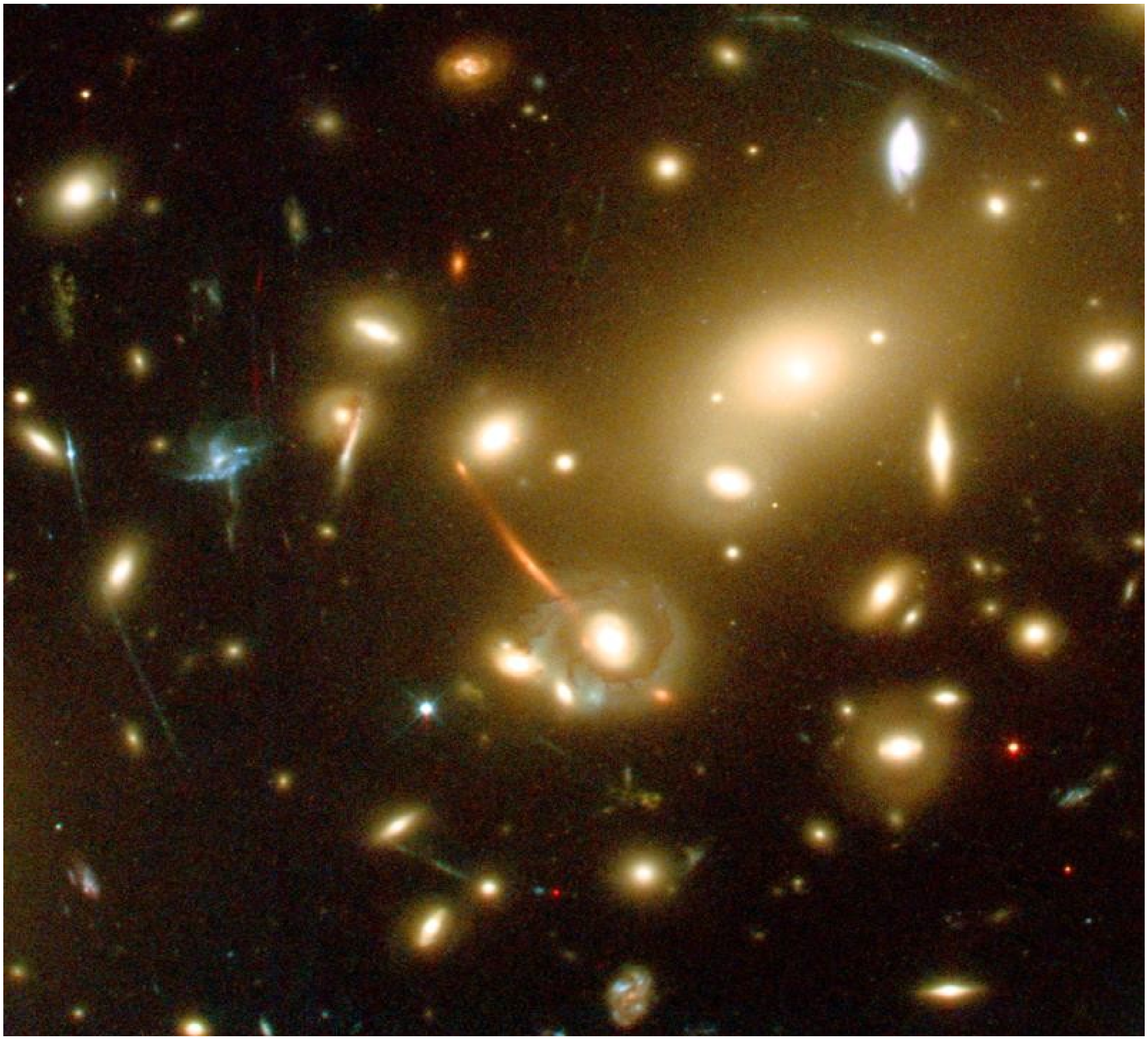
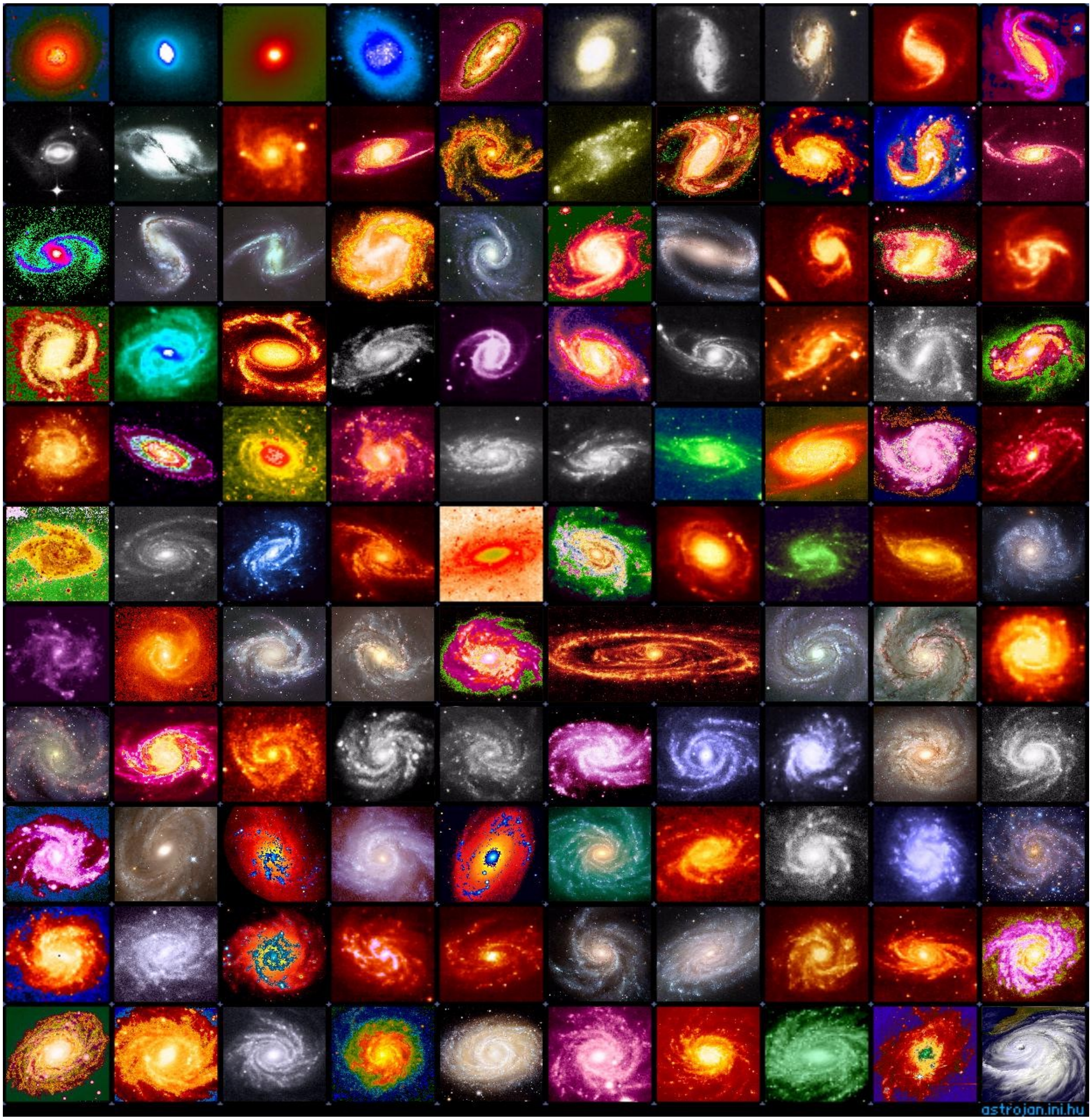
Illustrated regularities of the Pareto-Zipf-Mandelbrot type
Data Source: Google Images

Astrophysics, Nuclear networks

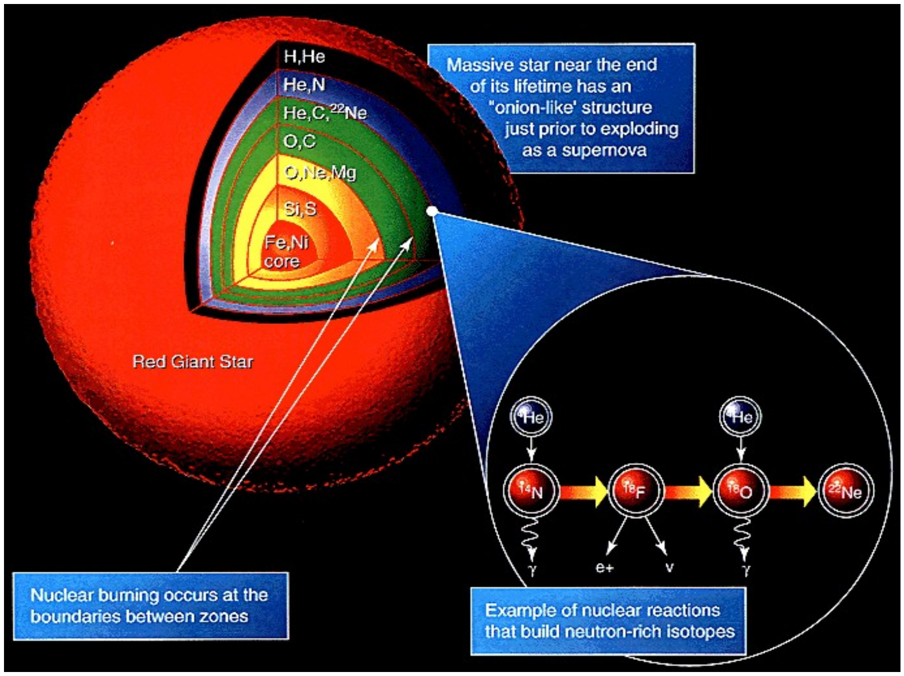


Universe network: PZM distribution of galaxy cluster size



Universe network: PZM distribution of galaxy sizes

Galaxy network: PZM distribution of star size



Massive star nuclear network : PZM distribution of chemical element frequencies from Hydrogen to Uranium

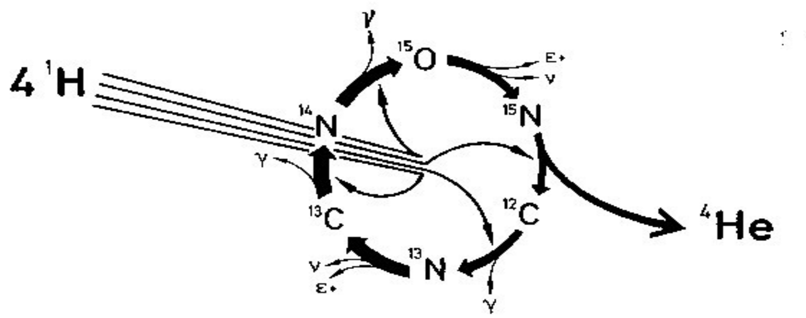
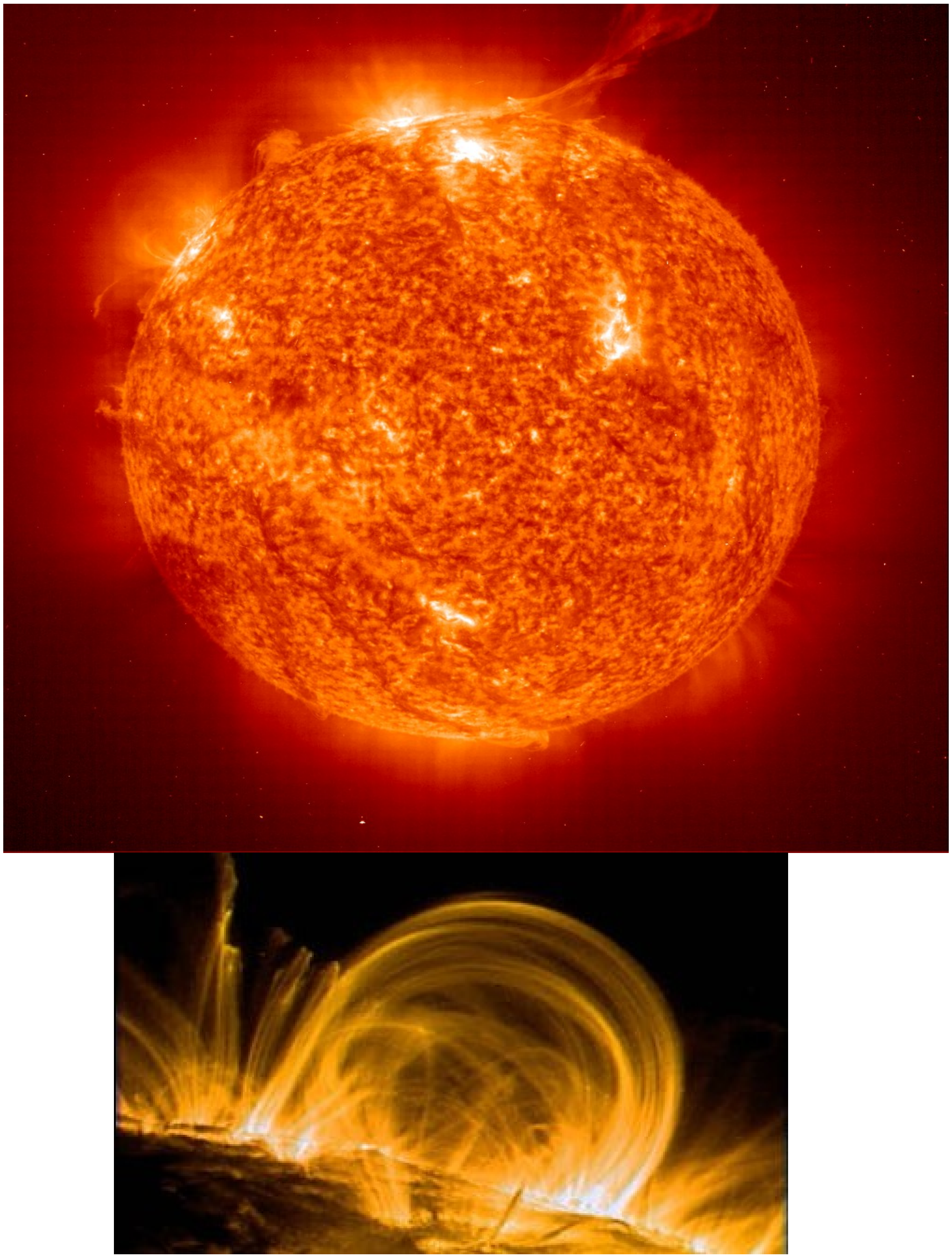
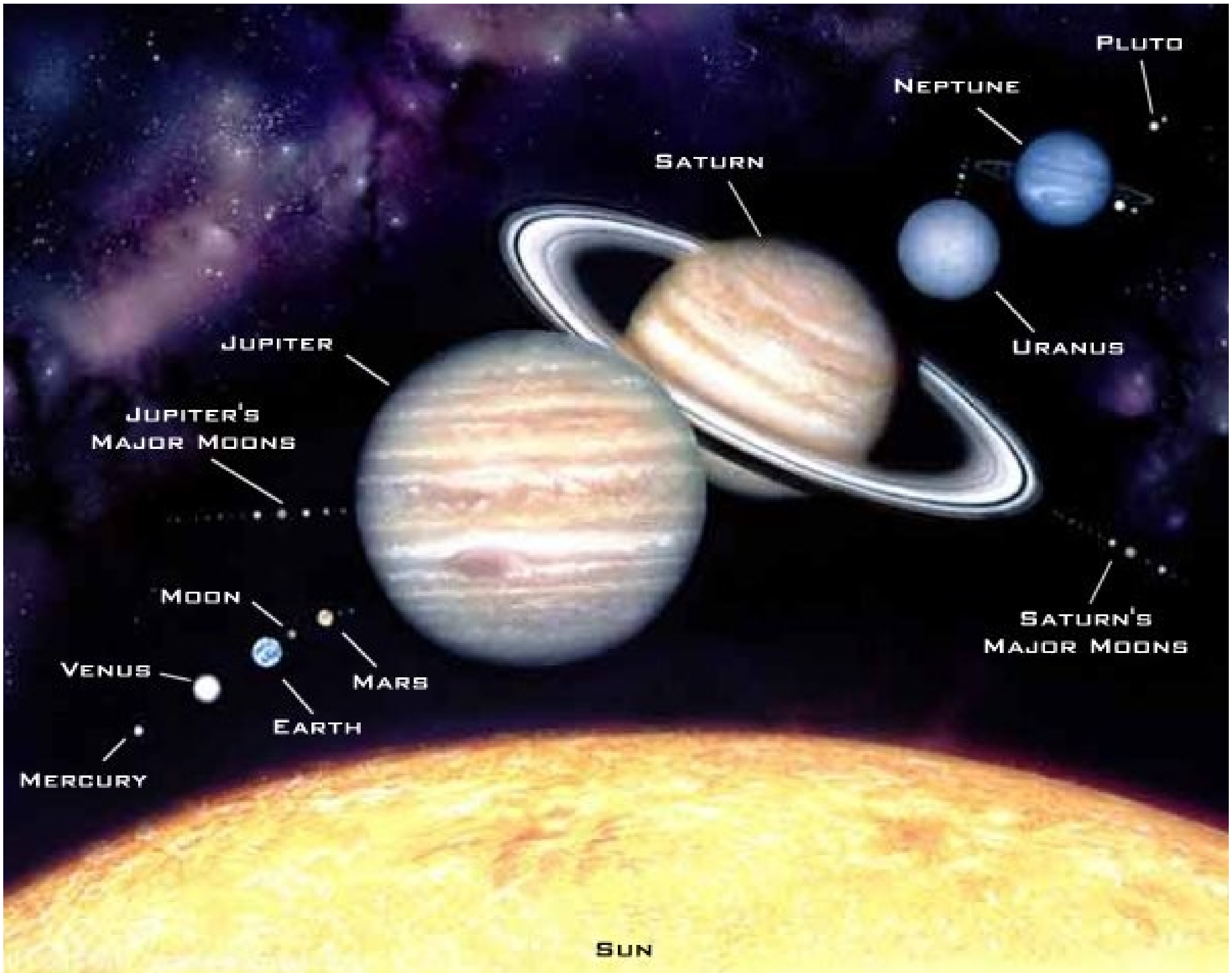


