

# Oxford Dictionary of Biology by Robert S. Hine and the Graphical Law

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## Abstract

We study Oxford Dictionary of Biology, the eighth edition, by Robert S. Hine. We draw the natural logarithm of the number of entries, head as well as all, normalised, starting with a letter vs the natural logarithm of the rank of the letter, normalised. We conclude that the Dictionary can be characterised by  $BP(4, \beta H = 0.01)$ , i.e. the Bethe-Peierls curve in the presence of four nearest neighbours and little external magnetic field,  $H$ , with  $\beta H = 0.01$ .  $\beta$  is  $\frac{1}{k_B T}$  where,  $T$  is temperature and  $k_B$  is the tiny Boltzmann constant.

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## I. INTRODUCTION

We are biological objects, destined by biological limitations within this Universe. The Universe is threaded by magnetic fields. To probe into the ways magnetic fields might permeate the biological aspects of this world, we have taken ourselves to a Dictionary of Biology, the eighth edition, by Robert S. Hine, [1]. We study magnetic field pattern behind the entries of this dictionary, [1], in this article. We have started considering magnetic field pattern in [2], in the languages we converse with. We have studied there, a set of natural languages, [2] and have found existence of a magnetisation curve under each language. We have termed this phenomenon as the graphical law.

Then, we moved on to investigate into, [3], dictionaries of five disciplines of knowledge and found existence of a curve magnetisation under each discipline. This was followed by finding of the graphical law behind the bengali language,[4] and the basque language[5]. This was pursued by finding of the graphical law behind the Romanian language, [6], five more disciplines of knowledge, [7], Onsager core of Abor-Miri, Mising languages,[8], Onsager Core of Romanised Bengali language,[9], the graphical law behind the Little Oxford English Dictionary, [10], the Oxford Dictionary of Social Work and Social Care, [11], the Visayan-English Dictionary, [12], Garo to English School Dictionary, [13], Mursi-English-Amharic Dictionary, [14] and Names of Minor Planets, [15], A Dictionary of Tibetan and English, [16], Khasi English Dictionary, [17], Turkmen-English Dictionary, [18], Webster's Universal Spanish-English Dictionary, [19], A Dictionary of Modern Italian, [20], Langenscheidt's German-English Dictionary, [21], Essential Dutch dictionary by G. Quist and D. Strik, [22], Swahili-English dictionary by C. W. Rechenbach, [23], Larousse Dictionnaire De Poche for the French, [24], the Onsager's solution behind the Arabic, [25], the graphical law behind Langenscheidt Taschenwörterbuch Deutsch-Englisch / Englisch-Deutsch, Völlige Neubearbeitung, [26], the graphical law behind the NTC's Hebrew and English Dictionary by Arie Comey and Naomi Tsur, [27], the graphical law behind the Oxford Dictionary Of Media and Communication, [28], the graphical law behind the Oxford Dictionary Of Mathematics, Penguin Dictionary Of Mathematics, [29], the Onsager's solution behind the Arabic Second part, [30], the graphical law behind the Penguin Dictionary Of Sociology, [31], behind the Concise Oxford Dictionary Of Politics, [32], a Dictionary Of Critical Theory by Ian Buchanan, [33], the Penguin Dictionary Of Economics, [34], the

Concise Gojri-English Dictionary by Dr. Rafeeq Anjum, [35], A Dictionary of the Kachin Language by Rev.O.Hanson, [36], A Dictionary Of World History by Edmund Wright, [37], Ekagi-Dutch-English-Indonesian Dictionary by J. Steltenpool, [38], A Dictionary of Plant Sciences by Michael Allaby, [39], respectively. The graphical law was pursued more in Along the side of the Onsager's solution, the Ekagi language ,[40], Along the side of the Onsager's solution, the Ekagi language-Part Three, [41], respectively.

We describe how the graphical law is hidden within A Dictionary of Biology, the eighth edition, by Robert S. Hine, [1], in this article. The planning of the paper is as follows. We give an introduction to the standard curves of magnetisation of Ising model in the section II. In the sections III and IV, we describe the analysis of head entries and all the entries respectively of A Dictionary of Biology, the eighth edition, by Robert S. Hine, [1]. The section V is Acknowledgment. The last section is Bibliography.

## II. MAGNETISATION

### A. Bragg-Williams approximation

Let us consider a coin. Let us toss it many times. Probability of getting head or, tale is half i.e. we will get head and tale equal number of times. If we attach value one to head, minus one to tale, the average value we obtain, after many tossing is zero. Instead let us consider a one-sided loaded coin, say on the head side. The probability of getting head is more than one half, getting tale is less than one-half. Average value, in this case, after many tossing we obtain is non-zero, the precise number depends on the loading. The loaded coin is like ferromagnet, the unloaded coin is like para magnet, at zero external magnetic field. Average value we obtain is like magnetisation, loading is like coupling among the spins of the ferromagnetic units. Outcome of single coin toss is random, but average value we get after long sequence of tossing is fixed. This is long-range order. But if we take a small sequence of tossing, say, three consecutive tossing, the average value we obtain is not fixed, can be anything. There is no short-range order.

Let us consider a row of spins, one can imagine them as spears which can be vertically up or, down. Assume there is a long-range order with probability to get a spin up is two third.

That would mean when we consider a long sequence of spins, two third of those are with spin up. Moreover, assign with each up spin a value one and a down spin a value minus one. Then total spin we obtain is one third. This value is referred to as the value of long-range order parameter. Now consider a short-range order existing which is identical with the long-range order. That would mean if we pick up any three consecutive spins, two will be up, one down. Bragg-Williams approximation means short-range order is identical with long-range order, applied to a lattice of spins, in general. Row of spins is a lattice of one dimension.

Now let us imagine an arbitrary lattice, with each up spin assigned a value one and a down spin a value minus one, with an unspecified long-range order parameter defined as above by  $L = \frac{1}{N}\sum_i\sigma_i$ , where  $\sigma_i$  is i-th spin, N being total number of spins. L can vary from minus one to one.  $N = N_+ + N_-$ , where  $N_+$  is the number of up spins,  $N_-$  is the number of down spins.  $L = \frac{1}{N}(N_+ - N_-)$ . As a result,  $N_+ = \frac{N}{2}(1 + L)$  and  $N_- = \frac{N}{2}(1 - L)$ . Magnetisation or, net magnetic moment,  $M$  is  $\mu\sum_i\sigma_i$  or,  $\mu(N_+ - N_-)$  or,  $\mu NL$ ,  $M_{max} = \mu N$ .  $\frac{M}{M_{max}} = L$ .  $\frac{M}{M_{max}}$  is referred to as reduced magnetisation. Moreover, the Ising Hamiltonian,[42], for the lattice of spins, setting  $\mu$  to one, is  $-\epsilon\sum_{n,n}\sigma_i\sigma_j - H\sum_i\sigma_i$ , where n.n refers to nearest neighbour pairs. The difference  $\Delta E$  of energy if we flip an up spin to down spin is, [43],  $2\epsilon\gamma\bar{\sigma} + 2H$ , where  $\gamma$  is the number of nearest neighbours of a spin. According to Boltzmann principle,  $\frac{N_-}{N_+}$  equals  $exp(-\frac{\Delta E}{k_B T})$ , [44]. In the Bragg-Williams approximation,[45],  $\bar{\sigma} = L$ , considered in the thermal average sense. Consequently,

$$\ln \frac{1+L}{1-L} = 2 \frac{\gamma\epsilon L + H}{k_B T} = 2 \frac{L + \frac{H}{\gamma\epsilon}}{\frac{T}{\gamma\epsilon/k_B}} = 2 \frac{L + c}{\frac{T}{T_c}} \quad (1)$$

where,  $c = \frac{H}{\gamma\epsilon}$ ,  $T_c = \gamma\epsilon/k_B$ , [46].  $\frac{T}{T_c}$  is referred to as reduced temperature.

Plot of  $L$  vs  $\frac{T}{T_c}$  or, reduced magnetisation vs. reduced temperature is used as reference curve. In the presence of magnetic field,  $c \neq 0$ , the curve bulges outward. Bragg-Williams is a Mean Field approximation. This approximation holds when number of neighbours interacting with a site is very large, reducing the importance of local fluctuation or, local order, making the long-range order or, average degree of freedom as the only degree of freedom of the lattice. To have a feeling how this approximation leads to matching between experimental and Ising model prediction one can refer to FIG.12.12 of [43]. W. L. Bragg was a professor of Hans Bethe. Rudolf Peierls was a friend of Hans Bethe. At the suggestion of W. L. Bragg, Rudolf Peierls following Hans Bethe improved the approximation scheme, applying quasi-chemical

method.

