Communications of the Blyth Institute

Volume 3, Issue 1

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Blyth Institute Press

CBI Communications of the Blyth Institute

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About This Journal

1 The Purpose of the Journal

Communications of the Blyth Institute was founded due to needs both within The Blyth Institute as well as needs in the wider research community. As The Blyth Institute has grown, it has become more difficult to share and disseminate research and ideas for research within our own community. Mailing lists are ephemeral, blogs are trite and difficult to cite in later research, and forums tend to be worse on both accounts. Therefore, this journal was established to provide a means of communicating ideas that is more formal than conversation, but also more expeditious than other journals.

Likewise, in the wider research community, ideas often need time as well as participation to grow. That is, the first iteration of an idea, even of a great idea, is often fraught with problems that need to be ironed out. Most journals quite reasonably want to have ideas more fully formed before publication. However, sharing ideas informally prior to publication increases the risk for researchers of others taking credit for their ideas.

Therefore, *Communications of the Blyth Institute* fills a role for creating a space for the formal publication and peer review of inchoate ideas, both inside and outside of The Blyth Institute.

2 Paper Submission Policies

2.1 Submitting to the Journal

Because the primary goal of *Communications* is to serve the membership of The Blyth Institute, all submissions must either be by a Blyth Institute member or be sponsored by a Blyth Institute member. "Sponsorship" in this case merely means that the Blyth Institute member believes that the paper is worth considering by members of The Blyth Institute. The sponsoring member does not have to have any official association with the paper. If someone who is not a member of The Blyth Institute wishes to submit a paper for consideration, all that is needed is for them to submit the paper to someone who is a Blyth Institute member and ask that they sponsor it for you. The sponsoring member will then submit it on your behalf.

Members of The Blyth Institute may submit their ideas to communications@blythinstitute.org.

2.2 Submission Review Process

Communications employs a prompt review process for formal papers submitted to the journal. The editor will appoint one or more reviewers to review the paper. Reviewers will review the paper to verify that the paper fulfills the following qualities:

- The idea is original (unless explicitly marked as a review paper).
- The idea is of interest to either Blyth Institute members or the wider research community.
- The author makes reasonably clear distinctions between assumption, fact, inference, proposal, opinion, and conjecture.[1]
- The author presents reasonable data and evidence for their conclusions.

Additionally, reviewers should provide commentary on the ideas themselves. Reviewers may weigh in as to whether the paper should be published, though ultimate publication authority lies with the editor.

Authors will then be given a chance to revise their paper and respond to the comments and cricitisms of the reviewers. The editor will then make a final determination for publication.

[1] Because this journal focuses on more inchoate ideas, we want readers to be clear how well-founded each part of the author's proposal is. The goal isn't to make an overly-wordy paper, but simply to make sure readers are appropriately informed as to the levels of confidence that should be attached to various ideas presented in the paper.

2.3 Scope of the Journal

The scope of the journal is not strictly limited. The Blyth Institute is a loose consortium of researchers scattered throughout the world, with many diverse interests. The main focus of The Blyth Institute has been in non-reductionist perspectives on biology and cognition. While this will likely remain the focus of the journal, any topic that a Blyth Institute member thinks that other Blyth Institute members will benefit from can be included. *Communications* accepts papers in a wide variety of fields including most sciences, mathematics, and philosophy.

The editors have the final say for inclusion and exclusion for the journal.

2.4 Formatting Papers for Submission

Ideally, papers should be submitted in LaTeX format using an "article" document class. Because the journal is presently run entirely by volunteers, we request that papers utilize a minimum of LaTeX trickery, focusing instead on basic LaTeX features to simplify inclusion in the journal.

If you are unfamiliar with LaTeX, you may submit your file as a Word document (.doc or .docx). Please keep formatting to a minimum, and submit all figures and tables as *separate* files.

For smaller submissions such as news items, letters, and notes, feel free to simply email them directly as text.

3 Other Journal Content

3.1 Student Papers

The Blyth Institute has always recognized the importance of enabling the next generation of researchers. As such, we welcome contributions from students. The Blyth Institute recognizes that students do not always research and write on the same level as more established researchers, as their breadth of experience and knowledge is not the same.

Therefore, The Blyth Institue will also allow papers from students that undergo a lighter level of review, and for which our standards are relaxed. These papers will be marked as "Student Papers." Any student is free to make regular submissions as well. Readers should be aware, however, that papers marked as student papers will have relaxed standards applied.

3.2 Letters and Notes

Communications will also publish letters and notes sent to the editor. These letters and notes can be for a variety of purposes, including but not limited to (a) responding to a previously published *Communications* paper, (b) responding to publications elsewhere, (c) responding to news events or cultural aspects of science, and (d) communicating short ideas that have not yet been developed into paper-length submissions. Letters and notes are primarily reviewed by the editors, but the editors, at their discretion, can request additional review from other sources.

3.3 Tutorials and Reviews of Fundamentals

In addition to typical reviews covering the latest results in a field, *Communications* also publishes tutorials and reviews of the fundamentals of a field, aimed at providing experts in other fields information that they may need for cross-disciplinary work. Tutorials focus on the performing of a task while a fundamentals review focuses more on concepts.

3.4 Book Reviews

Communications encourages the submission of book reviews, especially by newer contributors. Book reviews are an excellent way for new researchers to both gain knowledge in their field as well as publication experience. Book reviews for *Communications* should include both summaries and critical engagement with the material. The books should be scholarly works which would be of interest to Blyth Institute members.

3.5 News Items

Communications also supplies a news section. This section will include news about The Blyth Institute itself, as well as anything that Blyth Institute members find interesting and worth sharing with other members. If you are a member of The Blyth Institute, notices of peer-reviewed papers published elsewhere will appear within the news section.

From the Editors

The Blyth Institute was originally founded in 2010 through the encouragement and assistance of Philip Feist, who donated his services and expertise to get the organization off the ground. Through the years we have hosted conferences, published proceedings, written papers and books, launched *Communications of the Blyth Institute* (*CBI*), helped students get access to quality scientific instruments, educated the public about various advances in science, and helped to fund and encourage researchers in their efforts. With our ten year anniversary, however, we are also considering some changes to the structure of the organization.

While our conferences and journal accept papers from scholars around the world, The Blyth Institute itself has historically been a relatively small, closed group. However, we have recently been thinking about how to open up to include more people in our organization. We believe that the health of the institute as a whole depends on having more people with a vested interest in its future. Therefore, we are considering a variety of options for membership and fellowship in the organization.

While details are still being worked on, the current idea is to have a broad membership which anyone can join. Perks of membership may include things like a shared LaTeX workspace, publication access to our preprint server, participation in a group chat or message board, a print subscription to *CBI*, and perhaps a more frequent newsletter from the organization. Additionally, an invited fellowship program would be created for researchers to have a more official status in the organization. Currently, fellows of the institute are voted on by the board of directors yearly. A more expedited process to approve fellows is neeeded. The benefits of fellowship would include highlighting of the fellow's research and publications on the website, notifications of new research and books in the news section of *CBI*, priority consideration for inclusion of papers in *CBI*, and having a say in the direction of the organization as a whole.

As it says on our website, the vision of The Blyth Institute is as follows:

> The 20th century was a time of pulling things apart. Dissecting. Compartmentalization. Reducing everything to the tiniest part. Without a doubt, these were important steps in the history of science. However, the new century demands a new journey of science. A science of integration.
>
> The Blyth Institute is on the leading edge of the interdisciplinary integration that will lay the foundation and set the standard for science in the 21st century and beyond. The Industrial Revolution led to a science of breaking things down. The Information Revolution is leading us to a science that brings the parts back together.

We hope that readers consider joining us for this journey. Details on what that will look like will hopefully be announced within the next few months.

Sincerely,

—The Editors

A Corollary of the Conant-Ashby Theorem Applied to Abiogenesis

Eugenio Darbesio

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Abstract

From the Conant-Ashby theorem about the "good regulator" is possible to derive a corollary about the origin of life (OOL). This corollary introduces the concept of "good constructor." Then it is shown as nature, seen as a material system ruled by the laws of physics, cannot be a "good constructor" of the basic machinery necessary for a living cell. As a consequence OOL needs intelligent design.

Norbert Wiener defined cybernetics as "the science that deals with control and communication in systems and organisms"(Wiener, 1948). Biochemist Michael Behe states: "the essence of cellular life is regulation: the cell controls how much and what kinds of chemicals it makes; when it loses control, it dies" (Behe, 2006).

Given these statements on the importance of control, one wonders if cybernetics can say something about naturalistic origin of life (abiogenesis) and evolution. The answer is a bold yes. Even one of the theorems of cybernetics can provide us the basis for a disproof of abiogenesis. In theoretical cybernetics a fundamental result is the "good regulator theorem" by Roger C.Conant and William Ross Ashby (Conant and Ashby, 1970), henceforth referred to as the "C&A theorem":

> Theorem: The simplest optimal regulator R of a reguland S produces events R which are related to the events S by a mapping h : S → R .
>
> Restated somewhat less rigorously, the theorem says that the best regulator of a system is one which is a model of that system in the sense that the regulator's actions are merely the system's actions as seen through a mapping h. The type of isomorphism here is that expressed (in the form used above) by
>
> $$\exists h : \forall i : \rho(i)=\mathrm{h}[\sigma(i)]$$
>
> where ρ and σ are the mappings that R and S impose on their common input I. [...] **The effect of this theorem is to change the status of model-making from optional to compulsory**.

In a sense the C&A theorem is intuitive: to regulate a system you must know the system. More the knowledge more good the regulation and control. Without knowledge it is likely you damage the system instead of regulating it. This is the reason why children are not allowed to drive cars and manage weapons, entrance in the aircraft cockpit is forbidden to passengers, etc..

Cybernetician Daniel L.Scholten, in his revisitation of the C&A theorem (Scholten, 2010), stress its importance in many fields: "The C&A theorem is a fundamental theorem of problem solving and as such shows us how to make meaningful progress toward the solution of any problem whatsoever." He adds:

> As an example of a *static* control-model, consider an inexperienced cook attempting to make a roast duck with the help of a recipe. In this case, the system to be regulated consists of the various ingredients and kitchen tools to be used to create the meal, the dynamic good-regulator model is the human being doing the cooking, and the recipe is what we are calling the *static* "control-model".

The intuitive cook's example can be generalized to any constructor/assembler of systems. In this more general case, by paraphrasing Scholten, we can say that the system to be regulated consists of the various elements/parts and assembly tools to be used for the job, the "dynamic good-regulator model" is the "good constructor" making the construction, and the "design" is the static "control-model."

Also the constructor corollary of the C&A theorem considered here is intuitive: to construct a system one must have it in his mind in any detail. In other words this corollary is consistent with any intelligent design scenario where a designer conceives before and eventually construct after a system. The designer must contain in his mind an internal isomorphism of the external design. This is the reason why laymen are not in charge of projecting nuclear plants, why to build houses they hire architects and so on. John von Neumann's in his researches about automata perfectly expressed the "constructor corollary" this way: "Generally speaking, an automaton A, which can make an automaton B, must contain a complete description of B and also rules on how to behave while effecting the synthesis" (von Neumann, 1966). The constructor corollary is coherent with causation theory: any cause virtually contains all its effects just from the beginning. It is consistent also with the potentiality principle: any system can produce only what is potentially contained in itself and its potentiality.

Here, as a follow-up or corollary of the C&A theorem, I will consider its application to the question whether origin of life may have a naturalistic cause or an intelligent one. In other terms, can the natural forces alone, acting on sparse atoms and molecules, regulate and construct a first biological cell? To the goal it is necessary to construct the "GRC" (Genome + Ribosome + genomic Code), a dynamic chemical system that produces proteins from amino acids according to the genomic language and instructions. The GRC, a fundamental system in the molecular machinery of any biological cell, involves Turing machines (TM). In informatics a TM is defined as a finite-state machine able to write and read symbolic instructions in a memory device.

As part of the GRC, the DNA-polymerase molecular machine produces RNA from DNA (genome). The DNA, a couple of complementary strands of polimers composed of four symbols {A, T, G, C} which can be written and read according to the "genetic code," may be thought of as a tape of a TM. Another part of the GRC is the ribosome. The ribosome is a molecular machine which translates messenger RNA (mRNA) and builds polypeptide chains (proteins) using amino acids carried by transfer RNA (tRNA).

Leonard Adleman, a mathematician who pioneered the so-called "DNA computing," in his first groundbreaking work, recognised that "biology and informatics, life and computers are tied toghether," and said that "it's hard to imagine something more similar to a Turing machine than the DNA-polymerase" (Adleman, 1994). The DNA-polymerase is an important enzyme of the cell that is able, starting from a DNA strand, to produce another complementary DNA strand (complementarism means that C changes to G and T changes to A). This nano-machine slides along the filament of the original DNA reading its bases and at the same time writes the complementary filament. As a TM begins an elaboration from a starting instruction on the tape likewise the DNA-polymerase needs a start mark telling it where to begin producing the complementary copy. Normally this mark consists of a DNA segment called a "primer." Analogously in the genetic code a stop codon (or termination codon) is a nucleotide triplet within messenger RNA that signals the termination of translation.

Biological computers are even more advanced, efficient and miniaturized than artificial ones. First the DNA language and the genetic code are highly optimized. Moreover the memory is used more efficiently. In fact, according to many researches, often the same sequence of DNA contains multiple information (e.g. it codifies for proteins and in the same time stores data related to other cellular processes or structures). Biological technology is superior because in multiple-coding DNA sometimes we derive different levels of interpretation from the same piece of code. Such astounding compression of data is very difficult to design, in fact it has rarely been attempted in human technology. It is clear that the problem of writing/reading memory in these cases of multiple interpretations becomes ever more unreachable by chance and necessity.

Back to the issue, can the system composed of the natural laws and randomness acting on atoms (henceforth "chance and necessity," "C&N") regulate them until arriving to spontaneously assembly a GRC system? Since the isomorphism that is considered in the C&A theorem must exist between GRC and C&N (if the latter must be the regulator of the construction process of the former) then we must analyze their structures and compare them (isomorphism is similarity of structure).

By doing that we discover that at least two things belonging to the structure of the GRC have no counterpart in C&N (obviously this doesn't exclude other differences).

(1) First to be missing is the genetic code the GRC uses, i.e. the mapping between all the symbolic RNA nucleotide triplets XXX (where X is G or A or C or U) and the amino-acids. Example of the mapping: the symbol "CGU" (the molecular sequence cytosine / guanine / uracil) references arginine amino acid. This mapping is fully contingent and arbitrary. It is a free choice, as is free the choice of naming my cat Felix instead of Red. Nowhere the laws of physics and chemistry, neither explicitly nor implicitly, specify the arginine symbolic reference or other references of the genetic code. For C&N and its potentiality the genetic code simply doesn't exist.

What we argue here is similarly expressed by Albert Voie:

> Due to the abstract character of function and sign systems, life is not a subsystem of natural laws...Life express both function and sign systems, which indicates that it is not a subsystem of the universe, since chance and necessity cannot explain sign systems, meaning, purpose and goals. (Voie, 2006)

Some could object that the interaction of randomness and physical laws causes things to happen that are not specified by any physical law (for example, the weird circuitous route that natural rivers generate, or crazy stone bridges from natural erosion). This object doesn't refute point (1) because circuitous route of rivers or stone bridges are not *codes*, that is abstract formalisms that map together abstract entities, whose reality transcends the physical plane. Routes of a river or stone bridges don't transcend the physical plane.

(2) The GRC, being an instruction driven system, implements decision/control structures. The simplest of these programming structures has the form:

```
# prior situation

 if (condition) {
    action1
} else {
    action2
}

# after situation
```

Note that a decision/control implies choice among two or more alternatives, depending on some conditions. A decision breaks the causal chain and inserts a choice discontinuity between "prior situation" and "after situation." This decision/choice is fully contingent and arbitrary. This kind of decision constructs can be nested ad libitum in a program to create complex control chains. Software, whatever be the material medium of the symbolic processing, is control. But complex control/regulation chains is something you find also countless times in the literature on cellular biology and systems biology.

Natural laws can be described by means of a basic set of equations. These equations represent the direct relations between variables, and directly assign values to these variables. Here a key point is the term "direct" and "directly." Example, in mechanics the Newton's formula **F=m*a** assigns a value to "**F**" when the values of the other two variables "**m**" and "**a**" are known. That is simple and unconditioned. The formula neither contains nor depends on any control structure related to some contingent/arbitrary constraint, which could insert a discontinuity in the Newton law. In other words, given any "**m**" and "**a**" there is no something like the following working on:

```
# prior situation

 if (arbitrary condition) {
     F = k1 * m * a
} else {
     F = k2 * m * a
}

# after situation
```

In the original formula **F=m*a**, between any "prior situation" and "after situation," there is no discontinuity due to decisions that break the physicodynamic determinism by introducing free choices (above symbolized by the different coefficients $\mathbf{k_1}$ and $\mathbf{k_2}$). This is an important point: in natural laws there aren't arbitrary contingent decisions like exist in software. Natural laws have no choices, no freedom, they have only constraints. This is true for all physical laws, also when they are expressed as differential equations (e.g., wave equation, Maxwell's equations, Schrödinger equation, etc.).

Obviously if natural laws (necessity) haven't decision structures involving contingency and arbitrariness, to greater reason randomness (chance) has no decision power or freedom. In fact, randomness not even has the minimal structure that natural laws have. Random events are fully uncorrelated by definition of chance.