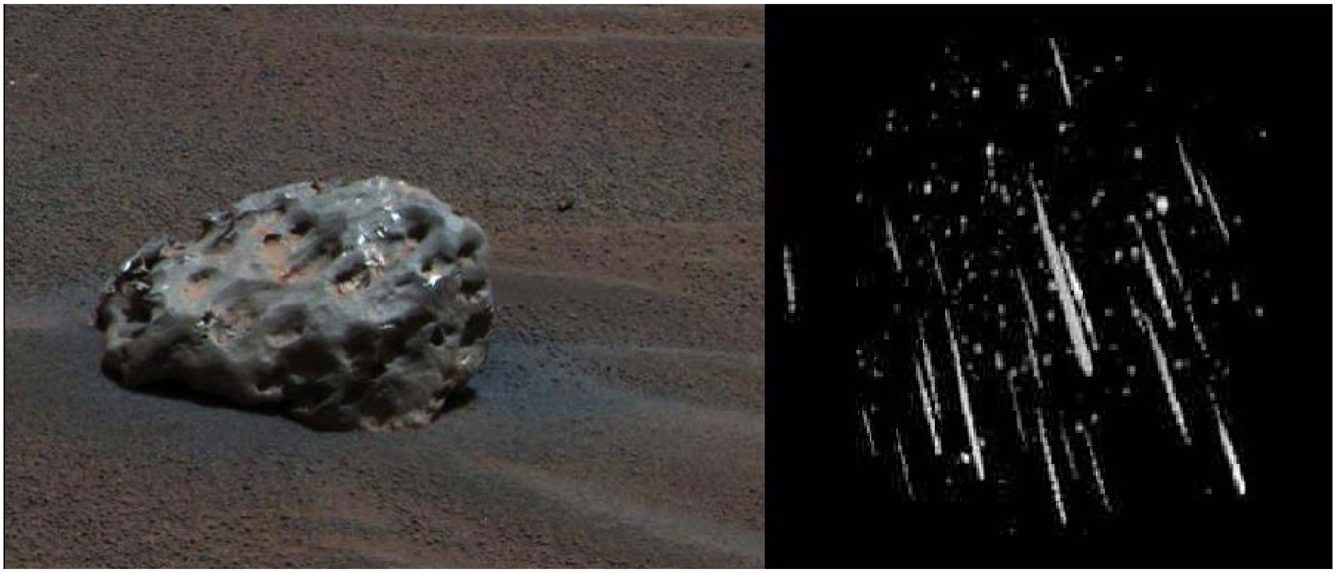
Fig. 2. *The carbon cycle,* proposed by Bethe and v. Weizsäcker, is responsible – at least in part – for the energy production of massive stars. The constituents: ^{12}C, ^{13}N, ^{13}C, ^{14}N, ^{15}O, and ^{15}N are steadily reconstituted by the cyclic reaction. The cyclic scheme as a whole represents a catalyst which converts four ^{1}H atoms to one ^{4}He atom, with the release of energy in the form of γ-quanta, positrons (ε^{+}) and neutrinos (ν).



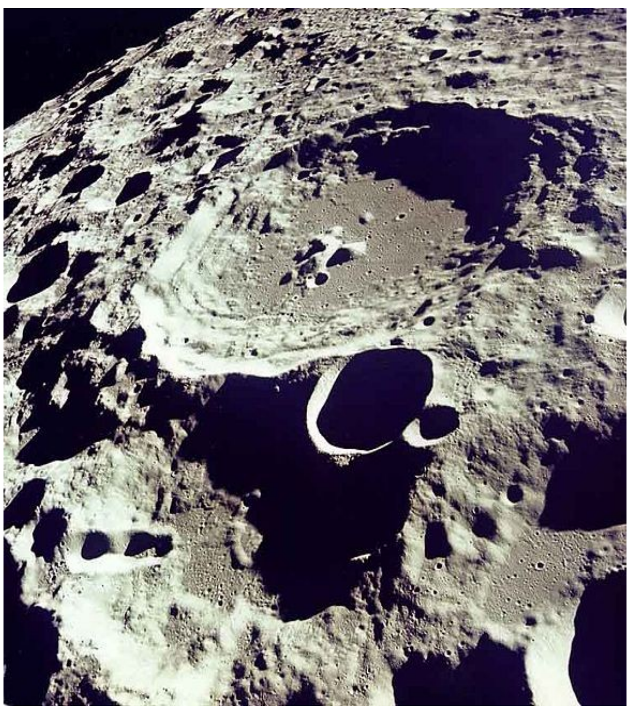
Sun network: solar flares reveal PZM distribution



Solar Planetary network: planet size, satellite of planet (moon) size distributions are of the PZM Pareto-Zipf-Mandelbrot type (parabolic fractal)

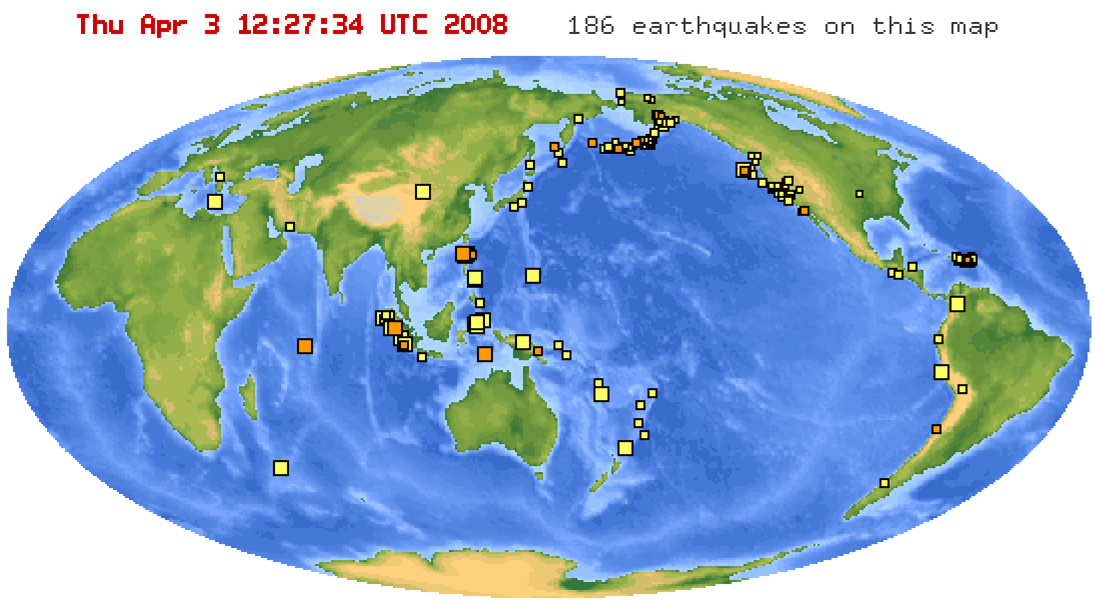


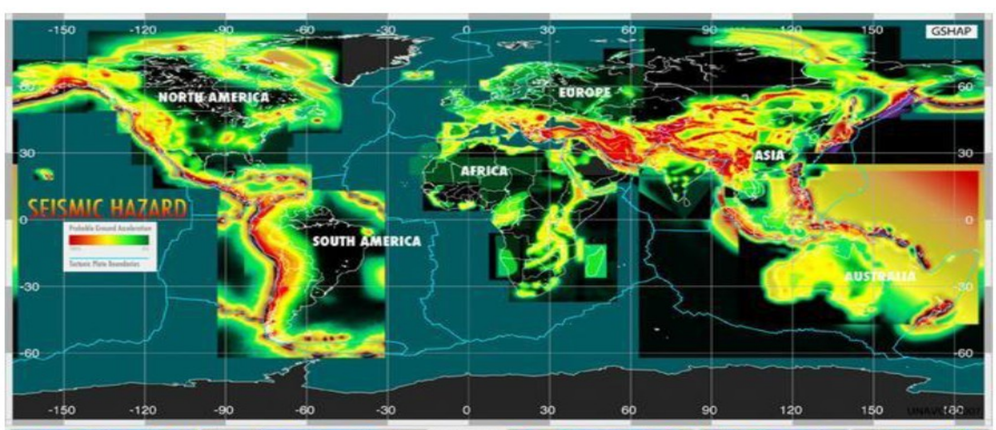
Satellite network: Meteorites show PZM distribution

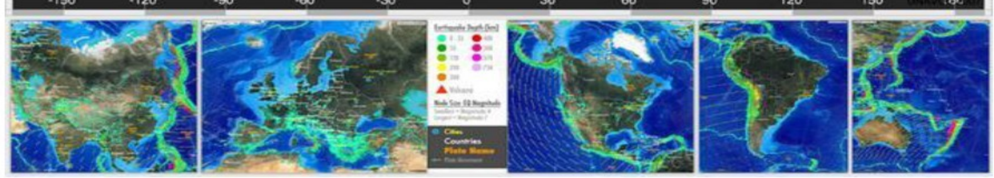


Moon surface network : craters reveal PZM distribution

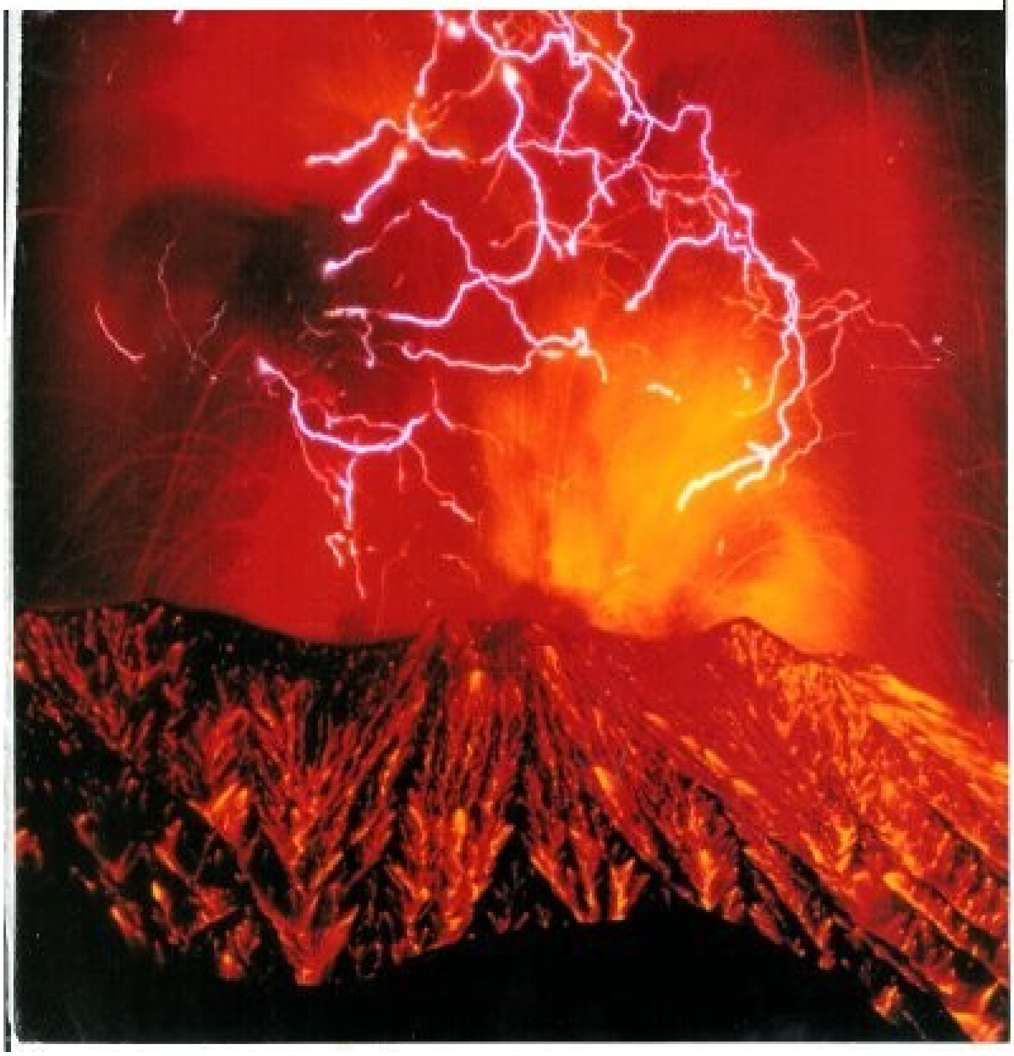
Geophysics (Gaia), Tectonic networks



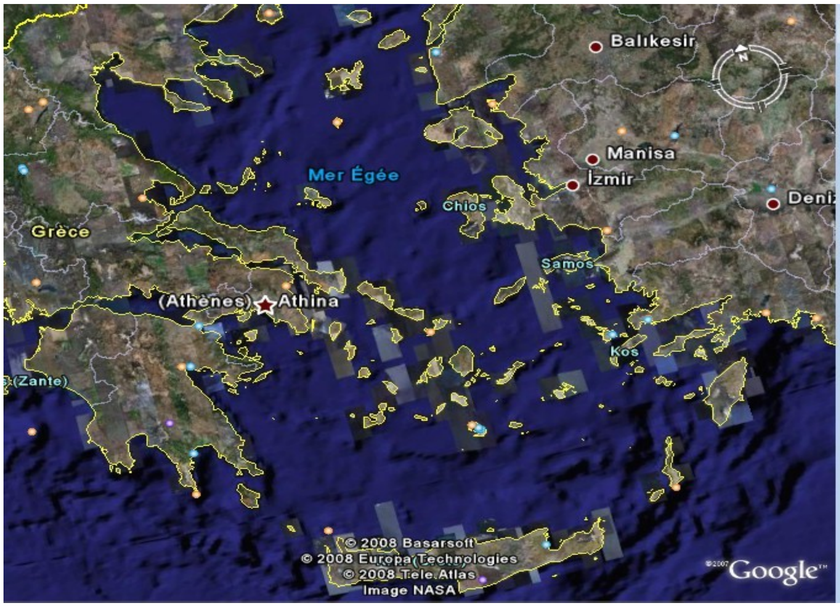




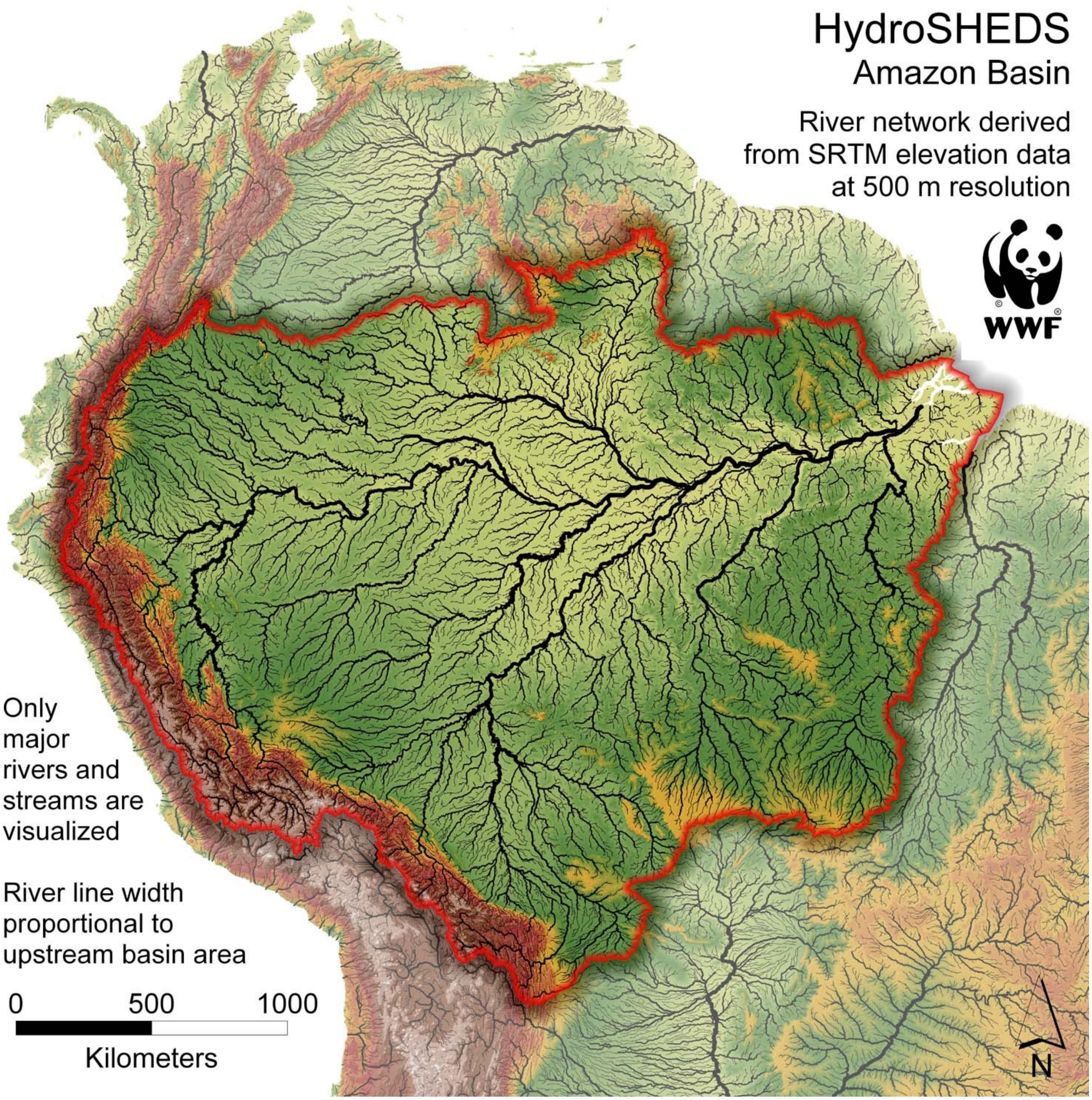
Tectonic Networks: PZM distributions of earthquake energy size are observed for all regions of the globe



