Projections & Scale

Outline

- Updates from Evan
- Review/clarifications
- Projections
- Scale

Review

- Elements of latitude
  - Parallels
  - Tropic of Cancer & Tropic of Capricorn
  - Arctic & Antarctic circle
- Approximations of the shape of the earth
  - Geoid
  - Ellipsoid
  - Sphere

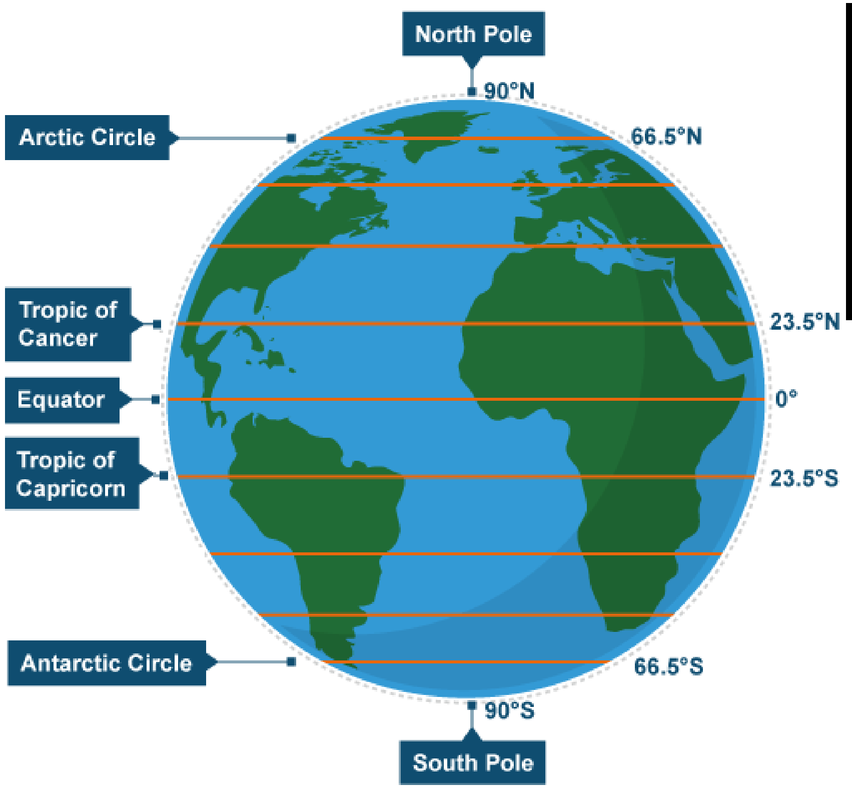
Elements of Latitude

Arctic Circle: Southernmost latitude in the Northern Hemisphere where the Sun can remain continuously above or below the horizon for 24 h.

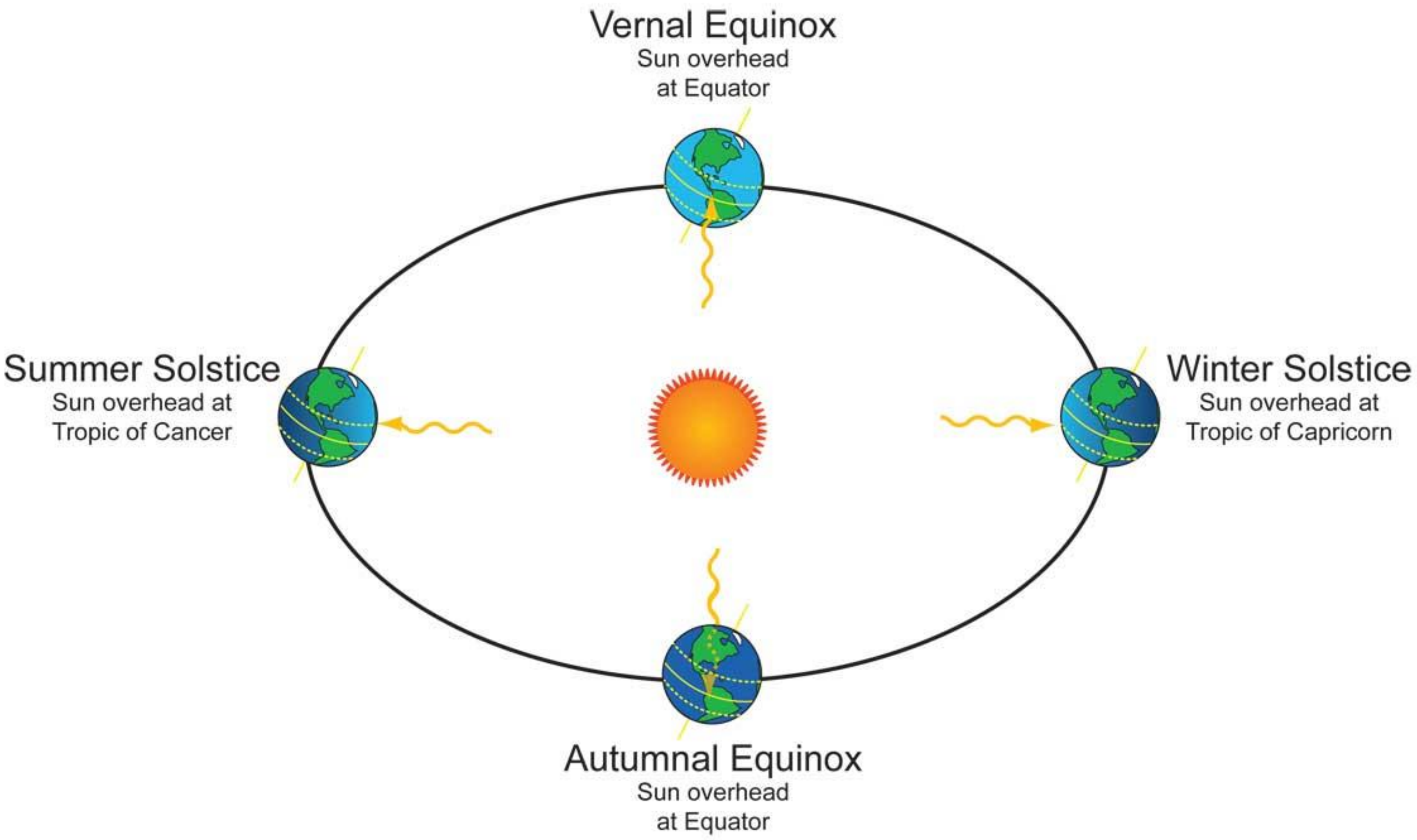
Antarctic Circle: Northernmost latitude in the Southern Hemisphere where the sun can remain continuously above or below the horizon for 24 h.

Tropic of Cancer: Northernmost circle of latitude where the Sun can be directly overhead .

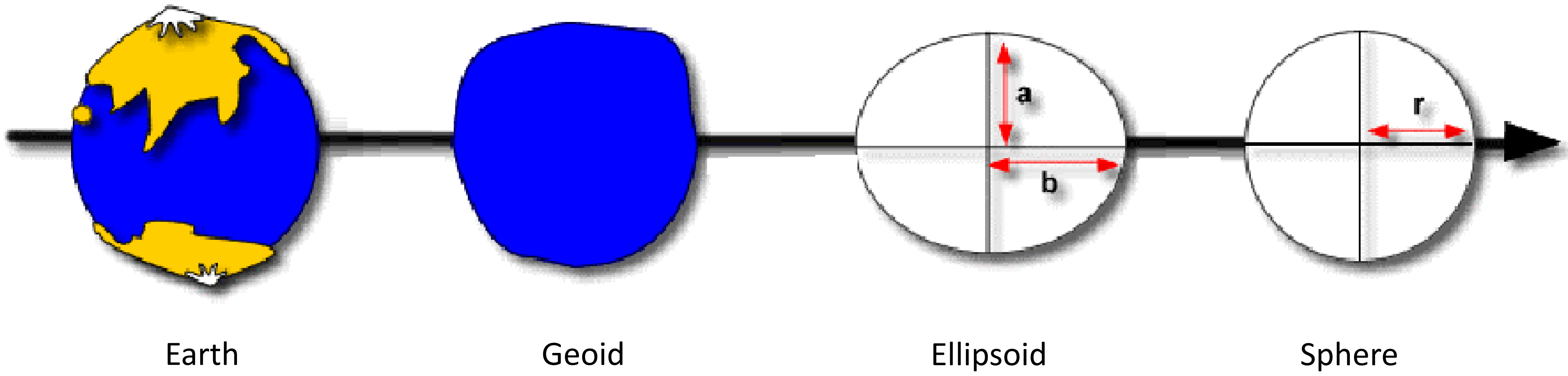
Tropic of Capricorn: Southernmost circle of latitude where the Sun can be directly overhead.



Elements of latitude. (source: BBC)


Vernal Equinox
Sun overhead
at Equator
Summer Solstice
Sun overhead at
Tropic of Cancer
Winter Solstice
Sun overhead at
Tropic of Capricorn
Autumnal Equinox
Sun overhead
at Equator

The Shape of the Earth



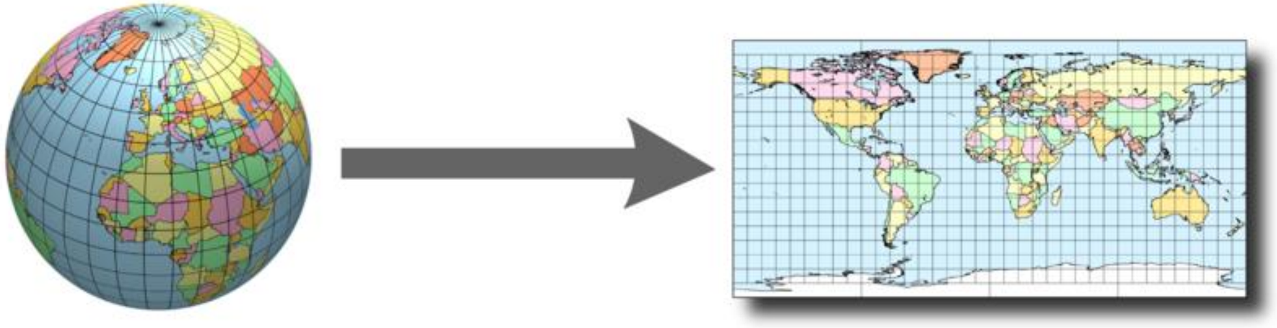
Levels of approximation to the figure of the Earth: from more complex to simplest. (source: University of Alaska System)

Learning Objectives

- In this lecture you will learn…
  - How the earth is projected into maps
  - Which units we use to measure what we observe
  - The scales of the features we observe using cameras and images from space
  - Which instruments we use to observe features at different scales
  - How we represent what we observe: maps & scales

Projecting the World

- For centuries, the most vexing dilemma for cartographers has been how to transfer the Earth – a 3D globe– onto a 2D page.
- A **map projection** is a set of mathematical formulas and equations that enables Earth's curved surface to be shown on a flat map.