**B. Bethe-peierls approximation in presence of four nearest neighbours, in absence of external magnetic field**

In the approximation scheme which is improvement over the Bragg-Williams, [42],[43],[44],[45],[46], due to Bethe-Peierls, [47], reduced magnetisation varies with reduced temperature, for  $\gamma$  neighbours, in absence of external magnetic field, as

$$\frac{\ln \frac{\gamma}{\gamma-2}}{\ln \frac{factor-1}{factor^{\frac{\gamma-1}{\gamma}} - factor^{\frac{1}{\gamma}}}} = \frac{T}{T_c}; factor = \frac{\frac{M}{M_{max}} + 1}{1 - \frac{M}{M_{max}}}. \quad (2)$$

$\ln \frac{\gamma}{\gamma-2}$  for four nearest neighbours i.e. for  $\gamma = 4$  is 0.693. For a snapshot of different kind of magnetisation curves for magnetic materials the reader is urged to give a google search "reduced magnetisation vs reduced temperature curve". In the following, we describe data s generated from the equation(1) and the equation(2) in the table, I, and curves of magnetisation plotted on the basis of those data s. BW stands for reduced temperature in Bragg-Williams approximation, calculated from the equation(1). BP(4) represents reduced temperature in the Bethe-Peierls approximation, for four nearest neighbours, computed from the equation(2). The data set is used to plot fig.1. Empty spaces in the table, I, mean corresponding point pairs were not used for plotting a line.

reduced temperature, $\frac{T}{T_c}$				$\frac{M}{M_{max}}$ ,
BW(c=0)	BW(c=0.005)	BW(c=0.01)	BP(4, $\beta H = 0$ )	reduced magnetisation
0	0	0	0	1
0.435	0.437	0.439	0.563	0.978
0.439	0.441	0.443	0.568	0.977
0.491	0.493	0.495	0.624	0.961
0.501	0.504	0.507	0.630	0.957
0.514	0.517	0.519	0.648	0.952
0.559	0.562	0.565	0.654	0.931
0.566	0.569	0.573	0.7	0.927
0.584	0.587	0.590	0.7	0.917
0.601	0.604	0.607	0.722	0.907
0.607	0.610	0.613	0.729	0.903
0.653	0.658	0.661	0.770	0.869
0.659	0.663	0.666	0.773	0.865
0.669	0.674	0.678	0.784	0.856
0.679	0.684	0.688	0.792	0.847
0.701	0.705	0.709	0.807	0.828
0.723	0.728	0.732	0.828	0.805
0.732	0.736	0.743	0.832	0.796
0.753	0.758	0.766	0.845	0.772
0.779	0.784	0.788	0.864	0.740
0.838	0.844	0.853	0.911	0.651
0.850	0.858	0.864	0.911	0.628
0.870	0.877	0.885	0.923	0.592
0.883	0.891	0.899	0.928	0.564
0.899	0.908	0.918		0.527
0.905	0.914	0.926	0.941	0.513
0.944	0.956	0.968	0.965	0.400
		0.985		0.350
		0.998		0.310
0.969	0.985		0.965	0.300
	0.998			0.250
0.987			1	0.200
0.997			1	0.100
1			1	0

TABLE I. Datas for Reduced temperature[ for the Bragg-Williams approximation, in the absence (BW(c=0)) and in the presence (BW(c=0.005), BW(c=0.01)) of magnetic field,  $c = 0$ ,  $c = \frac{H}{\gamma\epsilon} = 0.005$ ,  $c = \frac{H}{\gamma\epsilon} = 0.01$  respectively and in the Bethe-Peierls approximation, BP(4, $\beta H=0$ ), in the absence of magnetic field, for four nearest neighbours] vs reduced magnetisation. Reduced temperature data set( say, data set BW(c=0)) is drawn along the x-axis and the corresponding Reduced magnetisation data set is drawn along the y-axis. In gnuplot the command is plot ".dat" using 1:2 with line; 1 standing for x-axis and 2 standing for y-axis datas.[For example, for drawing BW(c=0), ".dat" file, say denoted as "0.dat", contains BW(c=0) data set in first column and reduced magnetisation data set in second column. Moreover, after (0.944,0.400), next pair of points will be (0.969,0.300), then (0.987,0.200), ...and so on in the "0.dat" file.]

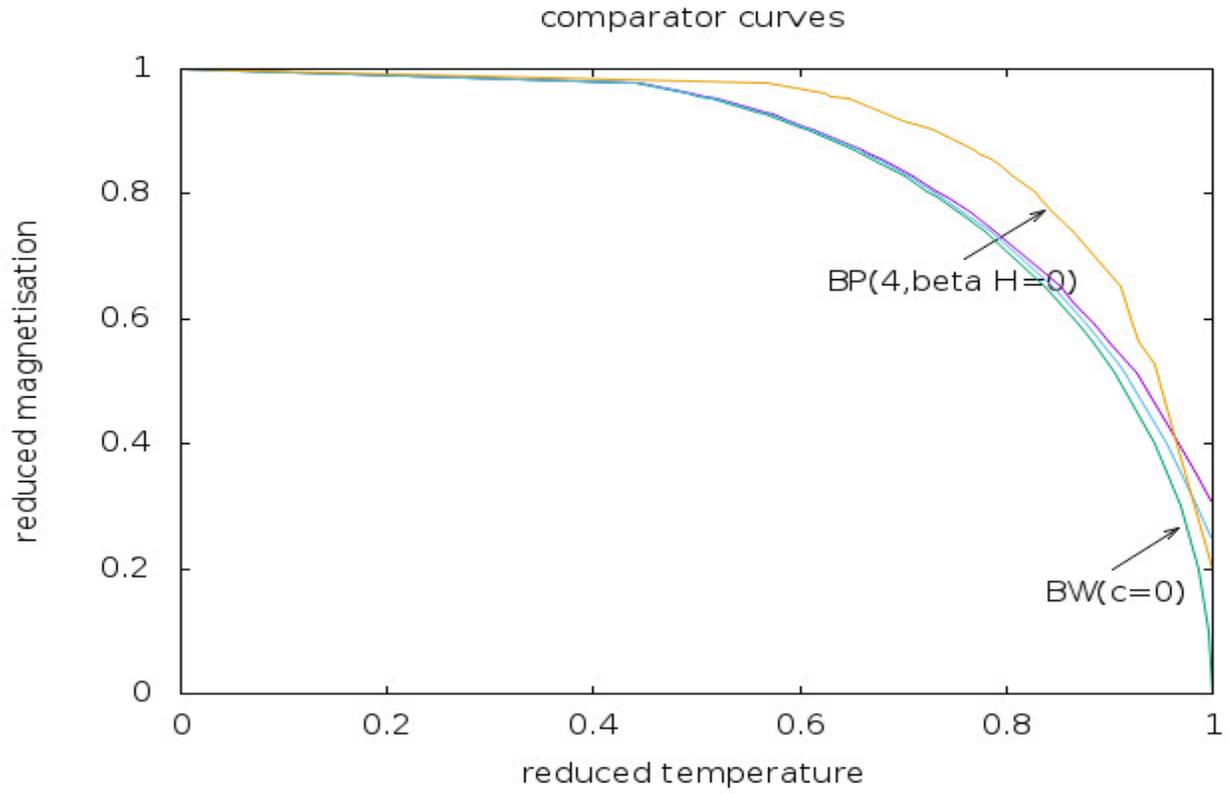


FIG. 1. Reduced magnetisation vs reduced temperature curves, for the Bragg-Williams approximation, in the absence (BW( $c=0$ )) and in the presence (BW( $c=0.005$ ), BW( $c=0.01$ )) of magnetic field,  $c = 0$ ,  $c = \frac{H}{\gamma\epsilon} = 0.005$ ,  $c = \frac{H}{\gamma\epsilon} = 0.01$ , outwards; and in the Bethe-Peierls approximation, BP(4, $\beta H=0$ ), in the absence of magnetic field, for four nearest neighbours (outer in the top).