A critic could claim that interaction of physical objects can also create conditional discontinuities (for example, iron is normally not magnetic, but when a magnet is placed near a piece of iron it becomes magnetic). Again this criticism doesn't apply to our point (2) because in the statement "IF a magnet is placed near a piece of iron it becomes magnetic" the IF is static and part of nature (no choice, a piece of iron near a magnet becomes *always* magnetic). Differently, in the instruction driven systems considered in bio-cybernetic (or computer programming) the IFs are artificial, dependent on the highly specific configuration of the codes. Additionally, for control theory and C&A, these statements are dependent on the holistic state of the system. For a biological example, in the cell a tRNA loaded with an amino acid doesn't produce *always* a piece of protein. It does it only IF the tRNA gets in the ribosome assembly machine. But this is a contingent choice, in the spacetime, of the cellular design. It is both artificial (dependent on code sequence) and holistic (dependent on the holistic state of the organism). In short, the "conditional discontinuity" of the iron-magnet is not a real *conditional* in the programming sense. Programming, in computers and bio-cybernetics, is *freedom*. Iron and magnets have no freedom.

To sum up the necessary isomorphism condition of the C&A theorem is not satisfied just for the above two differences. C&N cannot be the "good constructor" of a GRC. It is necessary a constructor implying the isomorphism between itself and the GRC, i.e. an intelligent constructor.

In a sense the C&A theorem is intuitive: to regulate a system one must know the system. Also the corollary considered here is intuitive: to construct a system one must have it in his mind. In short, if to regulate something one must know it, to greater reason one must know it to construct it ex novo.

Of course the C&A theorem and its corollary perfectly agree with all the ideas of design theorists:

- William Dembski's "conservation of information" principle (Dembski, 1998)
- David Abel's "Formalism > Physicality (F > P)" principle (Abel, 2011)

- Donald Johnson: “while life uses the laws of chemistry and physics, those laws cannot define or explain life any more than the rules of grammar that were used during the preparation of a book define its content” (Johnson, 2010)

We have seen that C&N is unable to regulate the construction of the first GRC. The C&A theorem prescribes an isomorphism between C&N and what it pretends to construct. Since C&N lacks an isomorphism with GRC, then no C&N process can produce a GRC. Since GRC is a key feature of any biological cell, then the cell cannot be produce by C&N. Life didn’t arise from a primordial soup this way. This means that an intelligent cause was at work. Because only intelligence is able to contain and inject models and formalisms into the systems it designs.

References

Abel, David (2011). *The First Gene: The Birth of Programming, Messaging, and Formal Control*. Longview Press.

Adleman, Leonard (1994). “Molecular Computation of Solutions to Combinatorial Problems”. In: *Science* 266.5187, pp. 1021–1024. DOI: 10.1126/science.7973651.

Behe, Michael (2006). *Darwin’s Black Box*.

Conant, R C and R Ashby (1970). “Every Good Regulator of a System Must be a Model of that System”. In: *International Journal of Systems Science* 1.2, pp. 89–97.

Dembski, W A (1998). *The Design Inference*. Cambridge University Press.

Johnson, Donald (2010). *Programming of Life*.

Scholten, D L (2010). *Every Good Key Must be a Model of the Lock it Opens (The Conant & Ashby Theorem Revisited)*.

Voie, Albert (2006). “Biological Function and the Genetic Code are Interdependent”. In: *Chaos, Solitons, and Fractals* 28.4.

von Neumann, J (1966). *Theory of Self-Reproducing Automata*. Urbana: University of Illinois Press.

Wiener, N (1948). *Cybernetics: Or Control and Communication in the Animal and the Machine*. MIT Press.

Comets, Water, and Big Bang Nucleosynthesis

Robert Sheldon

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Abstract

We argue that the cosmological origin-of-life problem is tightly connected to the origin-of-water problem, because life is not possible without abundant water. Since comets are astronomically dark and composed of water, as well as possessing microfossils, they are an underestimated candidate for the origin of life. If in addition dark matter is composed of comets, then water outweighs the visible stars, possibly solving several cosmological mysteries simultaneously. This motivates us to consider how it is possible to build a cosmological model in which water is formed in the Big Bang and then hidden from modern astronomy. In the process, we discover that magnetic fields play an important role in making water, as well as addressing several well-known deficiencies of the standard ΛCDM cosmological model of the Big Bang. We do not see this paper as a demonstration but as an outline of how to address the origin of life problem with dark comets.

1 Introduction

This paper attempts an outline of how to solve several hard problems simultaneously. This approach will satisfy no one, but without the coupling, the individual pieces remain unmotivated, and perhaps, unconvincing. We think that by addressing them all-at-once, not only will they make the whole more significant, but they will lend credibility to the model. At any rate, there did not seem to be a way to break the problem down into smaller, publishable parts.

The Origin-of-Life (OOL) is a "hard problem" of biology, since evolution manifestly cannot influence non-replicating, non-living objects, making OOL a bottleneck for the entire Darwinian theory. Since the Earth was molten and dry throughout the Hadean until the Late Heavy Bombardment delivered water, OOL could not commence until perhaps 3.85 Gya. But since the oldest stromatolite fossils date to perhaps 3.75 Gya, OOL must take less than 100My, a geologically brief time (Nutman et al., 2016). However if OOL takes so little time, then given the 3700My since, at least thirty-seven different types of life should now exist, yet no "shadow biosphere" has ever been found (Davies et al., 2009). Instead all life utilizes the same DNA code and appears to be descended from the same complex lifeform—the last universal common ancestor (Weiss et al., 2016). Indeed, with many of life's basic building blocks now available in the oceans from decaying organics, this calculation suggests OOL should be ridiculously easy today, as Hoyle was fond of remarking (Hoyle, 1999). Instead, Pasteur's flasks show that in 150 years since he sealed them up, life has not spontaneously generated.[1] Rather take an already unlikely spontaneous OOL theory and add *ad hoc* assumptions to explain the present absence of other spontaneous life, we postulate that life did not originate on Earth, but was transported here.

The recent discovery of microfossils on carbonaceous chondrite type I (CI) meteorites, widely thought to be extinct comets, suggests that life could be transported by comets (R. Hoover, 2011). In this case, we bypass the unlikely OOL on Earth and rely on the much more likely transport to Earth. Since comets outnumber and outweigh Earth-like planets in the universe, the cometary biosphere may be many orders of magnitude larger than the Earth biosphere. Then life is not just optimized for comets but is endemic throughout the galaxy, because comets can stably exist not just in the "Goldilocks zone" but anywhere (R. B. Sheldon and R B Hoover, 2007). This expanded locale can improve the OOL likelihood by some six to ten orders of magnitude. And if comets also make up the dark matter of the universe, as we argue later, we gain another ten to twelve orders of magnitude in probability.

Even this improvement in probability for OOL, however, pales in comparison to the 40,000 or so orders of magnitude improbability for spontaneous life estimated by Hoyle, calculated by assuming a random ordering of the amino acids making up the essential proteins of a cell (Hoyle and Wickramasinghe, 1982). On the other hand, if phase space is somehow structured, if the die are loaded, then there may be a way to beat the house odds (Davies, 1999). So in addition to dark matter comets, we also argue for a low-entropy, high-information, initial state

[1] Swan-necked flasks prepared by Louis Pasteur (1862) in the Pasteur Museum, 25, rue du Docteur Roux – 75015 Paris.

for the universe, in essence, front loading information into the Big Bang. This paper traces the outline of a possible scenario for OOL where the initial state of the universe has high information, and comets are ubiquitous. Such a scenario makes predictions for the distribution of matter and life that can be tested by observation. It also changes the standard model of the Big Bang.

2 Benefits of a Magnetized Big Bang and Dark Matter Comets

2.1 Dark matter comets

The observed excess speed of stars orbiting the center of the Andromeda galaxy enabled astronomers to calculate the "extra" gravitational attraction necessary to keep the stars from flying out of the galaxy, which became the original definition of "dark matter" (DM) (Zwicky, 1933; Rubin and Jr, 1970). Integrating this force gives the gravitational potential, which in galactic cross-section is a flat-bottomed well, unlike the cuspy potential of, say, a black hole at the center. Since galaxies are ~12Gy old, the evenly distributed DM must not be susceptible to viscous drag, the force which collapsed the nebular matter of our solar system to make the Sun and planets 5Gya. But the same gravitational attraction that binds the galaxy also inevitably produces viscosity, which over time should condense the majority of the DM to the center of the galaxy. Added to this mystery, is the "universal" shape of the galactic DM density curve when plotted against the gradient of the gravitational potential, a shape that is not "cuspy" but "cored" and tracks the visible matter outside of the galactic center (McGaugh, Lelli, and Schombert, 2016).

There are several solutions to this problem, with the majority of cosmologists adopting a cold dark matter (CDM) / weakly interacting massive particle (WIMP) solution. Unfortunately WIMP searches (LUX, IceCube, SuperKamiokande, etc.) have all come up negative, as have particle physics experiments that attempt to make WIMPs (Supersymmetry, axions, sterile neutrinos, etc.). The alternative option of massive compact halo objects (MACHOs) or black holes, has been observed in the galaxy, but not in sufficient quantities. Even the unorthodox modified newtonian dynamics/gravity (MOND) has not worked for all galaxy types, leaving theorists without a viable DM candidate (Joyce et al., 2015). In desperation, theorists propose new physics that only applies to exotic dark matter, called "dark interactions" or "dark sector", which, when evaluated by the rule that every theory is allowed one tooth fairy, is several tooth fairies too many.

In contrast to all these failed theories, we propose that ordinary comets possess exactly the right dynamical properties for DM that satisfy the galactic distribution as well as McGaugh's third law of galaxy rotation (R. Sheldon, 2015). There are three objections against the comet hypothesis that are often raised: DM lacks viscosity, visibility, and baryons (protons, neutrons, atoms).

Addressing the first objection that DM is apparently inviscid, whereas normal matter should have a viscosity that transfers angular momentum within the swirling nebula or galaxy so as to minimize (or thermalize) the kinetic energy while conserving the total angular momentum. In the proto-solar nebula, this viscosity resulted in the majority of the matter collecting in the Sun at the center, while a small amount is spun off at high speed in the equatorial plane. But if the viscous small-angle collisions are unlikely, this transfer of angular momentum is slow, and the cloud does not collapse to a plane. Since DM has not collapsed to a disk, this lack of viscosity is usually taken to be an intrinsic property of some exotic particle, such as a neutrino or a WIMP that barely interacts with matter at all.

Low viscosity, however, can be achieved by other means than a low interaction cross section. If a directed energy source overcomes the viscous drag such as swimming bacteria, magnetic colloids, or buoyant particles in a boiling pot, they are called "active particles", a new field of study (Magistris and Marenduzzo, 2015). Likewise, comets that form steam jets as they approach a star have a "negative viscosity" that counters their stellar drag. These jets cause the comets to gain kinetic energy as the stellar density increases, so as to smooth out their distribution (or even decrease their density) in the crowded galactic center, naturally producing a "cored" distribution like the observed DM, or a flat distribution highly correlated to stellar densities. Notice that the surface temperature of the comets is low, making them invisible to astronomers, but the dynamic temperature is high, making them slightly more energetic than the visible stars, and expanding their density a bit beyond the radial extant of the galaxy, as observations show.

This also addresses McGaugh's observation that the DM follows the baryonic matter distribution very closely, but becomes more dominant as the acceleration decreases. If we consider that comets gravitationally couple strongly to stars, then the faster the star is moving, the faster the comet leaves the star, it is dynamically heated by rapidly moving outer disk stars. But from a simple Bernoulli fluid model, the faster the comets are moving, the lower their density. Hence McGaugh's third law: high acceleration lowers DM density, no MOND required.

The second objection is that astronomers cannot see this dark gravitating matter, whereas comets were thought to be "dirty snowballs" with high albedo and high molecular outgassing that should be observed with telescopes. But in the past 30 years, several satellite missions to comets (Giotto, Deep Impact, Deep Space 1, Rosetta) have revealed comet nuclei with extremely low albedo and a rigid crust that resists outgassing (R. B. Sheldon and R B Hoover, 2005). Even in our solar system, most comets are hard to detect and "stealthy" until they are within the orbit of Mars, and only pristine or long period comets retain their high-albedo, dusty, outgassing exteriors. The controversy over Frank's "cometesimal" claims revealed just how difficult it was to observe these objects (Frank, 1990). Therefore invisibility is a property shared by both neutrinos and comets.

If comets are black, shouldn't they be observable in absorption of starlight?

If the DM were a gas, it would be observable because there is so much of it. But the clumpy nature of comets reduces their optical cross section and makes them invisible. Now if DM clumps were the size of Jupiter, they could be seen by their gravitational lensing, but intermediate-sizes between peas and moons render baryonic matter invisible to both starlight and gravitational lensing. Not completely, however, for both McGaugh's third law, and the recent observation that the absorption lines in quasars—the Lyman alpha forest—are examples where baryonic matter and gravitating dark matter track each other very closely, suggesting they are the same thing (Doux et al., 2016).

The last objection is that Big Bang Nucleosynthesis (BBN) models predict the ratio of H, D, He and Li in the pristine gas clouds of the universe, which is highly constrained since increasing the baryonic density of the Big Bang shifts the equilibrium toward He and Li. Since the DM cannot be a hydrogen or helium gas (or we could see it by the extinction of starlight), then a baryonic DM solution would require a denser universe than is compatible with the observed He/H ratios and BBN models. By this negative argument, DM must consist of exotic matter such as WIMPs that do not take part in the usual BBN.

Implicit in any negative argument, however, is the assumption that everything is known to high level of certainty, a "precision cosmology" (Jones, 2017). Several auxiliary data sets are sometimes used to validate the BBN negative prediction of non-baryonic DM, such as baryon-acoustic oscillations seen in the cosmic microwave background radiation, however, we counter-claim that many of these corroborating datasets have enough adjustable parameters to fit our model as well as the standard model, and are therefore not useful for separating the two hypotheses. More exactly, all these claims of "precision" in the BBN are model-based claims, which are only as precise as the models are correct, so it is essential that we separate these 2nd-order claims from model-independent, observational 1st-order claims.

Therefore in order to address this devastating cosmology modeling objection, we need to consider how the BBN model can be modified to handle a higher baryonic density. As it turns out, BBN models are not "parameter-free" but explicitly depend on uncertain initial conditions, in particular, the proton to neutron density ratio (p/n), which it turn, depends on all four of the fundamental physical constants: the strong, the weak, the electromagnetic and the gravitational (e.g., Cyburt et al., 2016). In the 21st century, there has been a growing awareness that one more constant must be added to this mix, the entropy or informational content of the universe (Susskind, 2008). Following Calkin, we argue that organization of charged particles (information) in the GeV plasma preceding the BBN era, leads to a non-zero polarization vector field (Panofsky), which encodes currents and magnetic fields (Calkin, 1963; Panofsky and Phillips, 1956). And magnetic fields change the neutron to proton ratio. Therefore adding this fifth quantity, this information quintessence, to the basic physics of the Big Bang fundamentally changes the initial conditions, the models, the outcome, and life itself.

Summarizing the analysis section below, the result of non-zero magnetic fields is that magnetic Big Bang nucleosynthesis (MBBN) begins with far more neutrons, so that nucleosynthesis proceeds toward He, C, and O faster than is currently modeled. The extra C and O is then bound up in cometary ices to remove them from the observational astronomical inventory, leading to the mistaken impression that they are not a major constituent of the BBN. Thus is it not necessary to posit exotic DM particles that do not affect the BBN, but simply add back in the overlooked baryons.

2.2 CEMP stars and Galaxy formation

Another astronomical objection to the MBBN model, is that if C and O are produced in the Big Bang, then main sequence stars should show a much higher abundance of these elements, rather than the typical H and He composition observed. We argue that stars recycle matter that has been expelled by supernovae and stellar winds, so it is important to find the oldest stars in the galaxy and observe their composition to determine the original galactic ratios. Unfortunately, these Population III stars are often identified by their composition, so it has been difficult to assemble an unbiased data set. Recently, however, special purpose telescopes have identified an unexpected Population III category of "carbon enriched metal-poor" (CEMP) stars that have abnormally low levels of Fe, the unburnable ash of stellar furnaces (e.g., Caffau et al., 2016). The lack of Fe suggests that these are the oldest stars in the galaxy, made from pristine BB gas clouds. But if the BBN models are correct, they should have almost no carbon in their atmospheres, being some seven orders of magnitude less abundant than hydrogen, yet CEMP stars exhibit comparable abundances (Maeder and Maynet, 2015).

We argue that these CEMP stars are not the anomaly, but the trend, and that many more CEMP stars are now at the white dwarf stage where they are mistaken for terminal main sequence stars. Since white dwarfs are no longer burning nuclear fuel, their cooling rate is highly predictable, and as equally anomalous as CEMP stars are the cool white dwarf stars in the galaxy predicted by our model (Kaplan et al., 2014).

Another difficulty for the standard hypothesis solved by comets is the measured smoothness of the early universe. In order for gravitational accretion of primordial gas cloud to create comets or stars, the gas must be seeded with density fluctuations before instabilities can condense stars and galaxies. On the other hand, density fluctuations in the BB would manifest as brighter regions of the cosmological microwave background radiation (CMBR), which has been characterized by COBE, WMAP and now Planck satellites. The CMBR is too smooth to account for galactic structure, so density fluctuations are attributed to the DM, which they argue, must be decoupled from the CMBR to keep it smooth.