From the globe to the map (source: modified from www.progonos.com)

- Only a globe can accurately represent all of the Earth's metric properties (area, distance, and shape/direction).
- Projected on a flat surface, only some of these properties can be accurately represented: *every map has some sort of distortion*.

Projection Surfaces

Cartographers found that 3 surfaces were suitable for projecting an image of the Earth without significant distortion:

a. Cylindrical projections

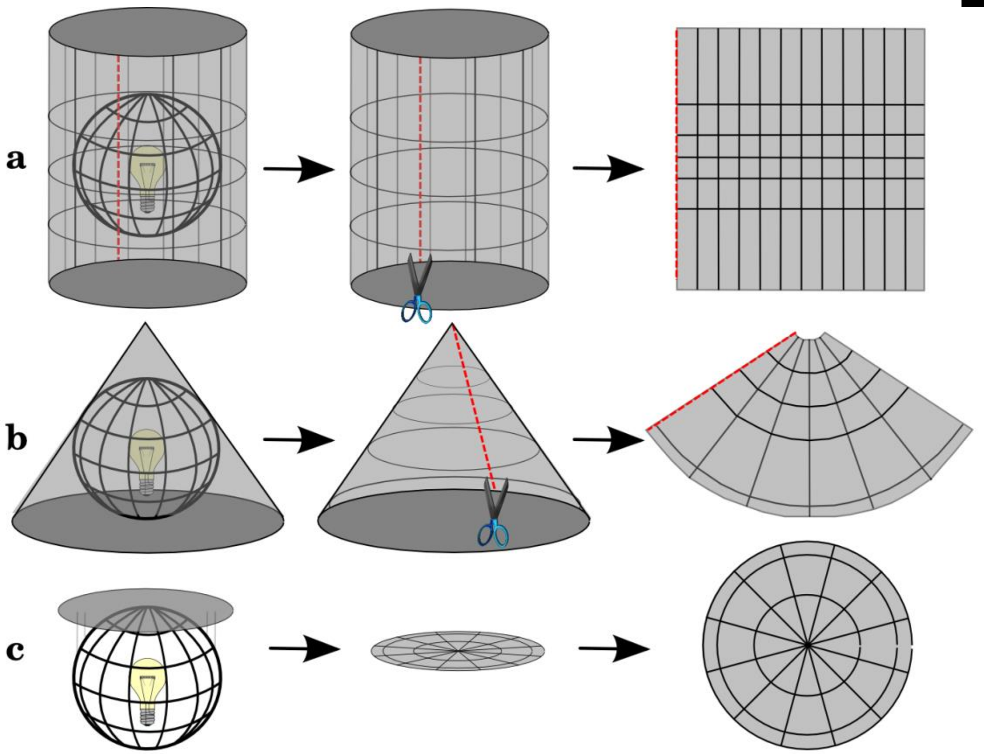
- The Earth is projected on a cylinder.
- Whole-world maps are rectangular.
- Distortion on the poles.

b. Conic projections

- The Earth is projected on a cone.
- Good for representing parts of the Earth.

c. Planar projections

- The Earth is projected on a plane.
- Lots of distortion towards the edges.

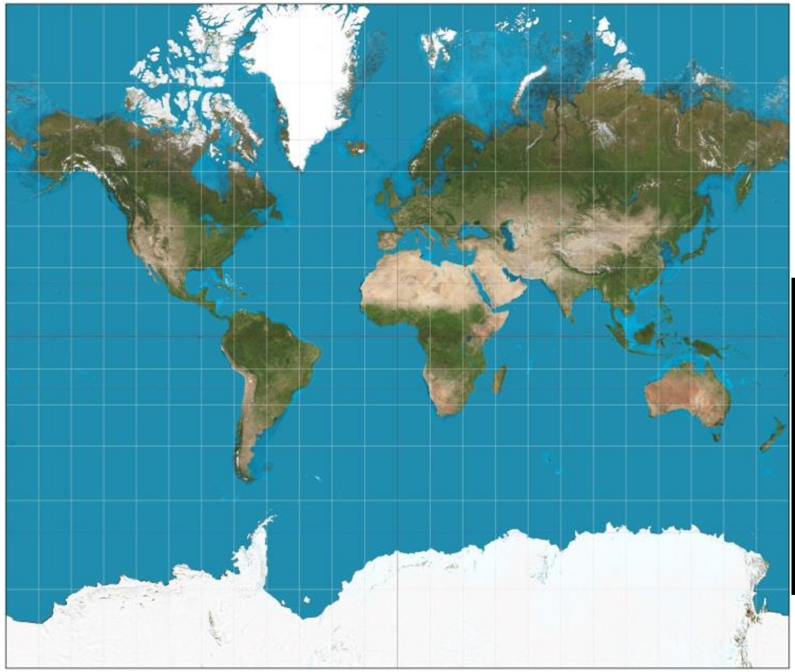


Projection surfaces: (a) cylindrical, (b) conic, (c) planar (Source: QGIS 2.0 documentation).

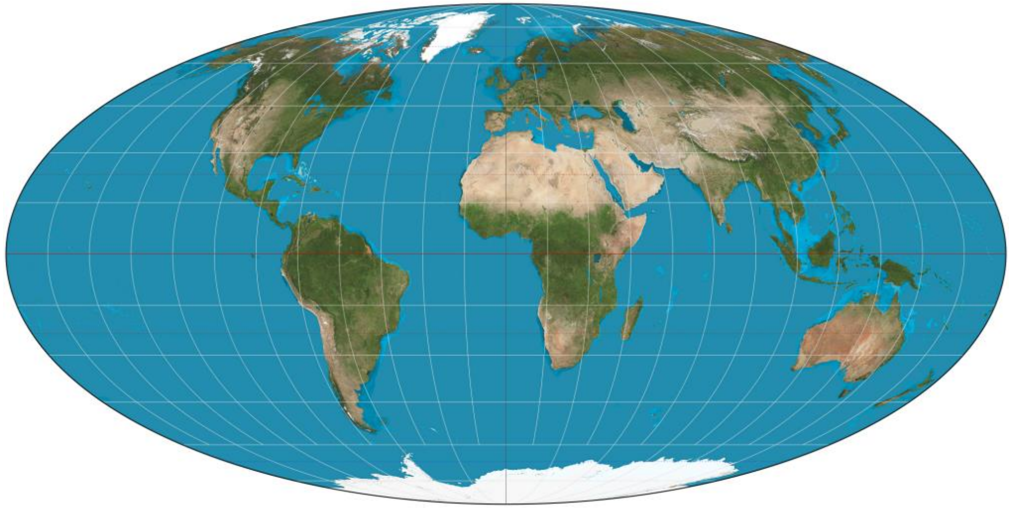
Types of Projections

- **Conformal:**
  - Angles between positions are preserved.
  - Convenient for sea navigation.
  - Distortion of countries/continents areas.
  - Example: Mercator.

- **Equivalent / Equal Area:**
  - The area of countries/continents is preserved.
  - Enables direct surface comparisons within the map.
  - The shape of countries/continents is distorted.
  - Example: Mollweide, Gall–Peters.



Mercator projection. (Source: Wikimedia commons)

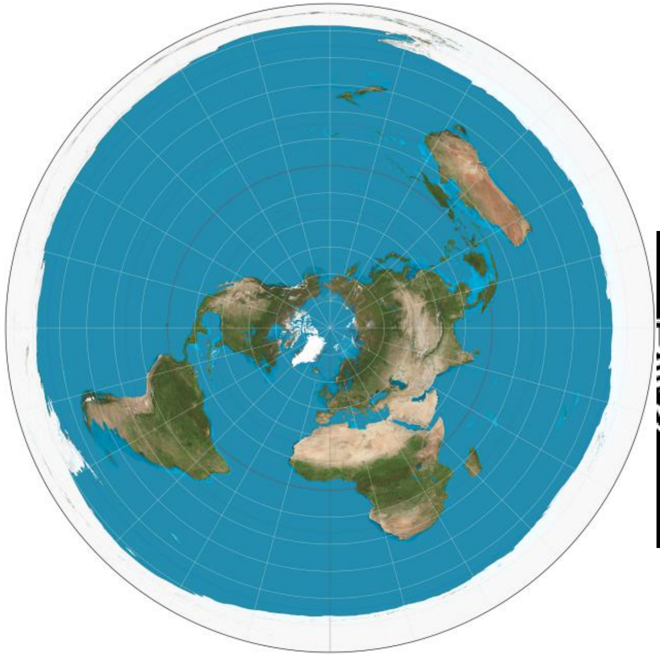


Mollweide projection. (Source: Wikimedia commons)

Types of Projections

Equidistant:

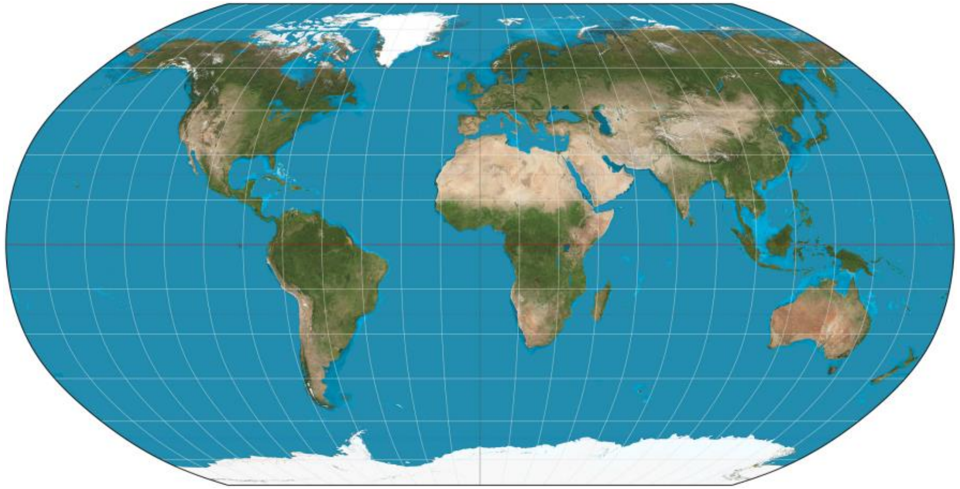
- All distances from a point (the projection center in the example on the right) are correct.
- Distances between any other points are incorrect.
- Convenient for radio communications, radar.
- Example: Azimuthal equidistant.



