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# Thermodynamics, Equilibration, Conservation Principles, Scientific and Societal Change: Is this the 'Rich get Richer' all Over Again?

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As the laws of thermodynamics were being developed In the nineteenth century, they were taken to imply an eventual equilibration of energy and the disappearance of temperature differences everywhere, that is every object was destined to attain the same final temperature as all others and is this total and complete democracy, the Universe as a whole was believed to suffer the ultimate heat death. This conclusion was championed by undisputed authorities such as Lord Kelvin (the 1st Baron) in Britain and Helmholtz in Germany. But later Max Planck questioned the conclusion amongst other reasons on the grounds that the concept of the total entropy of the entire universe is ill defined. Aside from the fact that over the years many of William Thomson's (Lord Kelvin) proclamations, such as the age of the earth end of all new physics or not accepting X-ray and others have fallen by the roadside. There remains a folk perception that with time nature works to smooth out uneven distributions or disparity and tends towards an equilibrium, a kind of 'all are equal' principle of nature; we can label it as the (yet to be proven) existence theorem of a 'fundamental fairness of natural laws' or something of that sort.

Here, I will discuss this expectation, especially the hyping by media, misunderstanding, misrepresentation, and in my opinion the real meaning of it. Anyone who surfs the web, listens to news or read journals have witnessed a media wide hue and cry about the rise of disparity between the gentry and the hoi polloi. Remember the 'Occupy Wall Street' movement, President Barack Obama's address in December 2013 about the growing economic inequality in the United States; the 2012 presidential candidate Mitt Romney's infamous 47% gaff. There is also a recent special issue of the influential journal Science [1].

There are a plethora of statistics, numbers, in this subject viz., the numbers from the Paris based Organization for Economic Cooperation and Development is an organization that is made up of 34 major economies of the world, including the US; according to OECD the top 1% of US earners earned 47% of the total income growth over the past three decades while in Canada, the '1-percenters' accounted for 37% of (income) growth, this income trend appears to be present even in more socioeconomically conscious Nordic countries, like Norway, Sweden and Finland. A group of University of Michigan researchers note that income inequality has been rapidly trending up in China as well; currently China surpasses that of the U.S., and is one of the highest in the world [2].

The internationally marketed and well-respected magazine 'Economist' reports [3] that more recent data show that between 2009 and 2012 the real[sic] income growth of the top 1%ter was 31%, and less than 1% for the bottom 99%ters. Furthermore according to this report for the bottom 90% of earners had income that actually [sic] shrank. In summary, these numbers show that since the 1970s [4] the income of the bottom 99% of the US has gone up a mere 7% were as that of the top 15 has increased by 213%. If this was not enough, real rich, I mean the top 0.1%ters have scored even better, up a whapping 413%!

Not surprisingly, there are learned opinions (on both side of the aisle), but the publication of the bestselling 600-page tome with a catchy title 'Capital in the Twenty-First Century' by the French economist Thomas Piketty, was the last straw that started the real frenzy around these numbers and the question of 'fairness'.

But let the reader beware, in the first book of the New Testament in the biblical stories of the Gospel According to Matthew, states that… "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken even that which he hath" [Matthew 25:29, King James Version (KJV)].

In other words, the rich getting richer is not really new news; furthermore, arguably this 'early modern English' wording, especially "unto every one that hath …"of the KJV enunciation puts the common man in a particularly, cold blooded, cycle of toils in a predetermined the winner take –all, shell game. Is this a blunt pre-historic message about 'how unfair' is human society or is there a lesson to be learnt for science in this 'whole parable'? Before we seek answers to these let us get some more 'facts' about growth in a wide variety of systems.

The systems whose growth that we are to look at, range from (i) human organization and activities, (ii) biological but not human systems, and thirdly (iii) inanimate systems.

In the first group we shall consider 'disproportionate growth' in, real networks, scientific research publication, research funding, gifts to Universities, Big-Law firms, Bitcoin market activity, gain modulation in human brains, and lastly student learning in math classes. There are two cases in second bio-related but not human systems; the growth of bio-films and bio-diversity in the spread of an alien species. Finally, we take a look at bond percolation in networks, fractal systems, condensation of water drops on a watch glass and gravitation.

What we will find is that in these cases the quantity of interest is not conserved. As a matter of fact, wealth (not the same, but related to money or currency) is not a conserved quantity in healthy economic systems wealth is created, in copious amounts, to whit! Only in closed systems the net sum shall add up to zero, in such closed systems, just as in a well-insulated calorimeter, wealth gain by the rich equals that lost by the poor.

## Societal and Human Systems

As Albert Laszlo Barabasi, the physicist noted for introducing the idea of 'scale-free network' and collaborators discovered [5] that

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in a network growth happens as more nodes join in, people plug into the system as they want to use the network. Soon a number of nodes develop more interconnections amongst themselves ( thru 'evolution' or by design) which creates hubs with more time a hub may grow still bigger and the system becomes an hierarchal network of nodes, hubs, clusters, super-cluster of mega hubs etc.