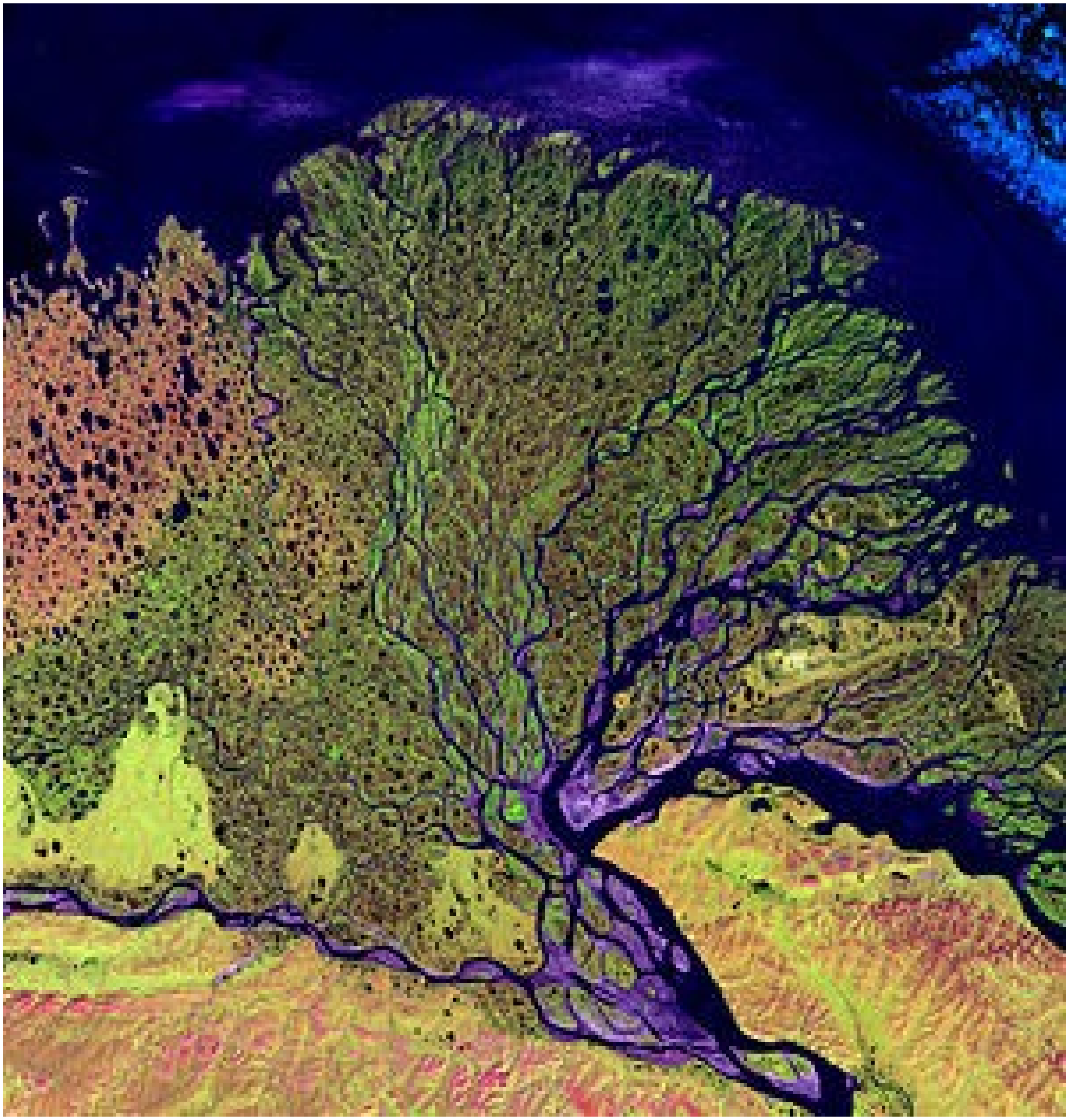
Geothermal network: volcanic eruption sizes show PZM distributions



Tectonic network: island size distributions are of the PZM type



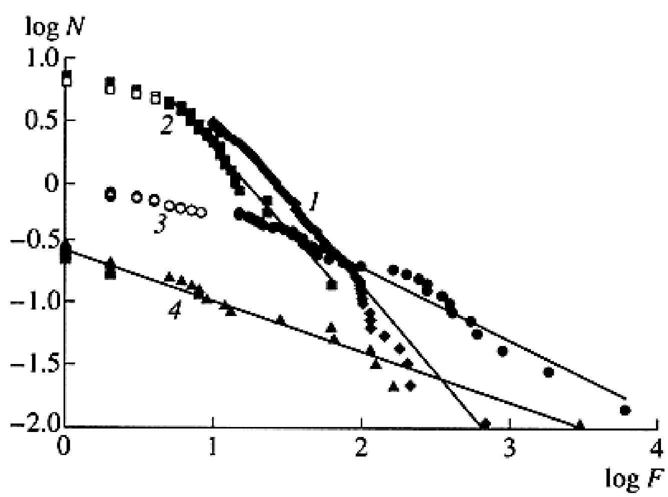
Water network: river size distributions are of the PZM type within a river basin



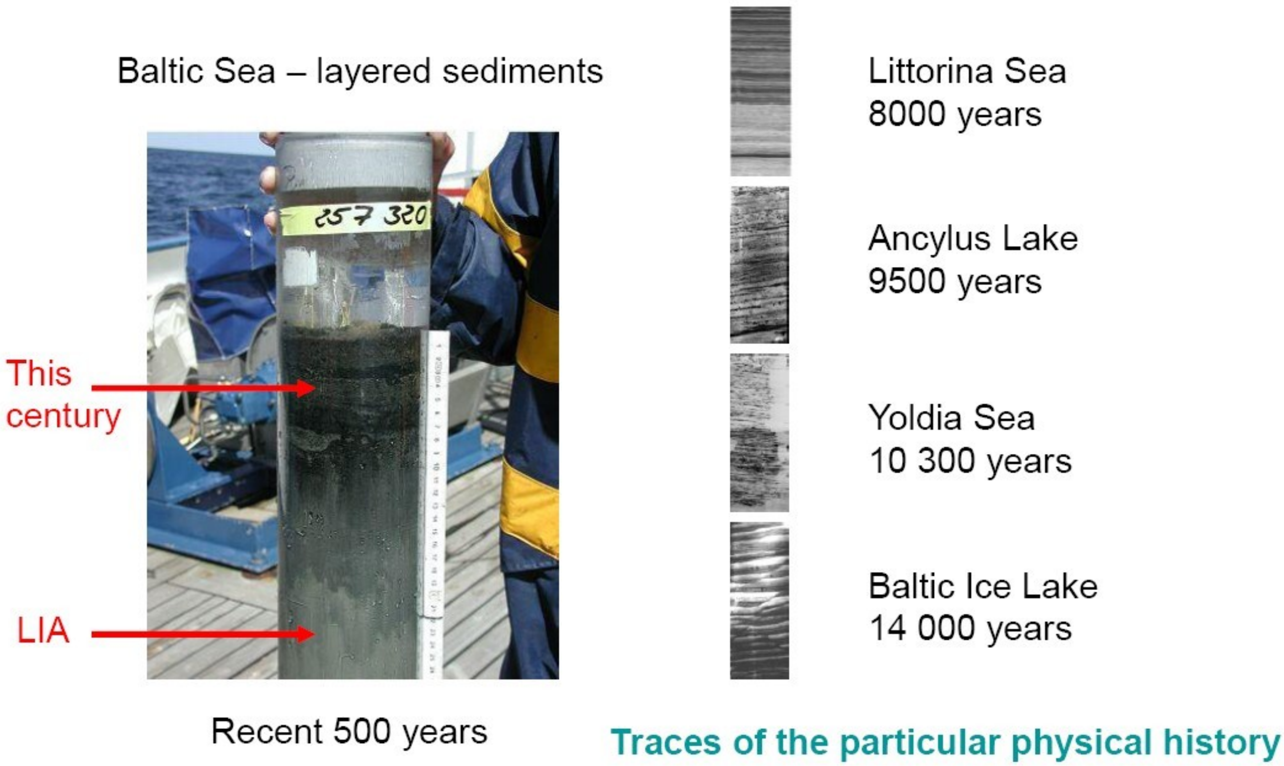
Water network: River Delta PZM distribution of river size

Water network: flood size and lake size distributions are of the PZM type

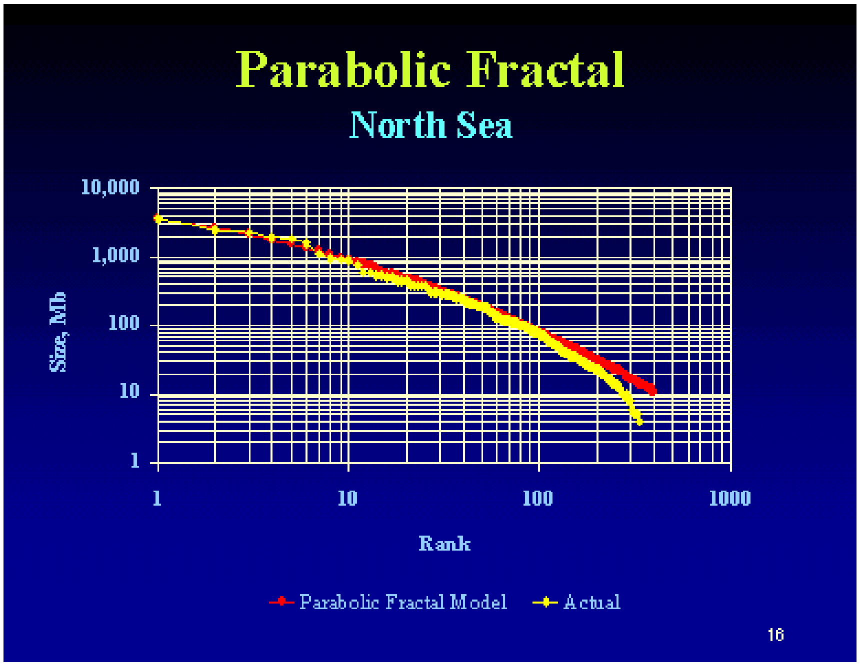
Atmosphere network: hurricane energy size distributions are of PZM type



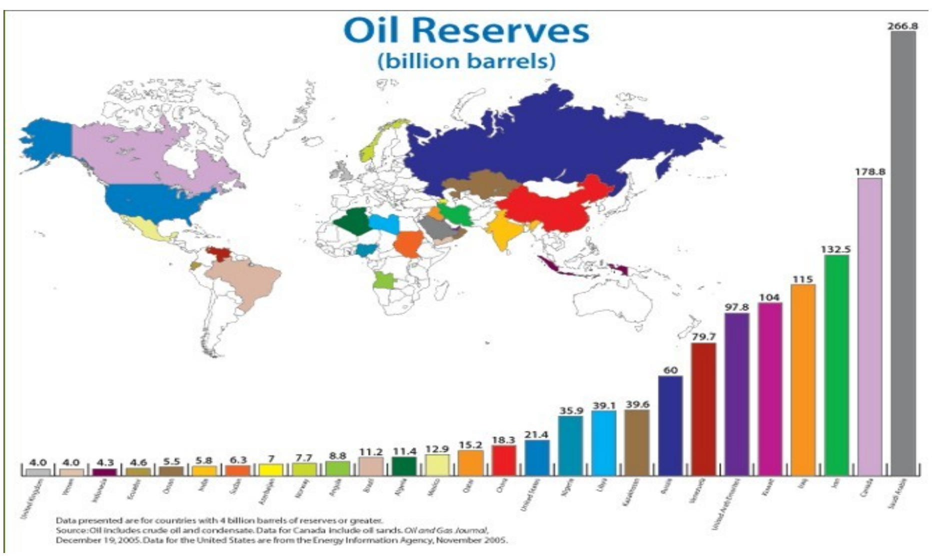
The fatality distribution of tornadoes (1), floods (2), hurricanes (3), earthquakes (4) in the 20th century in the United States show PZM regularity



Sediment network: cosmic and terrestrial dust size distributions are of the PZM type



Energy network: field size distributions of oil reserves (geologically transformed vegetation networks) are of PZM type



Prebiotic chemical networks (Hypercycles)

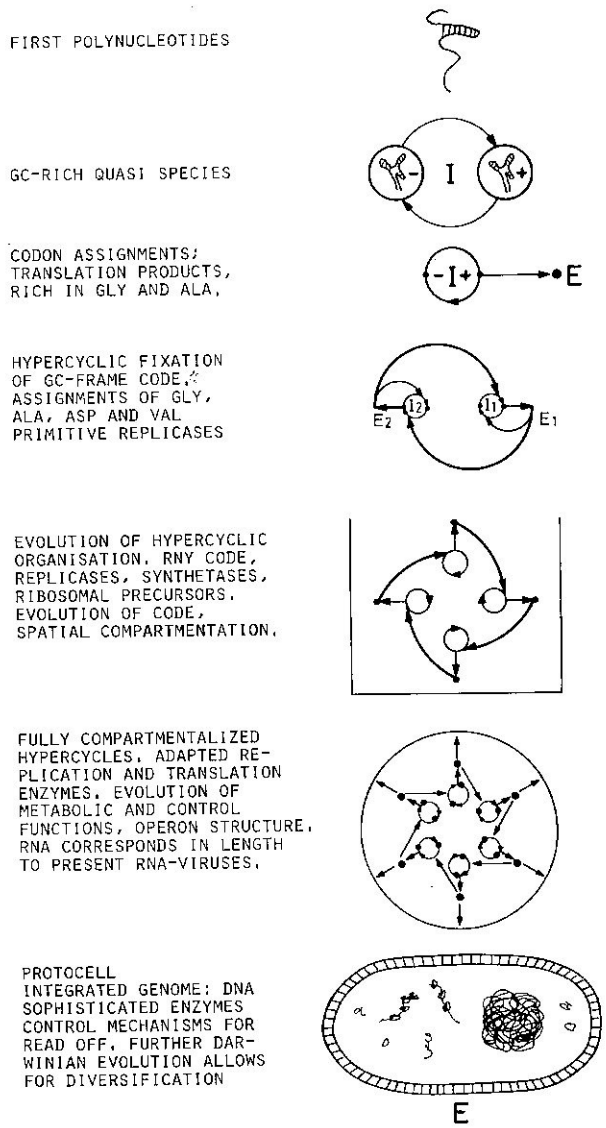
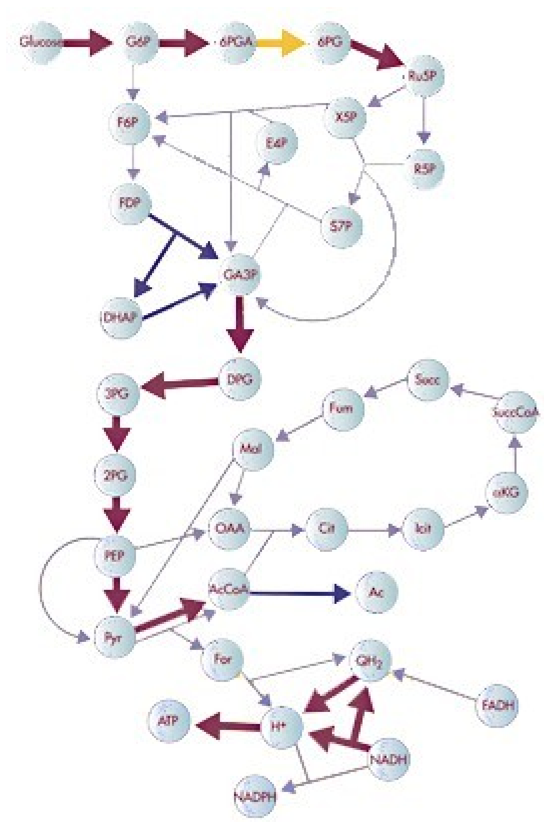