Azimuthal equidistant projection. (Source: Wikimedia commons)

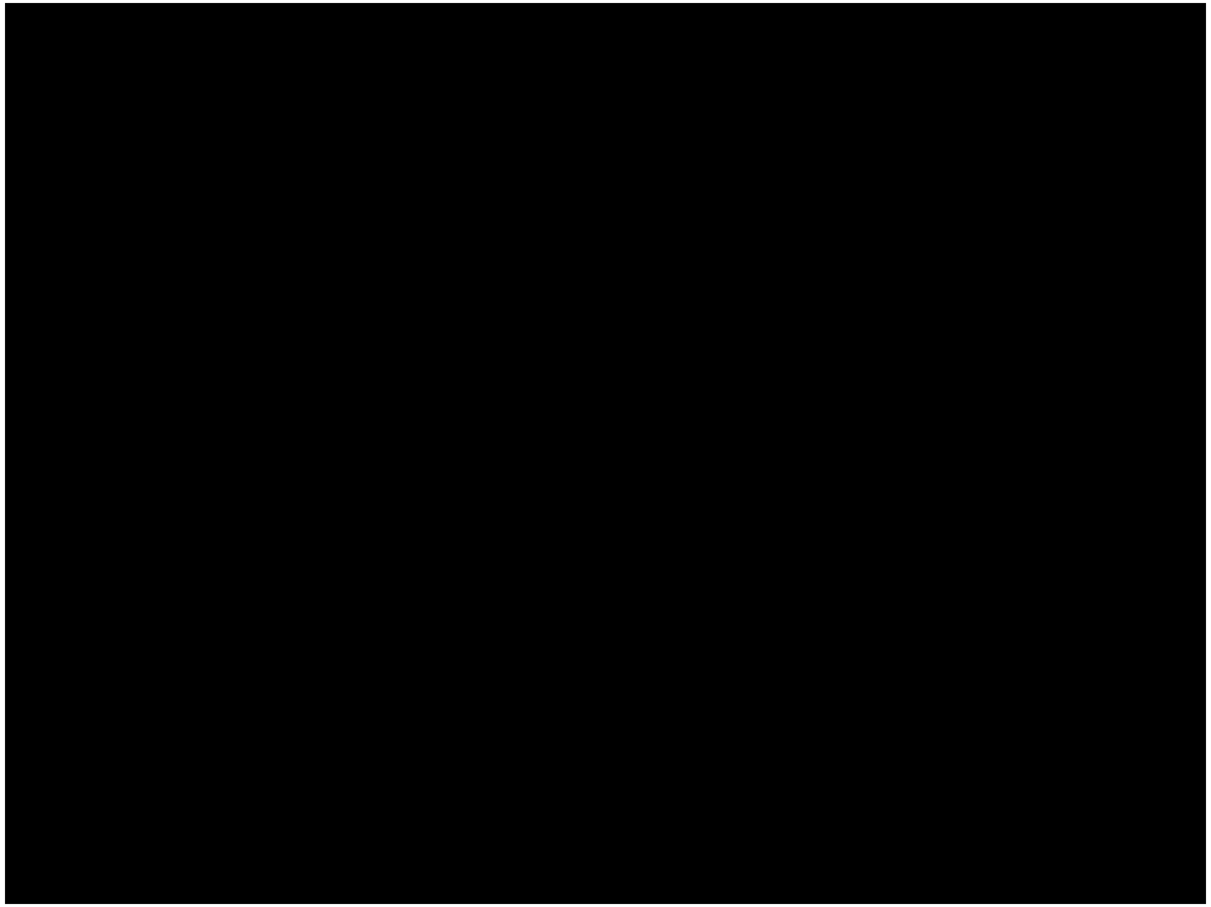
Compromise:

- Balances the distortions of shape and area.
- Produces visually appealing maps.
- No metric properties: areas, distances, and shapes cannot be measured.
- Examples: Robinson.



Robinson projection. (Source: Wikimedia commons)

How to Choose a Map Projection?



- Every projection has its own set of advantages and disadvantages.
- Depending on the map's purpose, cartographers must decide what elements of accuracy are most important to preserve. This determines which projection to use.

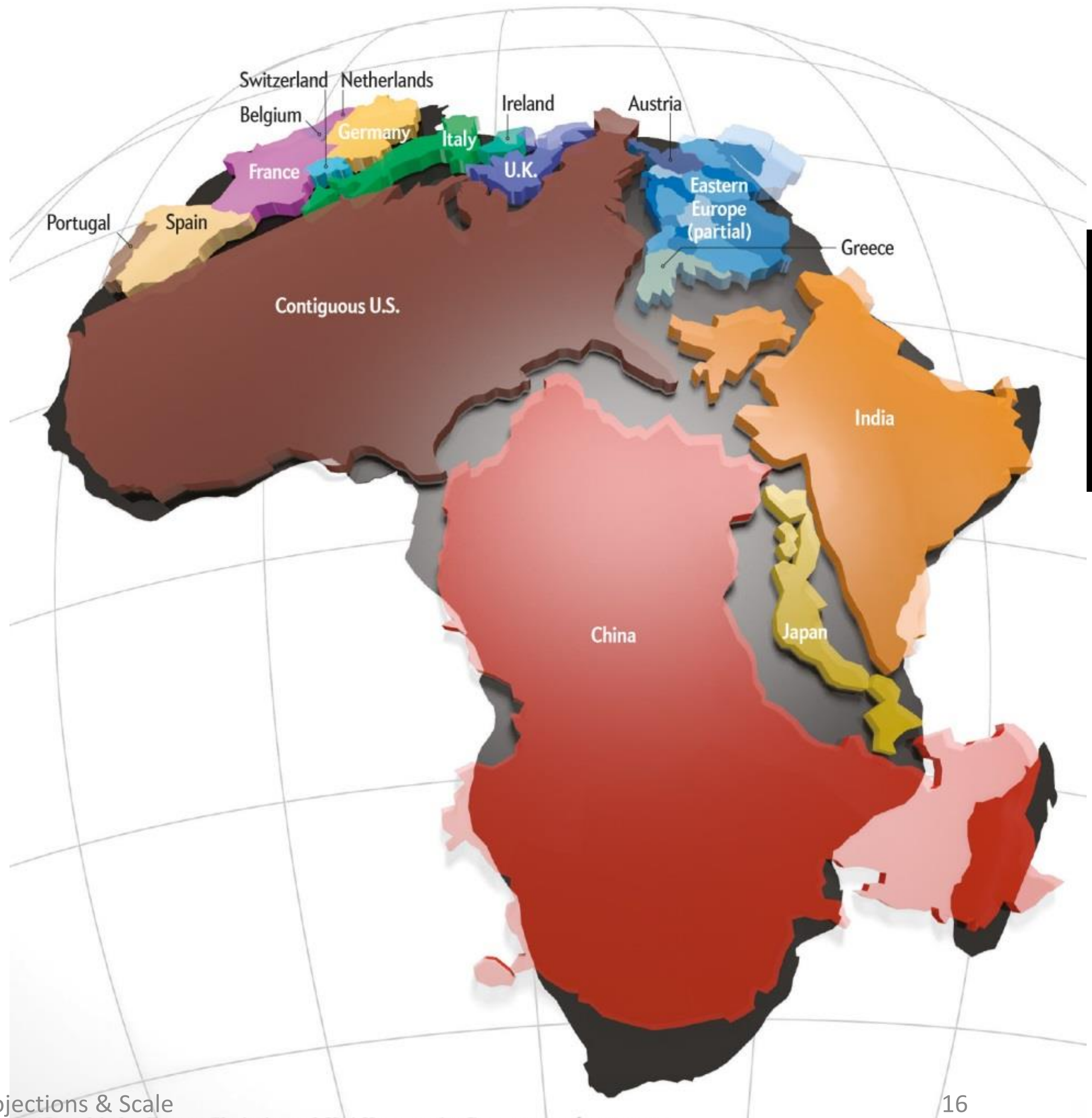
What are some issues with having a map which has distortions ?

Eurocentric Mapping and Africa

- The hypothesis about how Africa's importance has been diminished in the Western consciousness in part due to map projections making the continent appear smaller.