### C. Bethe-peierls approximation in presence of four nearest neighbours, in presence of external magnetic field

In the Bethe-Peierls approximation scheme, [47], reduced magnetisation varies with reduced temperature, for  $\gamma$  neighbours, in presence of external magnetic field, as

$$\frac{\ln \frac{\gamma}{\gamma-2}}{\ln \frac{e^{-\frac{2\beta H}{\gamma}} \text{factor}^{\frac{\gamma-1}{\gamma}} - e^{-\frac{2\beta H}{\gamma}} \text{factor}^{\frac{1}{\gamma}}}{\text{factor} - 1}} = \frac{T}{T_c}; \text{factor} = \frac{\frac{M}{M_{max}} + 1}{1 - \frac{M}{M_{max}}}. \quad (3)$$

Derivation of this formula Ala [47] is given in the appendix of [7].

$\ln \frac{\gamma}{\gamma-2}$  for four nearest neighbours i.e. for  $\gamma = 4$  is 0.693. For four neighbours,

$$\frac{0.693}{\ln \frac{e^{-\frac{2\beta H}{\gamma}} \text{factor}^{\frac{\gamma-1}{\gamma}} - e^{-\frac{2\beta H}{\gamma}} \text{factor}^{\frac{1}{\gamma}}}{\text{factor} - 1}} = \frac{T}{T_c}; \text{factor} = \frac{\frac{M}{M_{max}} + 1}{1 - \frac{M}{M_{max}}}. \quad (4)$$

In the following, we describe data s in the table, II, generated from the equation(4) and curves of magnetisation plotted on the basis of those data s. BP(m=0.03) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that  $\beta H = 0.06$ . calculated from the equation(4). BP(m=0.025) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that  $\beta H = 0.05$ . calculated from the equation(4). BP(m=0.02) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that  $\beta H = 0.04$ . calculated from the equation(4). BP(m=0.01) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that  $\beta H = 0.02$ . calculated from the equation(4). BP(m=0.005) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that  $\beta H = 0.01$ . calculated from the equation(4). The data set is used to plot fig.2. Similarly, we plot fig.3. Empty spaces in the table, II, mean corresponding point pairs were not used for plotting a line.

reduced temperature, $\frac{T}{T_c}$					$\frac{M}{M_{max}}$ ,
BP(m=0.03)	BP(m=0.025)	BP(m=0.02)	BP(m=0.01)	BP(m=0.005)	reduced magnetisation
0	0	0	0	0	1
0.583	0.580	0.577	0.572	0.569	0.978
0.587	0.584	0.581	0.575	0.572	0.977
0.647	0.643	0.639	0.632	0.628	0.961
0.657	0.653	0.649	0.641	0.637	0.957
0.671	0.667		0.654	0.650	0.952
	0.716			0.696	0.931
0.723	0.718	0.713	0.702	0.697	0.927
0.743	0.737	0.731	0.720	0.714	0.917
0.762	0.756	0.749	0.737	0.731	0.907
0.770	0.764	0.757	0.745	0.738	0.903
0.816	0.808	0.800	0.785	0.778	0.869
0.821	0.813	0.805	0.789	0.782	0.865
0.832	0.823	0.815	0.799	0.791	0.856
0.841	0.833	0.824	0.807	0.799	0.847
0.863	0.853	0.844	0.826	0.817	0.828
0.887	0.876	0.866	0.846	0.836	0.805
0.895	0.884	0.873	0.852	0.842	0.796
0.916	0.904	0.892	0.869	0.858	0.772
0.940	0.926	0.914	0.888	0.876	0.740
	0.929			0.877	0.735
	0.936			0.883	0.730
	0.944			0.889	0.720
	0.945				0.710
	0.955			0.897	0.700
	0.963			0.903	0.690
	0.973			0.910	0.680
				0.909	0.670
	0.993			0.925	0.650
		0.976	0.942		0.651
	1.00				0.640
		0.983	0.946	0.928	0.628
		1.00	0.963	0.943	0.592
			0.972	0.951	0.564
			0.990	0.967	0.527
				0.964	0.513
			1.00		0.500
				1.00	0.400
					0.300
					0.200
					0.100
					0

TABLE II. Bethe-Peierls approx. in presence of little external magnetic fields

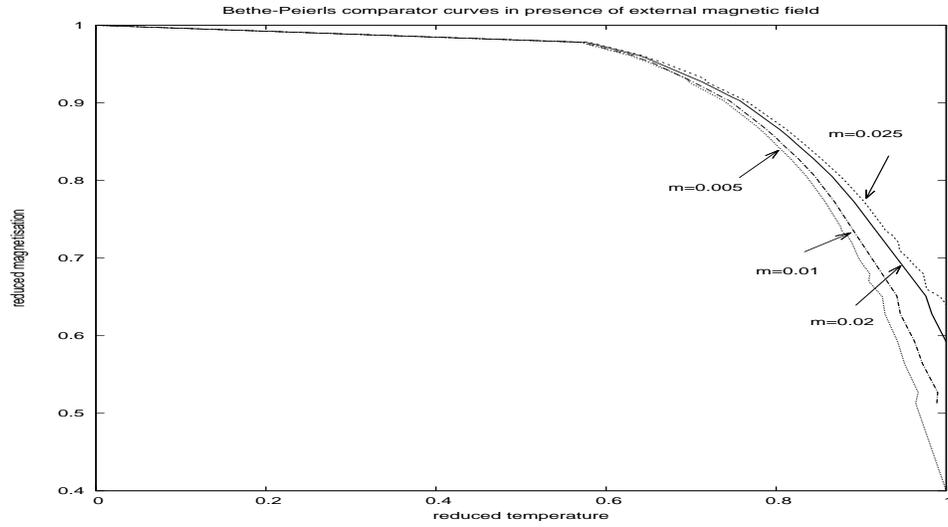


FIG. 2. Reduced magnetisation vs reduced temperature curves for Bethe-Peierls approximation in presence of little external magnetic fields, for four nearest neighbours, with  $\beta H = 2m$ .

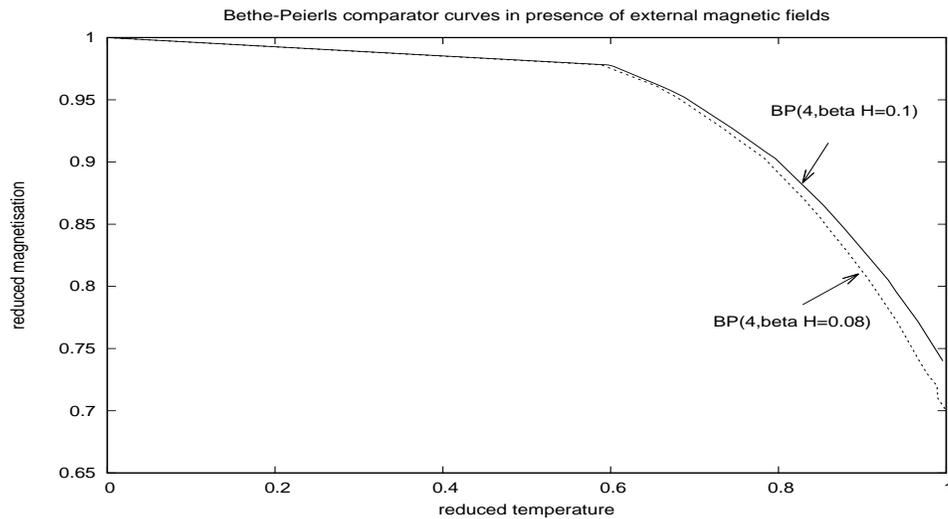


FIG. 3. Reduced magnetisation vs reduced temperature curves for Bethe-Peierls approximation in presence of little external magnetic fields, for four nearest neighbours, with  $\beta H = 2m$ .

