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spm 9550:
Diversity and Self-Similarity

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Lecture goals

- Understand how the diversity of Agents' (elements) influences the systems emergent properties
  - States
  - Behavior
  - Interfaces / interactions
- Understand the notion of Self-similarity across system levels
- Understand the notions of
  - Scale invariance
  - Power laws

Diversity

Individual Diversity

- Complex systems exhibit a high degree of diversity in their subsystems.
  - Ecosystems consists of different species and Society consists of many types of people.

Diversity of States

- Within a population of similar agents there is diversity
  - People and their wallets
  - Birds in flocks are all different, have different speeds, see different things
  - Think of the genetic diversity of all the people alive today
- Recent research shows that sufficiently diverse groups are superior at solving problems (http://www.cscs.umich.edu/~spage/thedifference.html)

Diversity of Behavior / Interaction

- Just as states, behavior can be diverse.
  - In markets, different (groups of) strategies lead to different system outcomes
- While interfaces must be similar if elements are to interact, their diversity increases the potential for interaction
  - The permutation space of interactions
  - Unix pipes
  - Electricity
  - Language

Self-similarity

Fractals

- a rough or fragmented geometric shape that can be split into parts, each of which is (at least approximately) a reduced-size copy of the whole
- Fractal
  - has a fine structure at arbitrarily small scales.
  - is too irregular to be easily described in traditional Euclidean geometric language.
  - is self-similar
  - has a Hausdorff dimension which is greater than its topological dimension
  - has a simple and recursive definition.

http://en.wikipedia.org/wiki/Fractal

How Long Is the Coast of Britain?

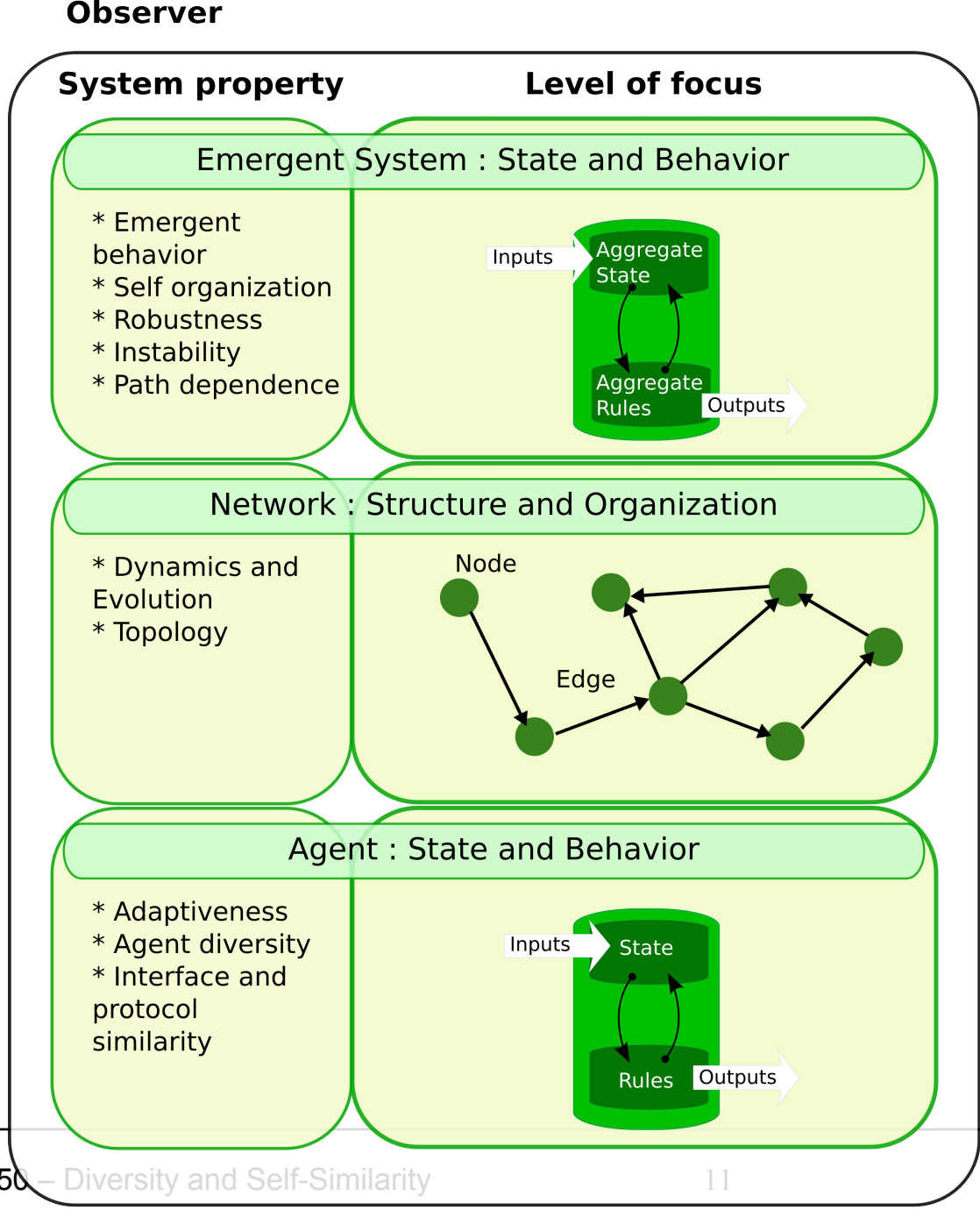
Unit = 200 km, length = 2400 km (approx.)

