

THE ORIGIN OF LIFE:

A Much Deeper Mystery Than Dark Energy

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General Characteristics of the Molecular Biology of Terrestrial Life

- Extraordinarily complex & inter-connected chemical processes, vastly richer and more intricate than any other known chemical systems
- Basic biochemistry shared by all known terrestrial organisms plus many of its details
- Carbon based and water dependent
- Hierarchically structured (using much simpler subcomponents), polymerized macromolecules
- Few (4) general classes of compounds but many individual ones with highly specialized and specific biological functions

Origin of Life

- Requires no exotic conditions or constituents
- Appears to have happened only once, but quite quickly, on Earth
- Intricate complexity -> origin problem
 - Vast complexity jump wrt other abiotic chemistry
 - No obvious route for gradual development nor surviving remnants/fossils of it
 - Little or no first-principle theoretical insights
- Evolutionary adaptation and development once natural selection started

Natural Selection Requirements

- Flexible information storage
- Functional expression of stored information
- Replication of stored information
 - Copies must be good but not perfect (“errors” crucial)
 - Replication must be robust despite “errors”
 - “Errors” must be stochastic
- Self-sustaining/powerful

Additional Downstream “Jumps”

- RNA World to DNA World
- Nucleic Acids to Proteins
- Prokaryotes to Eukaryotes
- Unicellular to multicellular organisms
- Nervous systems
- ...

Unattractive But Plausible Scenario: *Improbable Life*

Life on Earth arose via an extraordinarily improbable event or series of events, in other words by an extreme statistical anomaly.

Let us take this to mean that $P_{abiogenesis} \lll 1$ per Hubble volume per Hubble time, *i.e.*, that it is extremely unlikely that there is any extraterrestrial life in the observable universe.

It also implies that we are unlikely to ever understand the OoL on the Earth.

An Unappealing Theory

- Why it is unappealing (to most)
- Irrational consequences of its unappealing character
- Usual response = there are other possibilities
- Our goal today = a fair examination
- Fair = evidence that supports it, what it explains, what disfavors it & its relative merit compared to known alternatives

SUPPORTING/SUGGESTIVE EVIDENCE I:

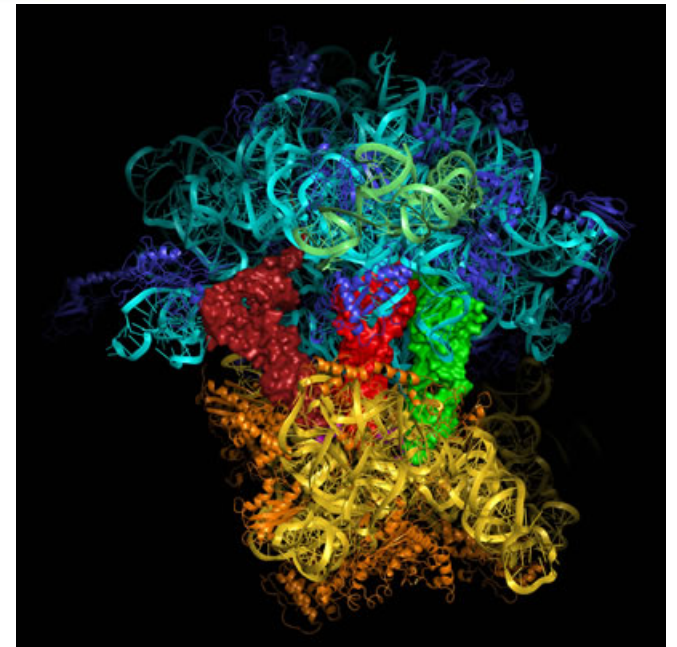
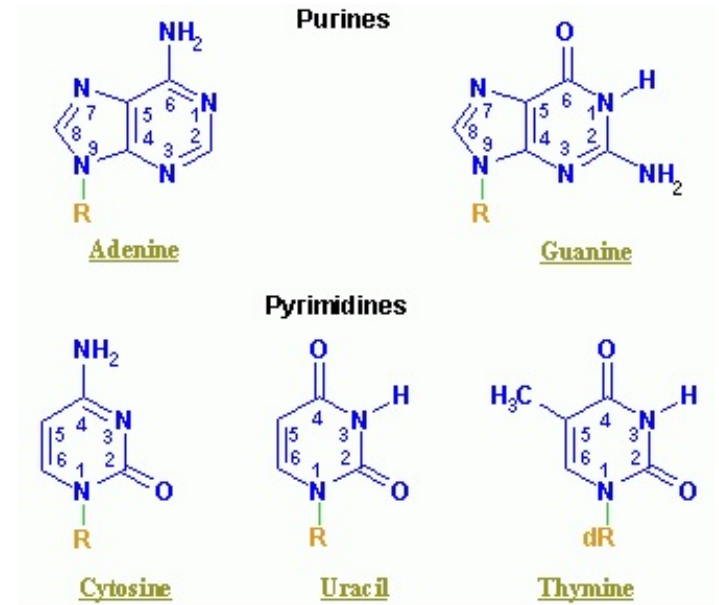
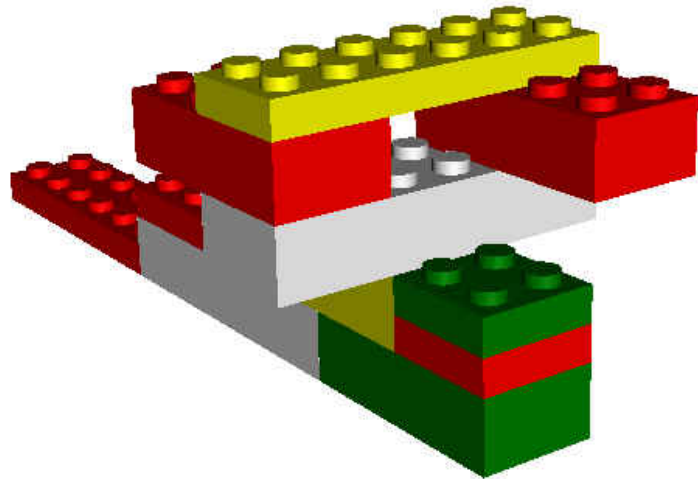
Combinatoric improbability of biopolymers