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
469	257	622	253	306	189	252	271	210	17	59	195	408	190	161	673	19	249	530	282	52	100	39	14	9	29

TABLE III. Head entries of the Oxford Dictionary of Biology

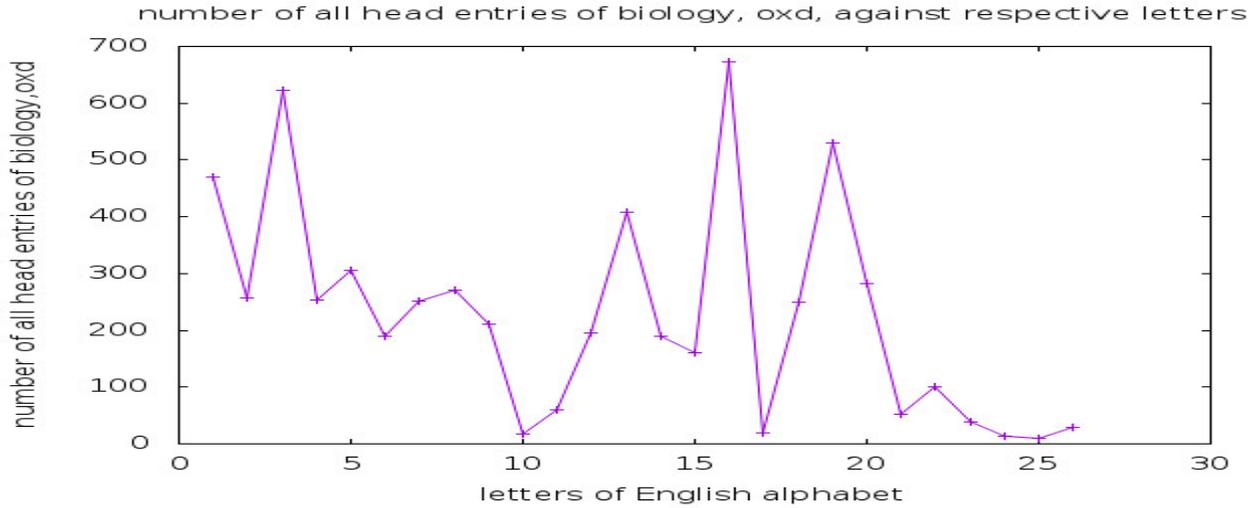


FIG. 4. The vertical axis is number of head entries in a Dictionary of Biology, [1]. The horizontal axis is the letters of the English alphabet. Letters are represented by the sequence number in the alphabet.

### III. ANALYSIS OF THE OXFORD DICTIONARY OF BIOLOGY: HEAD ENTRIES

In A Dictionary of Biology, the eighth edition, by Robert S. Hine from Oxford University Press, [1], we have counted the head entries, one by one from the beginning to the end, starting with different letters. The result is the table, III. Highest number of head entries, six hundred seventy three, start with the letter P followed by head entries numbering six hundred twenty two beginning with C, five hundred thirty with the letter S etc. To visualise we plot the number of entries again respective letters in the dictionary sequence,[1] in the adjoining figure, fig.4. For the purpose of exploring graphical law, we assort the letters according to the number of entries, in the descending order, denoted by  $f$  and the respective rank, [48], denoted by  $k$ .  $k$  is a positive integer starting from one. Moreover, we attach a limiting rank,  $k_{lim}$ , and a limiting number of entries. The limiting rank is maximum rank

plus one, here it is twenty seven and the limiting number of entries is one. As a result both  $\frac{lnf}{lnf_{max}}$  and  $\frac{lnk}{lnk_{lim}}$  varies from zero to one. Then we tabulate in the adjoining table,IV, and plot  $\frac{lnf}{lnf_{max}}$  against  $\frac{lnk}{lnk_{lim}}$  in the figure fig.5. We then ignore the letter with the highest of entries, tabulate in the adjoining table,IV,and redo the plot, normalising the  $lnfs$  with next-to-maximum  $lnf_{next-max}$ , and starting from  $k = 2$  in the figure fig.6. Normalising the  $lnfs$  with next-to-next-to-maximum  $lnf_{nextnext-max}$ , we tabulate in the adjoining table,IV, and starting from  $k = 3$  we draw in the figure fig.7. Normalising the  $lnfs$  with next-to-next-to-next-to-maximum  $lnf_{nextnextnext-max}$  we record in the adjoining table,IV, and plot starting from  $k = 4$  in the figure fig.8. This program we repeat upto  $k = 6$ , obtaining figures upto fig.10.

k	lnk	lnk/ $lnk_{lim}$	f	lnf	lnf/ $lnf_{max}$	lnf/ $lnf_{nmax}$	lnf/ $lnf_{2nmax}$	lnf/ $lnf_{3nmax}$	lnf/ $lnf_{4nmax}$	lnf/ $lnf_{5nmax}$
1	0	0	673	6.512	1	Blank	Blank	Blank	Blank	Blank
2	0.69	0.209	622	6.433	0.988	1	Blank	Blank	Blank	Blank
3	1.10	0.333	530	6.273	0.963	0.975	1	Blank	Blank	Blank
4	1.39	0.421	469	6.151	0.945	0.956	0.981	1	Blank	Blank
5	1.61	0.488	408	6.011	0.923	0.934	0.958	0.977	1	Blank
6	1.79	0.542	306	5.724	0.879	0.890	0.912	0.931	0.952	1
7	1.95	0.591	282	5.642	0.866	0.877	0.899	0.917	0.939	0.986
8	2.08	0.630	271	5.602	0.860	0.871	0.893	0.911	0.932	0.979
9	2.20	0.667	257	5.549	0.852	0.863	0.885	0.902	0.923	0.969
10	2.30	0.697	253	5.533	0.850	0.860	0.882	0.900	0.920	0.967
11	2.40	0.727	252	5.529	0.849	0.859	0.881	0.899	0.920	0.966
12	2.48	0.752	249	5.517	0.847	0.858	0.879	0.897	0.918	0.964
13	2.56	0.776	210	5.347	0.821	0.831	0.852	0.869	0.890	0.934
14	2.64	0.800	195	5.273	0.810	0.820	0.841	0.857	0.877	0.921
15	2.71	0.821	190	5.247	0.806	0.816	0.836	0.853	0.873	0.917
16	2.77	0.839	189	5.242	0.805	0.815	0.836	0.852	0.872	0.916
17	2.83	0.858	161	5.081	0.780	0.790	0.810	0.826	0.845	0.888
18	2.89	0.876	100	4.605	0.707	0.716	0.734	0.749	0.766	0.805
19	2.94	0.891	59	4.078	0.626	0.634	0.650	0.663	0.678	0.712
20	3.00	0.909	52	3.951	0.607	0.614	0.630	0.642	0.657	0.690
21	3.04	0.921	39	3.664	0.563	0.570	0.584	0.596	0.610	0.640
22	3.09	0.936	29	3.367	0.517	0.523	0.537	0.547	0.560	0.588
23	3.14	0.952	19	2.944	0.452	0.458	0.469	0.479	0.490	0.514
24	3.18	0.964	17	2.833	0.435	0.440	0.452	0.461	0.471	0.495
25	3.22	0.976	14	2.639	0.405	0.410	0.421	0.429	0.439	0.461
26	3.26	0.988	9	2.197	0.337	0.342	0.350	0.357	0.365	0.384
27	3.30	1	1	0	0	0	0	0	0	0

TABLE IV. Head entries of the Oxford Dictionary of Biology: ranking,natural logarithm,normalisations

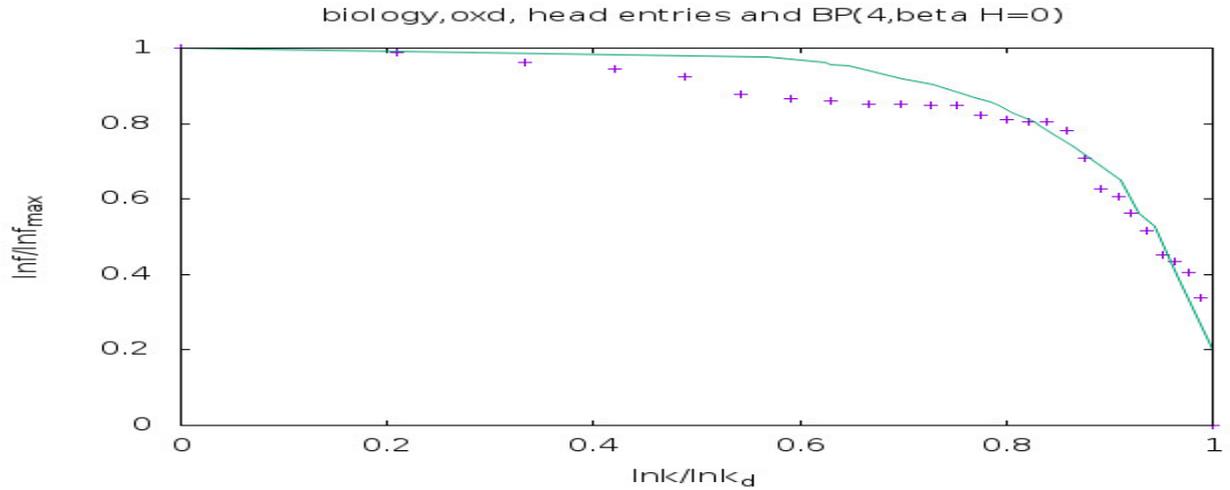


FIG. 5. The vertical axis is  $\frac{\ln f}{\ln f_{max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and no external magnetic field,  $m = 0$  or,  $\beta H = 0$ .