We are talking about networks that are time dependent that show 'preferential attachment', where the hubs grow faster than 'low-degree' or less connected nodes. It has been noted that in the case of the network of sites trading in the electronic currency Bitcoin the value or wealth of the rich nodes increase more rapidly than the rate of nodes with less value or lower balance, plus the wealth and the degree of a node are positively correlated [6].

Let us now consider a network of phones. If all goes well, starting with a few bonds or phone line a company can end up with many phones connected with many lines, be profitable and self-sustaining. Remember, a single phone is useless as a communication (read network connecting) device, phones increase in effectiveness when any single phone can be connected to many others; a system of a few phones may be of high security but little universal appeal and relatively less cost effective. Ceteris paribus people choose the phone company with more coverage. Shall we call these the first plays of the rich-get-richer 'game book', or sound judgments?

Moving on to a different activity; publication of scientific research is amongst the most sacred acts that a scholar undertakes. Analyzing [7] decades of research output by everyone publishing in the field of Evolutionary Biology Professors Ajay K. Agrawal, John McHale and Alexander Oettl reported that the 'star' scholars collaborate amongst each other, in groups that are formed often amongst graduate students & doctoral mentors, post-doctoral associates and their Post-doc advisors and the like furthermore such collaborations publish a disproportionate number of articles. May I ask these authors, are we to believe that it is 'not good' for researchers to pool their talents and resources to become scientifically more productive than they would be individually? Furthermore, is this disproportionate productivity making other researchers less productive in any way? Are scientific discoveries and publications a 'zero sum activity' that is if group 'A' publishes 10 papers does that forces researcher John public to publish less?

Another recent paper [8] in Science by a University of Michigan Ann Arbor, MI sociology professor, Dr Yu Xie reported on the distribution of science spending in the US. The author used a statistical tool, the Gini coefficient, which is a measure of inequality in a group; a Gini coefficient goes from zero to one; a value of 0.0 represents perfect equality and the other extreme value of 1.0 represents complete inequality. On the basis of his analysis Dr. Xie concluded that scientific opportunities in the US are distributed unequally. He found that from 1990 to 2010, the Gini-coefficient for total research expenditure has risen from 0.75 to 0.81 and for federal funding alone the coefficients are 0.77 to 0.82; by this measure, in 2010 research dollars are less evenly spread that two decades earlier.

Some large gift to certain University and academic fund raising has also drawn critical eyes of the media. The proverbial straw in gift-giving was the donation of 150 million USD to Harvard, from a successful, no, an eminently successful (!) hedge fund manager and Harvard alumnus Kevin Griffin. What was the rub, you may ask- go ahead; according to some including the Economist [9], Harvard is already got too much 'awash' with endowment assets currently with a quite pretty market value of something north of 32 billion USD, this is too much money imagine how much good this can do if given to some less endowed institution, too big a donation and too much of a tax break for Kevin Griffin!

It is clear that this perception of 'disproportion' is wide spread and has almost become a buzz phrase. Not only donations to big Universities, it seems big is getting bigger all-around, for instance, the statistics of the Biggest -100 law firms indicate that largest firms are also doing better than their smaller cousins [10]. Last year in a paper on 'Brain-wide gain modulation' that was published in Nature Neuroscience [11] Tobias H Donner & Sander Nieuwenhuis reported observations that can be construed as a' rich get richer' behavior. Also, as was reported in a recent education blog posting [12], a scenario of 'rich get richer' in math classes has also been noted by professors Keith Robinson and Anna S. Mueller, who observe that the more engaged students get more out of the classes and lessons such that the students with higher motivation and better scores get engaged more and obtain [still] better grades. It was stated that "Lower individual engagement means that a given student will be slower to acquire essential math skills" – so what have we here, students who individually engage more in the learning process get progressively more out of their [math] classes, is this unexpected and is taking initiative not a good thing?

## Biological but not Human Systems

Perhaps this success begets success things is only true of human or societal context, because isn't success a human idea, loaded with societal definition of good vs bad? Not so fast, as we will see something similar is equally at play in organizations that are not human but living individuals, such as plants animals and even micro-organisms. Let us take look; in a recent article [13] on the growth of micro colonies of 'bio- films', researchers Kun Zhao et al, write and I quote "… the bacterial community self-organizes in a manner analogous to a capitalist economic system, a 'rich-get-richer' mechanism of Psl accumulation that results in a small number of 'elite' cells becoming extremely enriched in communally produced Psl… and that high local Psl concentrations ultimately allow elite cells to serve as the founding population for initial microcolony development".

Another case in point, is the growth of a foreign or alien species in a native ecosystem, the nineteenth century view, was that the new [invading] species will flourish in the areas in the ecosystems with less competition so that regions with high native biodiversity will be eschewed by the alien species; as matter of fact the great Charles Darwin of evolution fame, was a believer of this view. But, Holy Shmoly (!) in a paper [14] on plant invasion in the US & Canada by Thomas J Stohlgren, etal in 2003, reported that the areas which are 'hot-spots' in native species are also more attractive and hence prone to invasion by alien plants.