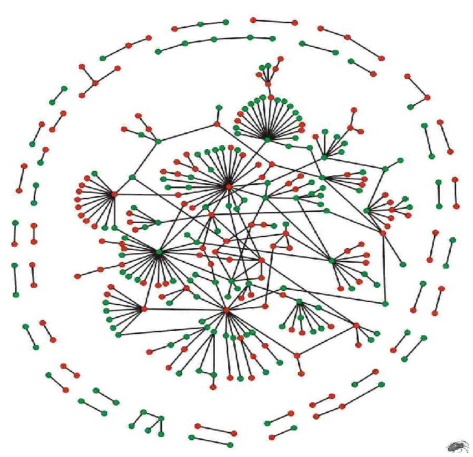
Fig. 63. Hypothetical scheme of evolution from single macromolecules to integrated cell structures

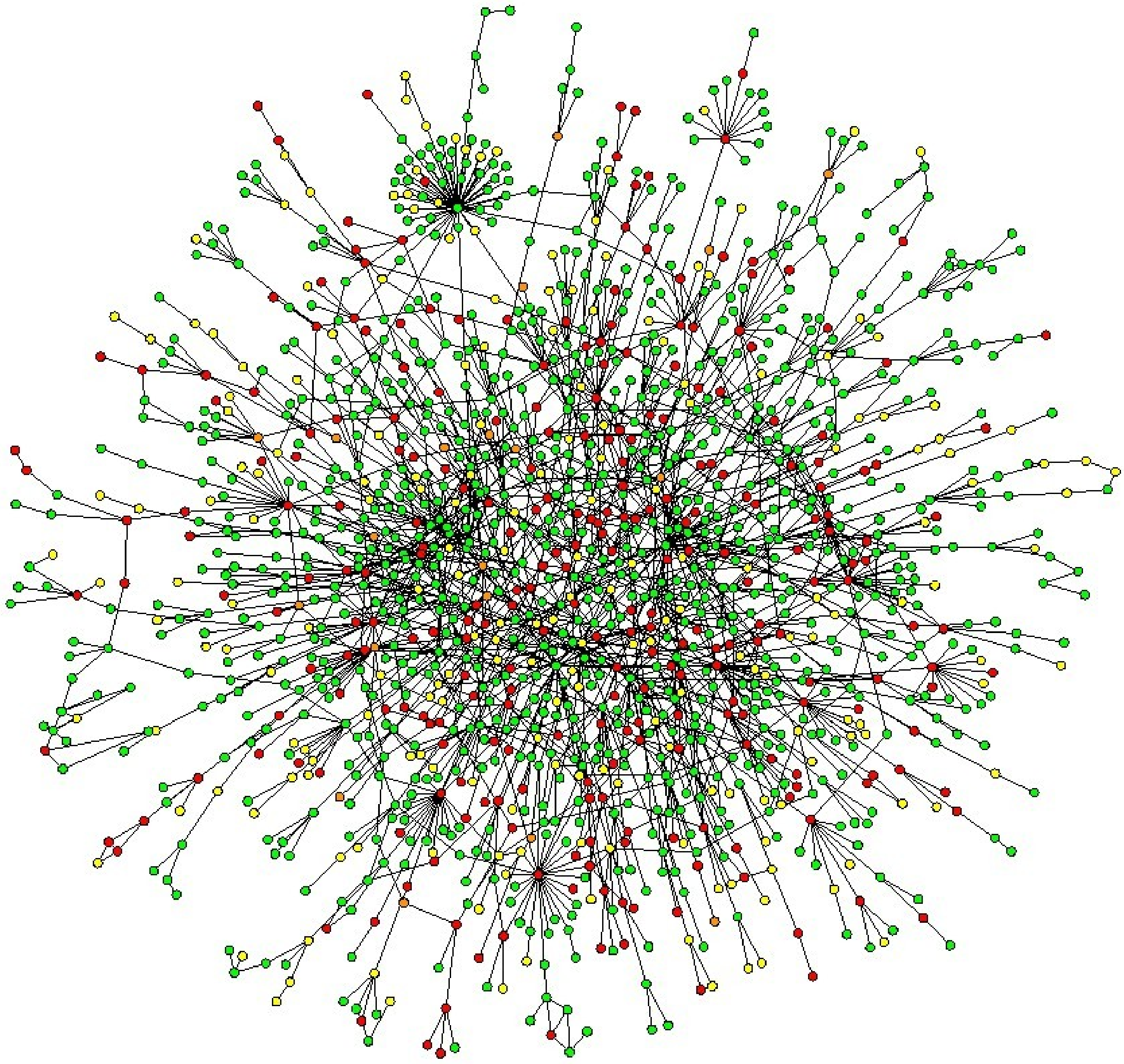
Chemical network: compounds of hypercycles show PZM distribution

<u>Biophysics, Biochemistry : protein and metabolic networks</u>



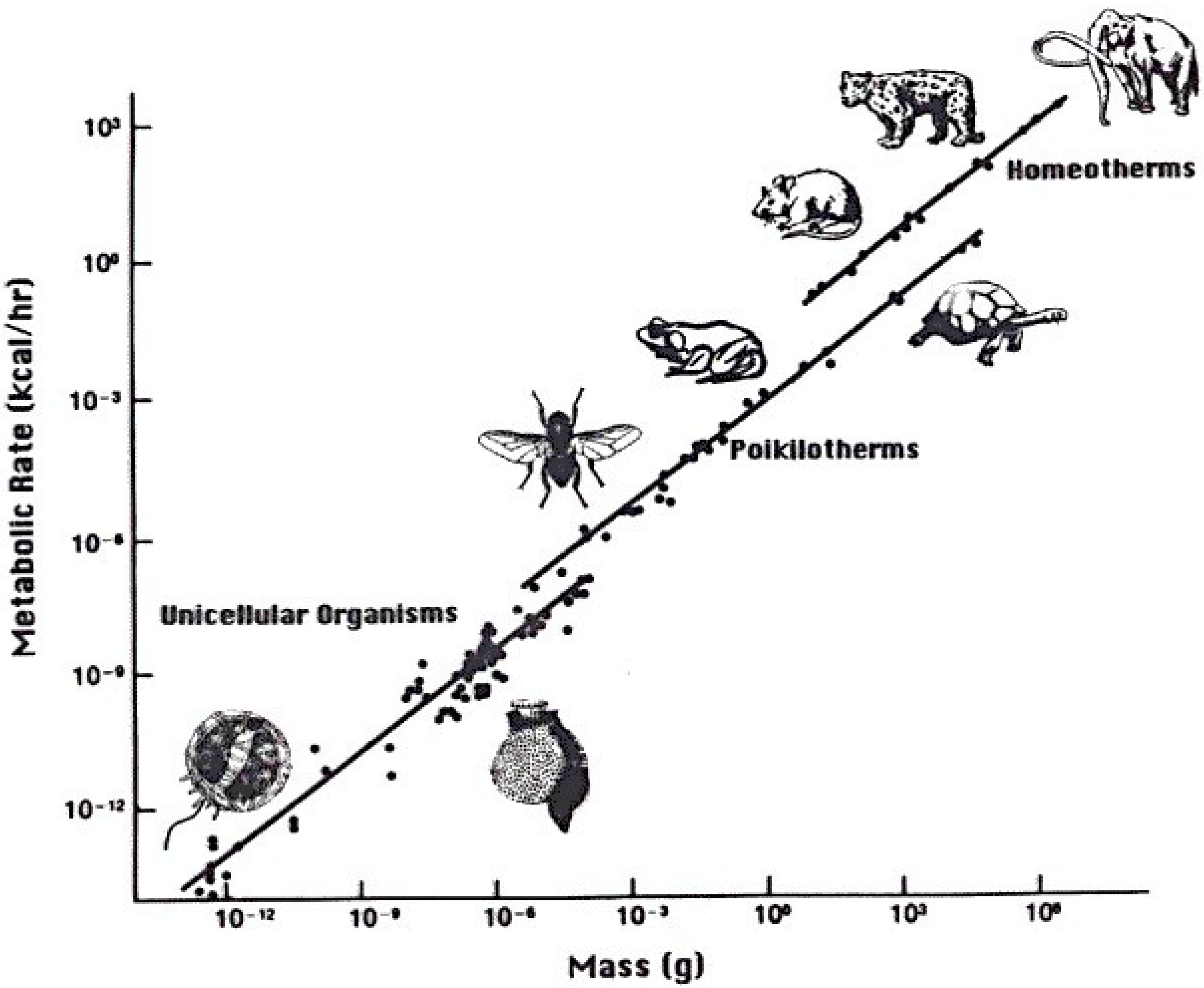
Metabolic network: the degree distribution of E. coli metabolic network is of PZM type





The yeast protein interaction network has a scalefree topology (PZM distribution) The scale-free nature of protein interaction networks is supposed to be a generic feature of all organisms.

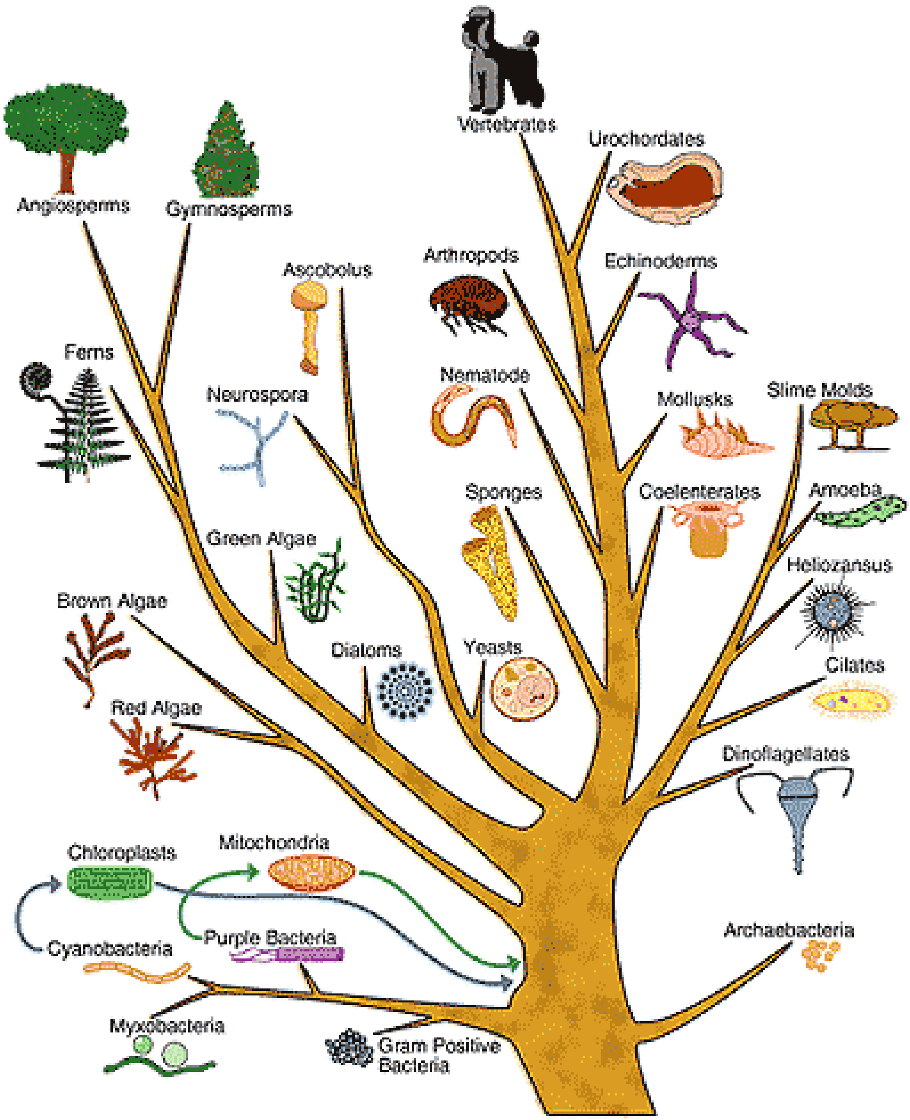
HEMMINGSEN ~1950'S



Allometric scaling of metabolic rate for a selection of homeotherms (birds and mammals), poikilotherms (fish, reptiles, amphibians, and invertebrates), and unicellular organisms. The solid lines all have a slope of .75. Modified from Hemmingsen, 1960.

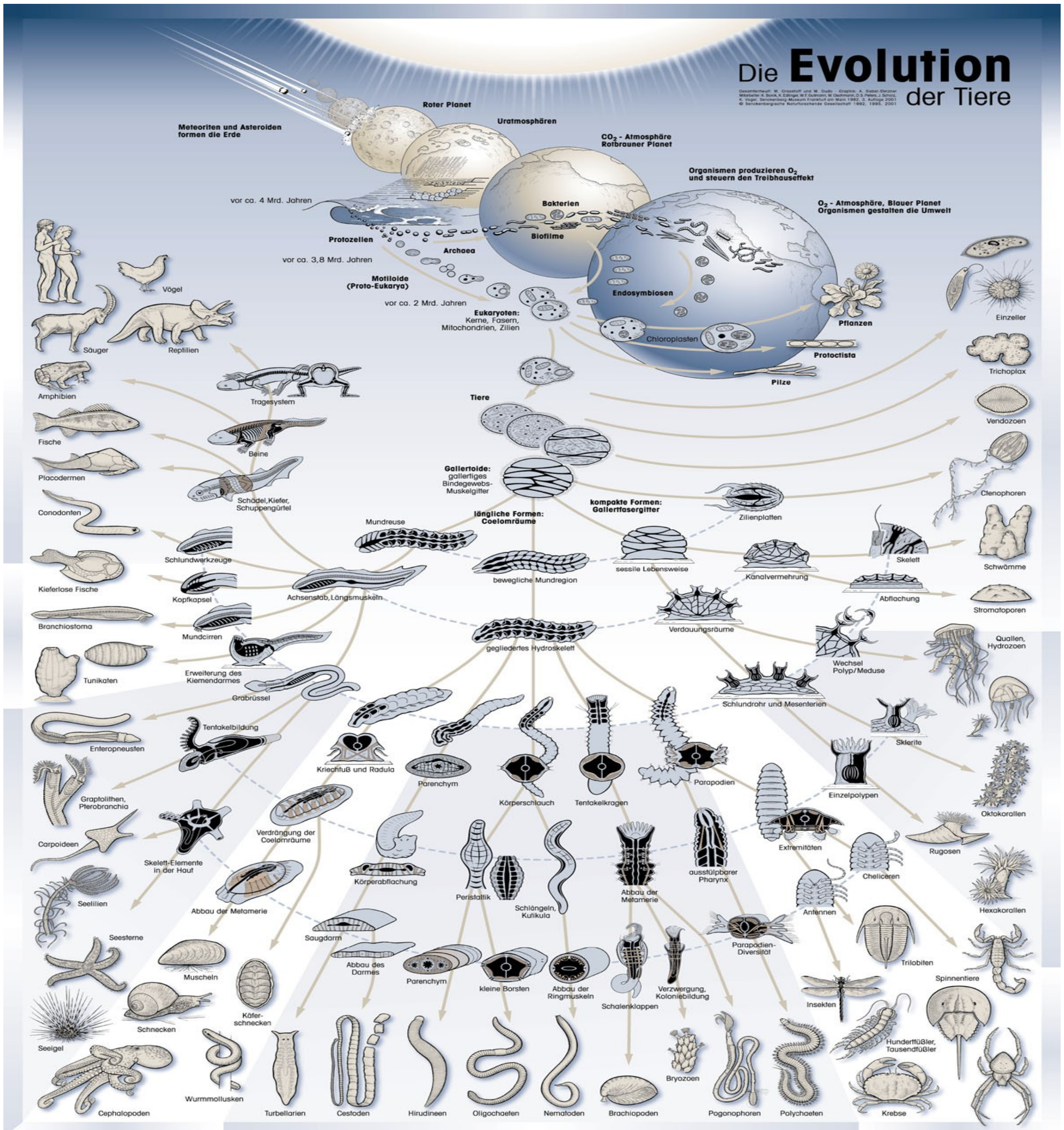
Biological energy transformation systems: the same scaling law is observed over 27 orders of magnitude