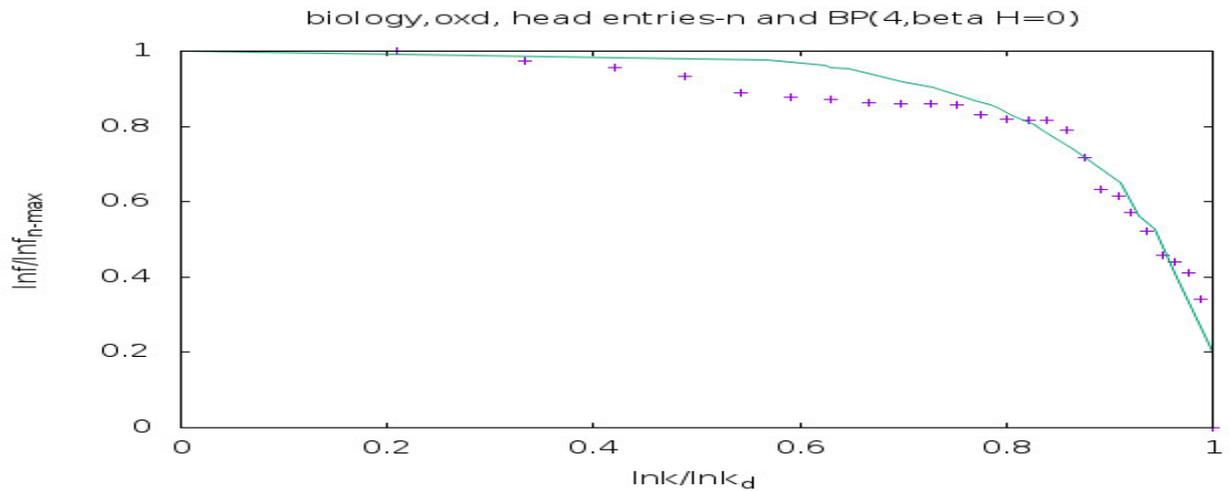


FIG. 6. The vertical axis is  $\frac{\ln f}{\ln f_{next-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and no external magnetic field,  $m = 0$  or,  $\beta H = 0$ .

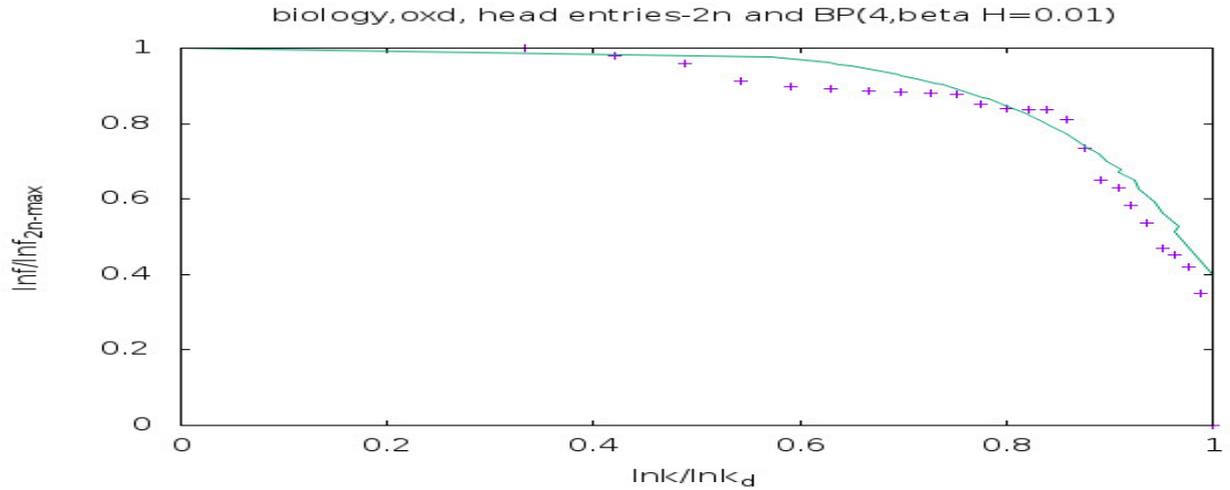


FIG. 7. The vertical axis is  $\frac{\ln f}{\ln f_{nextnext-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and little external magnetic field,  $m = 0.005$  or,  $\beta H = 0.01$ .

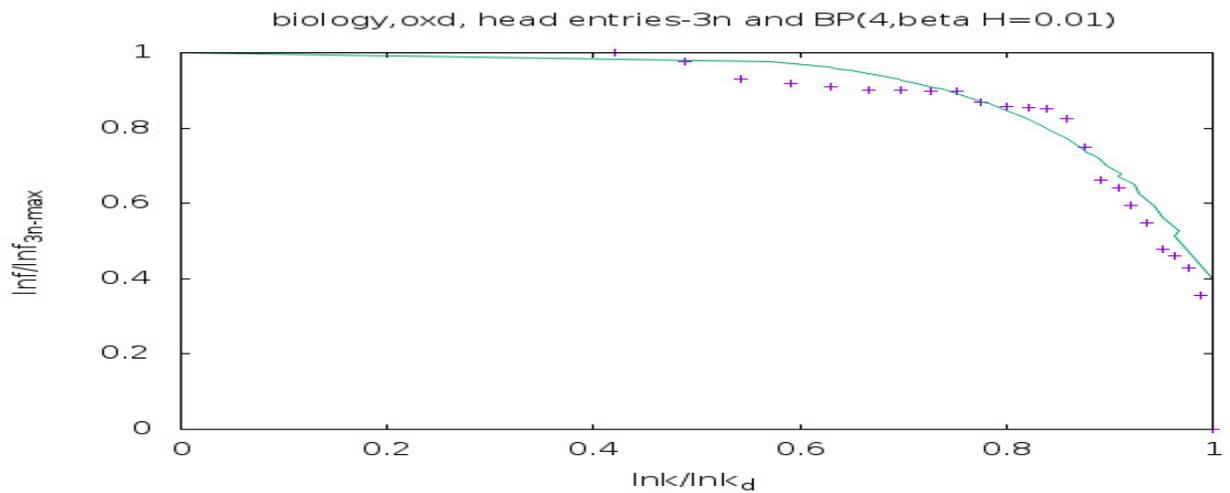


FIG. 8. The vertical axis is  $\frac{\ln f}{\ln f_{nextnextnext-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and little external magnetic field,  $m = 0.005$  or,  $\beta H = 0.01$ .

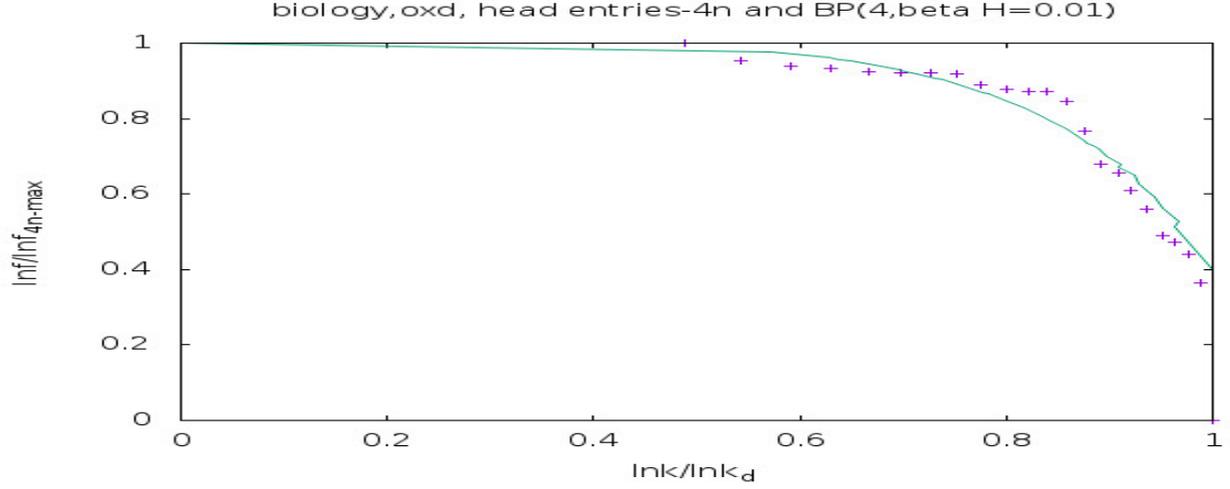


FIG. 9. The vertical axis is  $\frac{\ln f}{\ln f_{4n-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and little external magnetic field,  $m = 0.005$  or,  $\beta H = 0.01$ .