How Africa has historically been represented…

Eurocentric Mapping and Africa

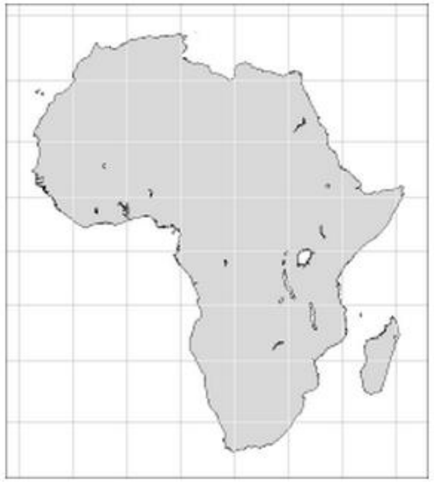


Graphic by Bryan Christie and Kai Krause, for SCIENTIFIC AMERICAN

How the reality is…

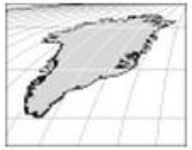
Mercator vs Mollweide: Comparisons between Greenland and Africa

Mercator



Source: www.progonos.co

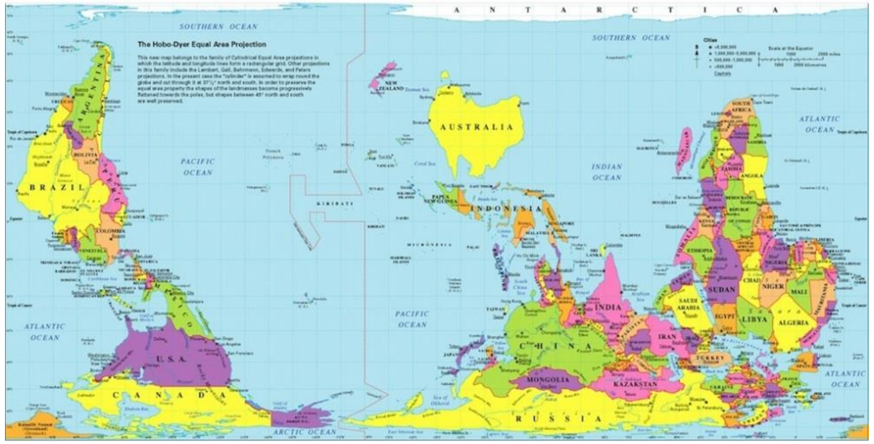
Mollweide



Source: www.progonos.com/furuti

Eurocentric Mapping

- Peters (1974) argued that its depiction of the world's countries in more realistic proportions to each other could encourage a more equitable sense, and thus treatment, of all the world's people.
- The location of the prime meridian has been claimed as an example of Eurocentrism.

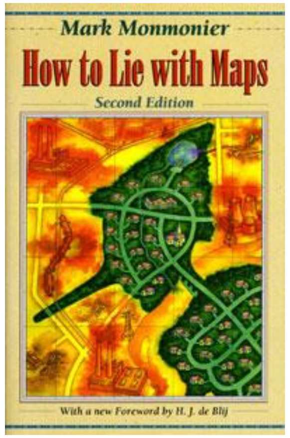


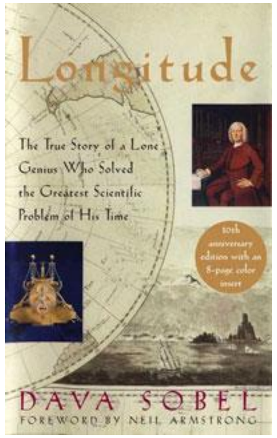
Upside down Hobo-Dyer projection map

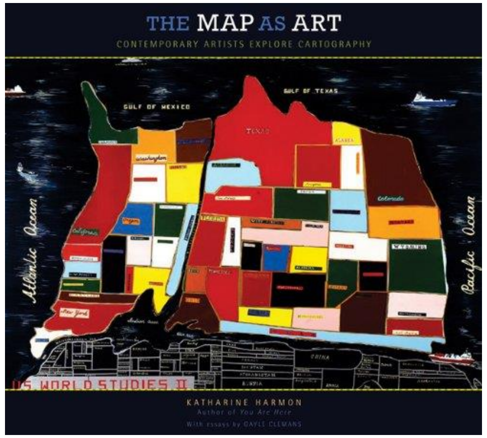
Mercator projection map centered on America

Additional Resources

- Books
  - How to lie with maps.
  - Longitude.
  - The map as art.







- Interesting readings
  - http://www.theage.com.au/technology/sci-tech/interactive-map-tool-shows-the-true-size-of-the-worlds-countries-20150911-gjkcvy.html
  - http://www.wired.com/2015/07/secret-cold-war-maps/
  - http://blog.visual.ly/you-are-here-using-maps-in-data-visualization/

- InterWebs
  - http://bigthink.com/articles?blog=strange-maps

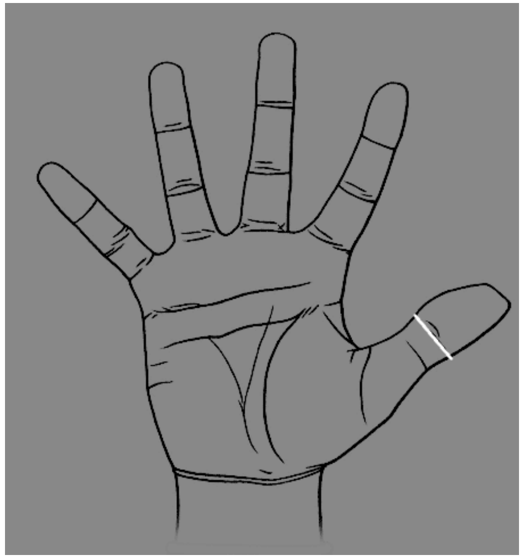
Measuring Distances:

- How do you think the very first measurements were made ?
- Using what units ?

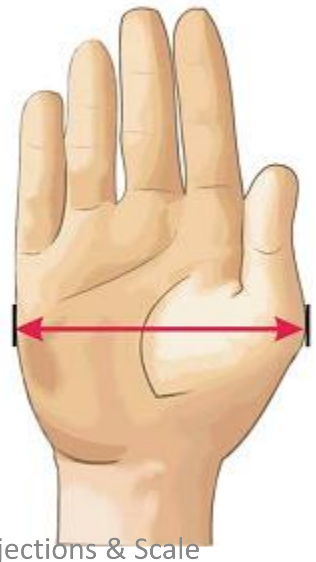
Measuring what we observe

- Original measurement metrics were derived from the human body or common travel distances.
- Common historical measurements are

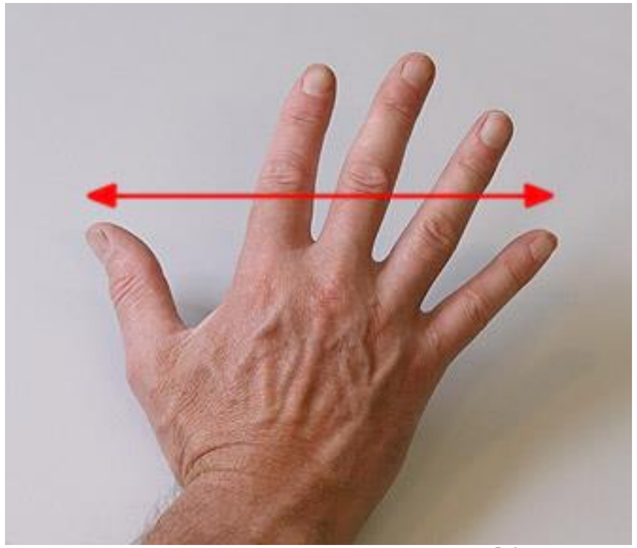
Thumb-breadth (2–2.4 cm)



Hand-breadth (8-9.6 cm)



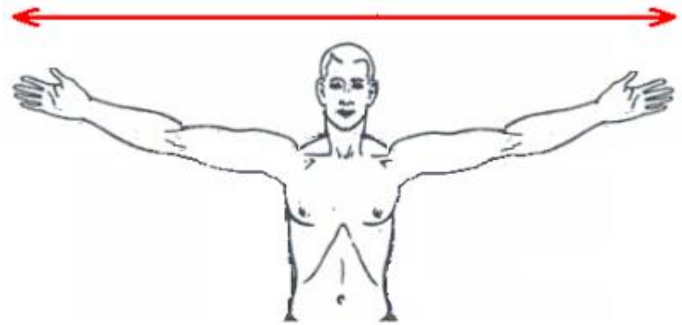
Span (24-28.8 cm)



Measuring what we observe

Fathom

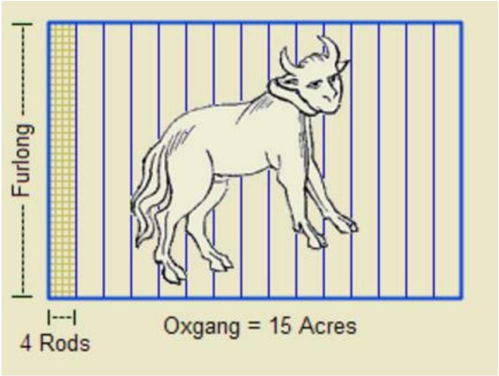
(1.82 m)



Furlong

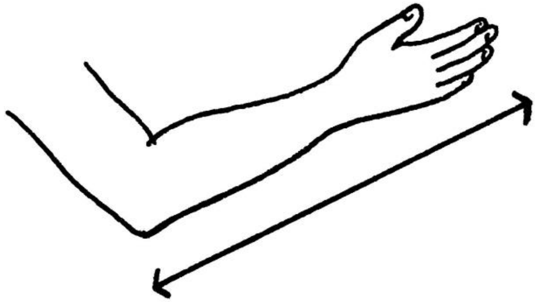
(128–153.6 m)

Distance a team of oxen could plough without resting



Cubit

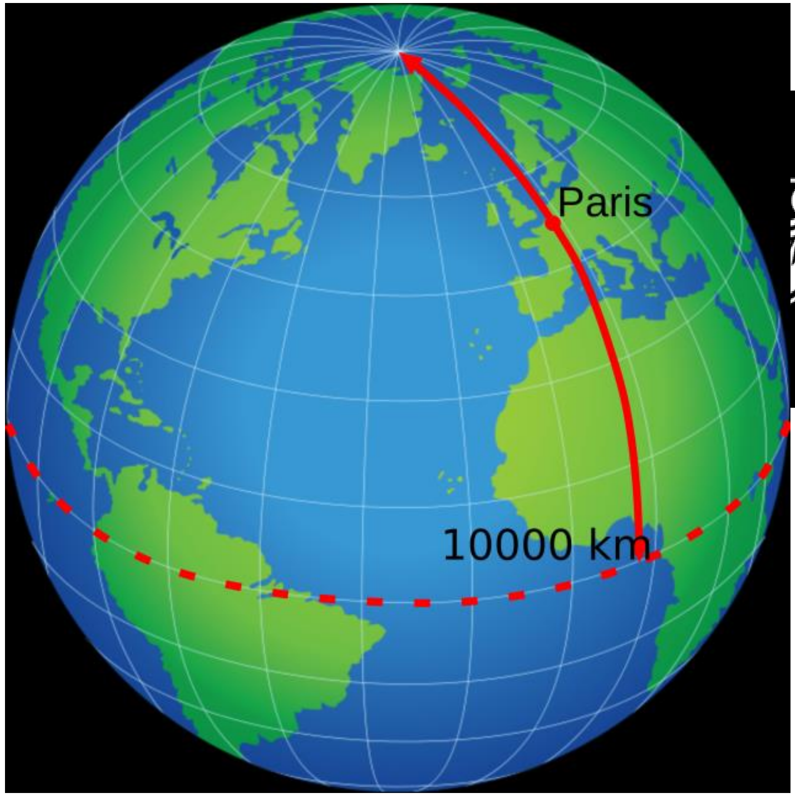
(48-57.6 cm)



Normalization: the metre

- After the French revolution a new normalized decimal metric system was proposed.