Biology Phylogeny: procariotes, eucariotes, genetic networks



Genetic network: ***population size distribution of species, species size distribution of genus, genera size distribution of biological family are of the PZM Pareto-Zipf-Mandelbrot type (hyperbolic fractal)***

"In terms of genetic evolution mankind is close to big apes, in terms of social evolution mankind is much closer to ants , termites and bees." Peter Winiwarter



PZM (Pareto-Zipf-Mandelbrot, parabolic fractal) distributions are observed for all species at <u>all times of biological evolution</u>

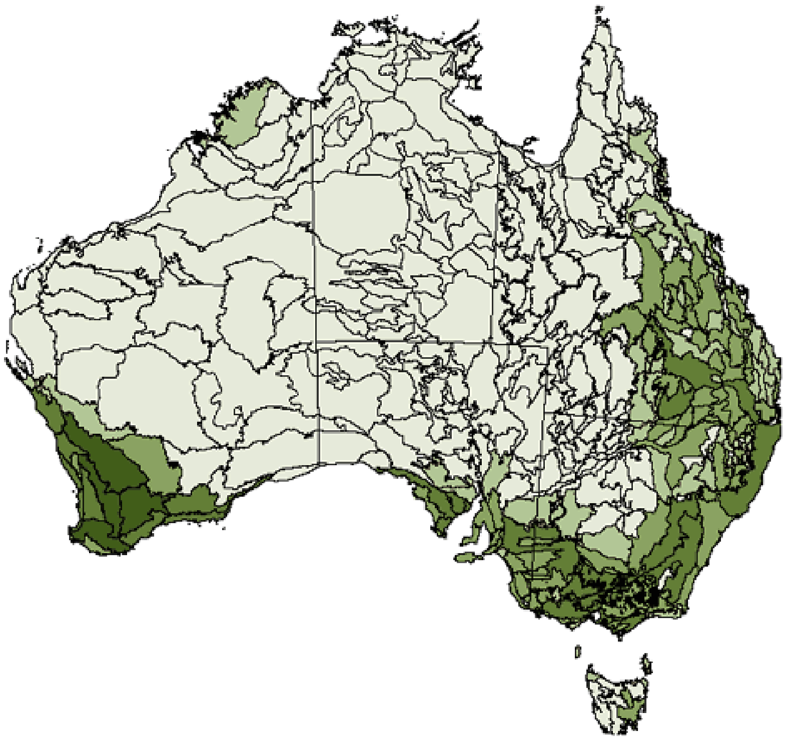
"its the same underlying computational algorithms which drive evolution. Mutations are not random, they are computed." Peter Winiwarter

Biology Ontogeny: trophic ecosystems, trophic networks

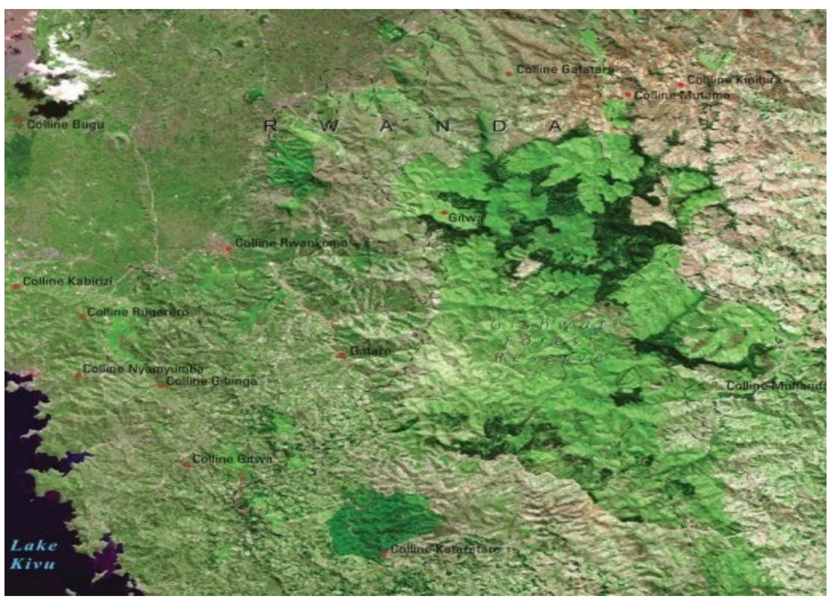
Forest network: branch size distributions, leave size distributions and the distribution of tree stem size are of PZM type

0 – 72
73 – 382
383 – 1814
1815 – 6171
6172 – 18 633

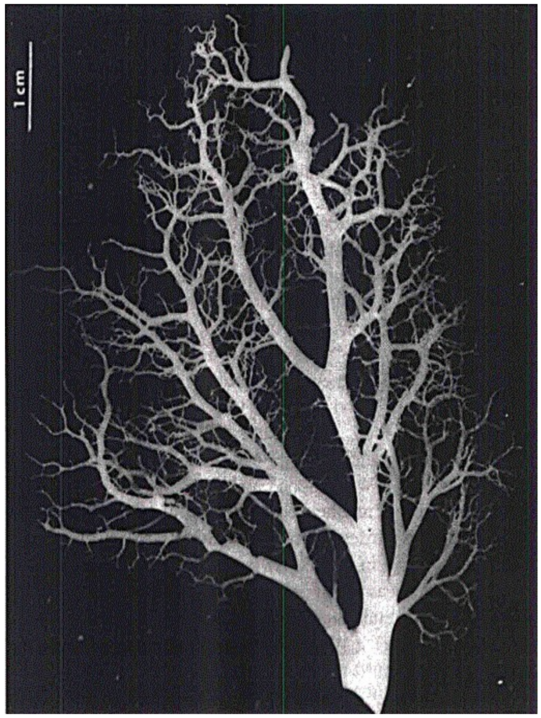
Source:
IBRA Subregions V. 5.1 Environment Australia 2001.
National Land and Water Resources Audit 2001.
Data used are assumed to be correct as received from the data suppliers.



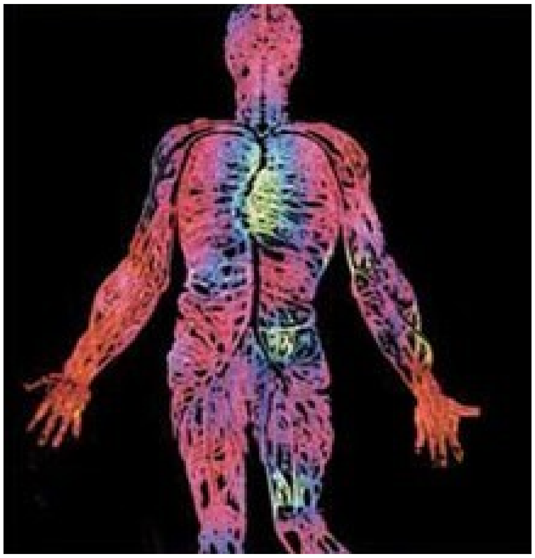
Solar energy transformation network: patches of vegetation size distribution are of the PZM type

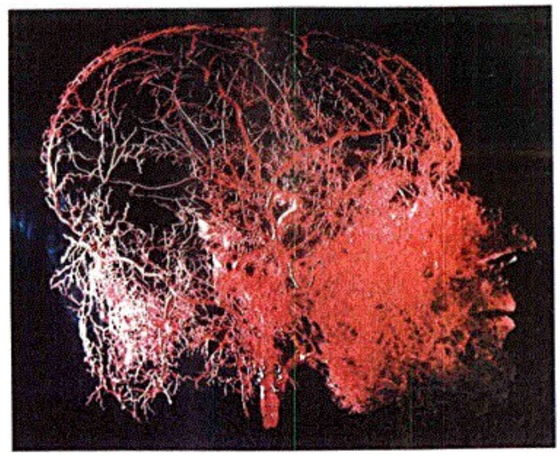


Forest network: distribution of areas burnt in forest fires are of the PZM Pareto-Zipf-Mandelbrot type (parabolic fractal)

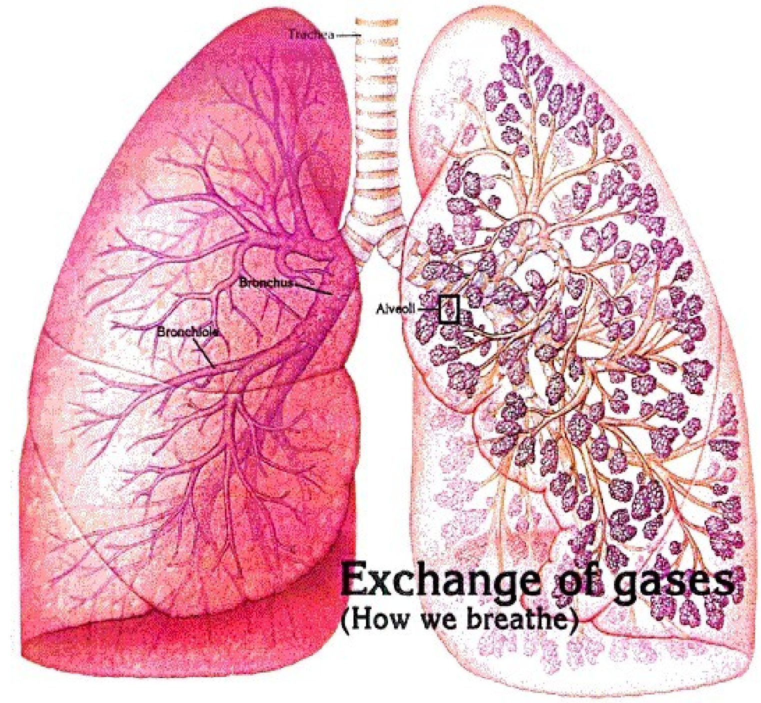


Blood vascular network: blood vessel shows PZM regularity

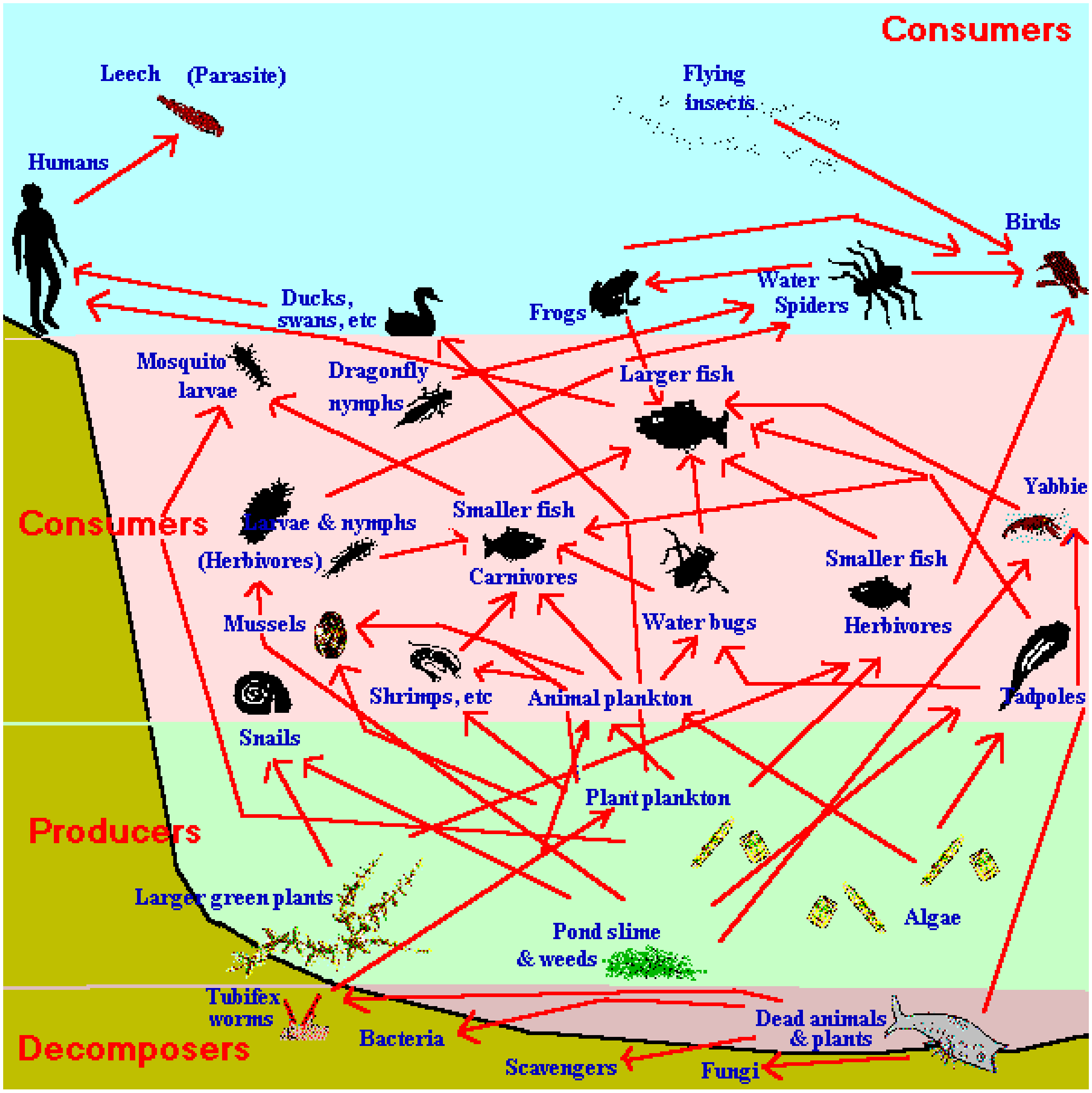




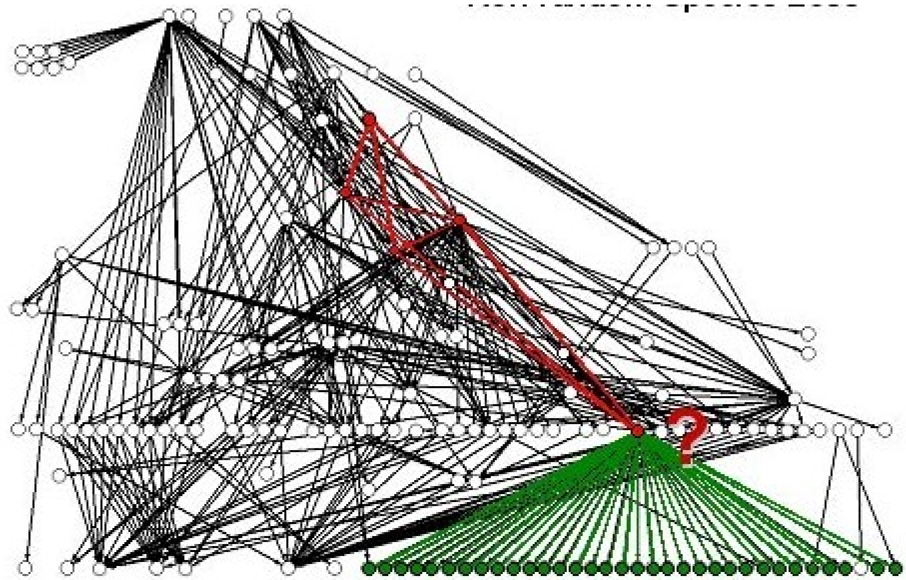
30.18 Blood vascular network in the human head
The human face, particularly the area around the lips, contains a dense array of capillaries.