How then can baryonic DM satisfy both the need for seeding density fluctuations and the observation of smooth CMBR radiation?

Even in the case of exotic DM, the Hubble "deep survey" of distant galaxies observed mature galaxies so ancient that they must have formed within 400My of the BB, before the reionization era and far too quickly for the slowly developing gravitational instabilities of baryonic or exotic DM (Oesch et al., 2016). In addition, DM surveys show that the DM is too smooth for gravitational instabilities to start (Secco et al., 2021). So neither baryonic nor non-baryonic dark matter appears to solve the riddle of early galactic origins.

Comets, on the other hand, do not originate from gravitational instabilities, but from a physico-chemical process of condensation and freezing. Gravitational instabilities take millions of years to accrete stars, whereas comets accrete in thousands of years. This non-gravitational accretion driven by temperature alone produces the density fluctuations necessary to kick-start the formation of the first "ice stars", which due to their high C and O content, are particularly blue. Subsequently, the ultraviolet (UV) light from these first stars produce steam jets on the comets, giving them the velocity to actively sweep up further gas and dust, accreting and growing until they initiate a new star, far from the first. Comets streaming away from stellar nurseries will catalyze more star formation. All of this stellar activity occurs at T<0.01eV long after the CMBR has decoupled from the BBN at T<13eV, so that the galactic structure is not reflected in the CMBR, nor is the smoothness of the CMBR limiting the galactic structure.

2.3 BBN formation of C, O

In the standard model of BBN, a network of (particle mediated) nuclear reactions couples the table of isotopes, such as H+n→D+γ, written H(n,γ)D where H is hydrogen, D is deuterium, n is a neutron, and γ is a gamma-ray photon. Some 40 to 120 reactions are then solved simultaneously to determine the ratios of H, He, Li, C and O (e.g., Kawano, 1992). Most of the networks do not go beyond O, because at that point the O/H ratio has reached parts-per-trillion, and heavier nuclides are essentially non-existent. The low concentration of elements heavier than He is attributed to the "deuterium bottleneck", whereby the rarity of three-body reactions at low density require stepwise construction of heavier isotopes such as the reactions H(n,γ)D and D(d,γ)4He or D(p,γ)3He. Likewise the lack of any stable A=5,8 elements (5He, 5Li, 8B, 8Be) require 4He(d,γ)6Li deuterium reactions to hop to A=6 which takes a D. But the fragile binding energy of D prevents its formation during the hot, dense phase of the BB, so by the time sufficient D exists for reactions, the BB density is too low to continue nucleosynthesis. This bottleneck means that over large ranges of parameters and p/n ratios, all BBN models produce nearly the same result: 25% He but very little Li and beyond.

This robust result, which was touted as BBN model validation has instead turned out to be an Achilles heel, for observations of 7Li find it to be more than 3-sigma from the BBN prediction, and no amount of fiddling over the past 20 years has brought the model into better agreement. That is, a model with three parameters fits the first three elements well but misses the fourth. The last theoretical cross-section in the network was experimentally measured recently, with no change in the discrepancy (Coc and Vangioni, 2017). Therefore we argue that the initial success of the BBN model has masked an absolute discrepancy that justifies a completely reworked initial condition.

In the original 1948 paper on Big Bang Nucleosynthesis, the initial state of the universe was proposed as "a highly compressed neutron gas" (Alpher, Bethe, and Gamow, 1948). Subsequent theory in 1953 argued that the neutron decays into a proton and electron via the weak interaction mediated by the W-boson at T>2MeV, so abundant neutrinos right before BBN-era cause the exothermic transformation of neutrons into protons and the BBN-era began with a 7:1 p/n ratio (Alpher, Follin, and Herman, 1953). Then the observed 25% He/H mass ratio is simply due to the tightly bound helium soaking up all available neutrons. In 1964, Zel'dovich argued that a quantum degeneracy of anti-neutrinos filling the "Fermi sea" would exact an energy penalty from the exothermic conversion of neutrons to protons so an overabundance of anti-neutrinos would prevent the destruction of neutrons and keep protons from being created (Zel'dovich, 1964). These extra energy terms in the reaction are called chemical potentials, which Wagoner's 1967 FORTRAN code made a free parameter, showing how it was able to change the initial ratio of *p/n*, and thereby change the He/H ratios from the BBN (Wagoner, Fowler, and Hoyle, 1967). In this paper we add another magnetic chemical potential to Zel'dovich's degeneracy, arguing that the initial *p/n* of the MBBN was $p/n < 1$.

We argue that indeed there is a justification for the neutrino chemical potential, and that in fact, the mechanism does more than simply modify the weak interaction, but also the electromagnetic energies as well. Schematically, if the three neutron destroying weak force reactions: (a) $n \rightarrow p+e+\nu^*$, (b) $n+\nu \rightarrow p+e$, (c) $n+e^* \rightarrow p+e$ (where * indicates anti-particle and ν a neutrino) represents the decay of a neutron into a proton and electron, then the conservation of momentum requires that the proton and electron be moving in opposite directions. Since they are also oppositely charged, they carry a current in the same direction, which produces a magnetic field, schematically written as $n \rightarrow p+e+\nu^*+b$. Since creating the magnetic field, b, in a background field, B, takes extra energy, $E=\mu_B/2\ [(B+b)^2-B^2] \sim \mu_B Bb$ then a strong background magnetic field will oppose the currents generated by the neutron decay, and favor the conservation of neutrons, adding to the neutrino degeneracy chemical potential.

If the BB is hot enough for neutrinos to temporarily exist as electrons, then the neutrino can interact with matter. During this "electroweak" era of the BB, the neutrino-dominated universe becomes an electrically conductive ν-ν^* plasma that permits n p reactions to reach an equilibrium favoring p because of its lighter mass (Beaudet and Goret, 1976). This same conductive plasma can carry a current that produces B, and the greater the B-field, the more the equilibrium is driven back toward neutrons. By itself, this thermal B-field provides a nearly negligible contribution to the chemical potential. But feedback makes it significant.

The electroweak interaction that enables a neutrino to moonlight as an electron depends on the magnetic field strength, so that the coupling that produces the neutrino current is itself enhanced by the current, which is a positive feedback situation. Fluctuations in the thermal B enhance the current which enhance the B which enhance the current, so that very quickly, the magnetic field grows until other non-linear effects cause its saturation (Dvornikov, 2016).

For this qualitative discussion, it is enough to simply assume a large and constant magnetic field strength develops, without discerning the saturation mechanisms. But if this magnetic field is strong enough to overwhelm the (now anisotropic) thermal fluctuations, it is expected that only neutrons will be produced during this era. Once the BB expands and cools below ~1MeV, however, there is insufficient energy to make *e*-*e** pairs, the neutrinos no longer couple to the matter, the current dissipates, and the resistance of the plasma increases exponentially. Then the energy stored in the magnetic field is discharged into electrons principally, reheating them as the magnetic field decays away. In the equilibrium reaction with protons, the heated electrons drive the reaction toward neutrons, decreasing the density of current carriers and increasing the resistance further. In addition, the diminished neutrino interaction also means that neutrons are more stable against weak decay, and so, contrary to the standard model, we enter the BBN nucleosynthesis era with a large overabundance of neutrons compared to protons.

One objection to this scenario, is that there is no evidence a strong primordial magnetic field (*pmf*) (Gasso and Rubinstein, 2001; Subramanian, 2016). And should a *pmf* exist, it would be anisotropic and its magnetic pressure would cause the BB to expand and cool even faster (Kernan, Starkman, and Vachaspati, 1996; Matthews, Kusakabe, and Kajino, 2017). We reply that if the *pmf* is chaotic, as it most certainly was, it would be isotropic. And a chaotic magnetic field would compress rather than expand the BB due to the magnetic tension force and reconnection of tangled fields. Finally, there is evidence of these strong *pmf*s in the early formation of quasars (and absence after 3Gy), in which the magnetic field is converted into jets of high speed particles. Quasar formation is beyond the scope of this paper, but the mechanism is described in an earlier paper (M. Sheldon and R. Sheldon, 2015).

In this magnetic scenario, essentially all the available protons are converted into He, which now floats in a bath of hot neutrons. But recalling that there are no A=5 stable elements, there are no fast, two-body reactions to begin the nucleosynthesis ladder beyond He. The only possible reactions are either minority projectiles such as 4He(d,γ)6Li, or metastable states like 4He(α,γ)8Be*. But if the temperature is too high for D, and the He density is large enough, then the dominant reaction channel becomes the triple-α, 8Be*(α,γ)12C, which can begin the carbon cycle that produces N and O. Further expansion of the universe cools and releases a cloud of neutrons that subsequently decay into protons, which in the now cooler universe can produce some deuterium.

In the Analysis section, we present the results of our magnetized BBN (MBBN) model, employing the Arbey code modified to include additional chemical potentials (Arbey, 2012). Therefore the strength and topology of the *pmf* supplies "tuning" knobs giving us the flexibility needed to avoid the "robust" but wrong solution of the standard BBN models.

2.4 Coherent Magnetic fields

The *pmf* does more than simply change the ratio of *p/n* at the beginning of the nucleosynthesis era, it also supplies a reservoir of energy and a globally coherent field. The global coherence means that the universe looks the same even in disconnected, "space-like" spacetime regions, thereby addressing the "horizon problem" of the BB. The energy reservoir means that the transition from electroweak to nucleosynthesis era is a first order phase transition, like boiling water or freezing ice, mapping the coherence of the field onto the coherence of the matter. That is why boiling water is uniformly at 100C, or freezing water uniformly at 0C.

For example, suppose that a patch of plasma were slightly colder than the rest, then the neutrinos decouple, the current decreases, and immediately the magnetic field starts to decay. The energy of the decaying field produces an *Emf=-dB/dt* that drives currents through the plasma, heating it up until the temperature is back to normal. A similar argument applies to density, whereby a low density patch decouples the neutrinos and drops the current, which lowers the magnetic pressure. This gradient accelerates nearby plasma into this patch until the pressure due to density (and adiabatic heating) is restored. The reservoir of energy in the phase transition maintains the system at the critical point.

As a consequence of this 1st order phase transition, the universe achieves a uniform temperature and density that is reflected in the CMBR, without the need for a global inflaton field. Or more precisely, the global magnetic field provides the coherence that was previously attributed to the global inflaton field (albeit indirectly).

The *pmf* does more than simply redistribute the matter and heat evenly, it also balances them. Recall that the expansion velocity of the BB is finely adjusted to the matter density by 1:10^{60} (since it balances in an exponential) (Krauss, 1998). Since the visible matter of the universe corresponds to about 10^{80} protons, this fine tuning is equivalent to a clump of 10^{20} protons, or about a grain of sand. Then one sand grain more and the universe would have collapsed into a black hole before now, or one grain less, and an over-expansion would have prevented the formation of galaxies, stars and us. If we associate that expansion with the temperature, then this means that the temperature and density of the BB must be highly, very highly, correlated, an unexpected attribute of the standard BB that is often called "fine tuning".

If a mechanism can be found that correlates temperature and density to this degree, then the fine tuning is explicable in terms of physical laws. This neutrino cross section has all the properties needed to keep the correlation tight. It depends on density, magnetic field and temperature, so it can couple magnetic field to thermal energy. Much as a 1st order phase transition stabilizes the temperature by coupling to a third energy source, the neutrinos set up a feedback that taps into the *pmf* to supply the constant temperature. As long as the neutrinos are coupled to the matter, they can correlate the density and temperature.

As an analogy, consider "entropy waves" in a plasma. If the plasma is supplied with a steady heat source, say, a globally decaying magnetic field that is driving current through the plasma, then equilibrium temperature is reached when the radiative cooling is exactly compensated by the inductive heating. But if the plasma temperature is such that a slight increase in temperature results in an increase of excited absorptive states, then the opacity of the plasma increases with temperature. A higher opacity lowers the cooling rate, so a new, higher temperature equilibrium is found. This positive feedback results in an exponential growth of "entropy waves" because the entropy is modulated as a function of position. Conversely, if the opacity decreases due to higher temperature, negative feedback creates a homogeneous plasma.

If we then consider the neutrinos as the "radiative cooling" term for the dense BB plasma, we can see that increased density or magnetic field increases the opacity which increases the temperature. Near the phase transition this holds the plasma at the phase transition temperature until it jumps to a lower value. So if the magnetic field energy is being dissipated into the neutrino plasma, the conditions for entropy waves are met making the transition very sharp. In this scenario, the cosmologically expanding magnetic field uniformly heats the neutrino plasma and stabilizes the temperature/density ratio, providing a solution to the Big Bang "flatness" problem.

2.5 Magnetic Helicity and Missing Antimatter

When the temperature drops below 1.1MeV *e-e** pairs can no longer form, so at these cold temperatures mutual annihilation converts a small excess of *e/e** into a matter-dominated (rather than anti-matter-dominated) mass density.

But why is there an excess at all? The conservation of lepton number means that *e-e** should balance with no excess at all, so where did all the anti-matter go?

Because of the electroweak interaction, we can convert $e^* \rightarrow \nu^*$ while conserving lepton number, e.g. $e^* + n \rightarrow p + \nu^*$. Then the apparent dominance of leptonic matter over anti-matter is achieved by hiding the anti-matter in an anti-neutrino. So the observed excess of $e/e*$ would naturally lead to an excess $\nu*/\nu$, a fermionic chemical potential, as discussed earlier. This is not the only factor in the chemical potential, however, there is also an energy term $\sim \mu_B \bullet B$, where μ_B is the magnetic moment of the particle.

Now electrons and protons have intrinsic QM magnetic moments which give them a chemical potential, and in the standard model of Dirac (not Majorana) the same electroweak conversion via W-bosons that carries current also generates a magnetic moment though it is small. Depending on the direction the additional energy can be either +/-, which naïvely cancel out in a spatial integral and do not contribute to the chemical potential. However if the magnetic field is twisted, or helical (the Chern-Simons term), then the non-QM, spatial integral of the dot product does not cancel but has two choices: either right-handed or left handed. It is this same twist that in a self-starting or α-dynamo, sets up an amplification of both magnetic field intensity and helicity that in the Sun has a magnetic cycle of some 22 years. This helicity term in the chemical potential is even stronger for electrons and protons than for neutrinos because this "MHD" component to the magnetic moment, derives not from the small intrinsic QM spin, but from the extrinsic gyration in a magnetic field, the "first adiabatic invariant". Heuristically, it is easier for a positive charge than a negative charge to travel along a magnetic field of positive helicity, so the magnetic helicity introduces a potential difference or a chemical potential between matter and anti-matter.

So if the neutrino plasma makes a helical magnetic field, then the *e-e** chemical potentials are affected, changing the matter/anti-matter equilibrium ratio. Whether this effect can account for the observed asymmetric preference for matter or not requires far more theory and modeling than presented here, but our purpose was only to show the importance of including the neglected magnetic fields in BB modeling.

2.6 Magnetic tension and tests of Primordial Magnetic Field

If *pmf* solves so many problems, why have numerous papers found such stringent limits on the strength of the *pmf*?

Once again, making an argument for the absence of *pmf* is a negative argument, and depends strongly on having a complete model with all the physics included. Our argument is that two crucial properties of the magnetic field have been neglected heretofore, which when included permit most of these limits to be exceeded: magnetic reconnection and the magnetic tension force. That is, many theorists treat the magnetic field as a conserved scalar field, when it is a non-conserved vector field. This means that *pmf* field can be destroyed (as well as created in dynamo) and that in addition to pressure, the *pmf* possesses a tension force.[2] These two properties work together as follows.

The tension force of the B-field, which is a topological or global property, remains after reconnection has converted the tangled local B-field into structured loops. This tension force resists the expansion of the universe, leading to a deceleration term in the BB. In qualitative terms, the *pmf* first contributes to expansion of the cosmos as the tangled field reconnects and turns into energy, then it decelerates the cosmos as the remnant tension force becomes dominant. Finally, when recombination decouples the magnetic field from the plasma, its tension grip is released, and the B-field forms quasars. This complicated interaction delays the recombination era, which explains why the Hubble constant derived from the timing of recombination gives a smaller value than the Hubble constant derived from galactic expansion (Riess, 2020). That is, a delayed recombination era gives less time for the expansion phase and therefore a larger Hubble constant bringing the CMBR Planck 67 km/s/Mpc value into alignment with the distance-ladder 73 km/s/Mpc value.

In summary, all papers that assume the magnetic energy of the *pmf* is conserved are underestimates of the *pmf* strength. Likewise, all papers that assume that the magnetic field contributes only a pressure proportional to B^2 are likewise overestimates of the magnetic pressure. Thus, for example, the field could be large in the nucleosynthesis era and practically vanish in the CMBR reconnection era.

Finally, a strong *pmf* has extremely low entropy. Not only is it global and ordered, but it spreads the energy levels of charged particles (analogous to the Zeeman effect) to such an extent that they have fewer QM states available to them at finite temperature, reducing their entropy. In short, the large B-field "cools" the electrons into a lowest Landau level that becomes the lowest entropy state possible for the universe. Since low entropy is often equated with high information, the *pmf* may be responsible for the subsequent high information state of OOL.

In summary, a magnetized BB may solve multiple problems with the standard model: matter/anti-matter asymmetry, flatness, horizon, Hubble tension, BBN D/Li deviations, dark matter, cold white dwarfs, CEMP stars, early galaxy formation, and ubiquitous comets with their payload of information.