- The metre was originally defined in 1793 as "*one ten-millionth of the distance from the equator to the North Pole*".



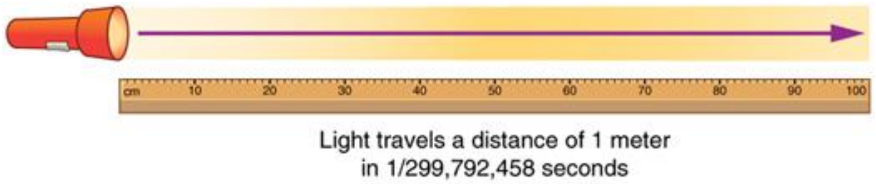
Original definition of the metre. (source: Wikimedia commons)

Normalization: the metre

- From 1889 to 1960s, the standard was a platinum and iridium bar stored in the International Bureau of Weights and Measures in Paris.

Historical metre bar. (source: Wikimedia commons)

- Since 1983 it is defined based on the speed of light: “*length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second*”.



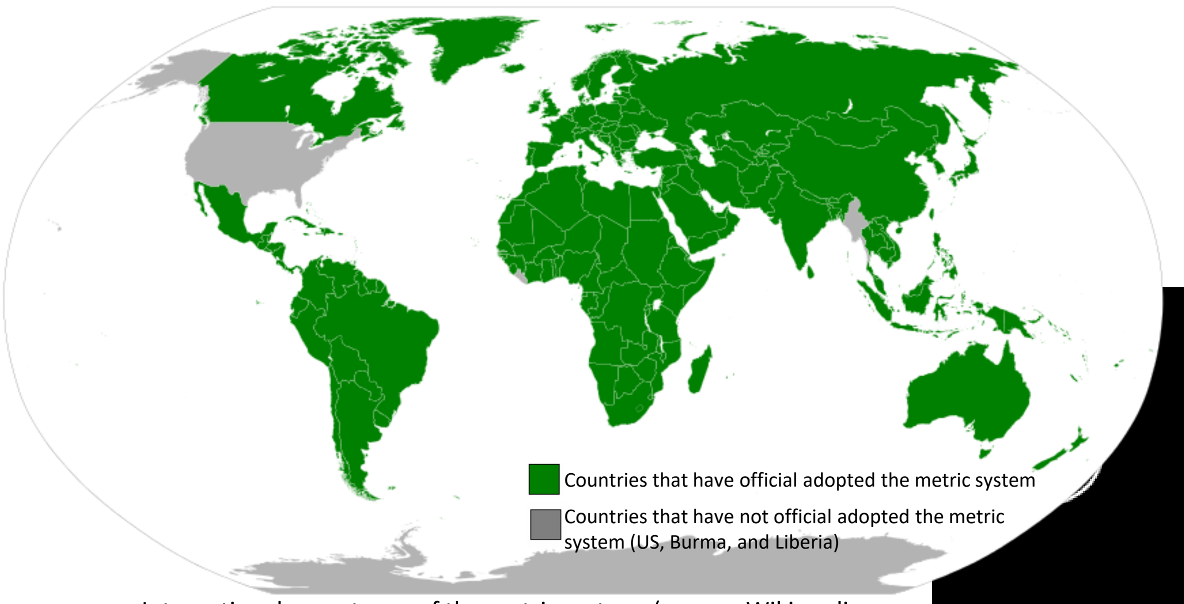
Light-speed based metre definition. (source: http://fringetruth.com/)

Metric system

- International agreed decimal system of measurement.

Most common distance units:

Unit	Symbol	Number	Power of ten
Kilometre	km	1 000	10^3
Metre	m	1	10^0
Centimetre	cm	0.01	10^{-2}
Millimetre	mm	0.001	10^{-3}
Micrometre / Micron	µm	0.000 001	10^{-6}
Nanometre	nm	0.000 000 001	10^{-9}



International acceptance of the metric system. (source: Wikimedia commons)

Multiples and Submultiples	Prefixes	Symbols
1 000 000 000 000 = 10^{12}	tera (tĕr′ȧ)	T
1 000 000 000 = 10^{9}	giga (jĭ′gȧ)	G
1 000 000 = 10^{6}	mega (mĕg′ȧ)	M*
1 000 = 10^{3}	kilo (kĭl′ō)	k*
100 = 10^{2}	hecto (hĕk′tō)	h
10 = 10	deka (dĕk′ȧ)	da
0.1 = 10^{-1}	deci (dĕs′ĭ)	d
0.01 = 10^{-2}	centi (sĕn′tĭ)	c*
0.001 = 10^{-3}	milli (mĭl′ĭ)	m*
0.000 001 = 10^{-6}	micro (mī′krō)	µ*
0.000 000 001 = 10^{-9}	nano (năn′ō)	n
0.000 000 000 001 = 10^{-12}	pico (pē′kō)	p
0.000 000 000 000 001 = 10^{-15}	femto (fĕm′tō)	f
0.000 000 000 000 000 001 = 10^{-18}	atto (ăt′tō)	a

*Most commonly used

Complete list of prefixes used in the metric system

Just late 2018 they re-defined the kilo

- Until then the kilo was a rock held at the International Bureau of Weights and Measures, near Paris.
- The 143 year old golf ball-sized metal cylinder was the global definition of a kilo.
- It was the last “measure” that was defined “physically”
- It is now defined using planck’s constant

- $6.626\ 070\ 15 \times 10^{-34}$ kg m^2 s^{-1}.

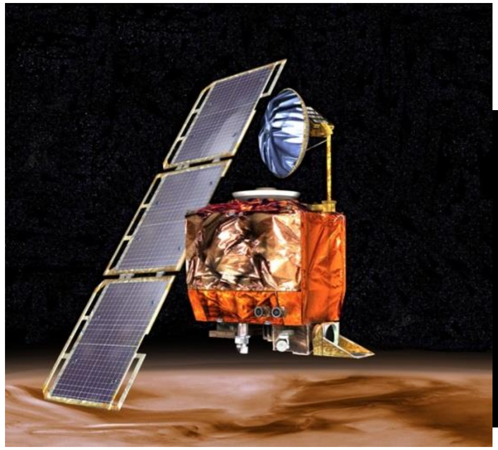
Metrification in the United States

- Initially Thomas Jefferson rejected the metric system because he thought it was too French.
- In 1866 the use of metric weights and measures became legal though not standard in the U.S.
- Since then many attempts have been carried out to standardize the use of the metric system in order to “maintain proper standards of ethical conduct throughout business and industry”.

Interstate 19, America’s only metric interstate

Conversion Catastrophes

- **Mars Climate Orbiter** was supposed to be the first weather satellite observing other planets.
- In 1999 it burned up when entering into the Martian atmosphere: engineers failed to convert units from imperial to metric.
- The software used calculated the force the thrusters needed to exert in **pounds**. A separate piece of software took in the data assuming it was in the metric unit: **newtons**.

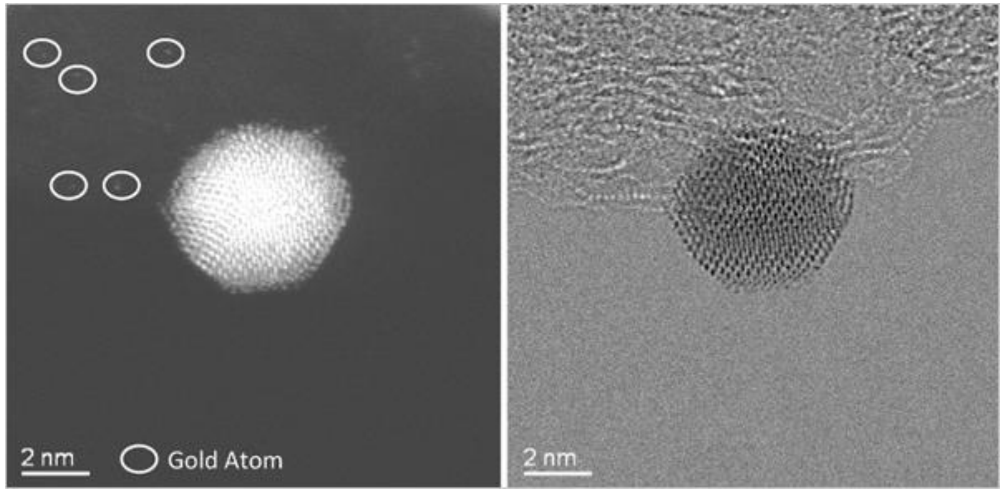


Mars Climate Orbiter. (source: Wired)

Scale

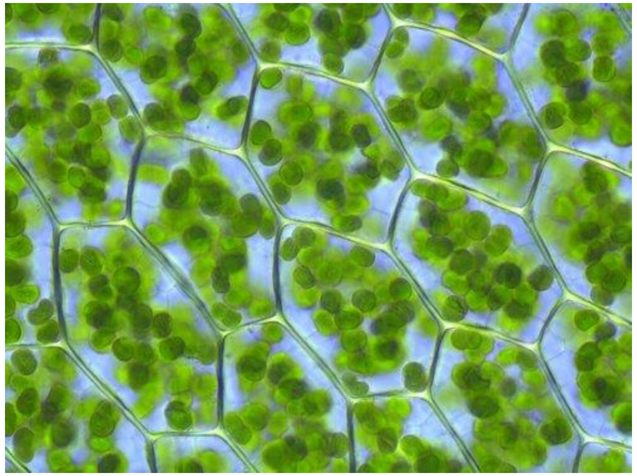
How We Observe Different Scales

- Electron microscope
- Optical microscope
- Camera
- Telescope



Gold Atom. (source: UNM Center for Micro-Engineered Materials)

Optical microscope. (source: Premium spores)



