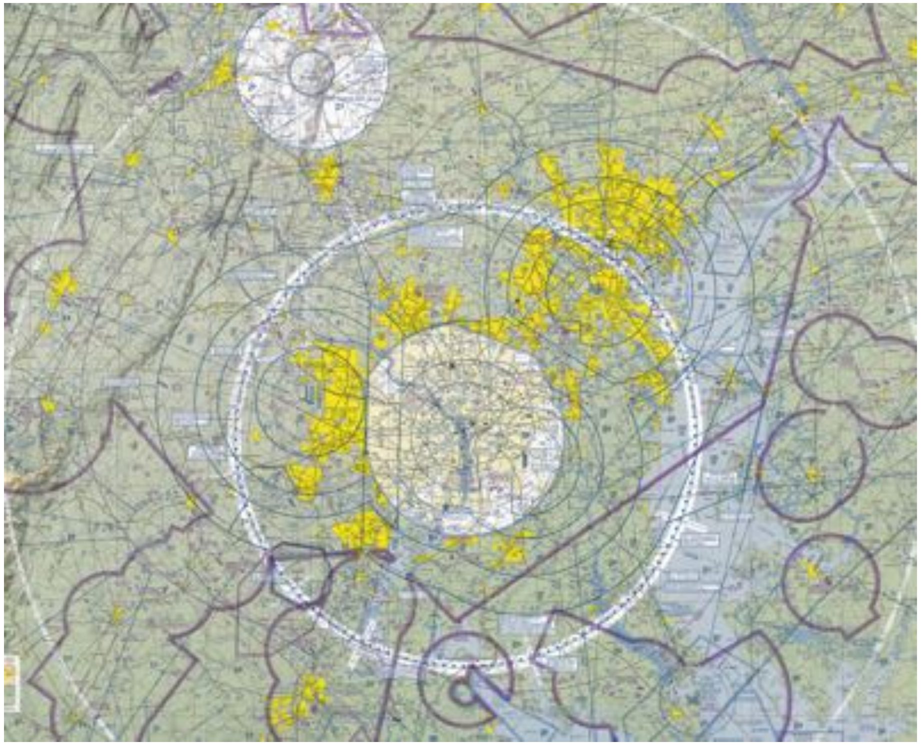


Albers USA U.S.-centric composite projection of 3 Albers equal-area conic projections. Alaska is at $0.35x$ of its true relative area.

LAMBERT CONFORMAL CONIC (LCC)

PROJECTION: CONIC, CONFORMAL

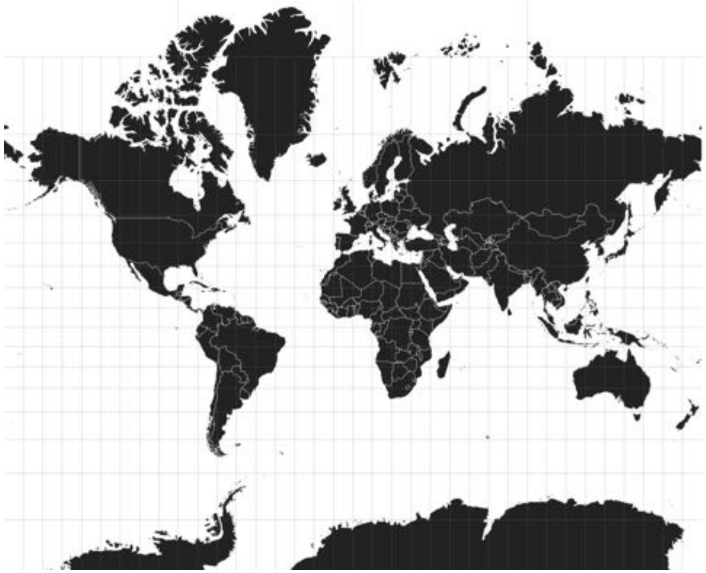
- Named after Johann H. Lambert
- **Useful for aeronautical charts**