[2] "the majority of studies analysing the magnetic effects on structure formation do not account for the tension contribution to the Lorentz force." (Kandus, Kunze, and Tsagos, 2011, pg. 20)

3 Consequences of Primordial Comets

We have traced backwards in time from the observation of comets to the conditions needed in the Big Bang to show the possibility of very early life, but, to show the inseparability of life from existence, we really must also go forwards in time, from the Big Bang to the present. Many physicalists/materialists who eschew teleology or purpose believe that life is a fortuitous accident, so that if the tape of the universe could be rewound, it would play a very different tune. We read statements such as "the appendix evolved independently 125 times" as if life is player in a Monte-Carlo casino with body parts for chips. What we would like to show is the exact opposite: that the glittering casino is itself the result of life paying a visit to a singularly rocky peninsula; that everything we see as we gaze at the starry night sky has been affected and created by life. Indeed, the marvellous, incomprehensibly beautiful world that we live on was constructed from a molten rock by life patiently carving the stubborn stone, the result of a cosmic computation whose closest gear is our solar system, whose farthest are the galaxies.

Susskind argues that QM requires information to be neither created nor destroyed, but Hawking's conception of black holes destroys information. After 10 years, Hawking conceded that his namesake radiation would destroy information, but unwilling to let go of his theory, he argues that black holes don't exist (Hawking, 2014)! If such notable physicists are having disagreements about the cosmological power of information, then perhaps it would not be too forward to suggest that the information in the Big Bang, represented by the enormous magnetic field is also responsible for OOL. We calculate this as follows:

Penrose argues that if the position of every atom in the universe holds significance, then the information in the universe is proportional to the likelihood of this particular state, particular arrangement of particles. The information is the number of permutations (bigger than a combination) of quantum states, calculated as n! (or "n factorial" where 4!=4x3x2x1). These are such big numbers, they are typically converted to logarithms, where log(n!) $\sim$ n log(n) – n, known as Stirling's approximation. Then if the visible universe has 10^{80} protons, and we add photons and the number of slots available to store them too, Penrose estimates n$\sim 10^{120}$ quantum states. Then log(n!)$\sim$119*(10^{120}). If we take anti-logs of both sides, we get $10^{10^{123}}$ for the amount of information in our universe today (Penrose, 1981, pg. 249). And if information is not created or destroyed, then this is also the information that had to be available at the very beginning in the BB. Comparing this number to Hoyle's estimate for life, $10^{40,000}$, we see that the BB contains more than enough information to create life (which is trivial, since Penrose's calculation includes present life). But perhaps we need to calculate instead the information density.

That is, if we treat entropy as a fluid, dS=dQ/T, then it would seem reasonable to treat information as a fluid too, as an arrangement of the particles. Where there are no particles, there can be no information. And if the BB spread those particles out evenly, then very likely the information is likewise diluted and scattered. But for OOL, that information must then be concentrated in a cell a few cubic microns in volume.

When we concentrate something, we are fighting entropy, we are battling diffusion and turbulence and mixing. So to concentrate information is also to add information, a seemingly impossible task. But like the heat pump on a house, we can concentrate the heat by supplying electricity to the pumps and raising the entropy of the coal in a distant power station. The gradient of heat energy gives us the Gibbs Free Energy, the ability to do work. We have no word for the gradients of information, but it turns out to be very important both mathematically and physically because it keeps the non-equilibrium system far from equilibrium. Assuming its importance without defining it, then the difficulty lies in all the special machinery needed to manipulate this fluid, a process we call computation.

To emphasize the non-material nature of information, we can analogize to a computer, where the information concentration is likened to a computation. Then the universe is a vast computer taking the information of the BB and carrying out an enormous calculation involving nebulae and comets and galaxies, and whose answer is us.

What evidence do we have that life is a cosmic computation?

We described how adding a global *pmf* to the BB model made the universe highly isotropic, which if absent (without other global fields), could only model massive superclusters with attendant black holes. That same *pmf* was a low-entropy event whose information created the chemical potential resulting in ice, but without it, water would have been unavailable until much later. And if water was unavailable, then H and He would not have condensed to form the first stars, and gravitational instabilities would have delayed the beginning of galaxies. And the delay in galaxy formation would delay the formation of stars that were necessary to burn sufficient hydrogen to make oxygen. And without oxygen, comets would not form, and further seeding would not start.

In fact, without *pmf* the universe is so inhospitable, that two arbitrary dials have been added to the standard model, a "dark matter" fluctuation to get the galaxies going, and a "dark energy" to prevent them from becoming monstrous black holes.

This balancing act is an attempt to give back to the standard model the information that was discarded in the hot early universe, despite there being no good reason why dark matter should have structure and why dark energy should exist (pax Perlmutter).

But if the information computation was successful and the first comets were able to achieve OOL, then life would begin the transformation of a harsh universe into a hospitable home (R. Sheldon, 2012). Cyanobacteria, whose fossils have been found on every carbonaceous chondrite or extinct comet, can make sugars and proteins from sterile sunlight, CO_2, H_2O and N_2. Some of those sugars polymerize to make polysaccharides that coat the outside of the comet, where they turn soot black in UV light, efficiently convert light to heat, melt ice, form a vapor barrier, permit liquid water to form, outgas in ruptures to form jets, and impart high velocity to these chunks of ice. High speed comets are then capable of escaping the star's gravity well, accreting more mass, and seeding new stars. Thus star and galaxy formation do not form diffusively like a melting scoop of ice cream driven by density gradients, nor do they send out supernovae shock waves in successive arcs of stellar formation, but expand fractally in streamers and trailers, like ants on a mission.

More precisely, the living strategy of an efficient search algorithm employed by bacteria, slime molds, ants and tigers, involves a fractal distribution, a lacy network of paths and voids. And this is precisely the structure revealed by galactic surveys, with galaxies and supergalaxies stretched out on a three-dimensional lace of lanes, voids and walls (Canavesi and Tapia, 2020). This structure is so information rich that modelers strain to reproduce it by balancing dark matter densities, fluctuation power laws and dark energy "anti-gravity" terms. It looks remarkably like the structure of neurons in the brain, because fractals are the natural organization of life, the most efficient search algorithm, and the way to maximize 3D connectivity with a minimum of matter.

And these comets labor tirelessly to make the universe fit for life; they evaporate, fragment and leave behind a trail of spores. Not only have these signatures been seen by infrared telescopes in quantities that make our Earth biosphere seem a mere speck (Hoyle and Wichramasinghe, 1977; Richard B Hoover et al., 1986; Rivilla et al., 2021), but they continuously filter down on the planets that plow through their meteor trails, as observed at Earth on stratospheric balloons (Brownlee, Tomandl, and Hodge, 1976). Earth-like planets are rare, but where they have sunlight and H_20 and N_2, spores of the same pioneering cyanobacterial life can begin the unheralded transformation of the world. Bacteria release oxygen to change the atmosphere; sequester carbon dioxide to prevent runaway greenhouse warming; release cloud seeding chemicals to regulate the temperature through cloud feedback; setting off ice ages whose glaciers grind down the mountains and fertilize the oceans. In the oceans they lay down a layer of nutrient rich goo, ideal for fungi and multicellular plants to grow on, and perhaps later on, acorn worms. They harbor viruses to transfer blueprints of cellular machinery among the fungi and algae, they encourage cooperation. All of these activities are processing information, concentrating more and more into the cellular DNA.

How can we tell that life is terraforming Earth?

Because the information on Earth, measured by metrics such as biomass, complexity, or species count, does not grow at a diffusion pace ($\text{time}^{1/2}$), nor at a delivery pace (time^{+1}), but at infectious pace (exp^{time}), a function whose derivative looks identical to the function. This suggests that the delivery of information is growing more efficient with time, the system is bootstrapping, adding more information channels as it grows more sophisticated (R. B. Sheldon and R B Hoover, 2008). This is a characteristic of life, not of diffusive chance.

And when a high-speed comet strikes this terraformed ocean splashing its water into space, other passing comets can pick up and carry the virus load into the galactic cometary biosphere, where the viral information gets passed from comet to comet until it too finds itself floating down into the stratosphere of some Earth-like planet. In such a way, comets are the conduit, the nerves, the messengers of the cosmos. Planet by planet, comet by comet, the information is carried, concentrated and repackaged until 3.75 billion years ago, it came to Earth.

How do we know that life was delivered to Earth and not developed *in situ*?

Because the moment the environment was ready, life appeared. The moment the earth had oceans, stromatolites appeared. The moment the atmosphere was oxygenated, the Cambrian Explosion occurred (Meyer, 2013). The history of evolution is a history of planned deployment, of staged development, of bootstrapping complexity.

4 Analysis

4.1 Magnetic Big Bang Nucleosynthesis (MBBN)

In order to simulate the addition of the *pmf*, several quantities in the standard BBN model have to be altered. We list the changes made to the Arbey code, where we follow the weak-interaction modifications of the Parthenope version as noted below. Each of them was made a semi-empirical adjustment with no attempt at theoretical rigor. The purpose of this exercise is to demonstrate the effect of modifying the parameter, not rigorously deriving a theoretical fit. By optimizing on the output, we then can discover which parameters have the largest effect on the model.

The coupling of neutrinos

The strength of the weak interaction is proportional to B, which we argue, exists as long as *e-e** pairs can be easily made (T>1.1MeV). When large currents can be maintained, the neutrino coupling is strengthened, and lacking any theoretical constraints on the magnitude of the currents, we argue that the positive feedback rapidly approach a saturation field strength. Thus the enhancement to the interaction is either present or absent, with a transition near T=2MeV. In the Arbey code, unfortunately, only the $p \rightarrow n$ weak reaction permits a fiddling with the coupling, all the others are simply polynomial fits independent of temperature or neutrino density. So this modification to the code has not been implemented. Initial results with the PRIMAT code, however, look promising (Pitrou et al., 2020).

The chemical potential of the weak interactions

Since the weak interaction converts neutrons to protons and electrons, it generates current where none existed before. When immersed in a magnetic field, this produces a potential energy term, which adds to the chemical potential. Therefore we insert a chemical potential into all weak interactions proportional to the energy of the emitted *e/e** current-carrier. We simulate it in the Arbey code with a factor added to the binding energy of the neutron multiplied by a tanh function of specified width, μ=tanh((T-T_0)/σ), where T_0=2GK, 1.5GK and 1.2GK, σ=2GK.

The chemical potential of neutrinos

When the density of neutrinos is high, then the Fermi exclusion principle makes it difficult to create an identical fermion of the same quantum number, so the new particle must be created at higher energy. So if there is a superabundance of anti-neutrinos, a reaction that produces an antineutrino will have a slightly higher energy barrier, which from analogy to physical chemistry, is called a chemical potential and depends on density. The Arbey code permits this ξ potential to bias both the decay of the neutron, and weak interactions involving the anti-neutrino. Because it has the same units as the magnetic-field related chemical potential, we plot the helium fraction Yp versus $\mu+\xi$.

4.2 Charts

The Arbey code already permits adjusting the neutrino degeneracy and the lifetime of the neutron. To those free parameters, we add a chemical potential to the weak interaction proportional to the energy of the *e/e** created (negative if destroyed). Since both the neutron and weak interaction depend on the external magnetic field, we parameterize this chemical potential with a tanh function centered on a variable 2-1.2 GK temperature with a 2GK width. One thing we have not yet introduced is the reduction in the entropy caused by the magnetic field, which shows up as a reduced number of degrees of freedom. As a kluge for this effect, we can change the "effective number" of neutrinos from 3 down to 1. This introduces two new parameters (magnetic chemical potential and temperature transition) to the existing four parameters (neutrino number, neutrino degeneracy, neutron lifetime, and baryon/photon ratio).

Our target BBN abundances are a DM constituent of CNO that is four times more abundant than stellar (H, He) masses. From consideration of both pristine comets and CEMP-no stars, we target the DM as principally water, methane and ammonia ice—$CNOH_9$. We have not discussed the process that makes the 12C, which has two primary channels through the intermediate 8Be* and 7Be, both of which consume 4He, but are often overlooked in BBN models including Arbey's (Coc, Uzan, and Vangioni, 2014). It also possible to make C through the triple-α which is possible given the higher density and temperature of the BBN era. Unfortunately this cross-section is also missing in the Arbey code. So postponing a discussion of CNO production, we simply convert all the metals to equivalent helium atoms deriving DM as $He_{10.5}H_9$. Comets also have CO and CO_2 ices which bind no hydrogen, so we round up the numbers to $He_{12}H_9$ for dark matter. When combined with the visible matter, DM+(num)HeH_{16} where num = 12/20 to make the visible mass 20% of the total. Then the BBN produced 4He (traditionally written as the mass fraction) Yp = (48+2.4)/(9+9.6+48+2.4) = 0.73 as our target Helium production.

In contrast to Helium, the Deuterium content will be not much greater in DM than in gaseous form, with a small amount of chemical fractionation due to the higher boiling point for D, but we expect that to be a few percent at most. Then our target D/H ratio remains unchanged from the observational constraints at 1.2<D/H*100k<5.3. Just as the 4He/H ratio is enhanced, so is the 3He, which we scale with the calculated 4He/H ratio, Yp=73/25, or 1.66<3He/D<4.44.

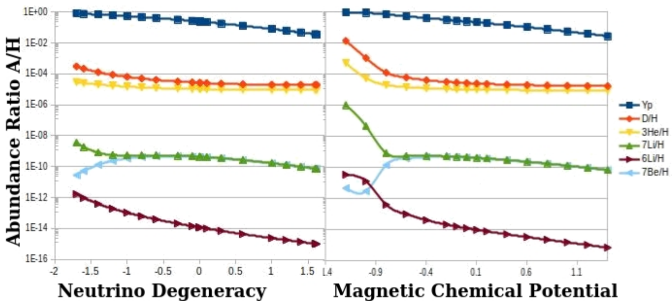

Figure 1: Abundance ratios of primordial elements from 4He/H to 6Li/H, as function of ξ=neutrino degeneracy parameter (left panel) and of μ=magnetic chemical potential (right panel).

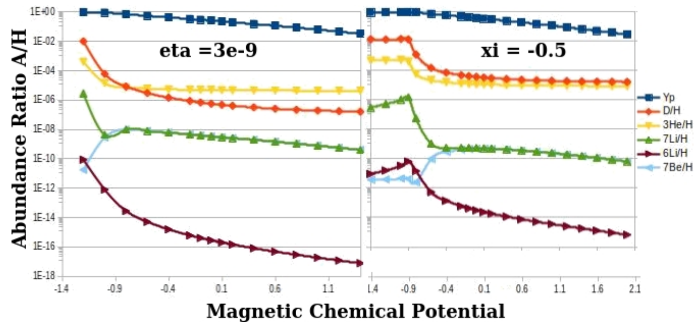

Figure 2: Abundance ratios of primordial elements as a function of μ, the magnetic chemical potential, where η=3e-9, the baryon/photon ratio (matter density), has been enhanced a factor of 4X (left panel), and where ξ=-0.5, the neutrino degeneracy, favors anti-neutrinos (right panel).

Are there reasonable solutions to the BBN model that achieve these two/three set points?

The answer is yes. In Figure 1 we show on the left the results of the Arbey code for changing ξ, the neutrino degeneracy, and on the right the results of adding μ, the magnetic chemical potential to the $n \rightarrow p$ weak reaction with a transition temperature of 1.5GK. Qualitatively they are very similar, though negative μ raises the neutron density more effectively than ξ. The important thing to note is that values of Yp=0.73 are easily obtained for $\mu+\xi<$ -0.5 (since they appear additively in the equilibrium).

The increase in neutron density also raises the D/H ratio, as well as puts 3He/D<1.0. A magnetic field confines the electrons and increases the baryon/photon ratio, η, by a factor of 4X, which also suppressed D while enhancing 3He, as the left panel in Figure 2 shows. Therefore around μ ~-0.4 has all the right numbers: a Yp~0.7, a D/H~2e-5, and a 3He/D>1.5. All 3 set-points of our DM universe have been accomplished, with the next step requiring a demonstration of how the excess He can be burnt into CNO. Since this requires entering new cross-sections into the Arbey code, we postpone that work for another paper.

In the right panel of Figure 2, we set η back to its nominal η=6e-10 value, but raise ξ to -0.5, favoring anti-neutrinos. When we do a scan in μ, the curves appear displaced, so that the equilibrium between 7Be and 7Li now occurs at μ=-0.4, which is what we expect if $\mu+\xi$ controls the p/n ratio of the initial conditions. But more significantly, this shifts the 7Li down without affecting the Yp and the D/H, which is exactly the solution to the "Lithium problem" plaguing current BBN models. That is to say, the magnetic chemical potential gives us an additional "dial" that may solve many problems with the current BBN model.

5 Conclusions

As we have argued in this paper, water is not just a necessary ingredient for life, it is the message of an information-rich Big Bang, and the medium that transfers it throughout the cosmos; it is the means to concentrate information, and the end of every message. Water in the Big Bang began the first ice stars, sealing comets in concrete shells, speeding them on lacy trails, seeding the galaxies and transforming the dark nebulae into starry skies. Water provided the gravitational attraction that held the spinning galaxies together and allowed the evolution of solar systems and rocky planets. Water transformed our molten rock into a blue-marble planet. Water tamed the climate by cloud-regulating albedo. Water formed the glaciers that recycled rock into the ocean, keeping the oceans fertilized. Water tidally locked the Moon to show a single face, which stabilized the Earth's axes and gave us summer and winter. It is safe to say that without water, our universe would be nothing but cooling gas, well on its way to heat death and oblivion.