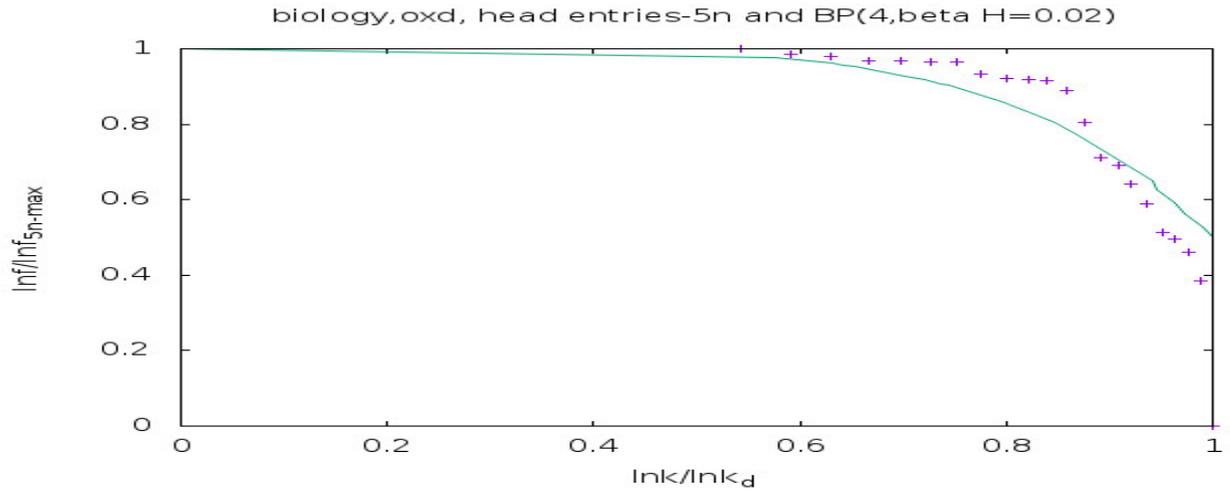


FIG. 10. The vertical axis is  $\frac{\ln f}{\ln f_{5n-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and little external magnetic field,  $m = 0.01$  or,  $\beta H = 0.02$ .

## A. conclusion

From the figures (fig.5-fig.10), we observe that there is a curve of magnetisation, behind the head entries of A Oxford Dictionary of Biology by Robert S. Hine,[1]. This is the magnetisation curve in the Bethe-Peierls approximation in the presence of four nearest neighbours and little external magnetic field,  $m = 0.005$  or,  $\beta H = 0.01$ .

Moreover, the associated correspondence is,

$$\frac{\ln f}{\ln f_{4n-max}} \longleftrightarrow \frac{M}{M_{max}},$$
$$\ln k \longleftrightarrow T.$$

k corresponds to temperature in an exponential scale, [49]. As temperature decreases, i.e.  $\ln k$  decreases, f increases. The letters which are recording higher entries .., S, C, P which get enriched more and more, fall at lower and lower temperatures. This is a manifestation of cooling effect, as was first observed in [50], in another way.

letter	A	B	C	D	E	F	G	H	I	J	K	L	M
number	629	334	857	327	423	274	341	367	312	25	76	275	572
splitting	568+61	308+26	759+98	279+48	356+67	230+44	297+44	336+31	262+50	22+3	65+11	238+37	488+84
letter	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
number	266	219	925	29	356	769	402	64	138	49	14	11	39
splitting	223+43	193+26	811+114	25+4	300+56	656+113	352+50	60+4	122+16	39+10	14+0	9+2	36+3

TABLE V. All entries of the Oxford Dictionary of Biology

#### IV. ANALYSIS OF THE OXFORD DICTIONARY OF BIOLOGY: ALL ENTRIES

In A Dictionary of Biology, the eighth edition, by Robert S. Hine from Oxford University Press, [1], we have counted also all the entries, one by one from the beginning to the end, starting with different letters. The result is the table, V. Highest number of entries, nine hundred twenty five, start with the letter P followed by entries numbering eight hundred fifty seven beginning with C, seven hundred sixty nine with the letter S etc. To visualise we plot the number of entries again respective letters in the dictionary sequence,[1] in the adjoining figure, fig.11. For the purpose of exploring graphical law, we assort the letters according to the number of entries, in the descending order, denoted by  $f$  and the respective rank, [48], denoted by  $k$ .  $k$  is a positive integer starting from one. Moreover, we attach a limiting rank,  $k_{lim}$ , and a limiting number of entries. The limiting rank is maximum rank plus one, here it is twenty seven and the limiting number of entries is one. As a result both  $\frac{\ln f}{\ln f_{max}}$  and  $\frac{\ln k}{\ln k_{lim}}$  varies from zero to one. Then we tabulate in the adjoining table,VI, and plot  $\frac{\ln f}{\ln f_{max}}$  against  $\frac{\ln k}{\ln k_{lim}}$  in the figure fig.12. We then ignore the letter with the highest of entries, tabulate in the adjoining table,VI,and redo the plot, normalising the  $\ln f$ s with next-to-maximum  $\ln f_{next-max}$ , and starting from  $k = 2$  in the figure fig.13. Normalising the  $\ln f$ s with next-to-next-to-maximum  $\ln f_{nextnext-max}$ , we tabulate in the adjoining table,VI, and starting from  $k = 3$  we draw in the figure fig.14. Normalising the  $\ln f$ s with next-to-next-to-next-to-maximum  $\ln f_{nextnextnext-max}$  we record in the adjoining table,VI, and plot starting from  $k = 4$  in the figure fig.15. This program we repeat up to  $k = 6$ , obtaining

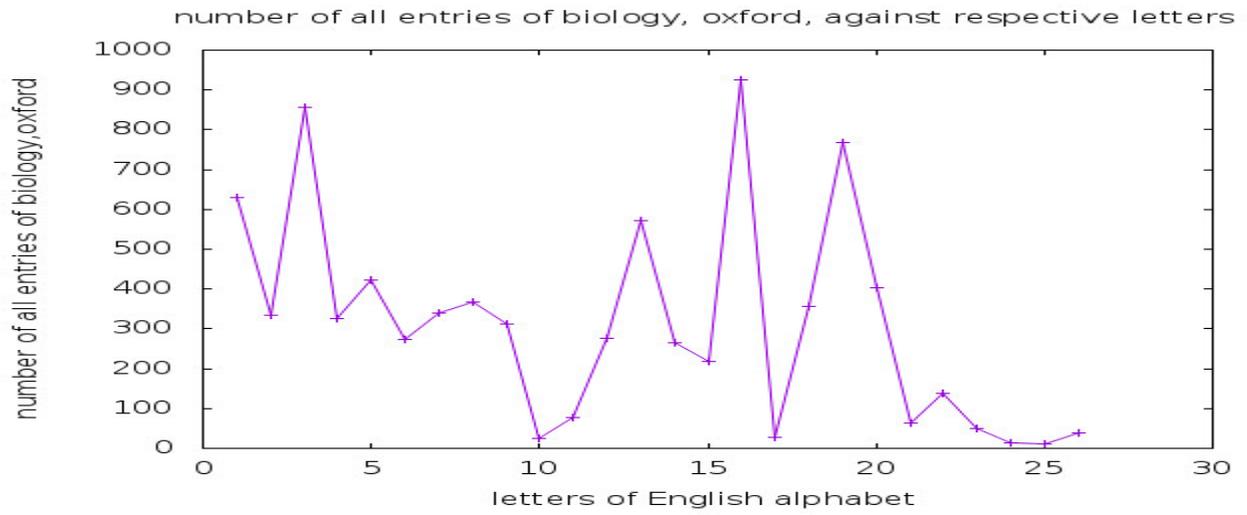


FIG. 11. The vertical axis is number of entries, all, in a Dictionary of Biology,[1]. The horizontal axis is the letters of the English alphabet. Letters are represented by the sequence number in the alphabet.

figures up to fig.17.