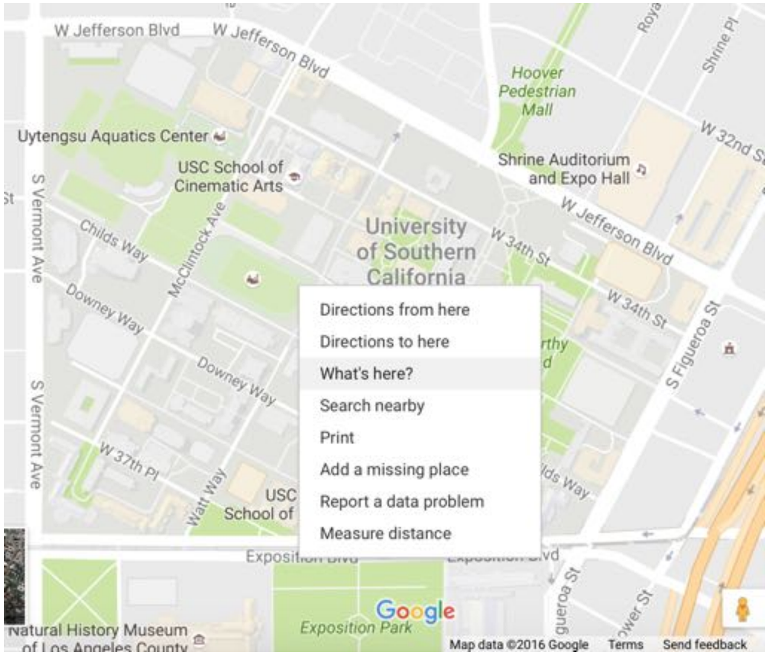


Aeronautical chart on Lambert conformal conic projection.

MERCATOR PROJECTION

PROJECTION: CYLINDRICAL, CONFORMAL



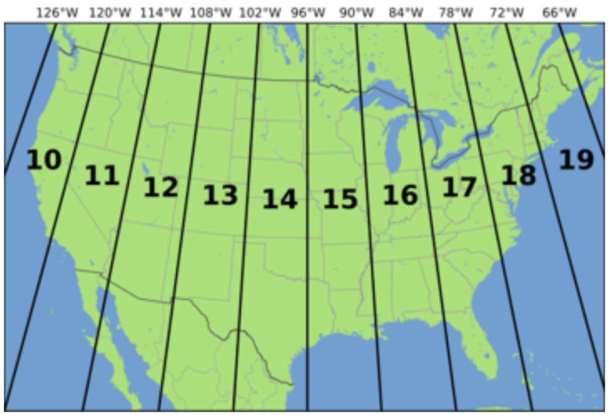


Google Maps uses Google Web Mercator

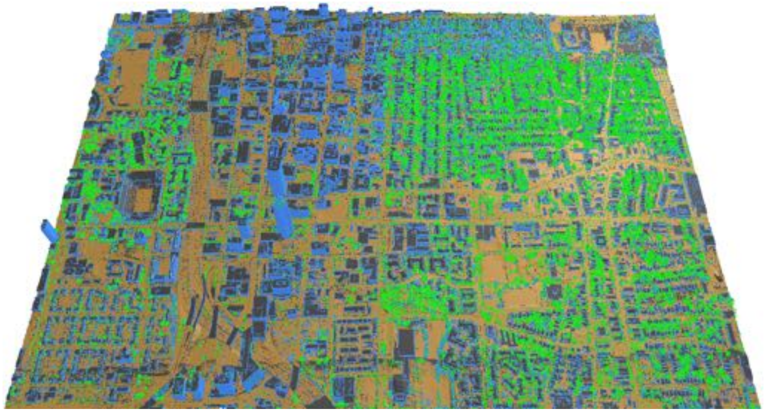
- Named after Gerardus Mercator
- **Standard for Web mapping applications**
- Variations include Web Mercator, Google Web Mercator, Spherical Mercator, WGS 84 Web Mercator

UNIVERSAL TRANSVERSE MERCATOR (UTM)

PROJECTION: SECANT CYLINDRICAL TRANSVERSE, CONFORMAL



- Named after Gerardus Mercator
- Over $61x6^o$ zones



Lidar points in UTM coordinates from Gao, Z., Nocera, L., Wang, M. & Neumann, U. Visualizing aerial LiDAR cities with hierarchical hybrid point-polygon structures, Graphics Interface Conference, 2014.