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References

Alpher, Ralph, Hans Bethe, and George Gamow (1948). "The Origin of Chemical Elements". In: *Physical Review* 73.7, pp. 803–804. DOI: 10.1103/PhysRev.73.803.

Alpher, Ralph, J Follin, and R Herman (1953). "Physical Conditions in the Initial Stages of the Expanding Universe". In: *Physical Review* 92, p. 1347. DOI: 10.1103/PhysRev.92.1347.

Arbey, Alexandre (2012). "AlterBBN: A Program for Calculating the BBN Abundances of the Elements in Alternative Cosmologies". In: *Computer Physics Communications* 183.8, pp. 1822–1831. DOI: 10.1016/j.cpc.2012.03.018.

Beaudet, G and P Goret (1976). "Leptonic Numbers and the Neutron to Proton Ratio in the Hot Big Bang Model". In: *Astronomy and Astrophysics* 49, pp. 415–419. URL: http://adsabs.harvard.edu/pdf/1976A%5C%26A....49..415B.

Brownlee, D E, D A Tomandl, and P W Hodge (1976). "Extraterrestrial Particles in the Stratosphere". In: *Interplanetary Dust and Zodiacal Light*. Ed. by H Elsässer and H Fechting. Springer-Vorlag, pp. 279–283. DOI: 10.1007/3-540-07615-8_494.

Caffau, E et al. (2016). "TOPoS: III. An Ultra Iron-poor Multiple CEMP System". In: *Astronomy and Astrophysics* 595, p. L6. DOI: 10.1051/0004-6361/201629776.

Calkin, M G (1963). "An Action Principle for Magnetohydrodynamics". In: *Canadian Journal of Physics* 41, pp. 2241–2251. DOI: 10.1139/p63-216.

Canavesi, T and T E Tapia (2020). "Observational evidence of fractality in the large-scale distribution of galaxies". In: *Boletín de Asociación Argentina de Astronomía* 62, pp. 1–3. URL: https://arxiv.org/pdf/2102.09010.pdf.

Coc, Alain, Jean-Philippe Uzan, and Elisabeth Vangioni (2014). "Standard Big Bang Nucleosynthesis and Primordial CNO Abundances After Planck". In: *Journal of Cosmology and Astroparticle Physics* 10, p. 050. DOI: 10.1088/1475-7516/2014/10/050.

Coc, Alain and Elisabeth Vangioni (2017). "Primordial Nucleosynthesis". In: *International Journal of Modern Physics E* 26.8, p. 1741002. DOI: 10.1142/S0218301317410026.

Cyburt, Richard H et al. (2016). "Big Bang Nucleosynthesis: 2015". In: *Reviews of Modern Physics* 88, p. 015004. DOI: 10.1103/RevModPhys.88.015004.

Davies, Paul (1999). *The Fifth Miracle*. Simon & Schuster.

Davies, Paul et al. (2009). "Signatures of a Shadow Biosphere". In: *Astrobiology* 9.2, pp. 241–249. DOI: 10.1089/ast.2008.0251.

Doux, Cyrille et al. (2016). "First Detection of Cosmic Microwave Background Lensing and Lyman-α forest bispectrum". In: *Physical Review D* 94, p. 103506. DOI: 10.1103/PhysRevD.94.103506.

Dvornikov, Maxim (2016). "Generation of Cosmic Magnetic Fields in Electroweak Plasma". In: *Nuclear and Particle Physics Processes* 273–275, pp. 2342–2344. DOI: 10.1016/j.nuclphysbps.2015.09.385.

Frank, Louis A (1990). *The Big Splash*. Birch Lane Press.

Gasso, Dario and Hector Rubinstein (2001). "Magnetic Fields in the Early Universe". In: *Physics Reports* 348, pp. 165–266. DOI: 10.1016/S0370-1573(00)00110-1.

Hawking, Stephen (2014). "Information Preservation and Weather Forecasting for Black Holes". In: *arXiv.org* 1401.5761. URL: https://arxiv.org/abs/1401.5761.

Hoover, Richard (2011). "Fossils of Cyanobacteria in CI1 Carbonaceous Meteorites: Implications to Life on Comets, Europa and Enceladus". In: *Journal of Cosmology* 13, pp. 3811–3848.

Hoover, Richard B et al. (1986). "Diatoms on Earth, Comets, Europa and in Interstellar Space". In: *Earth, Moon, and Planets* 35.1, pp. 19–45. DOI: 10.1007/BF00054132.

Hoyle, Fred (1999). *Mathematics of Evolution*. Acorn Enterprises.

Hoyle, Fred and N C Wichramasinghe (1977). "Polysaccharides and Infrared Spectra of Galactic Sources". In: *Nature* 268, pp. 610–612. DOI: 10.1038/268610a0.

Hoyle, Fred and C Wickramasinghe (1982). *Evolution from Space: A Theory of Cosmic Creationism*. Simon & Schuster.

Jones, Bernard (2017). *Precision Cosmology: The First Half-Million Years*. Cambridge University Press. DOI: 10.1017/CBO9781139027809.

Joyce, Austin et al. (2015). "Beyond the Cosmological Standard Model". In: *Physics Reports* 568, pp. 1–98. DOI: 10.1016/j.physrep.2014.12.002.

Kandus, Alejandra, Kerstin Kunze, and Christos Tsagos (2011). "Primordial Magnetogenesis". In: *Physics Reports* 505.1, pp. 1–58. DOI: 10.1016/j.physrep.2011.03.001.

Kaplan, David et al. (2014). "A 1.05 M Companion to PSR J2222-0137: The Coolest Known White Dwarf?" In: *The Astrophysical Journal* 789.2. DOI: 10.1088/0004-637X/789/2/119.

Kawano, Lawrence (1992). "Let's Go: Early Universe II: Primordial Nucleosynthesis the Computer Way". In: *Fermilab* FERMILAB-PUB-92-004-A. URL: https://inspirehep.net/record/332991.

Kernan, Peter J, Glenn D Starkman, and Tanmay Vachaspati (1996). "Big Bang Nucleosynthesis Constraints on Primordial Magnetic Fields". In: *Physical Review D* 54, p. 7207. DOI: 10.1103/PhysRevD.54.7207.

Krauss, Lawrence M (1998). "The End of the Age Problem, and the Case for a Cosmological Constant Revisited". In:

The Astrophysical Journal 501, pp. 461–466. DOI: 10.1086/305846.

Maeder, André and Georges Maynet (2015). "The First Stars: A Classification of CEMP-no Stars". In: *Astronomy and Astrophysics* 580, A32. DOI: 10.1051/0004-6361/201526234.

Magistris, G De and D Marenduzzo (2015). "An Introduction to the Physics of Active Matter". In: *Physica A* 418, pp. 65–77. DOI: 10.1016/j.physa.2014.06.061.

Matthews, Grant, Motohiko Kusakabe, and Toshitaka Kajino (2017). "Introduction to Big Bang Nucleosynthesis and Modern Cosmology". In: *International Journal of Modern Physics E* 26.8, p. 1741001. DOI: 10.1142/S0218301317020062.

McGaugh, Stacy S, Federico Lelli, and James M Schombert (2016). "The Radial Acceleration Relation in Rotationally Supported Galaxies". In: *Physical Review Letters* 117 (20). DOI: 10.1103/PhysRevLett.117.201101.

Meyer, Stephen (2013). *Darwin's Doubt: The Explosive Origin of Animal Life and the Case for Intelligent Design*. HarperOne.

Nutman, Allen et al. (2016). "Rapid Emergence of Life Shown by Discovery of 3,700-million-year-old Microbial Structures". In: *Nature* 537, pp. 535–538. DOI: 10.1038/nature19355.

Oesch, Pascal et al. (2016). "A Remarkably Luminous Galaxy at z=11.1 Measured with Hubble Space Telescope Grism Spectroscopy". In: *The Astrophysical Journal* 819.2. DOI: 10.3847/0004-637X/819/2/129.

Panofsky, Wolfgang and Melba Phillips (1956). *Classical Electricity and Magnetism*. Dover Press.

Penrose, Roger (1981). "Time-Asymmetry and Quantum Gravity". In: *Quantum Gravity 2*. Ed. by C J Isham, R Penrose, and D W Sciama. Oxford: Clarendon Press.

Pitrou, Cyril et al. (2020). "Precision Big Bang Nucleosynthesis with the New Code PRIMAT". In: *JPS Conference Proceedings* 31, p. 011034. DOI: 10.7566/JPSCP.31.011034.

Riess, A (2020). "The expansion of the Universe is faster than expected". In: *Nature Reviews Physics* 2, pp. 10–12.

Rivilla, Victor et al. (2021). "Discovery in Space of Ethanolamine, the Simplest Phospholipid Head Group". In: *Proceedings of the National Academy of Sciences* 118.22, e2101314118. DOI: 10.1073/pnas.2101314118.

Rubin, Vera and W Kent Ford Jr (1970). "Rotation of the Andromeda Nebula from a Spectroscopic Survey of Emission Regions". In: *Astrophysics Journal* 159, p. 379. URL: http://adsabs.harvard.edu/full/1933AcHPh...6..110Z.

Secco, L F et al. (2021). "Dark Energy Survey Year 3 Results: Cosmology from Cosmic Shear and Robustness to Modeling Uncertainty". In: *arXiv.org* 2105.13544. URL: https://arxiv.org/pdf/2105.13544.pdf.

Sheldon, Malkah and Robert Sheldon (2015). "Arrhenius Reconsidered: Astrophysical Jets and the Spread of Spores". In: *Instruments, Methods, and Missions for Astrobiology XVII (Proceedings of SPIE 9606)*. Ed. by R B Hoover et al., pp. 9606–9628. DOI: 10.1117/12.2187138.

Sheldon, R B and R B Hoover (2005). "Evidence for Liquid Water on Comets". In: *Instruments, Methods, and Missions for Astrobiology VIII (Proceedings of SPIE 5906)*. Ed. by R B Hoover et al., pp. 196–206. DOI: 10.1117/12.624092. URL: http://www.rbsp.info/rbs/PDF/spie05.pdf.

Sheldon, R B and R B Hoover (2007). "The Cometary Biosphere". In: *Instruments, Methods, and Missions for Astrobiology X (Proceedings of SPIE 6694)*. Ed. by R B Hoover et al., 66940H. DOI: 10.1117/12.729094. URL: http://www.rbsp.info/rbs/PDF/spie07.pdf.

Sheldon, R B and R B Hoover (2008). "Cosmological Evolution: Spatial Relativity and the Speed of Life". In: *Instruments, Methods, and Missions for Astrobiology XI (Proceedings of SPIE 7097)*. Ed. by Richard B Hoover et al. DOI: 10.1117/12.802195. URL: http://www.rbsp.info/rbs/PDF/spie08.pdf.

Sheldon, Robert (2012). "Comets, Information, and the Origin of Life". In: *Genesis—In the Beginning: Precursors of Life, Chemical Models and Early Biological Evolution; Volume 22 in Cellular Origin, Life in Extreme Habitats and Astrobiology*. Ed. by Joseph Seckbach, pp. 363–389. DOI: 10.1007/978-94-007-2941-4_21. URL: http://www.rbsp.info/rbs/PDF/cole2012.pdf.

Sheldon, Robert (2015). "Primordial Comets: Big Bang Nucleosynthesis, Dark Matter and Life". In: *Instruments, Methods, and Missions for Astrobiology XVII (Proceedings of SPIE 9606)*. Ed. by R B Hoover et al., 96060R. DOI: 10.1117/12.2187110. URL: http://www.rbsp.info/rbs/PDF/spie15a.pdf.

Subramanian, Kandaswamy (2016). "The Origin, Evolution and Signatures of Primordial Magnetic Fields". In: *Reports on Progress in Physics* 79.7, p. 076901. DOI: 10.1088/0034-4885/79/7/076901.

Susskind, Leonard (2008). *The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics*. Little, Brown & Co.

Wagoner, Robert, William Fowler, and Fred Hoyle (1967). "On the Synthesis of Elements at Very High Temperatures". In: *The Astrophysical Journal* 148, pp. 3–49. URL: http://adsabs.harvard.edu/full/1967ApJ...148....3W.

Weiss, Madeline C et al. (2016). "The Physiology and Habitat of the Last Universal Common Ancestor". In: *Nature Microbiology* 1, p. 16116. DOI: 10.1038/nmicrobiol.2016.116.

Zel'dovich, Ya B (1964). In: *Soviet Journal of Atomic Energy* 14, p. 83.

Zwicky, Fritz (1933). "Die Rotverschiebung von extragalaktischen Nebeln". In: *Helvetica Physica Acta* 6, pp. 110–127.

Solution of the Grazing Goat Problem: A Conflict between Beauty and Pragmatism

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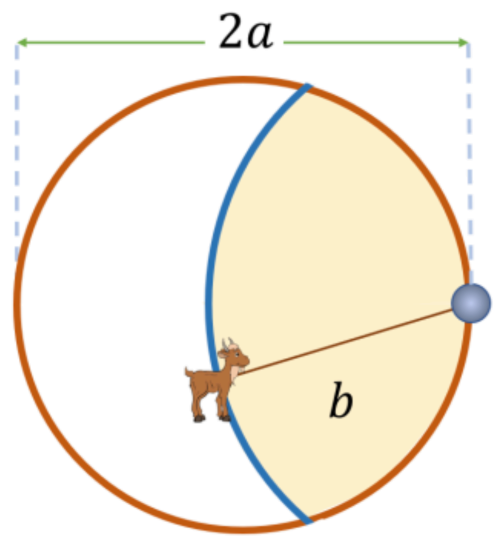
Abstract

What is the ideal solution of a problem in mathematics? It depends on your nerd ideology. Pure mathematicians worship the beauty of a mathematics result. Closed form solutions are particularly beautiful. Engineers and applied mathematicians, on the other hand, focus on the result independent of its beauty. If a solution exists and can be calculated, that's enough. The job is done. An example is solution of the *grazing goat problem*. A recent closed form solution in the form of a ratio of two contour integrals has been found for the grazing goat problem and its beauty has been admired by pure mathematicians. For the engineer and applied mathematician, numerical solution of the grazing goat problem comes from an easily derived transcendental equation. The transcendental equation, known for some time, was not considered a beautiful enough solution for the pure mathematician so they kept on looking until they found a closed form solution. The numerical evaluation of the transcendental equation is not as beautiful. It is not in closed form. But the accuracy of the solution can straightforwardly be evaluated to within any accuracy desired. To illustrate, we derive and solve the transcendental equation for a generalization of the grazing goat problem.

The *grazing goat problem* is a simply posed exercise in geometry that has been floating around for over two and a half centuries since at least 1748. Nadis gives a concise history of the problem (Nadis, 2020). A circular fence encloses a field of grass. A goat is tied to fence. How long is the leash such that the goat has access to one half of the grass within the circle?

Mathematicians have searched for an elegant closed form solution to the problem. We will show the problem can be solved straightforwardly to any accuracy using the solution to a transcendental equation. The answer is that the tether length is 1.15872847301812 times that of the circle's radius. The answer is neither beautiful nor exact. The true tether length, probably irrational, goes on forever and, like π or $\sqrt{2}$, can be computed to any accuracy desired. If the radius of the circular fence is ten meters, the number 1.15872847301812 provides accuracy of the tether length to less than a millionth of a millionth of a meter. Isn't this good enough? It depends on your nerd ideology.



A fence is circular with radius a. How long, b, should the tether be so the goat has access to one half of the area inside the fence?

Figure 1: The Grazing Goat Problem

1 Background

Mathematicians have been looking for a closed form solution for the grazing goat problem albeit unsuccessfully. Why a closed form solution? Because it is beautiful. The geometric infinite sum $\sum_{n=0}^{\infty} x^n$ has a beautiful closed form solution of $(1-x)^{-1}$ as long as $|x| < 1$. Mathematicians celebrate such beauty.

Paul Erdős celebrated the most beautiful of mathematical proofs as being in "God's book" (Andreescu and Dospinescu, 2010). Proving whether or not a proof is in "God's book" is not a mathematical problem itself but is, rather, a subjective call.

Likewise, the definition of a closed form mathematical solution is fuzzy. There are attempts to define *closed form* (Borwein and Crandall, 2013) but there is no widespread agreement on a precise mathy definition. Everyone agrees that the solution of the geometric series is in closed form. But what about the integral of a Gaussian curve, like $\int_0^y e^{-x^2} dx$? When there is no convenient solution, a new transcendental function is often defined. In case of the Gaussian integral, the solution is defined something like erf(y) where the erf stands for "error function." The error function is available in most computer languages and even in spread sheets. In the eyes of a mathematician, does this make the Gaussian integral solution in terms of erf a closed form solution?

Here's a similar example closer to home. In a paper currently under review, we required evaluation of the infinite series

$$\varphi(z) = \sum_{k=0}^{\infty} z^k \log_2 k!.$$

We could find no closed form simplification but did show the series converged for $|z| < 1$. The value of $\varphi(z)$ can then be evaluated to any accuracy desired, just like the number π. By defining $\varphi(z)$, can we say the series has a closed form solution like we do using $\mathrm{erf}(y)$?

