

Higher Up the Chain There Is Less of the Substance, Yet It Is More Concentrated

— what raises the concentration is not the substance gathering but the living mass in the denominator shrinking faster than the substance — the separator is whether one counts the substance or divides it by the living mass —

[Paper 864]

Yuuki YAMAGISHI (山岸 勇輝)

Yamagishi Complexity Torus Lab, Japan

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YOI: <https://www.yamagishiyuuki.com/yoi/864>

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Abstract

Substances are said to become more concentrated higher up a food chain. This paper counts that the amount of substance itself falls at higher levels, and separates what raises the concentration. No new theorem or law is claimed. First, living mass shrinks by 0.1 per level: if 0.1 of what is eaten becomes body, the fifth level holds 1.000000×10^{-4} of the first level's living mass (Section 2). Second, and this is the core. The substance decreases, yet the concentration rises: if 0.9 of an ingested substance stays in the body, the fifth level holds **0.656100** of it, at **6561.000000** times the concentration (Section 2). Third, magnification per level is the retained share divided by the share that becomes body: concentrations counted level by level by mass matched the fourth power of that ratio within a relative difference of 10^{-9} for all five retained shares (Section 3). Fourth, if the retained share is below the share that becomes body, higher levels are diluted: at a retained share of 0.1 the concentration stays at 1.000000; at 0.05 it becomes **0.062500** (Section 3). Fifth, even if all the substance is retained, its amount does not grow: at a retained share of 1.0 the fifth level holds 1.000000 of it at 10000.000000 times the concentration. The whole rise comes from the denominator (Section 3). Sixth, the separator is whether one counts the substance or divides it by the living mass: the amount falls with height and the concentration, divided by living mass, rises. The same chain points opposite ways depending on which is asked (Section 4). **Keywords:** biomagnification, food chain, magnification factor, transfer efficiency, concentration, model.

Scope of this paper (scope note): No new theorem or law is claimed: biomagnification, the loss of living mass from level to level, and writing the magnification factor as the ratio of retained share to the share that becomes body, are all known. No real values are claimed: the share 0.1 and the retained shares are model values matching no substance and no ecosystem. Mechanisms are not included: excretion rates, body size, solubility in fat and direct uptake from water are not included. The chain is simplified: each level eats all of the level below and nothing else. Toxicity is not discussed. What concentrations do to a body, or how to set limits, is not treated. Relation to earlier papers: Paper 417 showed that the ceiling on food-chain length is not a fact about animals. This paper stands beside it. There, energy shrinking to a tenth per level set the number of levels. Here the same tenth sits in the denominator and raises the concentration. What is added is laying out living mass, substance and concentration level by level, measuring a 6561.000000-fold concentration while the substance decreases, varying the retained share to find the border between concentration and dilution, and placing the separator on counting the substance versus dividing by living mass.

1. Notation and the Question

Setting: the first level has living mass 1 and substance 1 (concentration 1). Each next level eats all of the level below; a share ε of what is eaten becomes body and a share f of the ingested substance stays in the body. Living mass B_k , substance M_k and concentration C_k at level k are as follows.

$$B_{k+1} = \varepsilon B_k, \quad M_{k+1} = f M_k, \quad C_k = \frac{M_k}{B_k} = \left(\frac{f}{\varepsilon} \right)^{k-1}$$

The share becoming body is $\varepsilon = 0.1$ (the same tenth as Paper 417), with five levels.

Question: is the higher concentration at upper levels due to the substance gathering there?

2. Amount and Concentration by Level

Computation 2.1: with retained share $f = 0.9$, mass was followed one level at a time.

level	living mass	substance	concentration
1	1.000000	1.000000	1.000000
2	0.100000	0.900000	9.000000
3	0.010000	0.810000	81.000000
4	0.001000	0.729000	729.000000
5	0.000100	0.656100	6561.000000

Observation 2.2

this is the core. The substance decreases, yet the concentration rises. The fifth level holds 0.656100 of the substance, less than the first: the concentration still reaches 6561.000000 because living mass falls to 1.000000×10^{-4} , far faster than the substance.

3. Varying the Retained Share

Computation 3.1: the retained share f was varied five ways and the fifth level compared.

f	magnification per level f/ε	substance at level 5	concentration at level 5
0.05	0.500000	6.250000×10^{-6}	0.062500
0.10	1.000000	1.000000×10^{-4}	1.000000
0.50	5.000000	6.250000×10^{-2}	625.000000
0.90	9.000000	6.561000×10^{-1}	6561.000000
1.00	10.000000	1.000000	10000.000000

Observation 3.2

the border is where the retained share equals the share that becomes body. At $f = \varepsilon = 0.1$ the concentration stays at 1.000000; at $f = 0.05$ it is diluted to 0.062500: concentrations counted level by level by mass matched $(f/\varepsilon)^4$ within a relative difference of 10^{-9} in all five cases.

Observation 3.3

even if all the substance is retained, its amount does not grow. At $f = 1.0$ the fifth level still holds 1.000000 of the substance, at 10000.000000 times the concentration: the substance never exceeds 1 for any f . The whole rise in concentration comes from living mass in the denominator shrinking by a tenth per level.

4. The Separator

Observation 4.1

the separator is whether one counts the substance or divides it by the living mass. Counted as an amount it falls with height; divided by living mass it rises: the same numbers of the same chain point opposite ways depending on which is asked. “Substance gathers at the top” is wrong as a statement about amount and right only as a statement about concentration.

Observation 4.2

placed beside Paper 417.417 showed that energy shrinking to a tenth per level sets the ceiling on food-chain length. There the tenth worked as a loss. Here the same tenth sits in the denominator of the concentration and works to raise it.

Observation 4.3

what is not said. Real substances and ecosystems, excretion rates, body size, toxicity and limits are not treated. What is shown is that the rise in concentration comes not from the substance gathering but from how the denominator shrinks.

5. Census and Closing

1. concentration is $(f/\epsilon)^{k-1}$ (Section 1): **substance over living mass.**
2. fifth-level living mass 1.000000×10^{-4} (Computation 2.1): **0.1 per level.**
3. at $f = 0.9$ the substance is **0.656100** (Computation 2.1): **it has decreased.**
4. at $f = 0.9$ the concentration is **6561.000000** (Computation 2.1): **the core.**
5. at $f = 0.5$, **625.000000** (Computation 3.1): **5 per level.**
6. at $f = 0.1$, **1.000000** (Computation 3.1): **the border.**
7. at $f = 0.05$, **0.062500** (Computation 3.1): **the dilution side.**
8. at $f = 1.0$ the amount stays **1.000000** (Observation 3.3): **concentration 10000.000000.**
9. level-by-level count and formula within 10^{-9} (Observation 3.2): **independent.**
10. count the substance, or divide by living mass (Observation 4.1): **the separator; Paper 417.**

Closing: Higher up the chain there is less of the substance, yet it is more concentrated. If 0.1 of what is eaten becomes body and 0.9 of the substance is retained, the fifth level holds 0.656100 of the substance at 6561.000000 times the concentration, because living mass falls to 1.000000×10^{-4} , far faster than the substance. Magnification per level is the retained share divided by the share that becomes body: 625.000000 at 0.5, 1.000000 at 0.1, and dilution to 0.062500 at 0.05: even if everything is retained the amount does not exceed 1.000000, and the whole rise comes from the denominator. Placed among the earlier papers: beside the tenth that Paper 417 counted as the ceiling on chain length, we placed the same tenth working as the denominator of concentration. To be honest: the shares are model values, and excretion rates, body size and branching chains are not included.

References

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