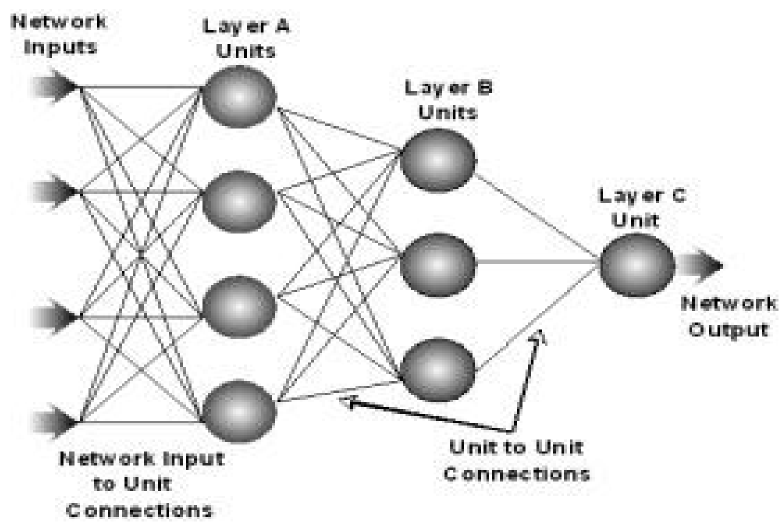
Metabolic network: the structure of the lung is fractal of th PZM type



Food web network:
biomass-size distribution of aquatic ecosystems (trophic web or foodweb) show PZM regularity



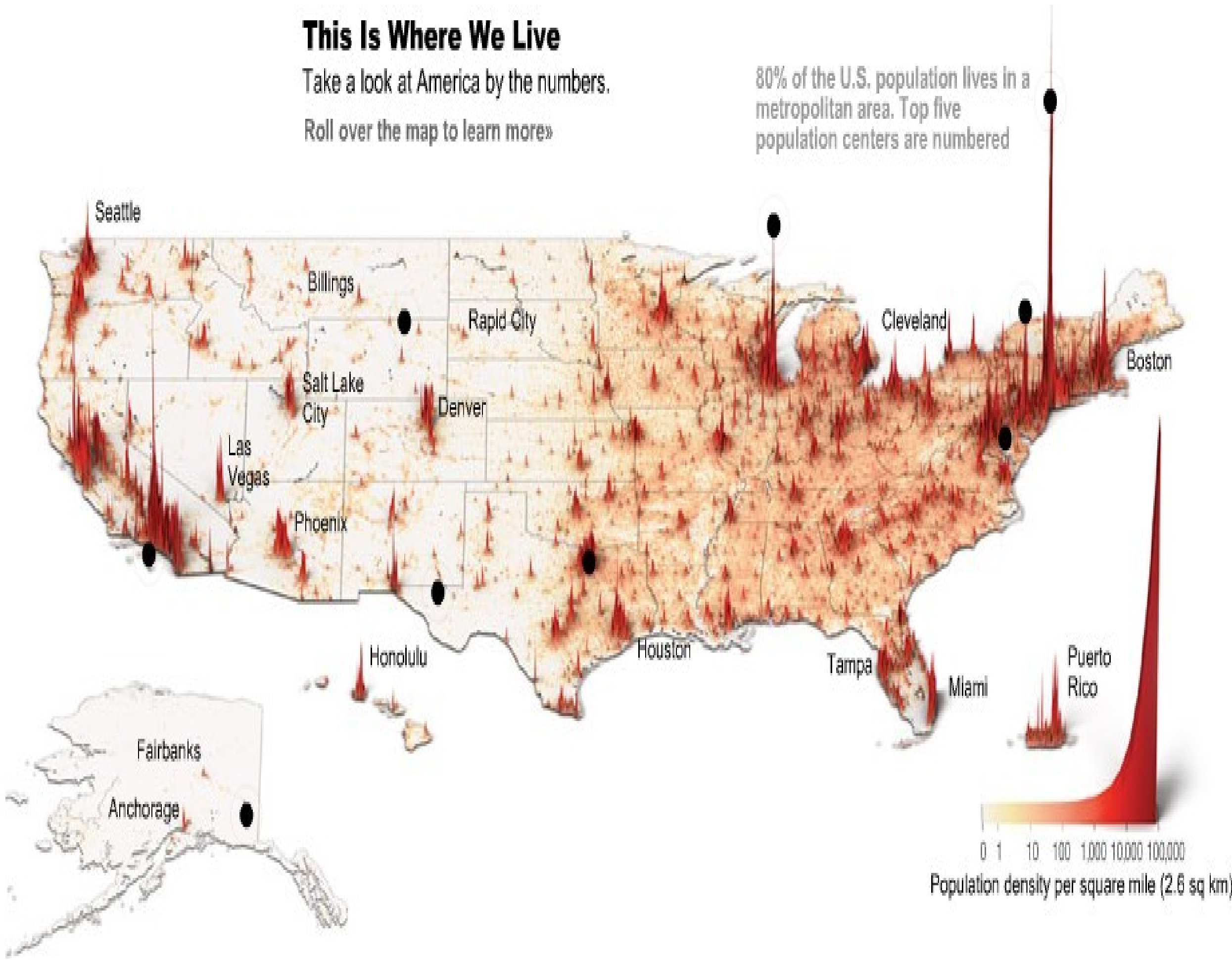
Winiwarter and Vidondo modelled the ecosystem evolution of the lake Constance by a neural network of the multilayer feed forward type with back-propagatio (multilayer perceptron)



Input layer: time series of daily solar energy input to the lake d, d-1,d-2, .. d-365

Output layer: a single constant, the slope of the PZM biomass size distribution at day d

Social networks: the small world of scalefree networks

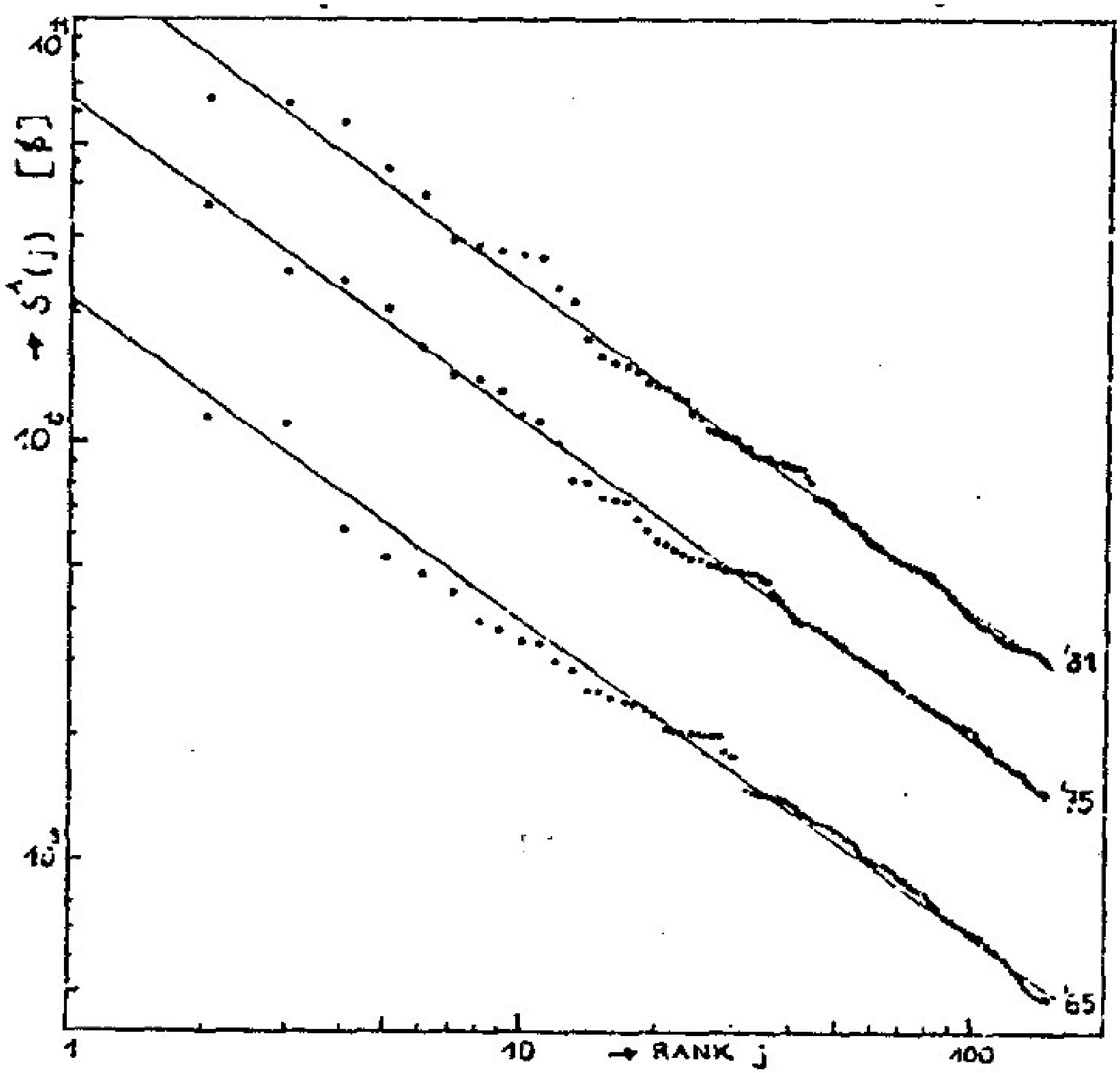


Population network: city size distributions of all countries follow a PZM regularity (rank size rule)

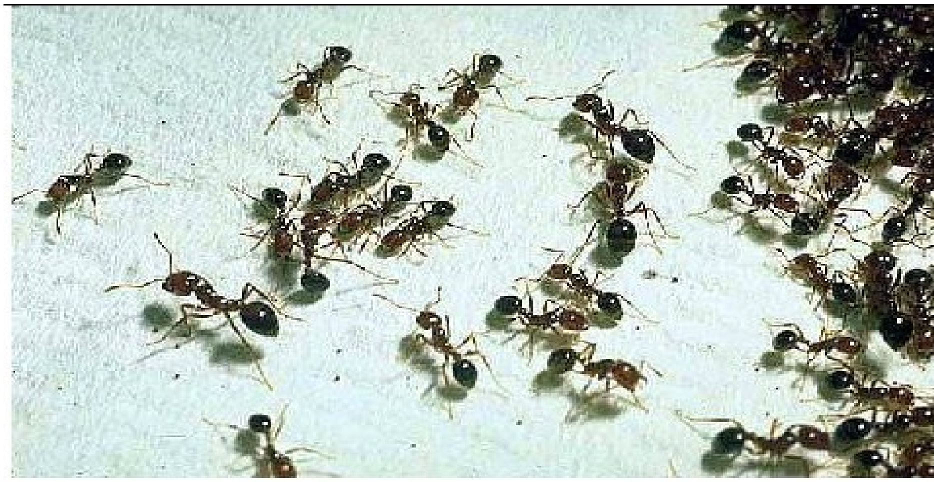
"The objective of social sciences does not consist any more in the reduction of complex to simple, but in the translation of complex into theory."
Peter Winiwarter

Network of personal wealth: the fortunes of individuals follow a PZM distribution

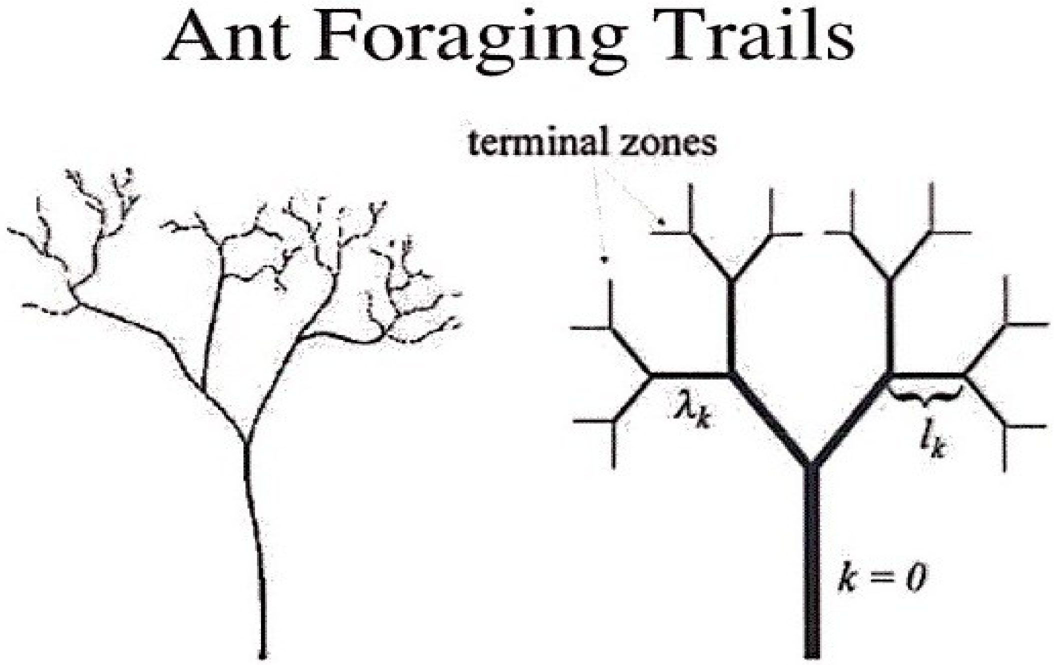
There are very few very rich, few rich, many small and and awful lot of poor



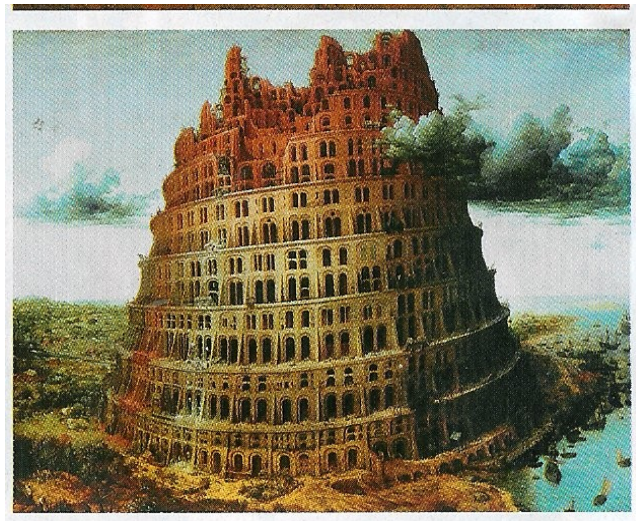
Network of business: the firm size distribution of the Fortune 500 follow a PZM regularity. Note that the slope of the diostribution is almost constant over time, only the size of the overall system grows (data from 1965, 1975 and 1981, the time of the study).



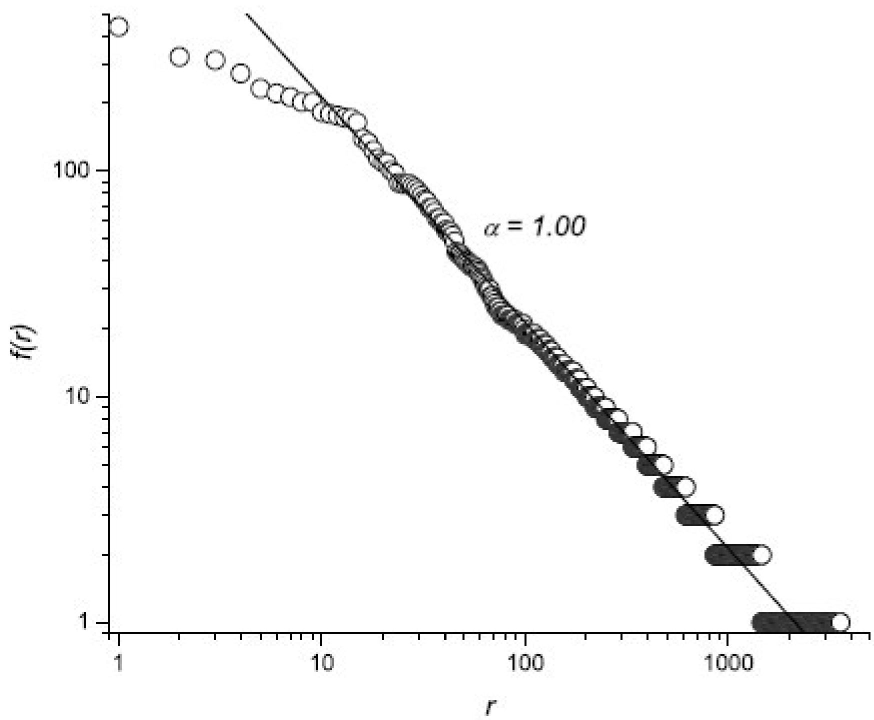
antswarm



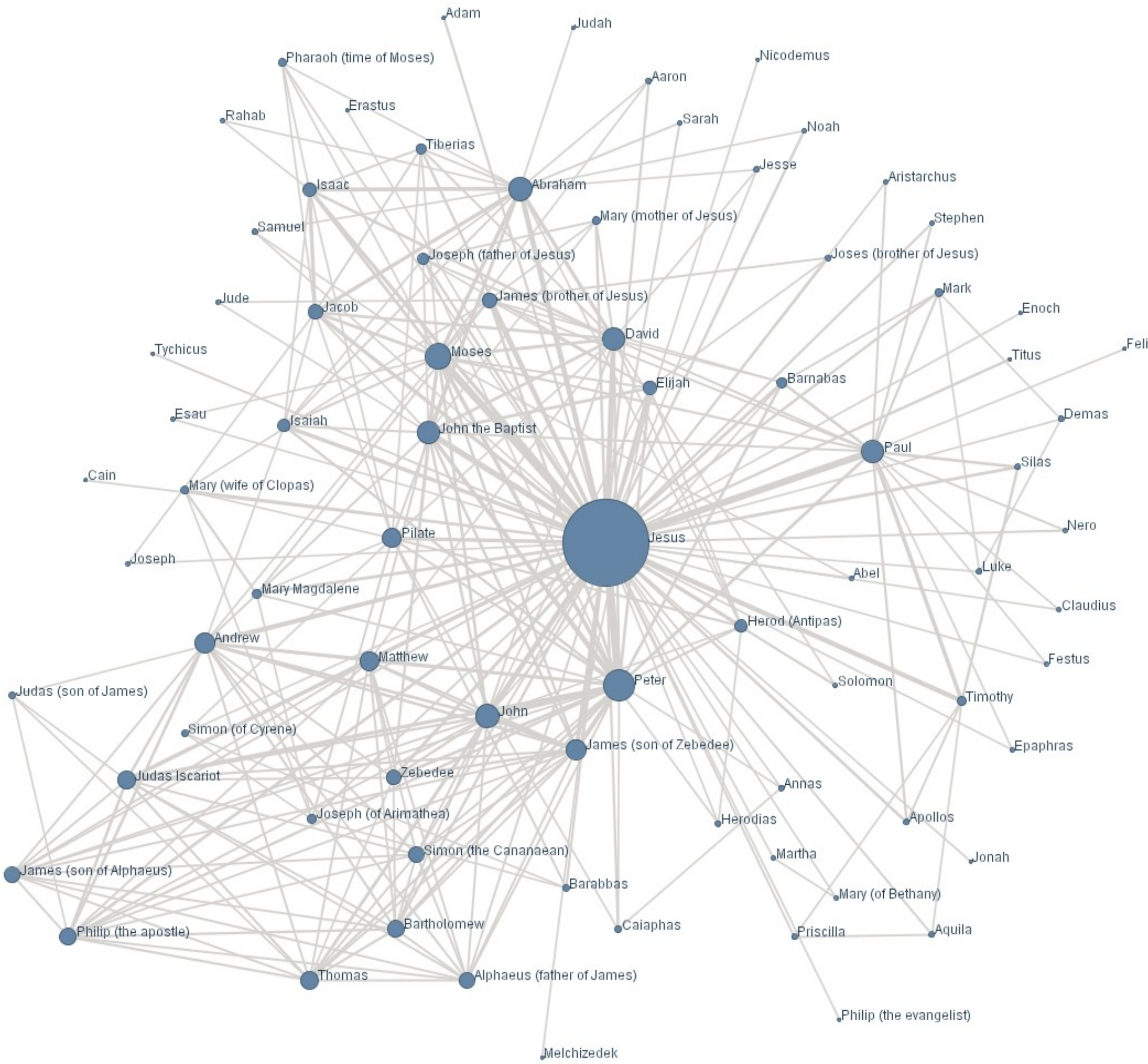
Social networks: ant foraging trails show a PZM regularity