Even more fundamentally, is it meaningful to ask for a closed form solution for a constant like π? Restricting closed form operations to predefined rules, Chow 1999 defines a closed form solution of π by

$$\pi = \sqrt{-1}\,\log(-1).$$

Going to such lengths to quantify *closed form* seems, to this author, silly. Like Erdős's idea of "God's book," the idea of *closed form* is best kept as a subjective judgement of beauty.

There are obvious examples in the extreme. All agree that most puppies are cute. On the other side, there is a "World's Ugliest Dog Contest." Most dogs lie between the extremes of cute and ugly.

Similarly in math, when there is an answer, all agree that closed form solutions to many Diophantine equations don't exist. Solutions to Diophantine equations are ugly. On the other extreme, we also agree that Euler's solution of the Basel problem is in a beautiful, closed form. Solving a problem that had eluded mathematicians for decades, Euler proved that

$$\sum_{n=1}^{\infty} \frac{1}{n^2} = \frac{\pi^2}{6}.$$

This is unquestionably an elegant closed form solution that deserves to be appreciated for its beauty.

Here's a more personal more difficult example. I was a coauthor on a paper presenting the first and thus far only closed form solution describing the performance of a Neyman-Pearson optimal detector in the presence of non-Gaussian noise (Marks II et al., 1978). The result, I thought, was beautiful. But over a decade later, C.W. Helstrom noted

> "Marks, Wise, Haldeman and Whited derived a *closed-form* expression for the complementary cumulative probability distribution ... Their formula involves a triple summation, the number of terms of which increase with n like n^3, and the terms alternate in sign." (Helstrom, 1989, emphasis added)

When trying to calculate our beautiful formula on a computer, Helstrom noted the requirement of using the differences between very large numbers which can be problematic. For example, computing the number 2 using the difference between

10100031378387528865875332083814206171776691473035982534904287554687311 5**2**

and

10100031378387528865875332083814206171776691473035982534904287554687311 5**0**

is troubling because high computational accuracy required. The differenced numbers in our closed form solution became larger and larger for higher order solutions.

Helstrom solved the same problem using digital evaluation of a contour integral. The solution was no longer in closed form, but there were no requirements of subtraction of large numbers that differed only at the least significant digits.

So which solution of the optimal detection problem was best? It depends on your nerd ideology. To the pure mathematician, my closed form solution was best. Evaluation required a finite number of terms defined using well know components and familiar math operations. Given unbounded computational resources, the answer is exact. To the engineer and applied mathematician, Helstrom's answer is best. Lower computational resources can be applied to compute a result to high computational accuracy.

Which brings us back to the grazing goat problem. A recent paper claimed to derive a closed form solution to the goat grazing problem (Ullisch, 2020). But the solution was in the form

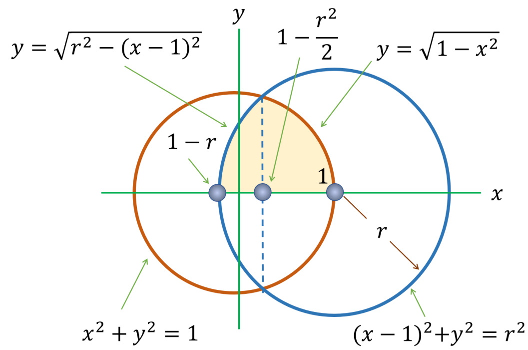


Figure 2: The geometry of the grazing goat problem

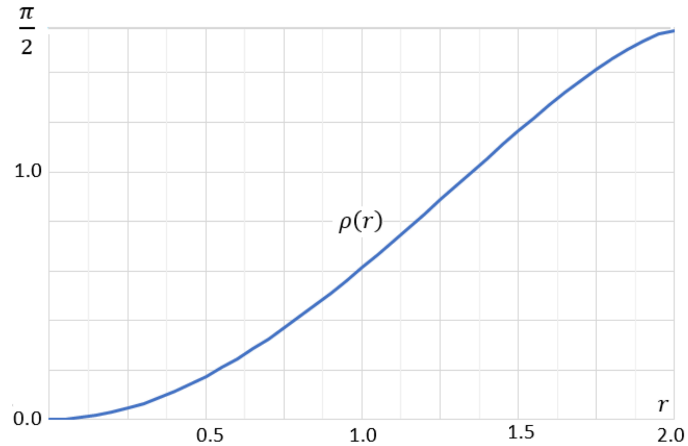


Figure 3: The plot of $\rho(r)$ in Equation 2

of the ratio of two contour integrals which had to be evaluated numerically. Some of the beauty of the closed form solution of the goat grazing problem is lost when such digital evaluation is required. As we now show, a computationally accessible solution of the grazing goat problem has been available for a long time.

2 Grazing Goat Problem Solution

The simple geometry of the grazing goat problem is shown in Figure 2. The goat fence is inside a circle with unit radius. The unknown goat tether is assumed to be r units long. There is no loss of generality in assuming the fenced circle has unit radius. If the fence radius is a, then the desired length of the tether is ra.

The circle of the fence has the familiar equation $x^2+y^2=1$ and the circle swept by the goat tether is $(x-1)^2+y^2=r^2$. Subtracting these two equations and solving for x gives the intersection point $1-\frac{r^2}{2}$ as shown in Figure 1. Also shown in Figure 2 is the functional form of the two circle equations, namely $y=\sqrt{1-x^2}$ and $y=\sqrt{r^2-(x-1)^2}$. The problem is now a straightforward integration problem. The desired shaded area under the curve, shown shaded in Figure 2, is one half of the grazing area available to the goat, namely $\frac{\pi}{4}$. From Figure 2, the problem is the solution to

$$\rho(r) = \int_{1-r}^{1-\frac{r^2}{2}} \sqrt{r^2-(x-1)^2}dx + \int_{1-\frac{r^2}{2}}^{1} \sqrt{1-x^2}\, dx. \quad (1)$$

where we would like to find the value of r so that $\rho(r)=\frac{\pi}{4}$.

The two indefinite integrals over the shaded area in Figure 2 can be evaluated as

$$\int^x \sqrt{1-x^2}dx = \frac{1}{2}\sqrt{1-x^2}\, x + \frac{1}{2}\arcsin(x)$$

and

$$\int^x \sqrt{r^2-(x-1)^2}dx$$
$$= \frac{1}{2}(x-1)\sqrt{r^2-(x-1)^2} + \frac{1}{2}r^2\arcsin\left(\frac{x-1}{r}\right).$$

The equation in (1) then, as described in Ullisch (2020), becomes

$$\rho(r) = \frac{1}{2}\left[(x-1)\sqrt{r^2-(x-1)^2} + r^2\arcsin\left(\frac{x-1}{r}\right)\right]\Bigg|_{x=1-r}^{1-\frac{r^2}{2}} + \frac{1}{2}\left[\sqrt{1-x^2}\, x + \frac{1}{2}\arcsin(x)\right]\Bigg|_{x=1-\frac{r^2}{2}}^{1}. \quad (2)$$

We could make the substitutions for the lower and upper limits shown in (2) but find it easier to let the computer do it.

A plot of $\rho(r)$ is shown in Figure 3. The function is strictly increasing. This is also evident from Figure 2 where the shaded area clearly increases as r increases reaching a maximum value of 2 giving a half grazing area of $\frac{\pi}{2}$.

There are many techniques to solve the for r in (2) when $\rho(r)=\frac{\pi}{4}$. Newton's method, taught in introductory calculus, comes to mind. A computationally simpler approach, not needing the derivative required by Newton's method, is interval halving also known as binary search.

The idea is simple as is seen in the straightforward algorithm here:

1. Set $low \ = 0$
2. Set $high = 2$
3. Evaluate the midpoint $r = \frac{\text{high+low}}{2}$
4. If $error = \ \rho\left(r\right) - \frac{\pi}{4} > 0$, set high = r
5. Otherwise, set low = r
6. Go to Step 3

The iteration continues until the desired accuracy, or when the error, constrained to the computational accuracy of the computer, is zero.

Looking at Figure 3, an eyeball estimate of $\rho\left(r\right) = \frac{\pi}{4} \approx 0.79$ safely places r between $low \ = 1.00$ and $high = 1.25$ so the interval halving algorithm could be initiated there. But the interval halving algorithm converges quickly and broader initialization only require a few more iterations. Every iteration reduces the interval on which the solution by half. Initially, the solution is known to be on the interval (0,2). The second iteration reduces the interval to (1,2). Then to (1,1.5), (1,1.25) and (1.125,1.25). The length of these intervals respectively are $\left[2,\ 1, \frac{1}{2}, \frac{1}{4}.\frac{1}{8}\right]$. If $I = 2$ is the width of the initial interval, the width of the interval after the Nth iteration is

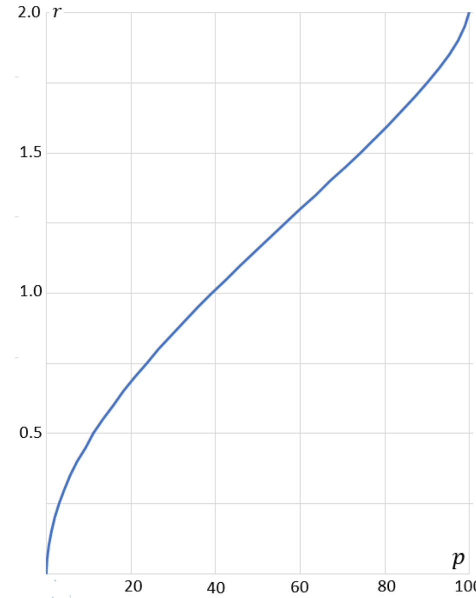
$$\text{Accuracy} = I{\times}2^{-N} \tag{3}$$

The algorithm zooms in on the correct answer quickly.

The iteration for the grazing goat problem converges to r =1.15872847301812 after 49 iterations to zero error when the algorithm is performed with the accuracy of a MS Excel spread sheet. The solution uses 14 digits to the right of the decimal consistent with (3) where Accuracy $= 2 \times \ 2^{-49} \approx 10^{-15}$. The result is the same with the digitally calculated "closed form" contour integration solution given by Ullisch - but boasts two more digits of accuracy. The last few digits of accuracy can be rightfully questioned, however, because of the accuracy of Excel at this precision.

3 Grazing Goat Problem Inversion

The grazing goat problem results can be easily generalized to the case where the goat is allowed to eat $p\%$ of the available grazing area inside of the circular fence. The solution thus



Instead of the grazing area, the percent p of half the available grazing area in the circular fence is used. $p = 100\%$ corresponds to an area of $\frac{\pi}{2}$.

Figure 4: Inversion of the $\rho\left(r\right)$ in Figure 3

far has concentrated on the specific case of p = 50% of the grazing area. In equation (2), the problem to solve is now

$$\rho\left(r\right) = \frac{p}{100}\ \frac{\pi}{2} \tag{4}$$

The original problem is for p=50% so that $\rho\left(r\right) = \frac{\pi}{4}$.

The radius r as a function of p is shown in Figure 4. All strictly increasing functions have a unique inverse, e.g. $y = e^x$ and $x = \log y$. The plot in Figure 4 is the inverse of Figure 3 except, instead of the true area, the percent of area p is used.

4 Final Thought

Nineteenth century romantic poet John Keats said, "Beauty is truth and truth beauty." In terms of the solution of mathematical problems, truth in a solution may not be beautiful. Closed form solutions are beautiful but in the case of accurate solutions to mathematical problems, like the grazing goat problem, truth need not be beautiful.

References

Andreescu, Titu and Gabriel Dospinescu (2010). *Problems from the Book*. 2nd Edition. XYZ Press.

Borwein, Jonathan M and Richard E Crandall (2013). "Closed Forms: What They are and Why We Care". In: *Notices of the AMS* 60.1, pp. 50–65. URL: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.190.4817%5C&rep=rep1%5C&type=pdf.

Chow, Timothy Y (1999). "What is a Closed-Form Number?" In: *The American Mathematical Monthly* 106.5, pp. 440–448. URL: https://www.tandfonline.com/doi/pdf/10.1080/00029890.1999.12005066?casa_token=V9Kvgbh4exMAAAAA:cVLDnRUzoUR9iW14739rU3bm_KZj7n5PPoNbfHTgJWSevq9poaHMSs7oJiN_TtLJS54TxxgiotM0.

Helstrom, C W (1989). "Detectability of Signals in Laplace Noise". In: *IEEE Transactions on Aerospace and Electronic Systems* AES-25.2, pp. 190–196.

Marks II, R J et al. (1978). "Detection in Laplace Noise". In: *IEEE Transactions on Aerospace and Electronic Systems* AES-14, pp. 866–872. DOI: 10.1109/TAES.1978.308550. URL: https://ieeexplore.ieee.org/document/4102075.

Nadis, Steve (2020). "After Centuries, a Seemingly Simple Math Problem Gets an Exact Solution". In: *Quanta Magazine*. URL: https://www.quantamagazine.org/mathematician-solves-centuries-old-grazing-goat-problem-exactly-20201209/.

Ullisch, Ingo (2020). "A Closed-Form Solution to the Geometric Goat Problem". In: *Mathematical Intelligencer* 42, pp. 1–5. DOI: 10.1007/s00283-020-09966-0. URL: https://link.springer.com/article/10.1007%2Fs00283-020-09966-0.

2D Puzzle Visualizations of Boolean Formulae

Eric Holloway

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Background

In the comparison between human and computational intelligence, often times the comparison is not straightforward because humans can possess domain knowledge inaccessible to the program they are competing with. To provide a level playing field, it is helpful to have humans and computers compete in a domain where both start with equal domain knowledge, and the domain is well understood.

One such domain is boolean formulae. These formulae are sets of boolean variables that are combined with the AND and OR logical operators. These formulae are well understood, and can be selected so the human and algorithm have no special advantage over the other in terms of domain knowledge, or even the algorithm has an advantage in order to make the success of the human even more significant.

The reason why the domain of boolean formulae is a good domain for comparing human and computational intelligence is because there are many problems dealing with these formulae that are NP complete and harder. Two such examples are:

1. determining if a particular formula can evaluate to true, an NP complete problem
2. inverting a truth table to derive the shortest logical expression that represents the table, an NP hard problem

If humans can outperform computers when faced with an NP complete problem, then insofar as NP is not the same as P, we can determine that humans at least outperform deterministic Turing machines, and human intelligence must be on the level of nondeterministic Turing machines.

However, the problem with this domain as far as humans are concerned is that truth tables are hard to visually process. We want to come up with a test that humans don't need a PhD to understand. Something visual is idea, as it can be addressed by a human with any level of expertise. In this paper, I present a 2D visualization of boolean formulae that allow humans to visually understand truth tables of up to 12 boolean variables.

I begin by explaining how to represent bitstrings (series of 1s and 0s) with a boolean formulae, which is another way to say we are representing truth tables, since a truth table can be represented by a bitstring.

Bitstrings as boolean formulae

All bitstrings b can be expressed as logic expressions with $\lceil \log_2(|b|) \rceil$ binary variables. For example, with four logic variables x_1,x_2,x_3, and x_4 we can describe all bitstrings of length 16 with logic expressions.

To generate a bitstring from a particular logic expression, we evaluate the expression for all variable assignments, and order the results lexicographically.

Here is an example with 2 variables, x_1 and x_2, and the logic expression $x_1 \vee \neg x_2$.

1. Evaluate the expression for all assignments.

x1	x2	$x_1 \vee \neg x_2$
0	0	1
0	1	0
1	0	1
1	1	1

2. Order the results lexicographically.

   The lexicographic order of the assignments is: 0 0, 0 1, 1 0, 1 1.

   So, the bitstring is: 1, 0, 1, 1.

The generating function is denoted G. If we apply G to a logic expression, then it generates the corresponding bitstring. From our previous example, $G(x_1 \vee \neg x_2) = 1011$.

A four variable example,

$$
\begin{aligned}
&G(\\
&\quad (x_1 \wedge x_2 \wedge \neg x_3) \\
&\quad \vee (x_1 \wedge x_3 \wedge \neg x_4) \\
&\quad \vee (\neg x_1 \wedge \neg x_2 \wedge \neg x_3 \wedge x_4) \\
&\ ) = 0001010110010000.
\end{aligned}
$$

Next, I talk about how to generate a boolean formula randomly. This is important, because we need a problem domain that is larger than can fit within a physical computer. With 12 boolean variables, there are $2^{2^{12}}$ possible unique formulae, which is more than can fit within the physical universe. That being said, we will only deal with a subset of these formulae, since most are random, and are not useful for the sort of puzzle that can distinguish whether human intelligence transcends computational intelligence.

Randomly sampling DNF formulae

A DNF formula is an OR of AND terms, such as $(v_1 \wedge \neg v_2) \vee (\neg v_1 \wedge v_2)$ to represent $v_1 \oplus v_2$.

The puzzles are generated by randomly sampling a DNF formula f from formulae with a set number of variables n, terms t, and maximum term size k. The random sampling of DNF formulae is close to uniform, with the exception that false terms are filtered out. Here is how it works.

1. The sampling process is given the number of variables n, maximum literals per term k and the number of terms t.
2. Each term is randomly fills with literals.
3. A term is refilled if its literals result in a contradiction.

Then, a bitstring is generated from f using $G(f)$, as explained earlier. A set of bits s are removed to be guessed. Noise is added by randomly flipping a certain number of bits m.

Converting formula to 2D image

To make the prediction process visual for the human, the bitstring generated by $G(f)$ is displayed as a 2D image.