Cartesian coordinates in meters as Easting and Northing:

48 N 377299m 1483035m

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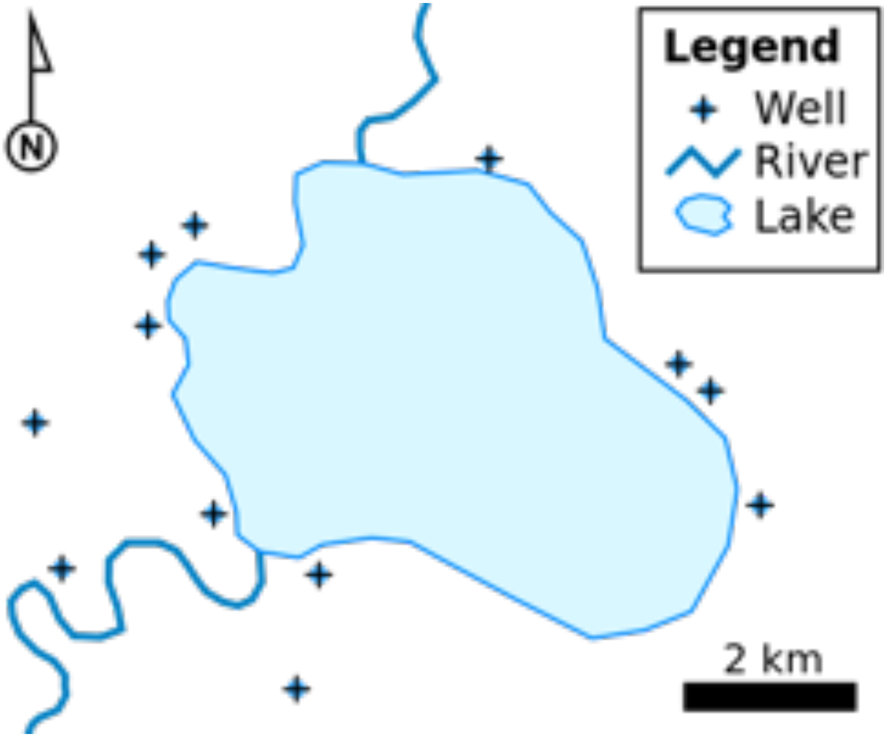
MAP FORMATS

RASTER

VECTOR

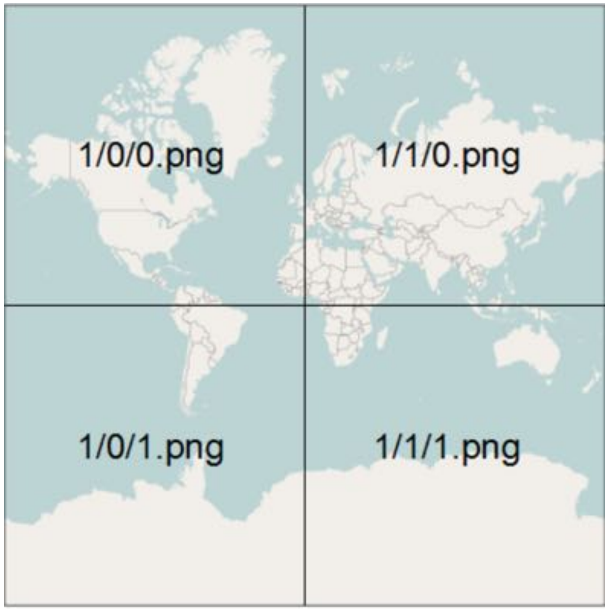


MAP DATA FORMATS AND SOFTWARE

Format	Software
Raster image, e.g., png, jpeg	Rendered with d3
Vector image, i.e., svg	SVG created with d3
Raster or vector tiles, a.k.a. **slippy maps**	Leaflet, Mapbox, Google Maps ...
JSON format: GeoJSON, TopoJSON	D3, Vega-Lite, Vega, Leaflet, Mapbox...
Shapefiles (ESRI proprietary format)	Specific map map apps and specialized GIS software

TILE MAPS (SLIPPY MAPS)

TILES ARE SERVED BY A TILE MAPS SERVICE (TMS)