k	lnk	lnk/ $lnk_{lim}$	f	lnf	lnf/ $lnf_{max}$	lnf/ $lnf_{nmax}$	lnf/ $lnf_{2nmax}$	lnf/ $lnf_{3nmax}$	lnf/ $lnf_{4nmax}$	lnf/ $lnf_{5nmax}$
1	0	0	925	6.830	1	Blank	Blank	Blank	Blank	Blank
2	0.69	0.209	857	6.753	0.989	1	Blank	Blank	Blank	Blank
3	1.10	0.333	769	6.645	0.973	0.984	1	Blank	Blank	Blank
4	1.39	0.421	629	6.444	0.943	0.954	0.970	1	Blank	Blank
5	1.61	0.488	572	6.349	0.930	0.940	0.955	0.985	1	Blank
6	1.79	0.542	423	6.047	0.885	0.895	0.910	0.938	0.952	1
7	1.95	0.591	402	5.996	0.878	0.888	0.902	0.930	0.944	0.992
8	2.08	0.630	367	5.905	0.865	0.874	0.889	0.916	0.930	0.977
9	2.20	0.667	356	5.875	0.860	0.870	0.884	0.912	0.925	0.972
10	2.30	0.697	341	5.832	0.854	0.864	0.878	0.905	0.919	0.964
11	2.40	0.727	334	5.811	0.851	0.861	0.874	0.902	0.915	0.961
12	2.48	0.752	327	5.790	0.848	0.857	0.871	0.899	0.912	0.957
13	2.56	0.776	312	5.743	0.841	0.850	0.864	0.891	0.905	0.950
14	2.64	0.800	275	5.617	0.822	0.832	0.845	0.872	0.885	0.929
15	2.71	0.821	274	5.613	0.822	0.831	0.845	0.871	0.884	0.928
16	2.77	0.839	266	5.583	0.817	0.827	0.840	0.866	0.879	0.923
17	2.83	0.858	219	5.389	0.789	0.798	0.811	0.836	0.849	0.891
18	2.89	0.876	138	4.927	0.721	0.730	0.741	0.765	0.776	0.815
19	2.94	0.891	76	4.331	0.634	0.641	0.652	0.672	0.682	0.716
20	3.00	0.909	64	4.159	0.609	0.616	0.626	0.645	0.655	0.688
21	3.04	0.921	49	3.892	0.570	0.576	0.586	0.604	0.613	0.644
22	3.09	0.936	39	3.664	0.536	0.543	0.551	0.569	0.577	0.606
23	3.14	0.952	29	3.367	0.493	0.499	0.507	0.523	0.530	0.557
24	3.18	0.964	25	3.219	0.471	0.477	0.484	0.500	0.507	0.532
25	3.22	0.976	14	2.639	0.386	0.391	0.397	0.410	0.416	0.436
26	3.26	0.988	11	2.398	0.351	0.355	0.361	0.372	0.378	0.397
27	3.30	1	1	0	0	0	0	0	0	0

TABLE VI. All entries of Oxford Dictionary of Biology: ranking,natural logarithm,normalisations

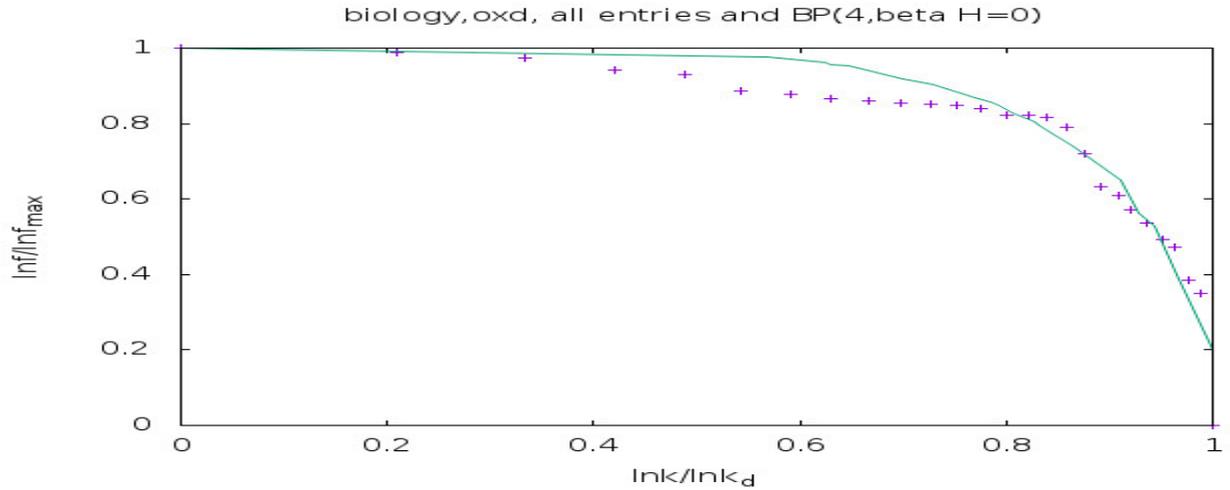


FIG. 12. The vertical axis is  $\frac{\ln f}{\ln f_{max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and no external magnetic field,  $m = 0$  or,  $\beta H = 0$ .

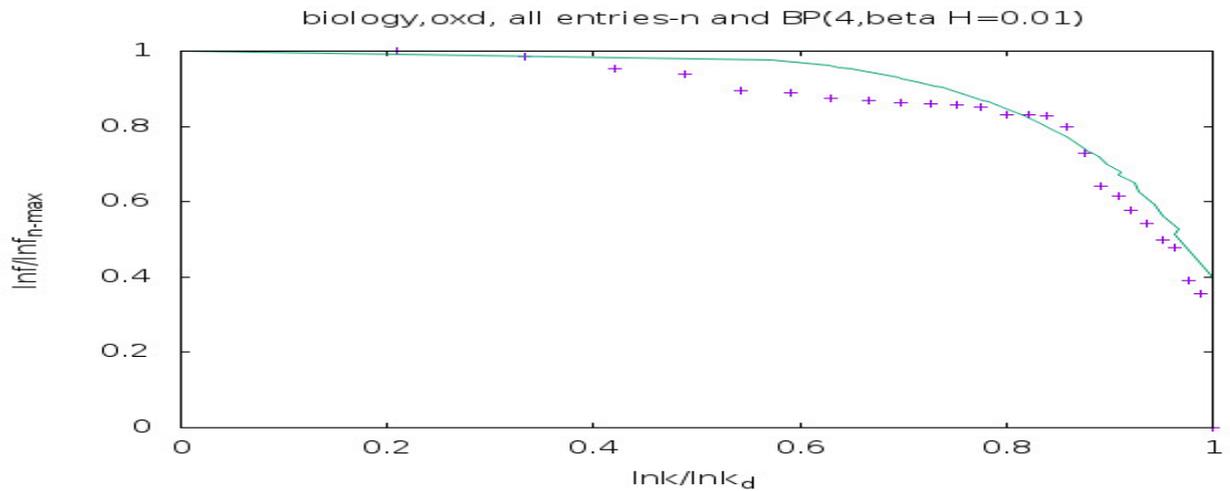


FIG. 13. The vertical axis is  $\frac{\ln f}{\ln f_{next-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and little external magnetic field,  $m = 0.005$  or,  $\beta H = 0.01$ .

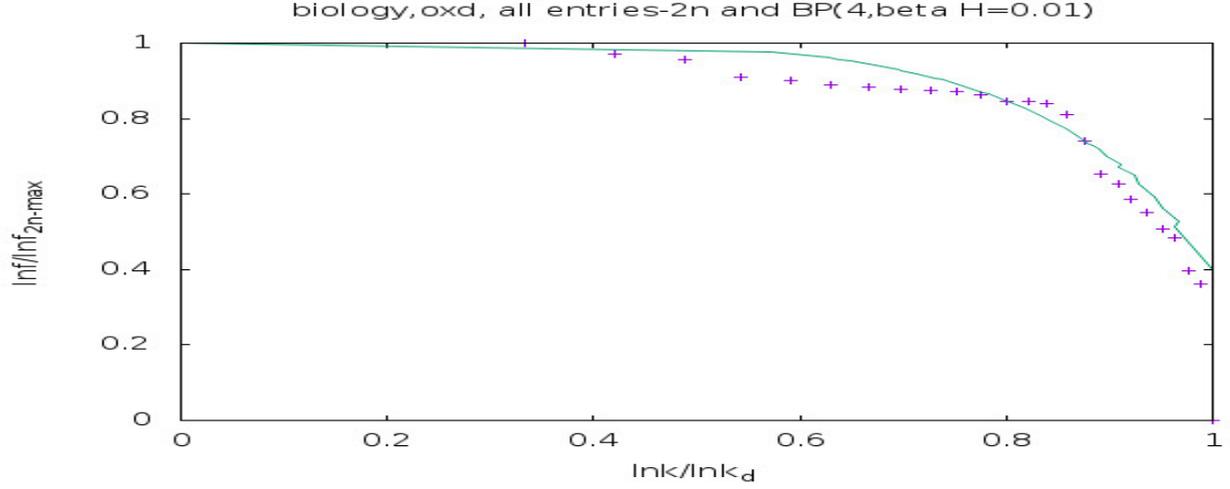


FIG. 14. The vertical axis is  $\frac{\ln f}{\ln f_{nextnext-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and little external magnetic field,  $m = 0.005$  or,  $\beta H = 0.01$ .