Unit = 100 km, length = 2800 km

Unit = 50 km, length = 3400 km

http://en.wikipedia.org/wiki/How_Long_Is_the_Coast_of_Britain%3F_Statistical_Self-Similarity_and_Fractional_Dimension

Self-similarity across levels



Unpredictable dynamic environment

Scale invariance

- Systems that are scale-invariant display behaviour that is self-similar across may time and spatial scales
- This is especially apparent at phase transitions

Examples of scale invariance

- Avalanches in piles of sand. The likelihood of an avalanche is in power-law proportion to the size of the avalanche, and avalanches are seen to occur at all size scales.
- The frequency of network outages on the Internet, as a function of size and duration.
- The frequency of citations of journal articles, considered in the network of all citations amongst all papers, as a function of the number of citations in a given paper.
- The formation and propagation of cracks and tears in materials ranging from steel to rock to paper. The variations of the direction of the tear, or the roughness of a fractured surface, are in power-law proportion to the size scale.

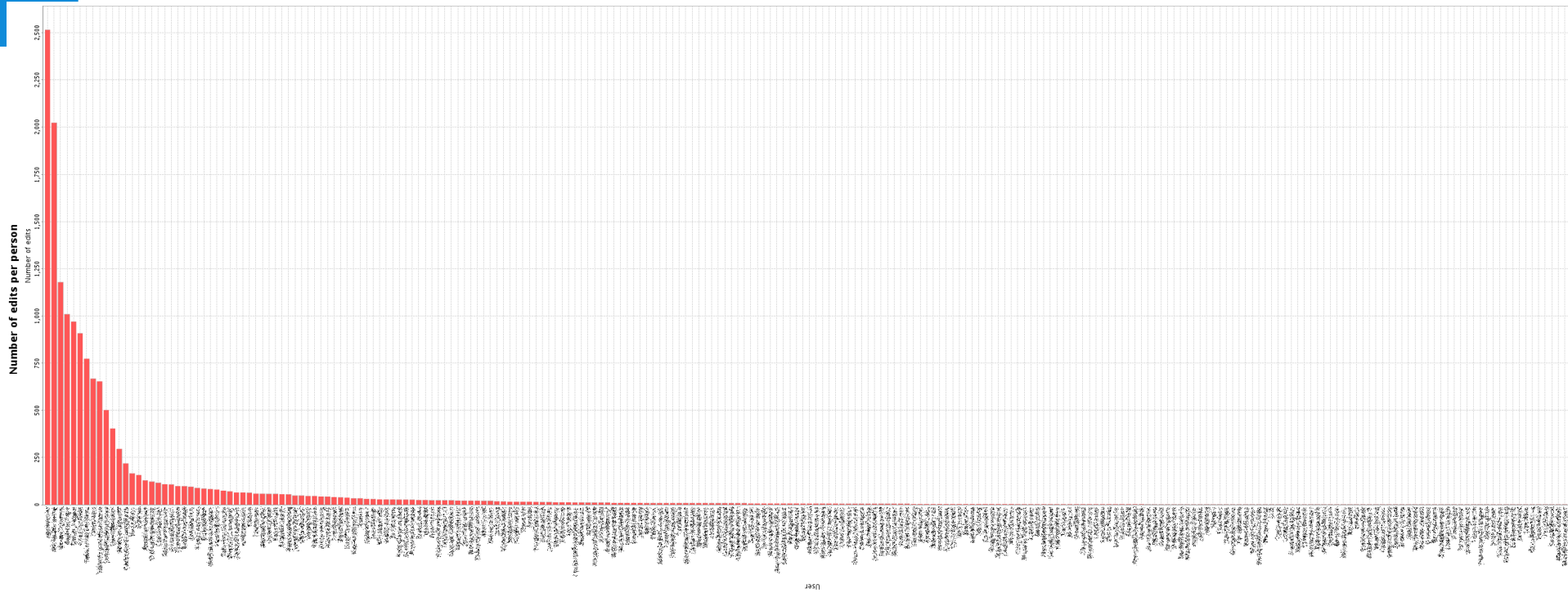
Scale invariance in biological and social systems