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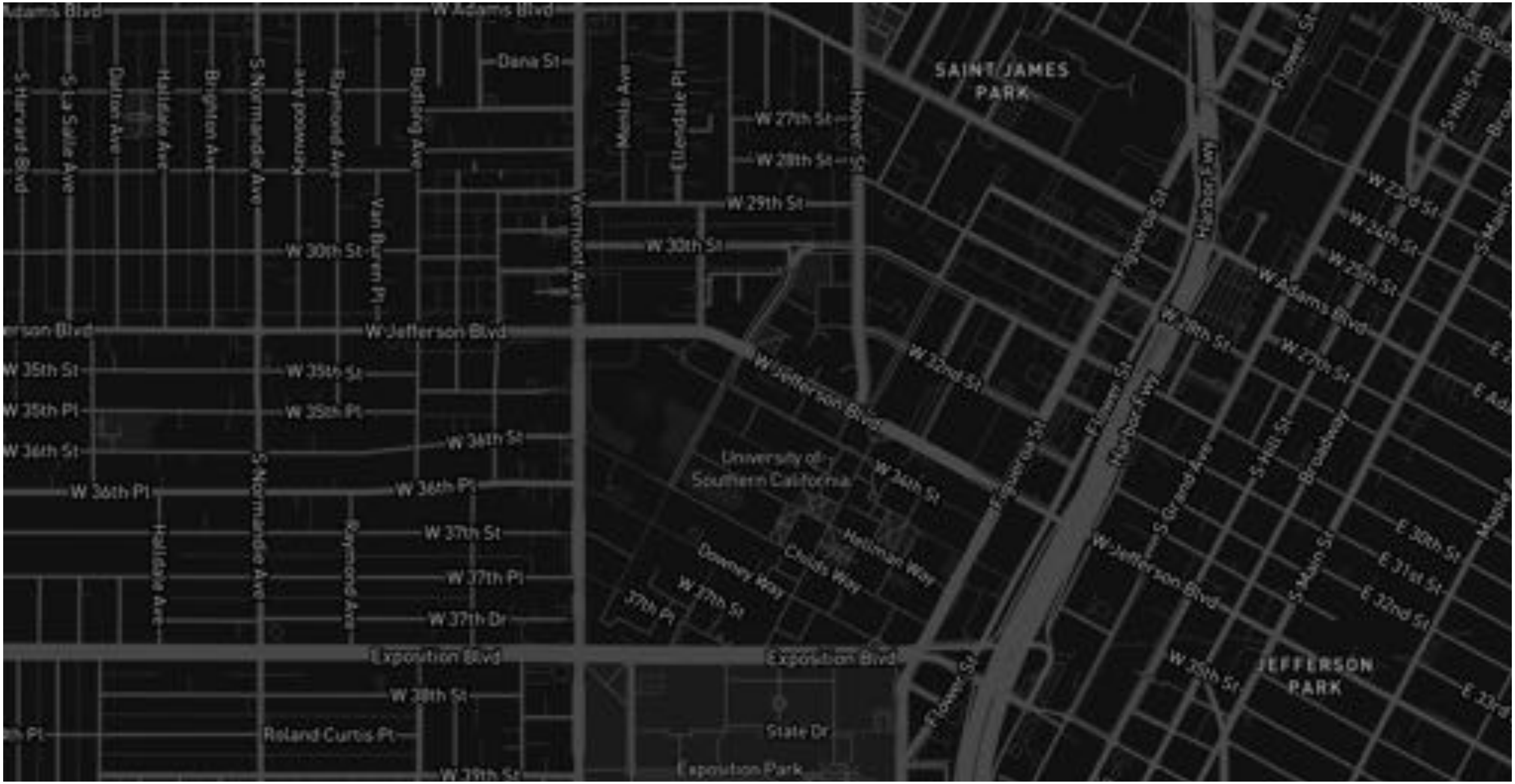
OSM: http://{s}.tile.openstreetmap.org/{z}/{x}/{y}.png
OSM B&W: http://{s}.www.toolserver.org/tiles/bw-mapnik/{z}/{x}/{y}.png
OpenCycleMap: http://{s}.tile.opencyclemap.org/cycle/{z}/{x}/{y}.png
MapQuest: http://otile{s}.mqcdn.com/tiles/1.0.0/sat/{z}/{x}/{y}.png
MapQuest-OSM: http://otile{s}.mqcdn.com/tiles/1.0.0/map/{z}/{x}/{y}.png
Stamen: http://{s}.tile.stamen.com/watercolor/{z}/{x}/{y}.jpg
OSM Mapnik bw: http://{s}.www.toolserver.org/tiles/bw-mapnik/{z}/{x}/{y}.png
```

SLIPPY MAP WITH MAPBOX



Mapbox GL JS API

GeoJSON