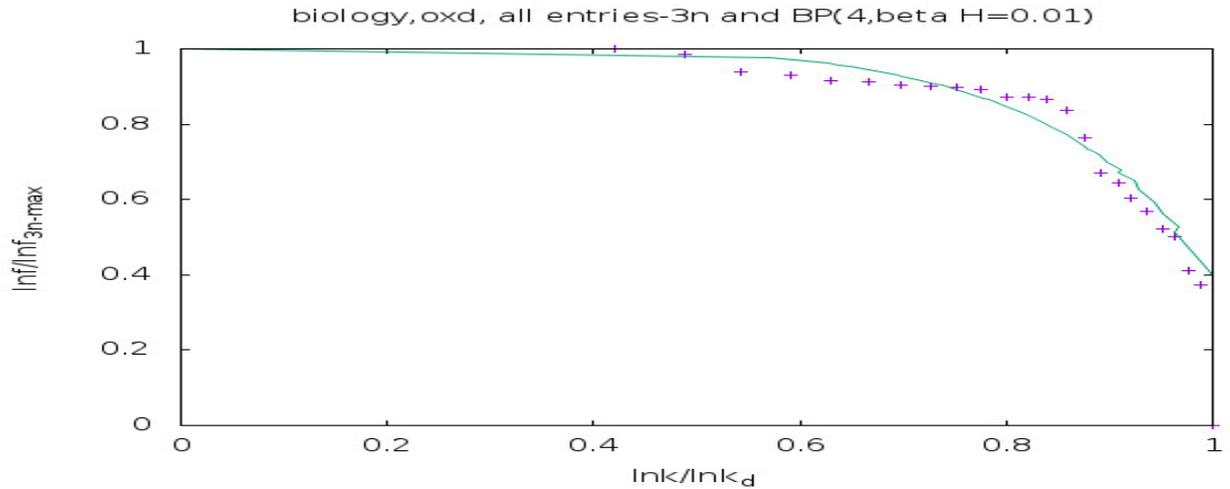


FIG. 15. The vertical axis is  $\frac{\ln f}{\ln f_{nextnextnext-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and little external magnetic field,  $m = 0.005$  or,  $\beta H = 0.01$ .

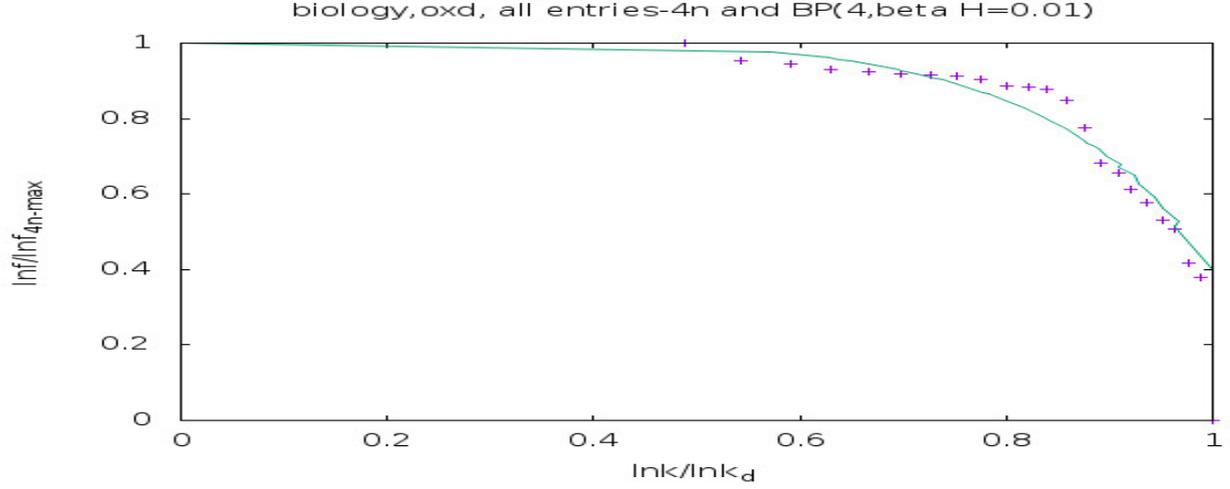


FIG. 16. The vertical axis is  $\frac{\ln f}{\ln f_{4n-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and little external magnetic field,  $m = 0.005$  or,  $\beta H = 0.01$ .

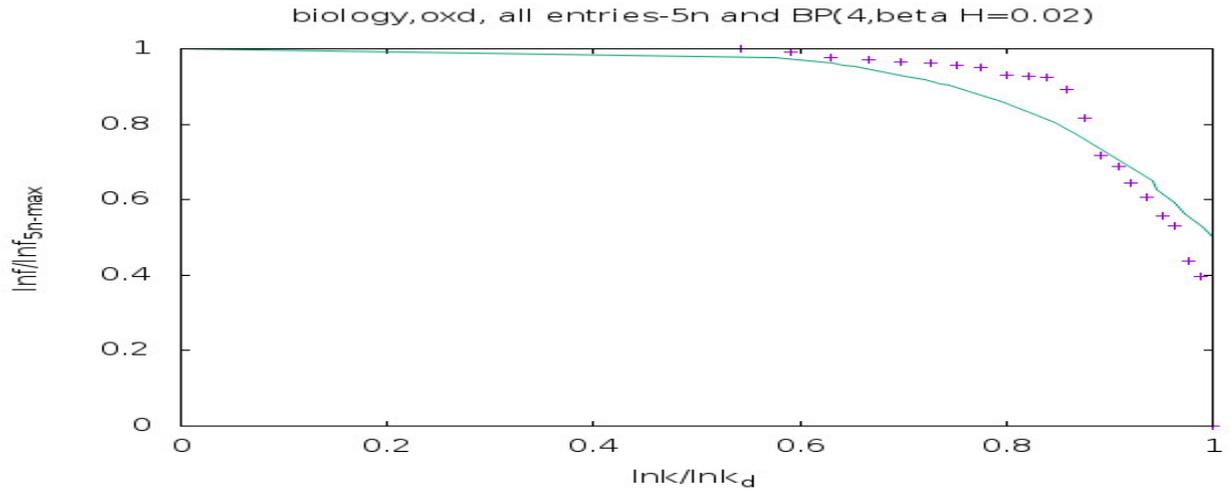


FIG. 17. The vertical axis is  $\frac{\ln f}{\ln f_{5n-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the entries of the Oxford Dictionary of Biology with the fit curve being the Bethe-Peierls curve in the presence of four nearest neighbours and little external magnetic field,  $m = 0.01$  or,  $\beta H = 0.02$ .

## A. conclusion

From the figures (fig.12-fig.17), we observe that there is a curve of magnetisation, behind the entries, all, of the Oxford Dictionary of Biology,[1]. This is the magnetisation curve in the Bethe-Peierls approximation in the presence of four nearest neighbours and little external magnetic field,  $m = 0.005$  or,  $\beta H = 0.01$ .

Moreover, the associated correspondence is,

$$\frac{\ln f}{\ln f_{4n-max}} \longleftrightarrow \frac{M}{M_{max}},$$
$$\ln k \longleftrightarrow T.$$

$k$  corresponds to temperature in an exponential scale, [49]. As temperature decreases, i.e.  $\ln k$  decreases,  $f$  increases. The letters which are recording higher entries ..., S, C, P which get enriched more and more, fall at lower and lower temperatures. This is a manifestation of cooling effect, as was first observed in [50], in another way.

## V. ACKNOWLEDGMENT

We have used gnuplot for plotting the figures in this paper.

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