The logic variables are split into two groups, and each group's binary values are converted into integers to form the coordinates.

For instance, with four variables we have two groups for the x and y coordinates. I.e. $x = \{v_1, v_2\}$ and $y = \{v_3, v_4\}$. If we assign the variables as: $v_1 = 0, v_2 = 1, v_3 = 1, v_4 = 0$, we see that x and y groups can represent binary numbers. I.e. $x = \{0, 1\}$ and $y = \{1, 0\}$. These binary numbers are then converted to integers, $x = 2$ and $y = 1$.

Each point in the boolean space described by the four variables has an assignment of 0 or 1 from f. Converting the boolean space to a 2D graph as previously described, and using f assignments to fill in the graph where 0 is black and 1 is white, turns the truth table into an image.

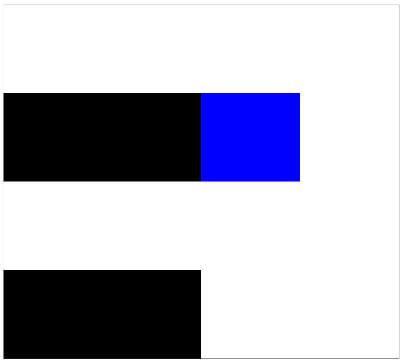
As an example, set $f = v_2 \vee v_3$. The logic table and coordinates are the following.

v_1	v_2	x	v_3	v_4	y	$v_2 \vee v_3$
0	0	0	0	0	0	0
1	0	1	0	0	0	0
0	1	2	0	0	0	1
1	1	3	0	0	0	1
0	0	0	1	0	1	1
1	0	1	1	0	1	1
0	1	2	1	0	1	1
1	1	3	1	0	1	1
0	0	0	0	1	2	0
1	0	1	0	1	2	0
0	1	2	0	1	2	1
1	1	3	0	1	2	1
0	0	0	1	1	3	1
1	0	1	1	1	3	1
0	1	2	1	1	3	1
1	1	3	1	1	3	1

Figure 1a and Figure 1b are a realization of this logic table converted into a 2D image. In the left pane, one bit has been removed and replaced with blue, and this is the bit to be guessed. The right pane shows the answer.

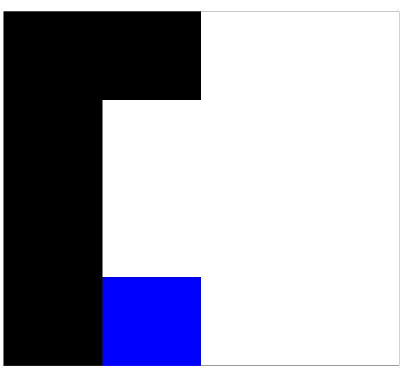
Figure 2a and Figure 2b are another puzzle of the same size, but this time with one bit of noise addded. The generation function for this puzzle is $G(v_1 \vee v_2)$.

Figure 3a, Figure 3b, Figure 4a, and Figure 4b show the prediction puzzles generated by more complex DNF formulae, with and without noise added.



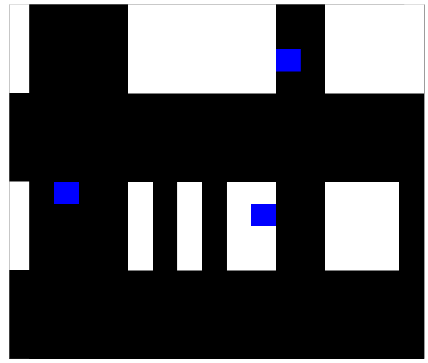
(a) Guess the blue bit.

Figure 1: Puzzle with 4 variables.



(a) Guess the blue bit.

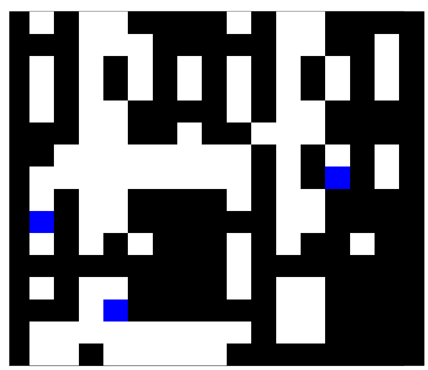
Figure 2: Puzzle with 4 variables and 1 bit of noise.



(a) Guess the blue bits.

(b) Answer to puzzle.

Figure 3: Puzzle with 8 variables.



(a) Guess the blue bits.

(b) Answer to puzzle, no noise.

Figure 4: Puzzle with 8 variables and 10 bits of noise.

The Products of Hyperreal Series and the Limitations of Cauchy Products

Jonathan Bartlett

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Abstract

Cauchy products are used to take the products of convergent series. Here, we show the limitations of this approach in divergent series. Alternative approaches and formulas for divergent series are suggested, as well as their benefits and drawbacks.

Bartlett, Gaastra, and Nemati (2020) set out to define a new way of assigning values to divergent series using hyperreal numbers, which we will refer to as the BGN method. This method operates using a small number of principles to allow value assignment for a divergent series:

1. Instead of summing to the ambiguous ∞, summations are done to a specific standard candle of hyperreal infinity, labeled ω.
2. Because summations are done to a specific infinity, then making sure that the number of positions are maintained during manipulations is important.
3. When these rules are kept, divergent series summation can be done just like partial sums up to a value of k, where $k = \omega$.

Because of principle 2, $1 + 2 + 3 + \ldots$ refers to a different value than $1 + 0 + 2 + 0 + 3 + 0 + \ldots$, because the latter only has non-zero numbers in half of the positions as the former. To get both of these series to sum to the same value, the former series would sum from 1 to ω, while the later series would have to sum from 1 to 2ω. Because of principle 3, rearrangements of the series do not affect the value of the series. Additionally, because these results operate identically to partial sums, standard summation formulas and discrete integrals can be used to simplify results.

As an example, the series

$$A = \sum_{i=1}^{\omega} i \tag{1}$$

can be given a value using the standard arithmetic series formula, yielding a value of $\frac{\omega^2}{2} - \frac{\omega}{2}$. This can be rounded to the primary part of the result, $\frac{\omega^2}{2}$.

Essentially, using hyperreals allows one to treat divergent series as if they were finite series. The point of this article is to point out that, while this makes divergent series work as if they were finite series, it *does not* make divergent series work as if they were convergent series. This is an important distinction that is easy to miss.

Figure 1: Cauchy Multiplication of Six Terms

	a_1	a_2	a_3	a_4	a_5	a_6
b_1	a_1b_1	a_2b_1	a_3b_1	a_4b_1	a_5b_1	a_6b_1
b_2	a_1b_2	a_2b_2	a_3b_2	a_4b_2	a_5b_2	a_6b_2
b_3	a_1b_3	a_2b_3	a_3b_3	a_4b_3	a_5b_3	a_6b_3
b_4	a_1b_4	a_2b_4	a_3b_4	a_4b_4	a_5b_4	a_6b_4
b_5	a_1b_5	a_2b_5	a_3b_5	a_4b_5	a_5b_5	a_6b_5
b_6	a_1b_6	a_2b_6	a_3b_6	a_4b_6	a_5b_6	a_6b_6

The Cauchy Product

To highlight the importance of this distinction, we will focus on the Cauchy product. The Cauchy product for two series A and B is

$$A \cdot B = \sum_{i=1}^{\omega} \left(\sum_{j=1}^{i} a_j \, b_{i-j+1} \right). \tag{2}$$

For convergent series, the Cauchy product is equivalent to the product of A and B. However, *even with hyperreals*, the Cauchy product is not equivalent to the product of A and B if A and B are divergent.

To understand why, it is important to recognize the shape of the Cauchy product for finite series. Imagine that A and B are finite series with k elements. In that case, it is easy to recognize that the sum does not work.

Let us imagine two series with six elements. The Cauchy product for such a series would be

$$A \cdot B = \sum_{i=1}^{6} \left(\sum_{j=1}^{i} a_j \, b_{i-j+1} \right). \tag{3}$$

Figure 1 shows what this would look like. Each stripe of the figure represents one iteration through the outermost summation. Notice, however, that there are no stripes past the center stripe. In other words, all of the values past the center stripe are *not considered* in the final summation.

This is obviously problematic for finite sums. Why is it non-problematic for convergent series?

Figure 2: The Rectangular Product of A and B

	a_1	a_2	a_3	a_4	a_5	a_6
b_1	a_1b_1	a_2b_1	a_3b_1	a_4b_1	a_5b_1	a_6b_1
b_2	a_1b_2	a_2b_2	a_3b_2	a_4b_2	a_5b_2	a_6b_2
b_3	a_1b_3	a_2b_3	a_3b_3	a_4b_3	a_5b_3	a_6b_3
b_4	a_1b_4	a_2b_4	a_3b_4	a_4b_4	a_5b_4	a_6b_4
b_5	a_1b_5	a_2b_5	a_3b_5	a_4b_5	a_5b_5	a_6b_5
b_6	a_1b_6	a_2b_6	a_3b_6	a_4b_6	a_5b_6	a_6b_6

For a convergent series, as the index approaches infinity, the value of the the term approaches zero. If you look at Figure 1, it is evident that the terms that are being ignored, if it is a convergent series, have at least one multiplicand of the term at a near-zero value. Therefore, in a convergent series, all of the terms being ignored are negligible.

However, that is *not* true of a finite series. When performing hyperreal summations, the values and manipulations are similar to *finite* series, not necessarily similar to *convergent* series.

Non-Cauchy Products

An advantage of Cauchy products is that it defines a way of understanding the behavior of a series in terms of a non-trivial manipulation of the previous series. It is obvious that we could represent the multiplication of hyperreal series A and B as

$$A \cdot B = \left(\sum_{i=1}^{\omega} a_i \right) \cdot \left(\sum_{i=1}^{\omega} b_i \right) \tag{4}$$

but that gives little additional information.

Another way of considering the multiplication is to take each element of A and multiply it by each element of B. This can be expressed as

$$A \cdot B = \sum_{i=1}^{\omega} \left(\sum_{j=1}^{\omega} a_i \, b_j \right). \tag{5}$$

This, however, is not as useful as it could be. Since it basically goes through every element of B before considering even the second element of A, partial sums will not provide much information about the behavior of the product as a whole.

A more informative formula can be found by tracing paths as outlined in Figure 2, which we will call the rectangular method. This is in contrast with the Cauchy multiplication method, which is triangular, removing half of the terms from consideration. In a rectangular product, at each index of the outer sum, all of the indices in both A and B up to that index are considered.

Figure 3: $(1 + 1 + 1 + \ldots) \cdot (1 + -1 + 0 + 0 + 0 + \ldots)$

	1	1	1	1	1	1
1	1	1	1	1	1	1
-1	-1	-1	-1	-1	-1	-1
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

This method can be represented by the formula

$$A \cdot B = \sum_{i=1}^{\omega} \left(\left(\sum_{j=1}^{i} a_i \, b_j \right) + \left(\sum_{k=1}^{i-1} a_k \, b_i \right) \right). \tag{6}$$

Because this formula incorporates *every* term of the series A and B, then the result will be equal to the naive multiplication in (4). Additionally, to the extent that the beginning of the series are representative of the series as a whole, this will allow the behavior of partial sums of the series to be used as approximations of the behavior of the series as a whole in certain circumstances. It also has the same number of elements as both the multiplicand series, so it can easily be used in operations with other series having the same number of infinite terms, which can be helpful in the context of the BGN series summation method.

An Example

The multiplication that first sparked this consideration is the product of the series $1 + 1 + 1 + \ldots$ multiplied by the series $1 + -1 + 0 + 0 + 0 + \ldots$ (with zeroes continuing). When put in the form specified by (1), the former sequence is equivalent to ω. The latter sequence is obviously 0.

Although $\omega \cdot 0 = 0$, the Cauchy product of these two series actually turns out to be 1. The reason for this can be seen in Figure 3. As can be seen, everything is included in this product except one term: -1. Therefore, since the entire product is 0, the product without the final -1 term will be 1.

This Cauchy product has this shape no matter how many terms (even an infinite number of terms), and therefore will always have the result of 1. However, in both the finite case and the infinite case, the *actual* product of the two series is zero.

Additional Considerations

The considerations given here should demonstrate why Cauchy products can be useful for convergent series while not being useful at all for multiplying two divergent series. Additionally, it should be evident that, even if the formula for the Cauchy product of a divergent series converges, it does not mean that the Cauchy product represents in any significant way the true value of the product of the two series. It simply means that, when half of the terms are not considered, the result is convergent. That does not yield a significant amount of confidence in such a result.

Conclusions and Clarifications

In (Bartlett, Gaastra, and Nemati, 2020), Section 11.2 hedged on the consideration of series rearrangement, suggesting that we could not rule out that rearranging series might cause the series to differ by an infinitesimal. However, the problem was that we were considering the results of Cauchy Products, which, here, we have shown are not representative of true products of divergent series.

As already noted, divergent series can, using hyperreals, be evaluated in the same way as if they were finite series. However, even though they can be treated similar to finite series, that is not the same as saying that they can be treated as convergent series.

Bartlett, J, L Gaastra, and D Nemati (2020). "Hyperreal Numbers for Infinite Divergent Series". In: *Communications of the Blyth Institute* 2.1, pp. 7–15.

Following the Science

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More and more frequently we are hearing the words "follow the science" spoken by those who believe that they are right and are frustrated by those who disagree with them. It sounds good: we should avoid illogical or emotional responses and just focus on what is proven to be correct. Of course, no one wants to be wrong, and so we tend to just go along with the opinion of experts in the field. We don't want to waste time in rehashing old arguments that have been proven to be incorrect. Let's just move on.

But what if this phrase is used to stifle questions that don't fit a socially or politically accepted idea, especially if the questions are targeted at some weakly supported foundational concepts? If you don't want to permit debate on a topic that you might not decisively win, you might just tend to bluster your way out through intimidation. Stating "Follow the Science" implies that the opposing view is unscientific, and so should be immediately discounted and dropped from consideration. How could anyone possibly support such a weak idea?

Are there any specific examples in which the "Follow the Science" slogan has been used to support an increasingly weak argument and deflect a question that can't be clearly countered? We think that the complexity of cells is one such area. It is framed in the struggles between the two camps: Evolution versus Intelligent Design.

Take, for example, the article "The Flaws in Intelligent Design" (Collinsworth, 2006). In explaining what is wrong with Intelligent Design, the author first characterizes ID proponents as those who want to "challenge evolution and promote fundamentalist-friendly 'science' in public education and public discourse" implying that ID proponents are not really scientists. It then goes on to state:

> "Regarding ID's specific claims, scientists object that the concept of "irreducible complexity" relies upon a mischaracterization of biological mutation as a relatively linear process involving only the addition of more and more "parts," rather than a dynamic process that can also reshape, rearrange, or fundamentally alter existing elements and features. Systems that must be fully formed to serve their current function could have developed from earlier forms that served a different function, or could be significantly reorganized versions of an earlier form that served the same function.
>
> Mathematicians are similarly critical of ID's mathematical arguments against evolution, which rely on an excess of subjective calculations, manipulation of numbers, and misrepresentations of evolutionary models."

The narrative in the first paragraph about dynamic reshaping and rearranging of existing elements would be more compelling if it included references to data, observations, or at least models of such modified biological forms, rather than just a shallow statement that it "could have developed". The best long-term data on real-life mutations is the 50,000 generation study of E. coli by the Richard Lenski lab at Michigan State University (Lenski, 2021). The data shows only a "relatively linear" and minor history of changes, rather than dynamic rearranging and reshaping. If millions of generations are needed to "fundamentally alter existing elements" by evolution, then some mathematical modeling should be included.

Within any community of researchers, certainly some work is bound to be questionable, but are all Intelligent Design proponents guilty of "subjective calculations" and "manipulation of numbers"? And are all evolution proponents "unbiased" scientists? We would encourage more specific criticisms of the mathematical models and underlying assumptions that have been proposed.

The website, *Rational Wiki* attempts to show the power of evolution by including Richard Dawkins' illustration of using a random letter generator to arrive at the phrase "METHINKS IT IS LIKE A WEASEL" from a random string of 28 letters and spaces after only 43 iterations (Rational Wiki, 2018). The problem with this illustration is that Dawkins programmed in the final outcome to decide which letters to keep for the next iteration. A truly random (undirected) experiment would not "know" its goal until it reached it. It would generate string after random string and compare it against the target phrase. Since there are about 10^40 possible combinations, even running the generator at once per second gives only an infinitesimal chance of arriving at the target in any reasonable time.

Even if you widen the target to any meaningful 28 character phrase, you still are swamped by wrong results. You might compare this to the chances of making some type of organelle out of pre-existing amino acids. Making the generous assumption that there might be 1 billion meaningful phrases, we would still have a hard time finding them among the other trillions of trillions that are meaningless gibberish. You can make a case that Dawkins' example is a one of "subjective calculations" and "manipulation of numbers". Ironically, Dawkin's example is actually a great example of irreducible complexity; all the letters need to be right at once to obtain the "functional" phrase. We need better illustrations of the power of Evolution.

Of course, the complexity of biology is such that you need many more than 28 characters of information (or of amino acids) to arrive at a functional unit (perhaps a protein), and the possible combinations grow exponentially. The numbers grow to where even the powers of trillions of trillions of organisms mutating over billions of years still fall short of what is necessary to produce the "current function" from an "earlier form", even by rearranging existing elements. We must remember that the organism and each sub-system must be marginally functional at each step in the process. It cannot continue to exist while waiting for the other needed components to be borrowed from other organisms. And there is no reason for components to be retained for future generations unless they perform some beneficial function in that generation.