- stockmarket fluctuations
- social network activity
- inflating a degassed lung is characterized by a cascade of avalanches, as the airways successively open, and that distribution functions characterizing this cascade are scale invariant.
  the sequence of interbeat intervals is characterized by scale-invariant correlations in health, but not in disease.
  the foraging behaviour of the wandering albatross is governed by a scale-invariant Levy distribution
  so are on urban growth patterns and trading networks

Power laws

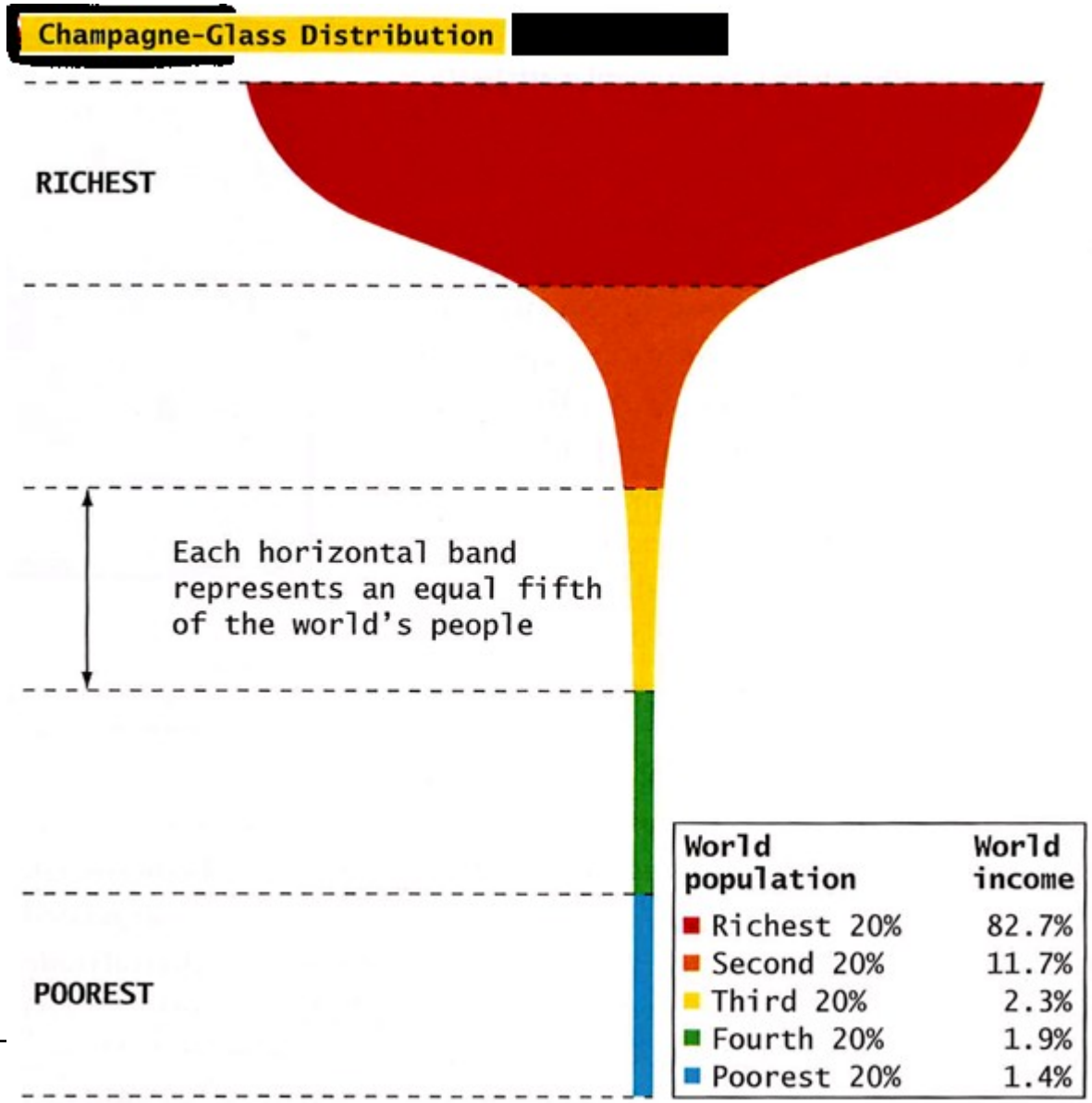
- Power law functions are a commonly observed scale-invariance
- $f(x) = ax^k + o(x^k),$
- Also known as
  - the 80/20 rule
  - Long/fat tail

In social systems – wiki edits



http://wiki.tudelft.nl/bin/view/Research/UsersReadAndWriteFrequencyBot

Income distribution



Conley, D. (2008) You may ask yourself: An introduction to thinking like a sociologist. New York: W.W. Norton and Company. p.392.