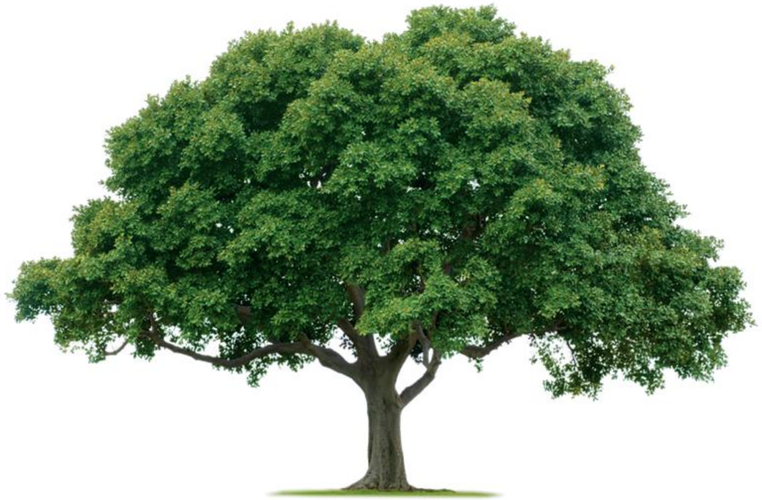
Leaf under a optical microscope: chlorophyll cells

How We Observe Different Scales

- Electron microscope
- Optical microscope
- Camera
- Telescope

Cameras. (source: Photographymad)

Tree leaf



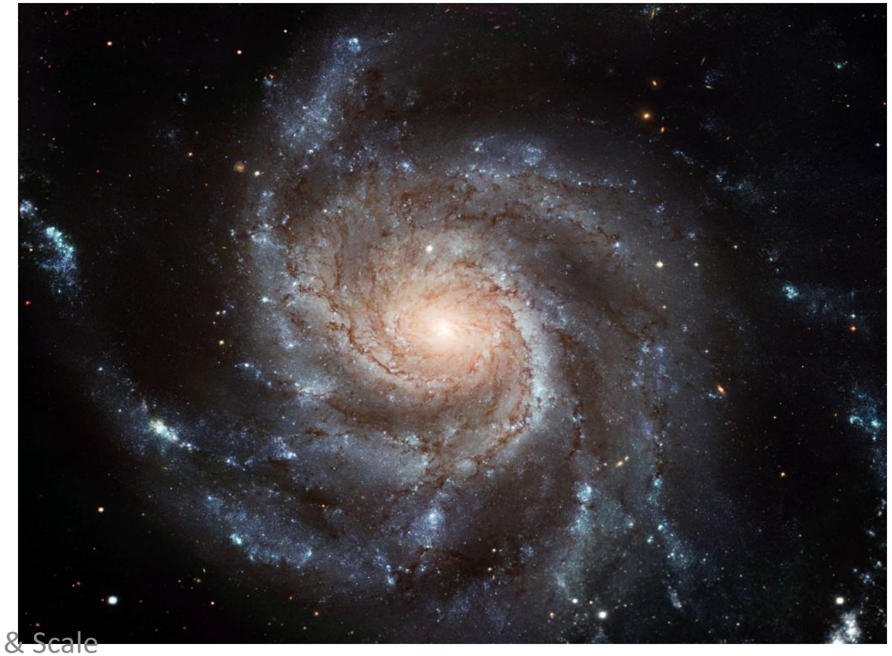
Tree

Forest

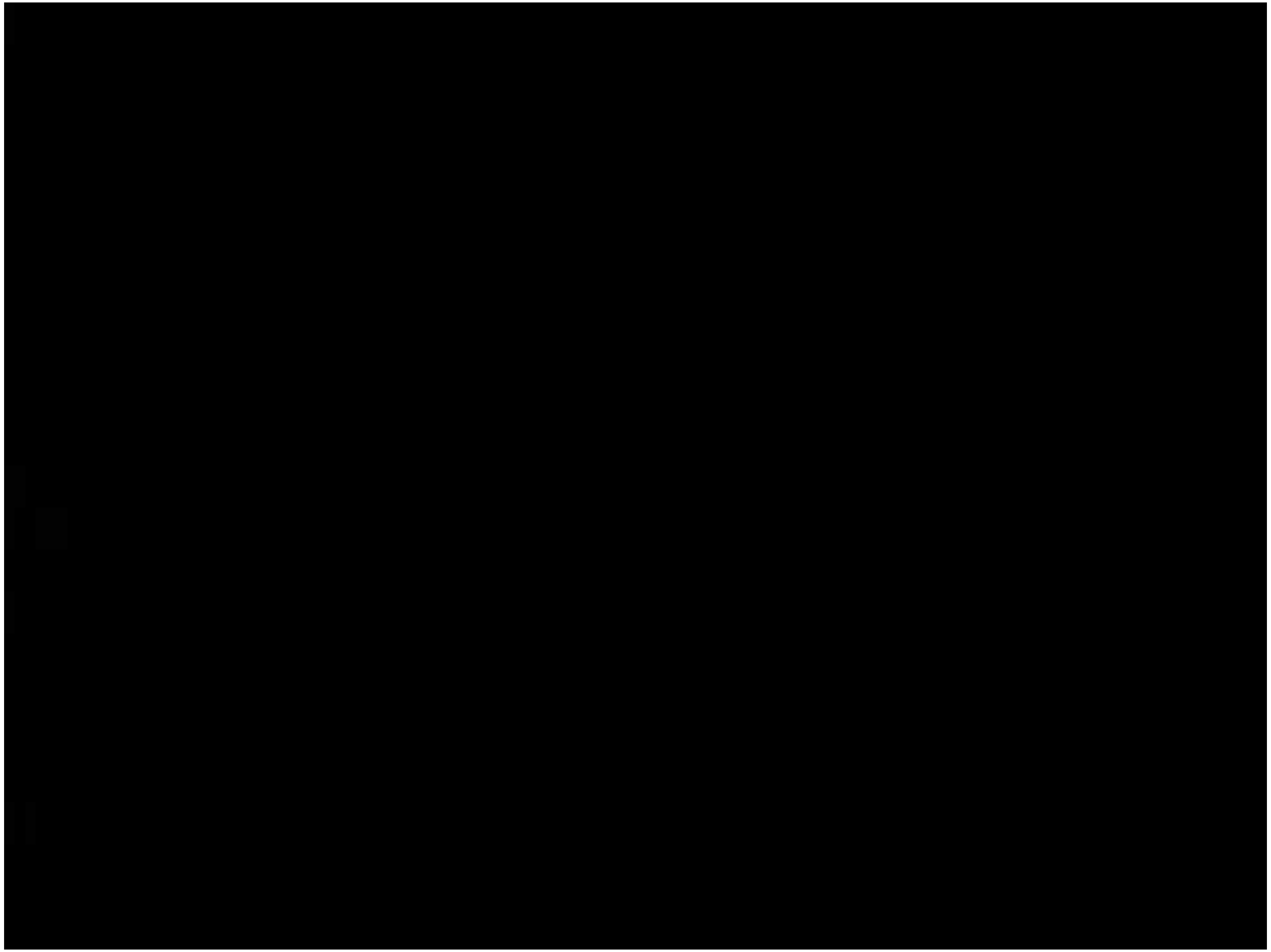
How We Observe Different Scales

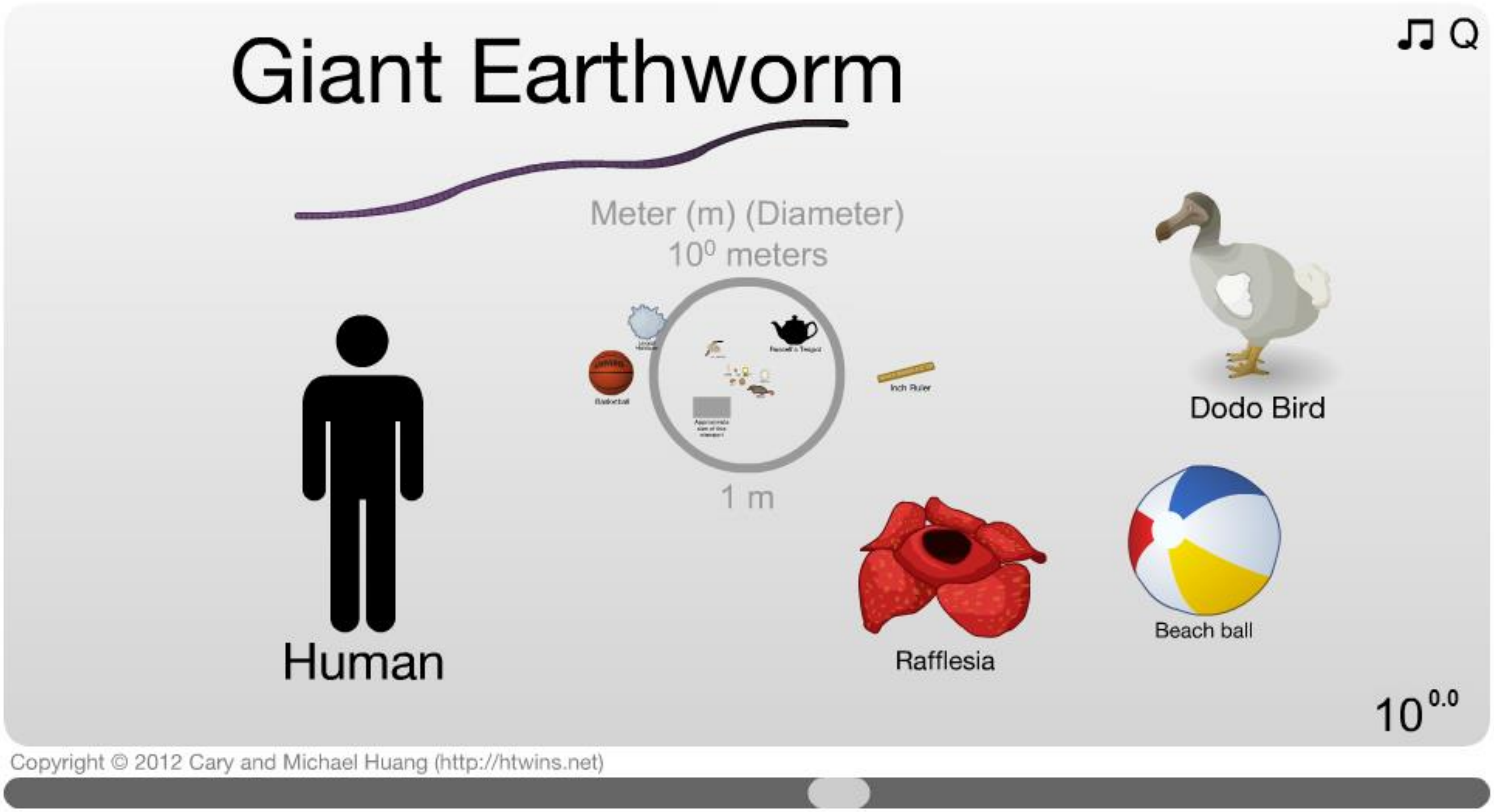
- Electron microscope
- Optical microscope
- Camera
- Telescope