```
{"type":"FeatureCollection",
  "features":[
    {"type":"Feature",
      "id":"01",
      "properties":{"name":"Alabama"},
      "geometry":{"type":"Polygon","coordinates":[[[-87.359296,35.00118],[-85.60
    {"type":"Feature",
      "id":"02",
      "properties":{"name":"Alaska"},
      "geometry":{"type":"MultiPolygon","coordinates":[[[[-131.602021,55.117982]
    {"type":"Feature",
      "id":"72",
      "properties":{"name":"Puerto Rico"},
      "geometry":{"type":"Polygon","coordinates":[[[-66.448338,17.984326],[-66.7
  ]
}
```

Example GeoJSON of Alabama, Alaska and Puerto Rico boundaries

GEOJSON

Geometry: Point, LineString, Polygon, MultiPoint, MultiLineString, MultiPolygon, GeometryCollection

```
"geometry": {
  "type": "Point",
  "coordinates": [-118.2851, 34.0224]
}
```

Feature: one or more geometry object with properties that can be used to encode the data

```
{
  "type": "Feature",
  "geometry": {
    "type": "Point",
    "coordinates": [-118.2851, 34.0224]
  },
  "properties": { "name": "USC" }
}
```

FeatureCollection: one or more Features

```
{
  "type": "FeatureCollection",
  "features": [ ... ]
}
```

DUPLICATE BOUNDARIES WITH GEOJSON (LARGE FILE SIZE)

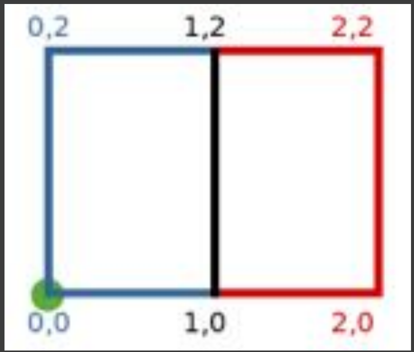
TOPOJSON

GeoJSON extension encoding topology where the **Geometry** is indexed with **arcs**

Up to 80% smaller than GeoJSON

See How To Infer Topology, Mike Bostok

```
{
  "type": "Topology",
  "transform": {
    "scale": [0.036003600360036005, 0.017361589674592462],
    "translate": [-180, -89.99892578124998]
  },
  "objects": {
    "aruba": {
      "type": "Polygon",
      "arcs": [[0]],
      "id": 533
    }
  },
  "arcs": [
    [[3058, 5901], [0, -2], [-2, 1], [-1, 3], [-2, 3], [0, 3], [1, 1], [1, -3], [2, -5], [1, -1]]
  ]
}
```



topojson/topojson Wiki ▸ Introduction

MAPS WITH D3

USING GEOJSON WITH D3

```
<svg width="960" height="600"></svg>

<script>
var svg = d3.select("svg"),
  width = +svg.attr("width"),
  height = +svg.attr("height");

d3.json("us.json").then(json => {  //1. load GeoJSON or TopoJSON

var projection = d3.geoAlbersUsa()  //2. set-up a projection (lat, lon) → (x, y)
  .fitSize([width, height], json);

var path = d3.geoPath()  //3. set-up a geographic path generator: feature → path
  .projection(projection);

svg.selectAll("path")
  .data(json.features)  //4. perform a data join with features
  .enter()
  .append("path")
  .attr("fill", "white")
  .attr("stroke", "black")
  .attr("d", path);  //apply the path generator to set the path d attribute
});
</script>
```

d3.geoPath d3.geoAlbersUsa
See d3-geo

USING TOPOJSON WITH D3

```
<svg width="960" height="600"></svg>

<script>
  d3.json("us-10m.v1.json").then(function (us) {  //us-10m.v1.json contains projected TopoJSON

  var path = d3.geoPath();  //set-up path generator
  //no projection needed as TopoJSON is already projected!

  var svg = d3.select("svg");
    svg.append("g")
      .attr("class", "states")
      .selectAll("path")
      .data(
        topojson.feature(us, us.objects.states).features  //convert TopoJSON → GeoJSON
      )
      .enter()
      .append("path")
      .attr("d", path);

    svg.append("path")
      .attr("class", "state-borders")
      .attr("d", path( //generate path for GeoJSON features of interior boundaries
        topojson.mesh(us, us.objects.states, function (a, b) { return a !== b; })
      ));
  });
</script>
```

See topojson.feature, topojson.mesh

ADDITIONAL NOTES ON GEOJSON AND TOPOJSON

- Arbitrary extensions, e.g., .json, .geojson, .topojson
- Load with d3.json
- Specify geometry in **geographical** or **projected** coordinates
- Encode the data:
  - As **separate files**
    - Nest d3.json and d3.csv
    - Use d3-queue, e.g., block 1696080
    - Use ES6 Promise.all()
  - **Embedded** as geometry properties