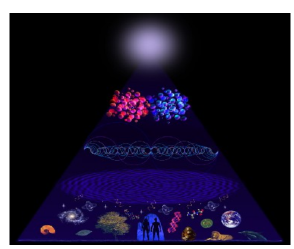
The network of language: all languages of the world and texts from all times follow a PZM regularity (Zipf's law)

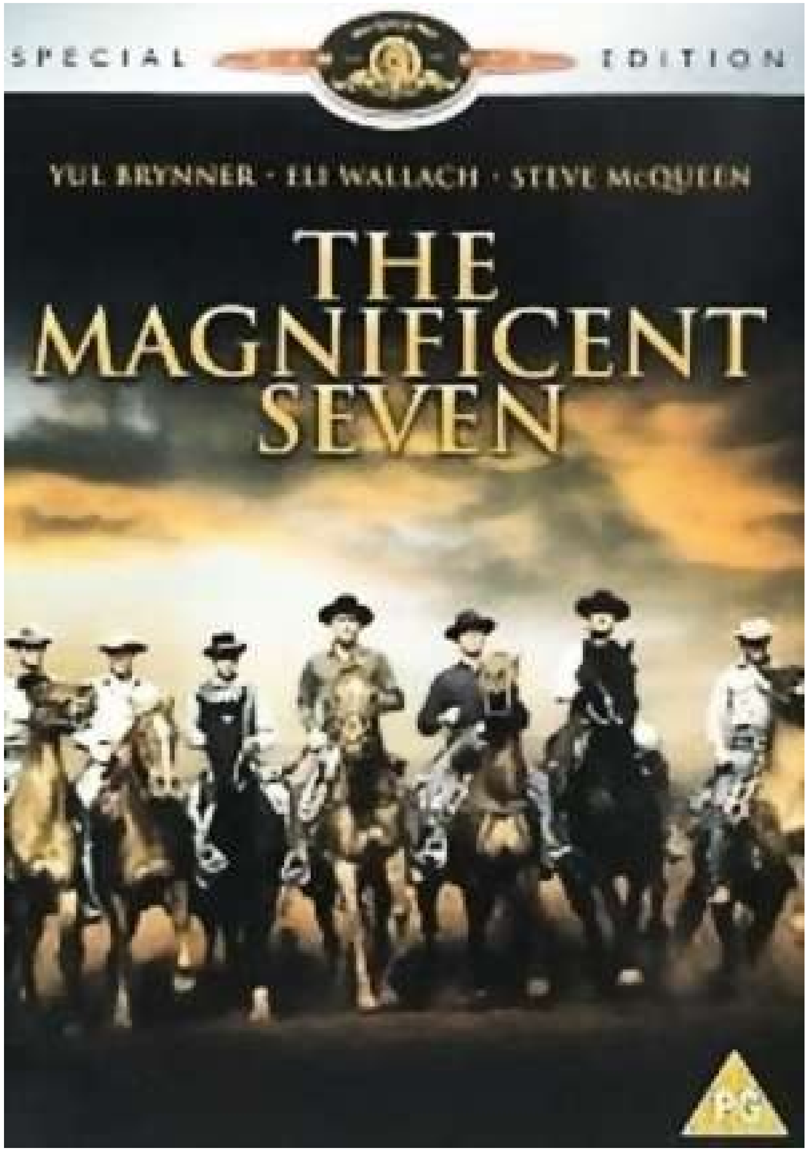


Genealogical networks: the degree distribution of genealogical networks are of the PZM type

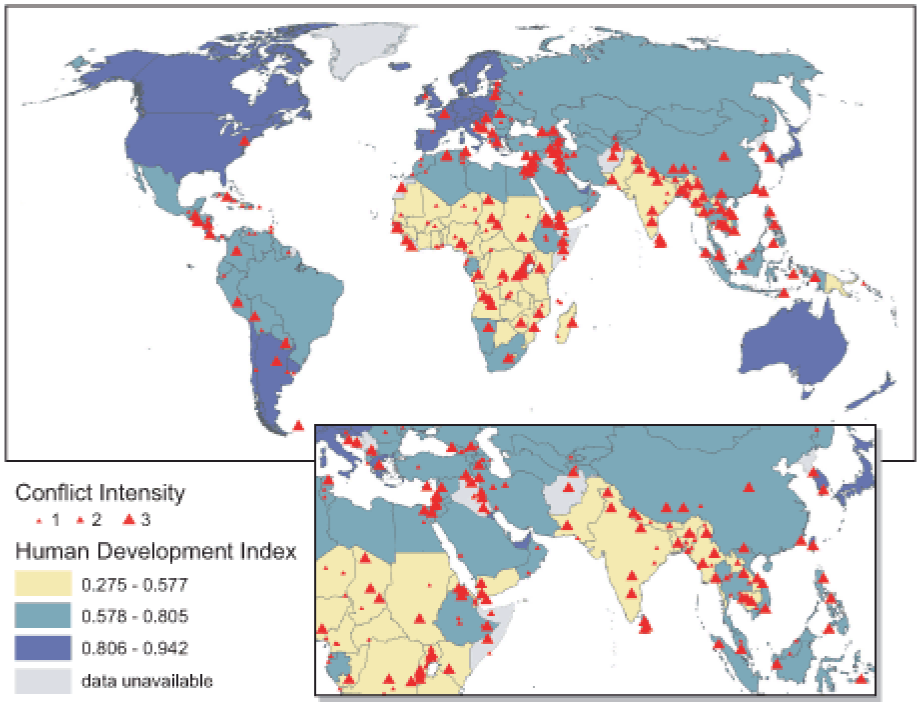


Mythology and Religion network: the network of figures in Greek and Roman mythology and in Christian religion reveal a degree distribution of PZM type





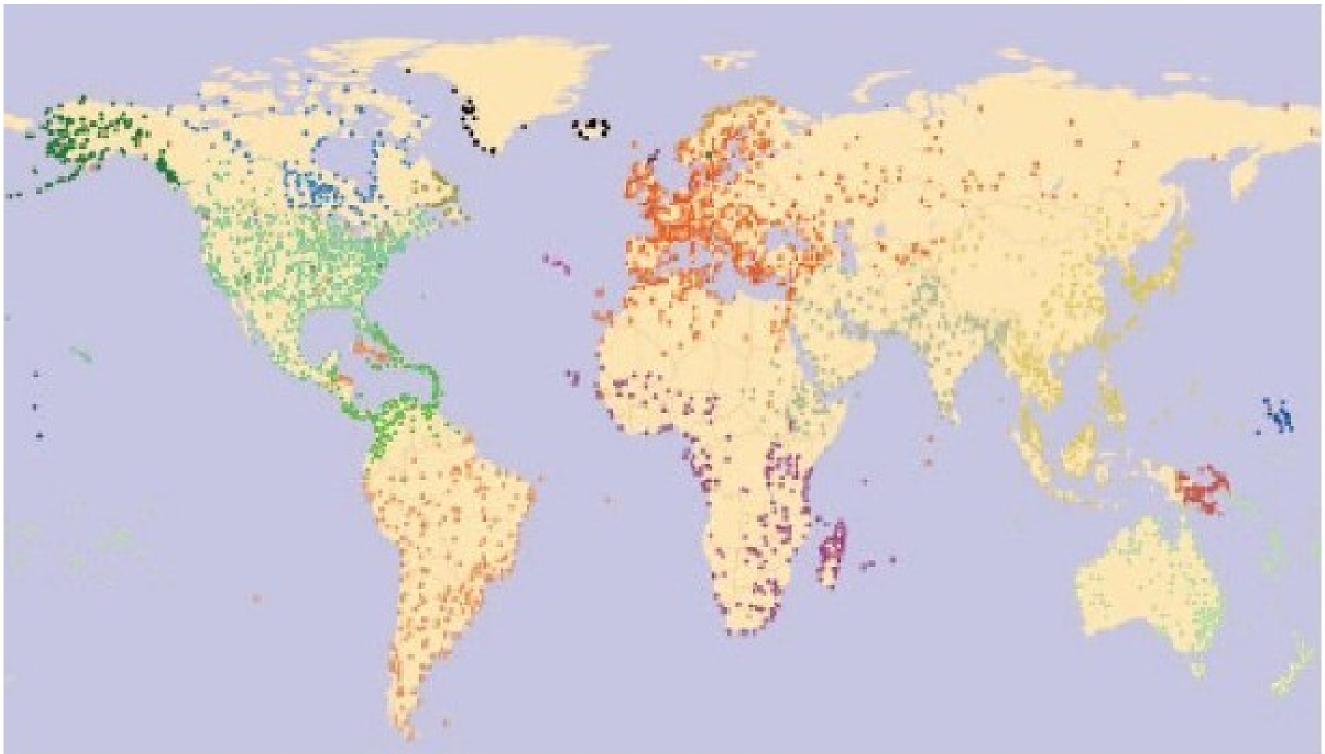
Hollywood network: the movie co-actors of the Internet Movie Database show a degree distribution of the PZM type. Any actor of any movie is not more than four movie links away from Kevin Bacon. (Actor A played with actor B in movie X, B played with C in movie Y, C played with Kevin Bacon in 'a few good man', hence actor A is only three links away from Kevin Bacon)



Network of national and international conflicts: the battle deaths per war distribution are of PZM type

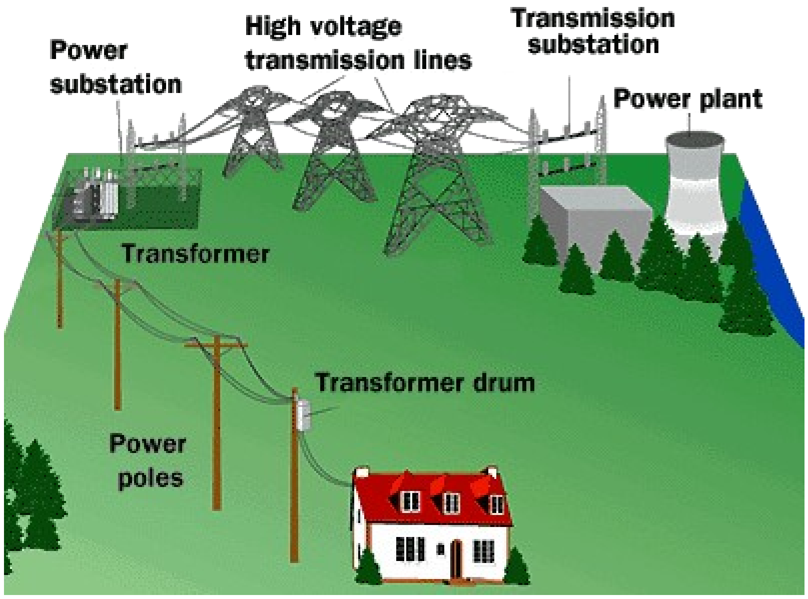
Technology networks: from stone tools to the internet

Transportation network: the Los Angeles Public Transportation Network consist of 1881 routes and 44629 stations (nodes) revealing PZM regularity. Similar regularities are observed for all major metropolitan areas of the world.

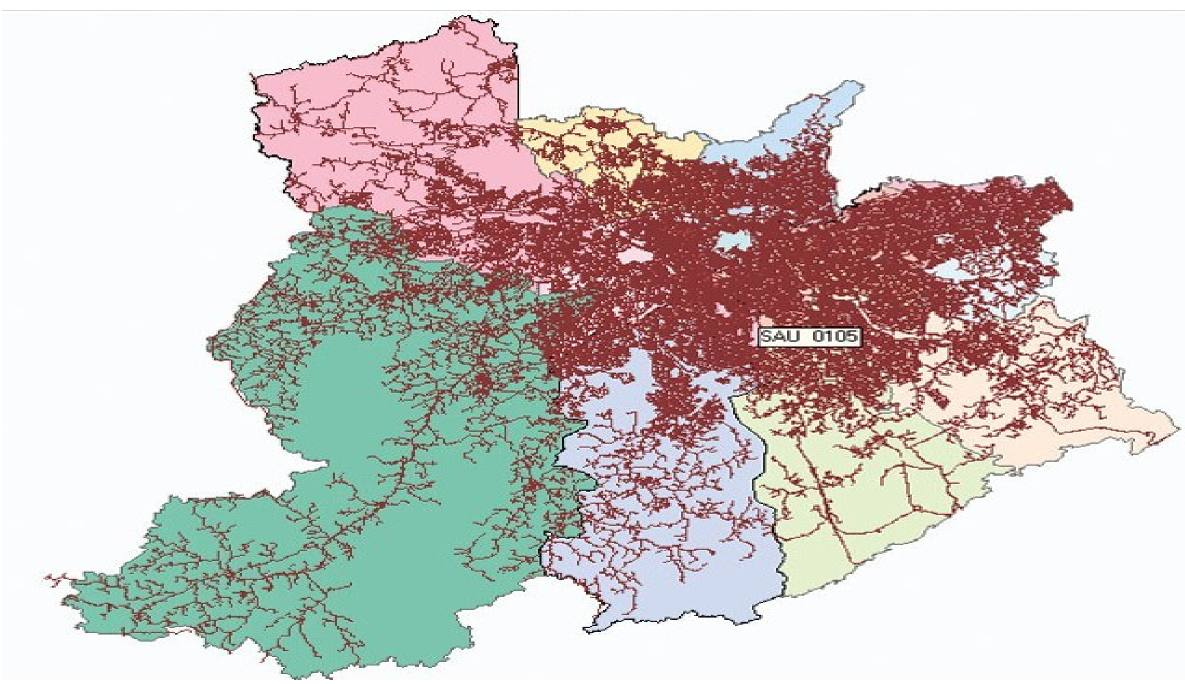


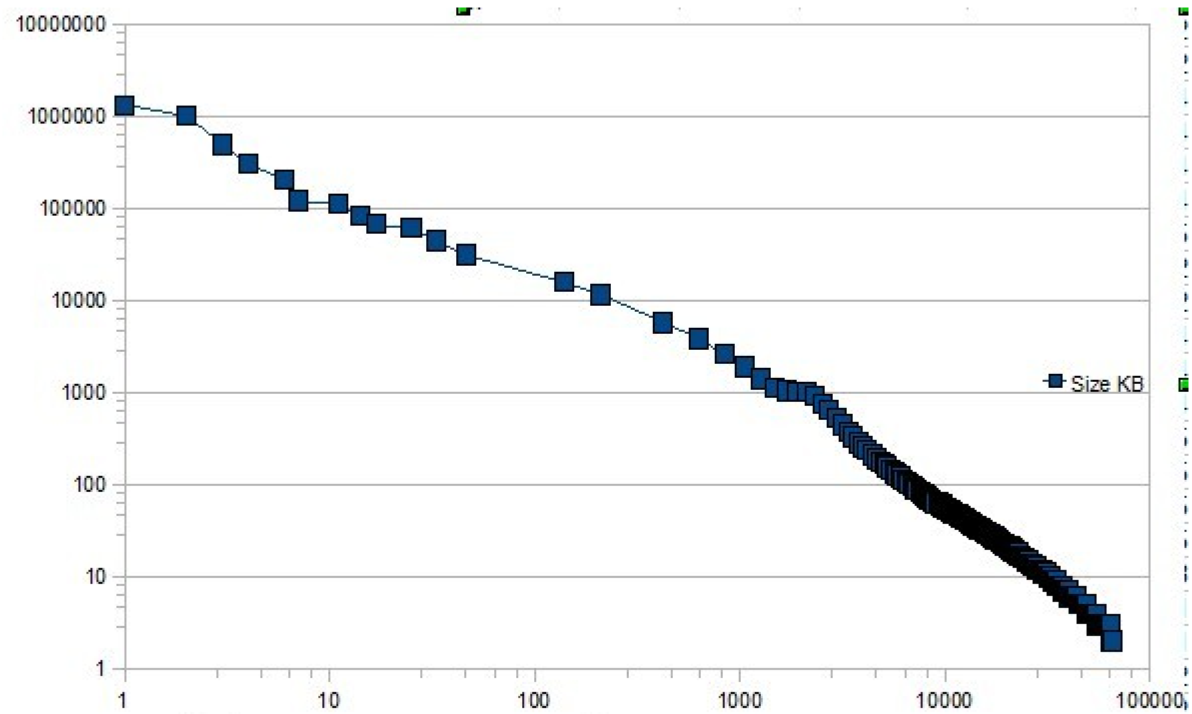
Airport network: the worldwide and national air transportation networks reveil small world property with a dregree distribution of the PZM type

network for which the number of direct connections
k to a given city (degree) has a cumulative distribution
P(> k) that decays as a truncated power-law
$P(>k) \propto k^{-\alpha} f(k/k_\times)$,
where $\alpha = 1.0 \pm 0.1$ *is the power-law exponent,* $f(u)$ *is*
a truncation function, and $k_\times$ *is a crossover value that*
depends on the size S of the network as $k_\times \sim S^{0.4}$.