Pluto (Source: Nasa)



Galaxies from Hubble Space Telescope (Source: Nasa)

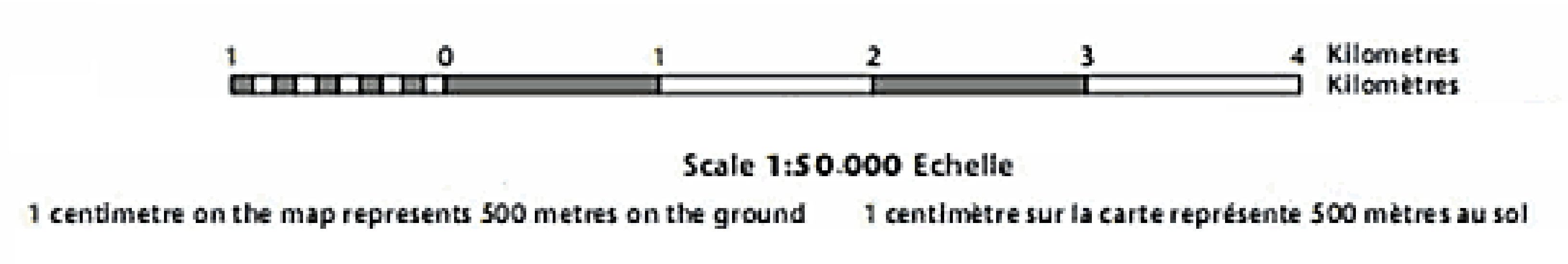




http://htwins.net/scale2/

How We Represent Scales on Maps

- To represent the observed world, maps and images are displayed to a specific scale.
- Map scale is defined as the ratio of the distance between two points on the map to the corresponding distance on the ground.



Map scales. (source: Natural Resources Canada)

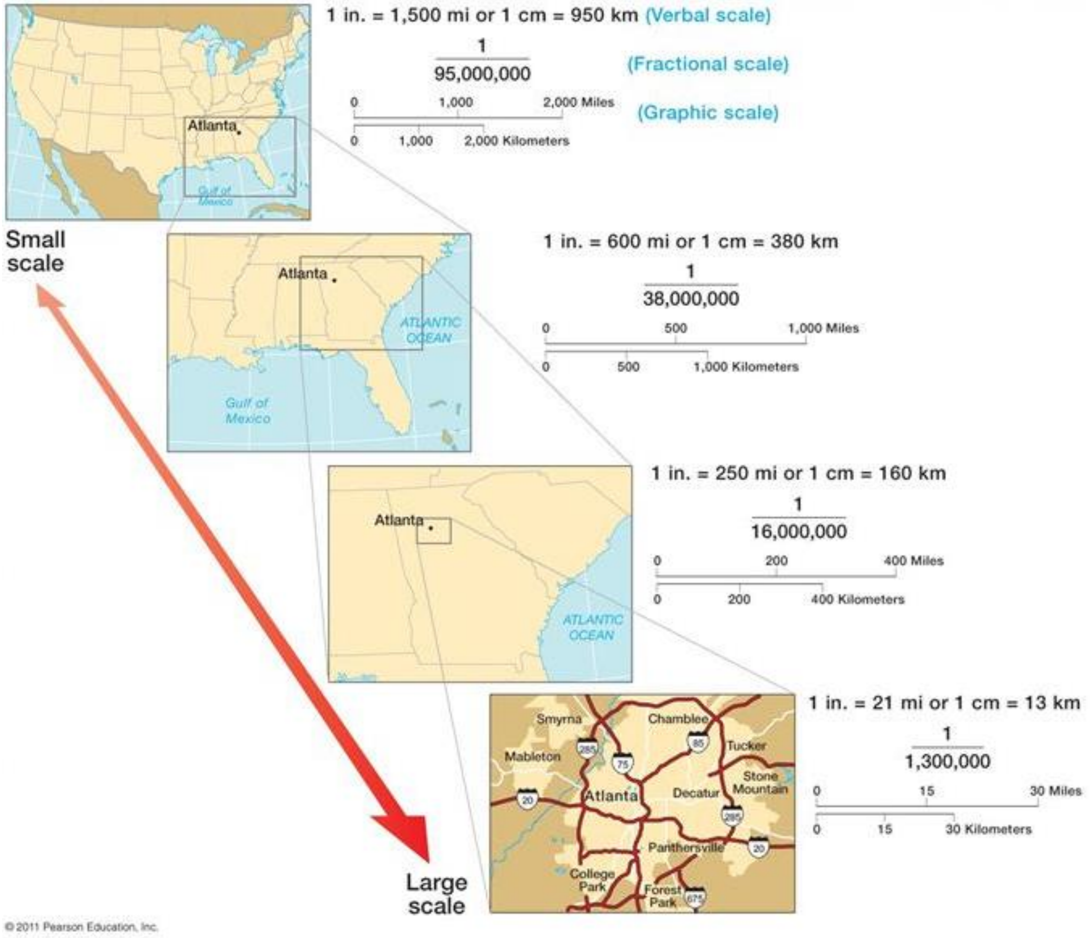
Graphic scale/Bar scale

Fractional scale/Ratio scale

Verbal scale

- Small scale maps cover a large area with coarse detail.
- Large scale maps cover a small area with great detail and accuracy.

Coarse and Fine Scale



Visualization of various map scales. (source: Pearson Education)

Map Scales: Worldwide (Scale= 1:40,000,000)

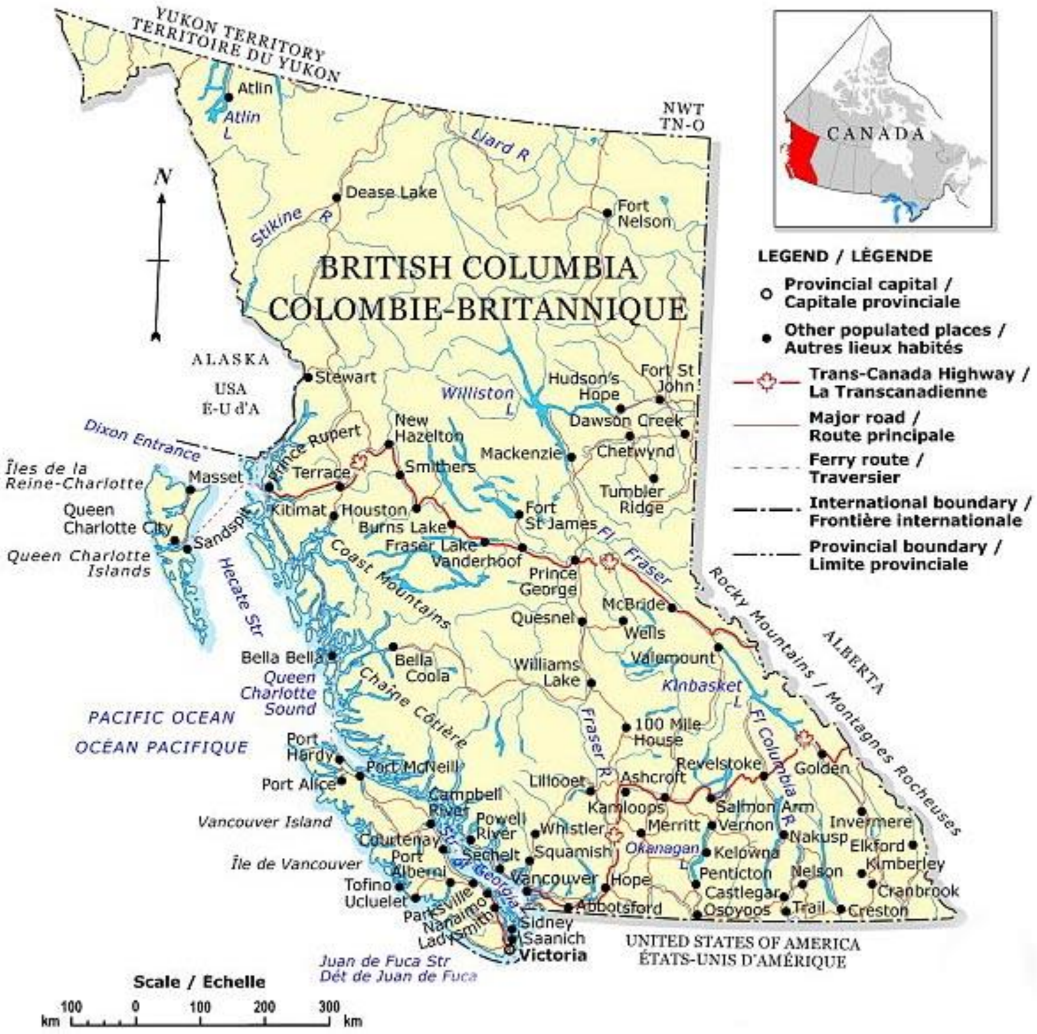
http://imgreal.net/world-map/

Map Scales: Continental (1: 20,000,000)