Come to think of it, is either observation non-intuitive? Absolutely no, both the bio-film growth and represent the simple fact that in each case the strategy taken leads to positive outcomes – in the first instance, the whole microcolony develops from the said nucleation and in the second first the region was denuded of native species to start with because it is an environment that is hostile to life, no wonder the newcomer carefully avoids these regions. This is not a matter of being unfairly making the 'bio-rich' regions richer. Guess where would the new emerge go, NYC or home town USA? Figure 1.

I have saved the consideration of non-living inanimate systems until now. So here we go, first think of any percolating system, these

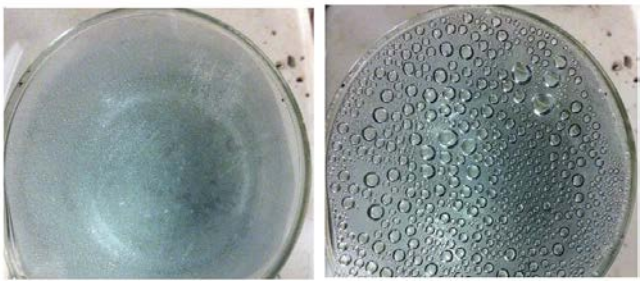

**Figure 1:** Nucleation of water drops on a cold watch glass; left panel early on during the process, the droplets are all small and nearly equal in size; right panel later a few large drops form as more and more water molecules get preferentially attached to the larger surfaces of the bigger drops.

systems grow just as networks but don't involve humans and can be bot living as well as non-living; evolution of the root (branch) system of trees of the buildup of electrical charge conduction in a disordered material are examples of percolation. In general percolation is the 'big tent' that includes a wide range of phenomena that are especially pesky for (mathematical) analytical solutions and hence treated by dimensional, simulation and scaling methods. Another related topic is fractal evolution; fractals are non-trivial examples self-similar, scale free systems, when visualized on grids they represent shapes with hierarchical geometric complexity; the rules for all these complicated extended structures are typically very simple algebraic rule that apply to any of the nodes, often termed the law of the 'celular automata'. Percolation and cellular automata results are classic examples where although the exact same probability applies equally to all the individual sites, however under repeated application of the rules outcomes with 'clustering' and complexities can follow. Notice, here the occupancy of the site is completely probabilistically random the rule doesn't have to include a bias towards having (or avoiding) neighbor occupancy, still clusters or regions with occupied sites grow larger and larger with time and the growth rates can depend on the current cluster size.

Clustering happens even in non-bio films growth, for illustration I had a colleague in the lab, take pictures of water drops condensing on the bottom surface of a cold watch glass; steam in generated in a beaker of water sitting on a hot plate below the watch glass; as the water vapor drifts up it comes in contact with the glass and first forms a random distribution of small droplets that are all about the same size(left panel), but as time goes on some of the drops grow much bigger than others while many more small drops get absorbed in the larger ones (right panel). Notice, as in the other cases this is an open system we have intentionally kept on adding more and more water molecule to increase the total amount of water collected under the glass.

For my last example let me choose systems under gravitation, nothing can be a more 'democratic' law of nature than the law of universal gravitation, A la Isaac Newton all objects no matter chemical composition or thermodynamic states attract each other pairwise with force proportional to the product of the two masses (in the pair) and as inverse square of their mutual separation distance. Know what? As the objects gravitate, they accumulate with increasing time and the bigger the accumulated mass gets the faster becomes the rate of growth, in cosmology the big definitely gets bigger- that is how gravity works.

So the take home message in this is that there is a purpose for a biocolony, the purpose is for it to be successful in getting food, grow and make more colonies etc, like wise a business is there because there are mercantile opportunities and in most cases it is 'better' for the society and all the parties involved to have a successful business, I said in most cases because it is the society that will have to make the call if a multinational illegal drug dealing organization is a good thing or not.

Should there be any concern that on June 20, 2014 the personal fortunes of Bill Gates, Carlos Slims or Amancio Ortegas of the world may grow billions in a single day that is many millions more than my daily earnings? Global market for commerce, especially after Nixon-Kissinger's Sino-US entente, has grown many folds in the last four decades. Has my academic activities/impact increased by the same factor? Besides, why should academic earnings be pegged to that of the corporations?

This is also the conventional wisdom amongst many economists including Harvard's Gregory Mankiw who has been reported to say that the rich are rich because of the great value of their work. This argument does not always stand up to scrutiny, large pay offs to the' top percenter' is not uncommon, even when the corporation in question disappears a perfect example of such pay offs is Tom Horton, the pre-merger CEO of American Airlines. Horton pocketed nearly $17 million USD under terms of the merger of American with US Airways! Big money corporations, too big to fail and bigger pay offs, often with tax payer dollars are societal problems. True, in the recent past there has been enough stories of 'Libor' rate fixing, monopolistic gauging, excessive 'rent collection' by the corporate brass or the insiders. We have to be earnest to eradicate harmful corporate and individual behaviors, but for heaven's sake, instead of vilifying success let us cheer and follow success. If your colleagues publish a dozen papers great, this is the signal to go ahead and send out your manuscripts, pronto!

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