We offer a specific challenge: to develop counter arguments to the assumptions and calculations in a paper describing the hurdle to adding a new feature to an existing organism. Several years ago, we calculated what it would take for a very simple, single-celled organism, *Chlamydononas reinhardtii*, to develop the ability to detect light. This organism is a motile, single-celled green alga. It has a chloroplast to make its own food (glucose), an eyespot to detect light, and flagella to swim to the light. We assumed that it was living in an appropriate environment and had assembled the structure of a simple eyespot, but only needed a few more proteins to begin to function. Obviously, a functioning eyespot would give it a great survival advantage. We assumed that most of the 200 or so proteins found in a modern day functioning eyespot were present, as well as the signaling and motility systems, and we would just need 10 more small proteins to make the eyespot functional. We calculated that there were over 10^600 ways of assembling amino acids into potentially functional proteins (E. A. Siewert and T. A. Siewert, 2017). Even if every particle in the universe (about 10^80) were an amino acid and they were interacting at 1000 Hz, they have only a negligible chance of forming the necessary proteins within the life of the universe, much less getting the proteins into the correct location in the eyespot. We would welcome alternative models/proposals to improve or criticize this model.

"Follow the Science" is good advice, but the hurdles to Evolution at the cellular level are substantial. We should carefully weigh all the data (both for and against) before we accept Evolution as a valid mechanism for the formation of complex life.

Collinsworth, Bryan (2006). "The Flaws in Intelligent Design". In: *Center for American Progress*. URL: https://www.americanprogress.org/issues/religion/news/2006/04/10/1934/the-flaws-in-intelligent-design/.

Lenski, R E (2021). *The E. coli long-term experimental evolution project site*. URL: http://myxo.css.msu.edu/ecoli.

Rational Wiki (2018). *Dawkins' Weasel*. URL: https://rationalwiki.org/wiki/Dawkins_weasel.

Siewert, E A and T A Siewert (2017). "The Need for a Quantifiable Model of Evolution". In: *Journal of Bio Innovation* 6.5, pp. 685–694.

News

Engineering and Evolution

Earlier this year, the *Engineering Research Group* (headed up by Steve Laufmann) held a "Conference on Engineering and Living Systems." The so-called *CELS* conference brought together biologists and engineers of every stripe to see how the disciplines might work together.

Of interest, this group is somewhat of an outgrowth of conferences held by The Blyth Institute over the years. In 2012, The Blyth Institute held an interdisciplinary conference at Oral Roberts University which brought together engineers with academics of many other disciplines to discuss how ideas, attitudes, techniques, and ways of thinking from engineering might usefully benefit other areas of inquiry, and vice-versa. Most of the talks from this conference are still available online at `https://www.youtube.com/playlist?list=PL392C752E633E1B6A`. This conference papers from this conference were collected and resulted in the book *Engineering and the Ultimate: An Interdisciplinary Investigation of Order and Design in Nature and Craft* (J. L. Bartlett, Halsmer, and Hall, 2014).

A few years later, The Blyth Institute did a followup online conference on methodological issues that stemmed from an engineering view of the world, titled the *Alternatives to Methodological Naturalism* (*AM-Nat*) conference. Most of the talks from this conference, too, are still available online, and can be found at `https://www.youtube.com/playlist?list=PL8ftIIJ7ANZhTWjlGMRClyXKDsI6VTk7R`. The papers from this conference were collected into the volume *Naturalism and Its Alternatives in Scientific Methodologies* (J. L. Bartlett and Holloway, 2017).

Although the leadership of the *Engineering Research Group* were not part of these conferences, much of the early interest around these subjects grew out of these conferences, and many of the early members of the *Engineering Research Group* came out of these two conferences. Indeed, several of the talks given at the *CELS* conference were outgrowths of research projects which were presented at the two early conferences. While The Blyth Institute did not present at the *CELS* conference, we are pleased to have played a part in laying the groundwork for these kinds of inquiries, conferences, and conversations.

Evotypes and the Engineering of Evolution

From a different angle, other research groups are considering the engineering applications of evolution. The *Biocompute Lab* from the University of Bristol is working on an "engineering theory of evolution." Castle, Grierson, and Gorochowski (n.d.) proposes that, because evolution is so different from anything humans normally design, we need a theory of engineering which encapsulates the way evolution works so that evolving systems can be integrated into engineering ones.

They propose the "evotype," which is essentially treating evolutionary capability as a phenotype. They consider the "design type" of a system to be a single system that exists as engineered, and the "evotype" captures the evolutionary dynamics of the system.

While Castle, Grierson, and Gorochowski (n.d.) was primarily concerned with using biological principles to build non-biological systems, similar ideas have been presented in the context of biological systems themselves. Caporale (2006) dealt with what she called the "implicit genome"—the set of all the likely future evolvable pathways, which is roughly equivalent to the "evotype." J. Bartlett, Gaastra, and Nemati (2020) pointed out that this sort of potentiality can actually be measured using active information, and proposed how this information could be used in engineering contexts.

While the "evotype" is not a brand new concept, the creation of a standardized term for this notion can help to better orient future inquiries.

The Passing of a Generation

The last several months has heralded the deaths of many prominent scientists and biologists, including:

- **Richard Lewontin** (1929–2021): Lewontin was a geneticist who was much more in tune with his philosophical side than many of his colleagues. He not only pioneered the application of molecular biology to the study of evolutionary dynamics, but also concerned himself with the philosophy of science and its intersection with the public dialogue. His most widely-read work was a popular review of Carl Sagan's *The Demon-Haunted World*, titled "Billions and Billions of Demons" (Lewontin, 1997). However, his most lasting contribution is likely his critique of the overly simplistic relationship between adaptation and natural selection often suggested by many biologists (Lewontin, 1978). An obituary can be found in Brown and Rose (2021).

- **Steven Weinberg** (1933–2021): Weinberg is often considered the greatest theoretical physicist of all time, earning the Nobel Prize in 1979. He unified electromagnetism and the weak force in physics into the electroweak force (Weinberg, 1967). An obituary can be found in Giudice (2021).

- **Thomas Cavalier-Smith** (1942–2021): Cavalier-Smith was a highly regarded taxonomist who pushed forward Lynn Margulis' endosymbiotic theory. He argued for a "mitochondrial-late" model, in which the eukaryotes develop without mitochondria, eventually engulfing relevant bacteria through phagocytosis (Cavalier-Smith, 2006; Archibald, 2015; Gray, 2017). An obituary can be found in Richards (2021).

- **Gilbert Levin** (1924–2021): Levin was the principal investigator for the *Viking* Mission Labeled Release experiment, which, though controversial, he believed showed evidence that there was microbial life on Mars (Levin, 2016). He continued to play a prominent role in the field of astrobiology throughout his life.

While *CBI* does not normally post obituaries, the passing of so many seminal scientists in such a short period seemed noteworthy.

Evolutionary Primality of the Bacterial Flagellum

One issue that has been contentious over the past few decades is whether or not the flagellar motor evolved from the Type III secretory system. This has sparked debate over the years, but it seems that this question is coming to a close in favor of the primality of the flagellum. This has been confirmed by multiple studies, most recently Deng et al. (2017), Denise, Abby, and Rocha (2020), and Coleman et al. (2021). Even former vocal critics of this idea (Pallen and Matzke, 2006) are now convinced (Matzke et al., 2021).

Writing Using (only) Your Imagination

A recent paper describes an amazing new technology which allows paralyzed people to write using their thoughts alone (Willett et al., n.d.). Essentially, implanted electrodes allow a person to simulate the motor output for handwriting. This "handwriting" is then used as input to a neural network, which decodes the handwriting into typed letters. The research group was able to achieve 90 characters per minute, which is close to the speed at which most people text (115 characters per minute).

Correcting Misconceptions About Abiogenesis

Synthetic chemist James Tour recently put together a video series correcting common mistakes about abiogenesis (Tour, 2021). This video series covers widespread confusion about abiogenesis from ordinary individuals, the media, and even professionals. Tour presents many issues that are not adequately publicized about abiogenesis research, focusing especially on two issues.

The first is the prevalence of using chemicals that are only found *within* biology to perform abiogenesis chemical tasks. From a synthetic chemistry perspective, since these reactions would have to occur outside the context of biology, using biologically-derived chemicals, while it may allow the reaction to work, prevents studies from actually discovering much about abiogenesis.

The second is the problem of using a "relay synthesis." Oftentimes in abiogenesis studies, reactions will result in a mixture of a variety of compounds. This variety of compounds will then prevent future reactions from going forward. Therefore, rather than using the products of the previous reaction to go into the next reaction, the desired isolated end-product is purchased pure and then diluted to the proper concentrations prior to the next reaction.

These two features are surprisingly common in abiogenesis research, and call into question much of the chemical claims for abiogenesis research about what could have been synthesized abiotically on the early earth.

The Science of Consensus-Forming

The AMISTAD lab from Harvey Mudd College in California shows that a "consensus" is only valid for believing a proof if the consensus was formed by people whose thinking was independent (Allen, Lay, and Montañez, 2020). That is, if multiple experts came to the same conclusion independently, then the consensus has a much higher probability of being true. However, if those same experts were coerced, or even influenced by the prior idea of a consensus, then the epistemic value of having a consensus shrinks quickly.

Novel Bacterial Evolved on the Space Station

Research has started to be done on the effect of space travel to evolution. Recently, four novel strains of *Methylobacteriaceae* have been found on the International Space Station (Bijlani, Singh, et al., 2021). These are being named after Ajmal Khan, a renowned Indian scientist and biodiversity specialist. In another article, the authors have discussed the present and future of space microbiology (Bijlani, Stephens, et al., n.d.).

Evolution and Teleonomy

A recent conference was held by the Linnaean Society of London called *Evolution 'On Purpose': Teleonomy in Living Systems*. This conference discussed the roles of intentionality in evolution, and how this affects evolutionary theory as a whole. Various aspects of teleonomy and teleology were discussed by a variety of renowned scholars, including Peter Corning, Richard Vane-Wright, Stuart Kauffman, Eugene Koonin, Eva Jablonka, and several others. Videos of the conference are available on the Linnaean Society YouTube channel on the playlist for the conference at `https://www.youtube.com/playlist?list=PLgVH1uF5LKVUjNAwFiZKeTDOZmFVaS4yd`. The Blyth Institue participated in the conference, giving a short analysis during the refereed commentary session and taking part the the discussion session.

Experimental Results

A new journal from Cambridge University Press was launched last year called the *Journal of Experimental Results*. The idea behind this journal is to record experiments that have less "story" to them. The aim of this journal is to support research groups doing replication experiments or who want to publish experimental results that don't necessarily have a surrounding theory. The journal will also publish negative or inconclusive results.

Typically, journals are biased towards results that are (a) positive, (b) novel, and (c) attached to an underlying theory. However, this does in fact bias the output of journals. The goal of the new journal is to combat this bias by providing an outlet for experimental studies that don't typically "fit in" in this way. The website for the journal can be found at `https://www.cambridge.org/core/journals/experimental-results`.

Human-Generated Machine Learning Models

Blyth Institute researcher Eric Holloway has done quite a bit of work with human-in-the-loop machine learning, which he terms "imagination sampling" where humans participate in building machine learning models (Holloway, 2017; Holloway, n.d.; Holloway and Marks II, 2016). Recently, another researcher has begun developing tools to facilitate imagination sampling with the "human learn" project (Warmerdam, 2020). This includes a tool that lets people draw groups around datasets, and the drawings get converted into machine learning models. We are excited that more people are recognizing the value of imagination sampling and its role in the machine learning ecosystem.

A demonstration of the tool can be found at `https://koaning.github.io/human-learn/#interactive-drawings`.

References

Allen, J, C Lay, and G D Montañez (2020). "A Castro Consensus: Understanding the Role of Dependence in Consensus Formation". In: *Proceedings of the 2020 Truth and Trust Online*, pp. 12–20. URL: https://www.cs.hmc.edu/~montanez/pdfs/allen-2020-castro-consensus.pdf.

Archibald, J M (2015). In: *Current Biology* 25, R911–R921. DOI: 10.1016/j.cub.2015.07.055.

Bartlett, J, L Gaastra, and D Nemati (2020). "Hyperreal Numbers for Infinite Divergent Series". In: *Communications of the Blyth Institute* 2.1, pp. 7–15.

Bartlett, J L, D Halsmer, and M R Hall (2014). *Engineering and the Ultimate: An Interdisciplinary Investigation of Order and Design in Nature and Craft*. Blyth Institute Press.

Bartlett, J L and E Holloway (2017). *Naturalism and Its Alternatives in Scientific Methodologies*. Blyth Institute Press.

Bijlani, S, N K Singh, et al. (2021). "*Methylobacterium ajmalii* sp. nov., Isolated From the International Space Station". In: *Frontiers in Microbiology* 12, pp. 1–14. DOI: 10.3389/fmicb.2021.639396.

Bijlani, S, E Stephens, et al. (n.d.). "Advances in space microbiology". In: *iScience* 24.5 (). DOI: 10.1016/j.isci.2021.102395.

Brown, A and S Rose (2021). "Richard Lewontin obituary". In: *The Guardian*. URL: https://www.theguardian.com/science/2021/jul/28/richard-lewontin-obituary.

Caporale, L H (2006). *The Implicit Genome*. Oxford University Press.

Castle, S D, C S Grierson, and T E Gorochowski (n.d.). "Towards an engineering theory of evolution". In: *Nature Communications* 12.3326 (). DOI: 10.1038/s41467-021-23573-3.

Cavalier-Smith, T (2006). "Origin of Mitochondria by Intracellular Enslavement of a Photosynthetic Purple Bacterium". In: *Proceedings of the Royal Society B* 273, pp. 1943–1952. DOI: 10.1098/rspb.2006.3531.

Coleman, G A et al. (2021). "A rooted phylogeny resolves early bacterial evolution". In: *Science* 372.6542. DOI: 10.1126/science.abe0511.

Deng, W et al. (2017). "Assembly, structure, function and regulation of type III secretion systems". In: *Nature Reviews Microbiology* 15, pp. 323–337.

Denise, R, S S Abby, and E P C Rocha (2020). "The Evolution of Protein Secretion Systems by Co-option and Tinkering of Cellular Machineries". In: *Trends in Microbiology* 28.5, pp. 372–386. DOI: 10.1016/j.tim.2020.01.005.

Giudice, G (2021). "Steven Weinberg 1933–2021". In: *CERN Courier*. URL: https://cerncourier.com/a/steven-weinberg-1933-2021/.

Gray, M W (2017). "Lynn Margulis and the endosymbiont hypothesis: 50 years later". In: *Molecular Biology of the Cell* 28.10, pp. 1285–1287. DOI: 10.1091/mbc.E16-07-0509.

Holloway, E (2017). "Imagination Sampling". In: *Naturalism and Its Alternatives in Scientific Methodologies*. Ed. by J L Bartlett and E Holloway. Blyth Institute Press, pp. 179–198.

Holloway, E (n.d.). "Improving XGBoost with Imagination Sampling". In: *Communications of the Blyth Institute* 2.1 (), pp. 3–6. DOI: 10.33014/issn.2640-5652.2.1.holloway.1.

Holloway, E and R J Marks II (2016). "High Dimensional Human Guided Machine Learning". In: *arXiv* 1609.00904. URL: https://arxiv.org/abs/1609.00904.

Levin, G V (2016). "The Case for Extant Life on Mars and its Possible Detection by the Viking Labeled Release Experiment". In: *Astrobiology* 16.10, pp. 798–810. DOI: 10.1089/ast.2015.1464.

Lewontin, R (1978). In: *Scientific American* 239.3, pp. 212–218. DOI: 10.1038/scientificamerican0978-212.

Lewontin, R (1997). "Billions and Billions of Demons". In: *New York Review of Books*. URL: https://www.nybooks.com/articles/1997/01/09/billions-and-billions-of-demons/.

Matzke, N J et al. (2021). "Flagellar export apparatus and ATP synthetase: Homology evidenced by synteny predating the Last Universal Common Ancestor". In: *BioEssays* 43.7. DOI: 10.1002/bies.202100004.

Pallen, M J and N J Matzke (2006). "From The *Origin of Species* to the origin of bacterial flagella". In: *Nature Reviews Microbiology* 4.10, pp. 784–790. DOI: 10.1038/nrmicro1493.

Richards, T (2021). "Thomas Cavalier-Smith (1942–2021)". In: *Nature* 593, p. 190. DOI: 10.1038/d41586-021-01250-1.

Tour, J (2021). *Addressing Abiogenesis and Common Misconceptions*. URL: https://www.youtube.com/playlist?list=PLILWudw_84t2THBvJZFyuLA0qvxwrIBDr.

Warmerdam, V D (2020). *Human Learn: Machine Learning models should play by the rules, literally*. URL: https://github.com/koaning/human-learn.

Weinberg, S (1967). "A Model of Leptons". In: *Physical Review Letters* 19.21, pp. 1264–1266. DOI: 10.1103/PhysRevLett.19.1264.

Willett, F R et al. (n.d.). "High-performance brain-to-text communication via handwriting". In: *Nature* 593 (), pp. 249–254. DOI: 10.1038/s41586-021-03506-2.