http://www.mapresources.com/media/catalog/product/N/S/NS-AMR-952802_comp_1.jpg

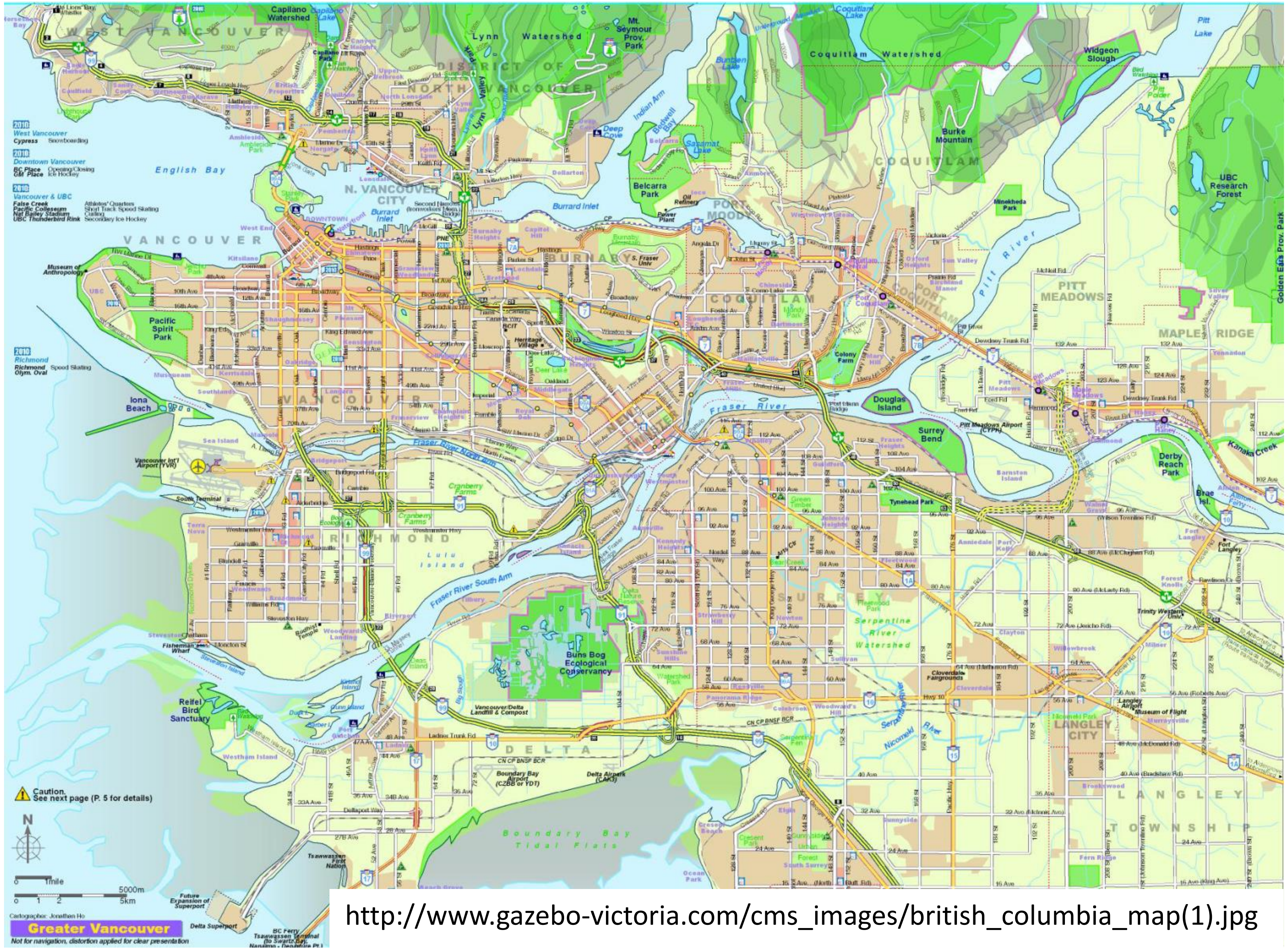
Map Scales: National (1:10,000,000)

Map Scales: Provincial, Regional, State (1:1,000,000)



http://www.gazebo-victoria.com/cms_images/british_columbia_map(1).jpg
http://www.basque.unr.edu/conferences/2011/slides/European%20Languages%20Basque%20000%20(2)_Part2.jpg

Map Scales: Metropolitan Areas (1:50,000)



http://www.gazebo-victoria.com/cms_images/british_columbia_map(1).jpg

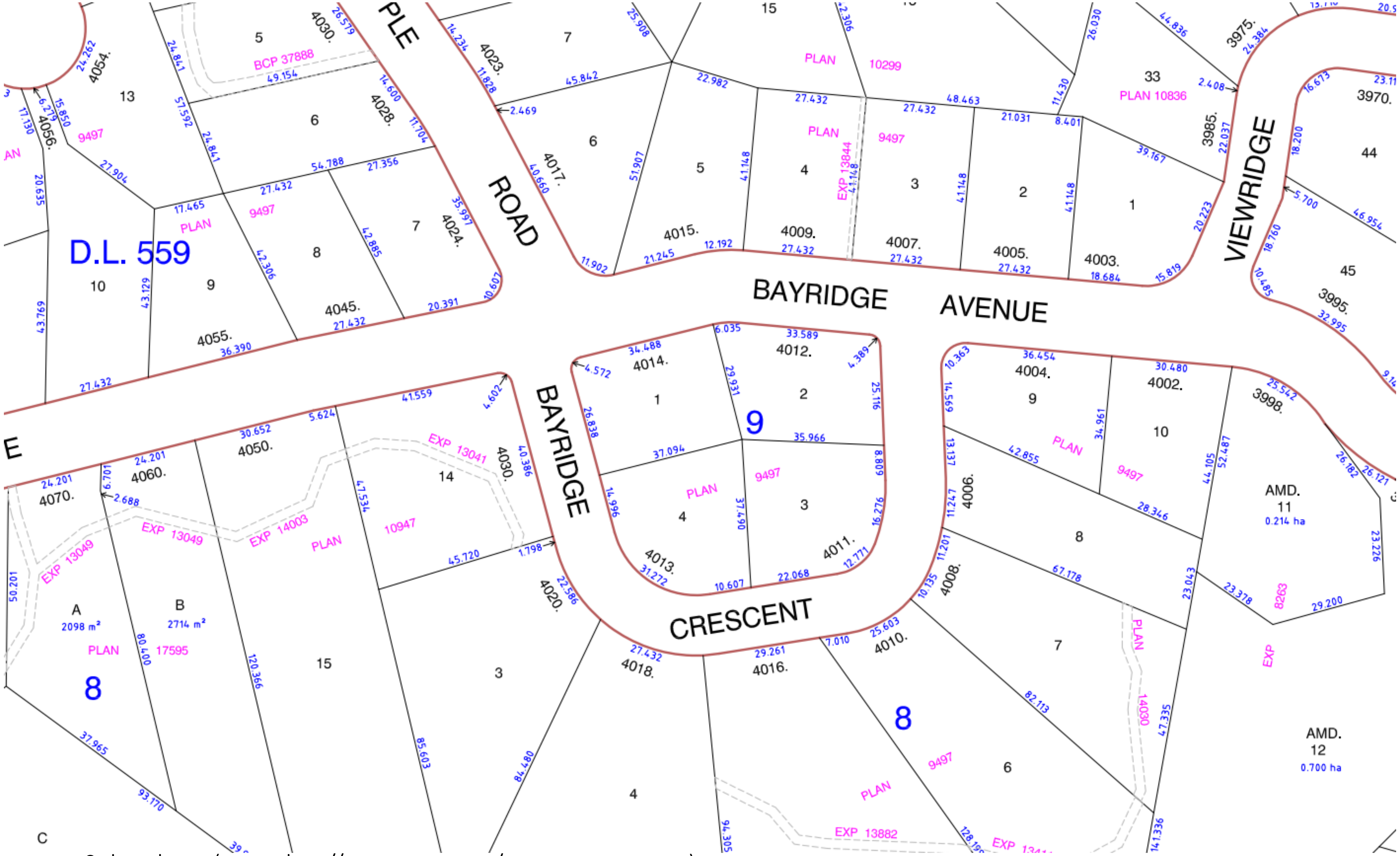
Map Scales: Cities (1:30,000)

http://www.tofinobcbritishcolumbia.com/maps/vancouver-maps/vancouver.gif

Map Scales: Neighbourhood (1:15,000)

http://blogs.britannica.com/wp-content/uploads/2010/09/0000071600-vancoe002-004.gif

Map scales: Cadastral (1:5000 – 1:500)

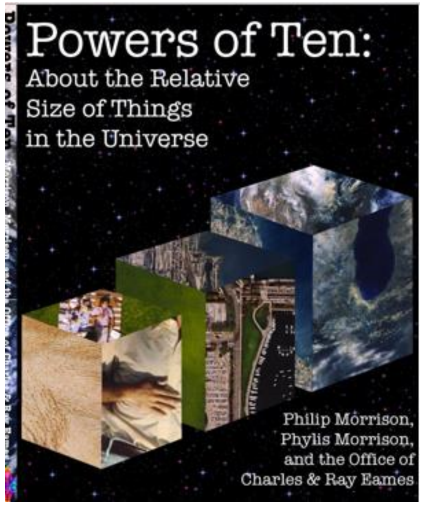


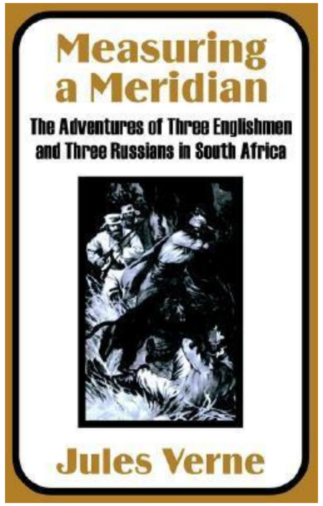
Cadastral map. (source: http://westvancouver.ca/maps-west-vancouver)

Practice Questions

- What type of distortion is minimized in a conformal projection?
- How have map projections perpetuated eurocentrism?
- How many microns is 1 metre?
- If I have a map with a scale 1:500
  - Is this a small scale or large scale map?
- How is a meter defined (originally and currently)?

Additional Resources





- Books
    - Powers of Ten.
    - Measuring a Meridian
- Websites

    http://scaleofuniverse.com/

- Videos
    - History of the definition of the metre (The metre and time)

      https://www.youtube.com/watch?v=dvVCNhWJvvo
    - TED talk (A 3D atlas of the Universe)

      http://www.ted.com/talks/carter_emmart_demos_a_3d_atlas_of_the_universe