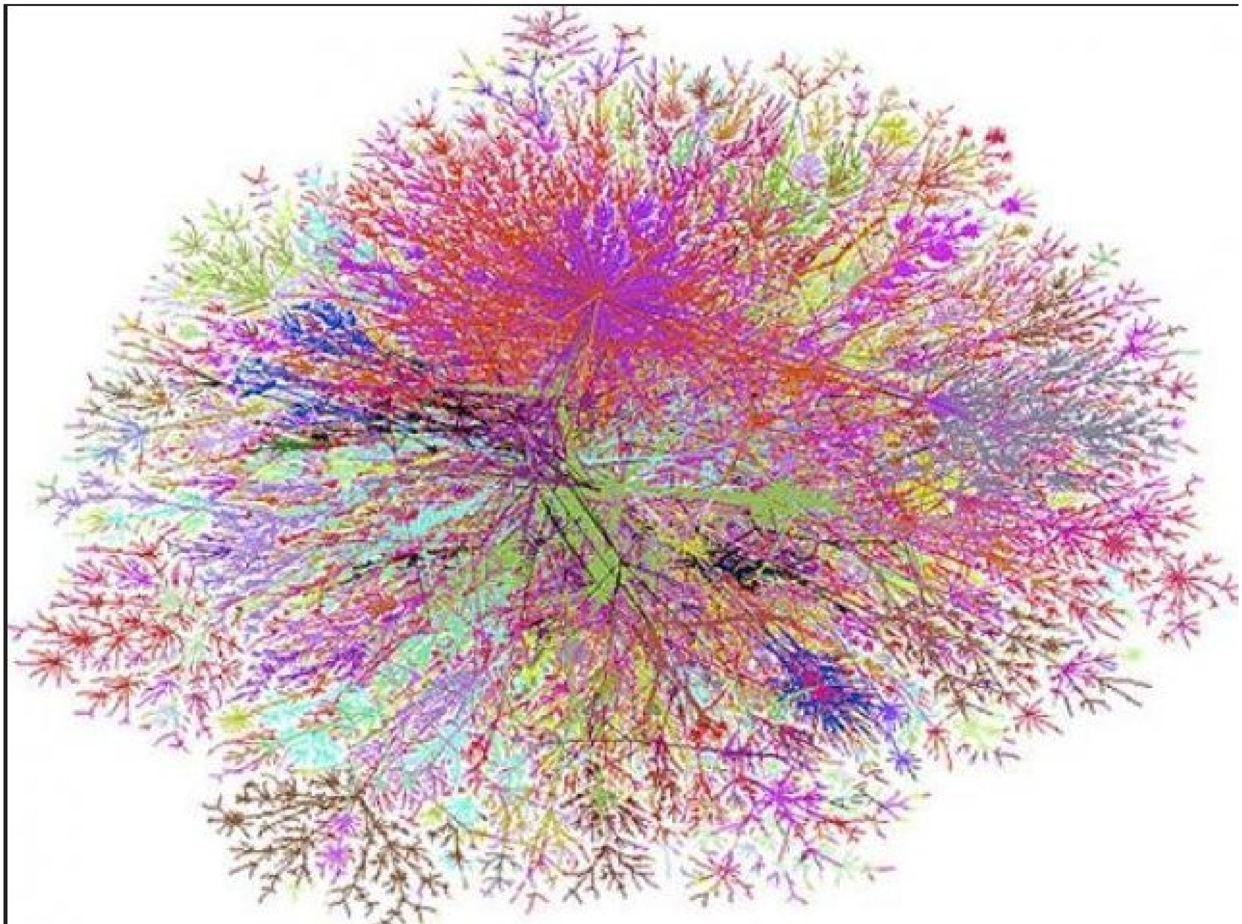
Electric energy distribution network: power grid distribution lines are of the PZM type





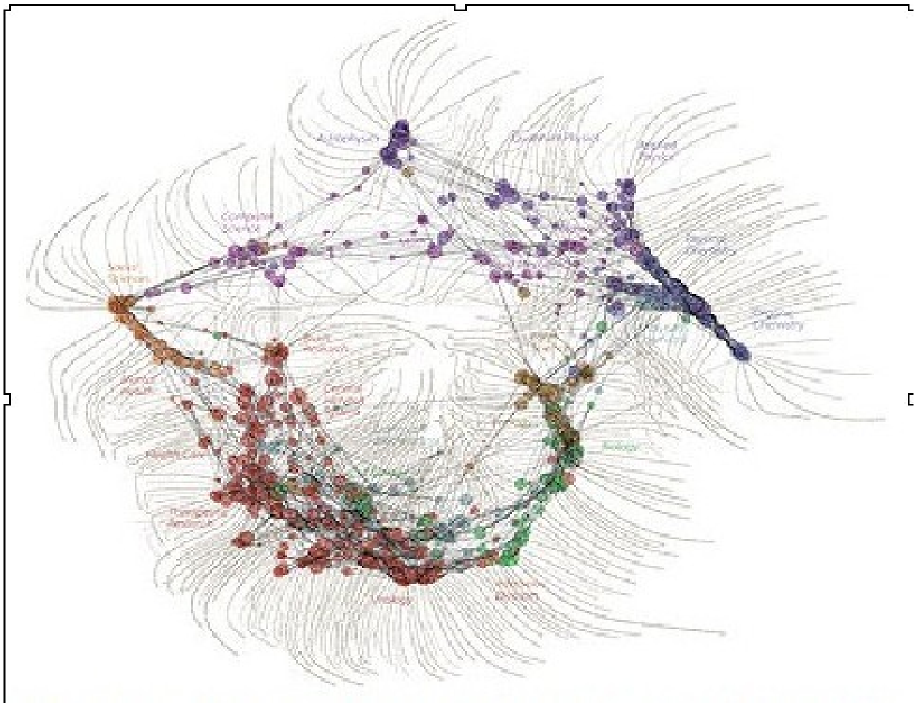
Computer file network: the file size distributions on the hard drive of a PC on a UNIX system and on the WEB are of PZM type

Nuclear energy network: the size of nuclear explosions follow a PZM regularity

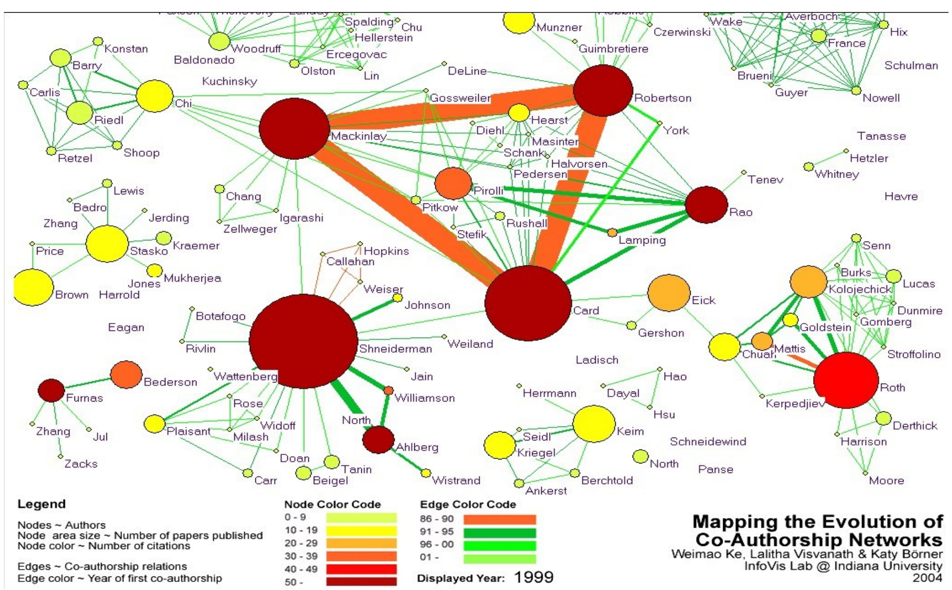


jurvetson, Internet Splat Map, Unknown

Information network: the World Wide Web reveals scalefree power laws of the PZM type for site size distribution, incoming links, outgoing links ...



Research network: the citation network of research reveal PZM degree distribution



What do all these illustrated regularities have in common?

"It is an interesting possibility that the power laws followed by so many different kinds of systems might be the result of downward constraintes exerted by encompassing supersystems."

Stanley N. Salthe, ***Entropy*** 2004, **6**, 335

- All the systems for which we observe Pareto-Zipf-Mandelbrot (PZM) regularities are **networks.**
- All networks have a '**small world**' topology between complete randomness and complete order.
- The networks belong to one of the three categories:
  1) **Matter** transportation networks (e.g. public transportation network, water network)
  2) **Energy** transformation and transportation networks (e.g. Electricity network)
  3) **Information** networks (e.g. Telephone Network, the Internet and WWW)
- All small world networks reveal a cyclic hierarchical **feed forward** process : bottom up flow of information from singular interaction units over local modules (threshold automata / switches) to global hubs.
- All small world networks reveal a **back-propagatio** process : top down flow of information from central hubs over local modules (threshold automata / switches) down to individual interaction units.
- As will be shown in the following chapter, any small world network can be mapped on an Artificial Neural Network of the multilayer feed forward type with back-propagatio (**multilayer perceptron**)
- Such the features of multilayer perceptrons like memory, learning and universal mapping capability are inherent to all systems/networks for which we observe Pareto-Zipf-Mandelbrot (PZM) regularities.

For example let us consider the world airport network. A passenger wants to travel from one desert airport El Centro in Imperial county in southern California to another desert airport Tamanrasset in the south of Algeria.

The travel schedule will bring him from the El Centro / Imperial county airport IPL to LAX, the hub of the Los Angeles airport. From LAX he will take a flight to PAR, the Paris Roissy airport hub of France. From PAR he will take a flight to the smaller modular hub of the Algiers airport ALG. Finally from ALG he will take a small plane to arrive at the Tamanrasset airport TMR in the deep south desert of the Sahara close to the Hoggar mountain chain where he intended to admire prehistoric wall paintings of our ancestors. It took our traveler only four flights and three correspondence changes to arrive from one distant location to another distant location of the world. It's a small world in the true sense of complex graph theory.

Let us take another axample, the network of the Internet and the world wide web. From my location (www.bordalierinstitute.com) I want to visit the home page of www.evodevouniverse.com. First the packages of my request will travel to the local hub of my French Internet service provider www.1and1.fr, from there it will be routed the nameserver of www.1and1.com in the US, which looks up the IP number of evodevouniverse, which is hosted by a US service provider and from there the packages of my request will be routed down to the final IP adress of my correspondent. Once reached a similar bottom up and top down direction will send the requested page through the routers of the web back to my site. In the case of the Internet the traveling packages of my message can take different routes, but they will be re-assembled at arrival. Again we observe a cyclic feed forward of information with subsequent back-propagation through the complex web of the network.

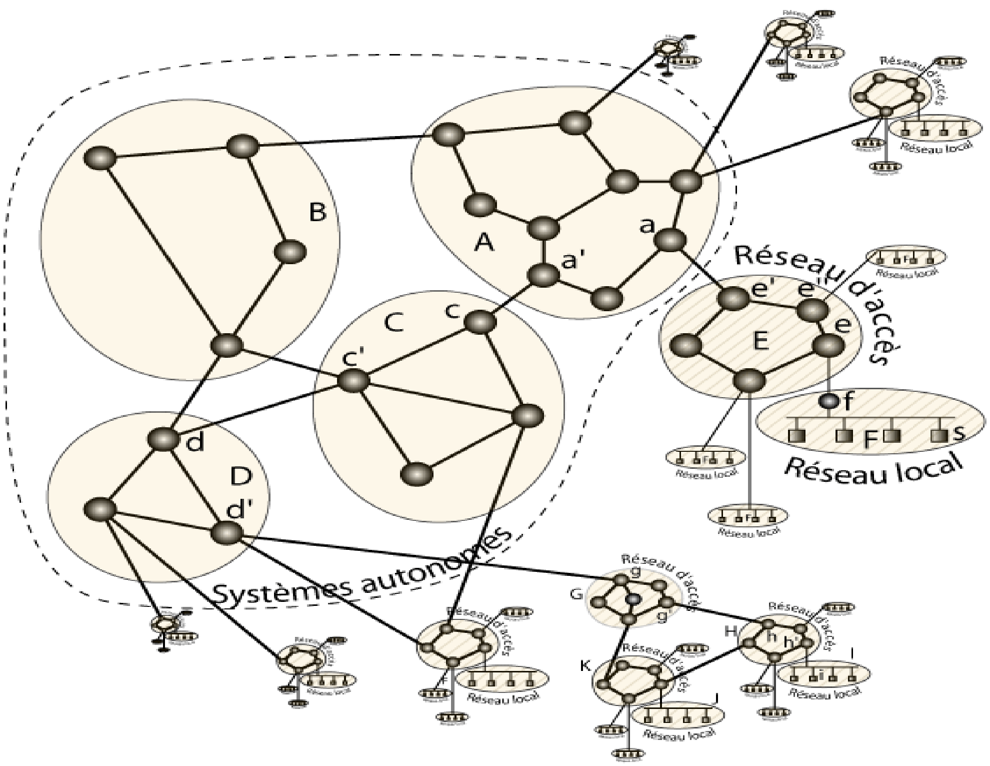


Figure: routing through the Internet: PC of local network, module of Internet access, autonomous Routers of Internet, module of Internet access, local network of PCs, individual interaction unit PC.

As third example we propose to examine the case of Citation webs. According to Lotka's law Citation webs exhibit a Pareto-Zipf-Mandelbrot distribution for citation frequencies.
A citation web can be modeled as a hierarchical multilayer feed forward Neural Network with cyclic back-propagatio (*Multilayer Perceptron*).
In a first approximation the hierarchical feed forward levels of a citation web are:

- single citation (a pointer to an idea) feeding into the
- paper level, which feeds into the
- referee level (peer-system) which feeds into the
- conference proceedings or journal publication level, which feeds into the
- book-editor level, which feeds into the
- book level, feeding the
- institute library level and finally feeding the
- Library of Congress level.

back-propagatio are the respective <u>reference lists of citations</u> fed down the levels of the hierarchy.
On each level there are binary threshold processors, which can be only **on** or **off**:

- Paper in progress vs. paper written,
- Paper submitted for conference vs. paper accepted for conference,
- Paper submitted to journal vs. paper published by journal,
- Book submitted to editor vs. book published by editor,
- Book proposed to library vs. book acquired by library
- Book on shelf vs. book scrapped from library ...

All these binary threshold automata of the citation web are interlinked in a hierarchical way and undergo a cyclic feed forward process with consecutive back-propagatio. If the Neural Network analogy holds we come to the following conclusions:

2. **Citation webs have «memory»**.
   It is the topology of the web's authors and their respective links in the citation webgraph which constitute the memory of the self-organized system.
3. **Citation webs are «learning».**
   Through a cyclic feedback process of *reference lists* through the different hierarchical levels of the system. An author's «weight» is proportional to the number of citations in the citation index.
4. **Citation webs are «intelligent».**
   The cyclic self-organization process (feed forward and consecutive back-propagatio) optimizes the overall coherence (synergy) of the system. Thus the system is striving to an extremal value of an objective function (goal).