- “Letters” of bio-alphabet produced naturally in fair concentrations
- Enormous flexibility – “Lego life”
- Vast "space" of possibilities -> any specific biopolymer vanishingly improbable
- Monkeys and typewriters writing sonnets and novels etc
- Minimal complexity (for natural selection to begin) appears to be substantial

- The basic molecular chemistry of all terrestrial life is essentially identical and very complex.
- Two classes of macro-molecules, proteins and nucleic acids, play central roles currently, but it is ***imagined*** that RNA alone might have sufficed for an earlier form of life (the “RNA world”).
- The building blocks of both proteins (amino acids) and nucleic acids (nucleotides) are a set of small molecules which form bonds in an arbitrary order to create the long polymers which are these macro-molecules.

- Both amino acids and nucleotides are produced in reasonable abundance by physical (abiotic) chemical reactions that can easily occur in nature.
- However, the polymers in question are *huge*, typically 100s to 100s of millions of “building blocks” long, with even minimally functional ones requiring ~ 100 nucleotides or amino acids
- Smallest genomes = 1821 & 112,091 base pairs (human genome about 3×10^9 base pairs)
- The probability of any specific one arising randomly is then *combinatorially small, easily $\approx 10^{-1000s}$ or much less.*
- A ribosome contains $\sim 4 \times 10^7$ base pairs + ~ 30 -50 proteins (nucleic acid info \rightarrow proteins)

Abiogenesis: Stochastic Lego Construction?



SUPPORTING/SUGGESTIVE EVIDENCE II: Benner Objections

- The Devolution Problem: tar
- The Water Problem: corrosion
- The Low Concentration Problem: isolation
- The Two Birds with One Stone Problem: both self-catalysis and controlled replication, but these are quite distinct in known RNA
- The Self-Destruction Problem: most probable RNA-enzymes destroy/cut RNA strands

SUPPORTING/SUGGESTIVE EVIDENCE III:

"Rare Earth" Type Arguments

- In the “Galactic habitable zone”
- A suitable central star and planetary system
- In the circumstellar habitable zone
- A suitable sized terrestrial planet
- A gas giant “guardian”, giant impact inhibitor
- A large satellite
- A magnetosphere
- Plate tectonics
- A favorable chemistry of the lithosphere
- Atmosphere and oceans
- ...

NATURALLY EXPLAINED I: Biological/Physical

- Huge "missing link" of intermediate complexity life and proto-life, no abiogenesis "fossils"
- Failure to synthesize life in the lab to date
- No high profile life elsewhere in the Solar System

NATURALLY EXPLAINED II:

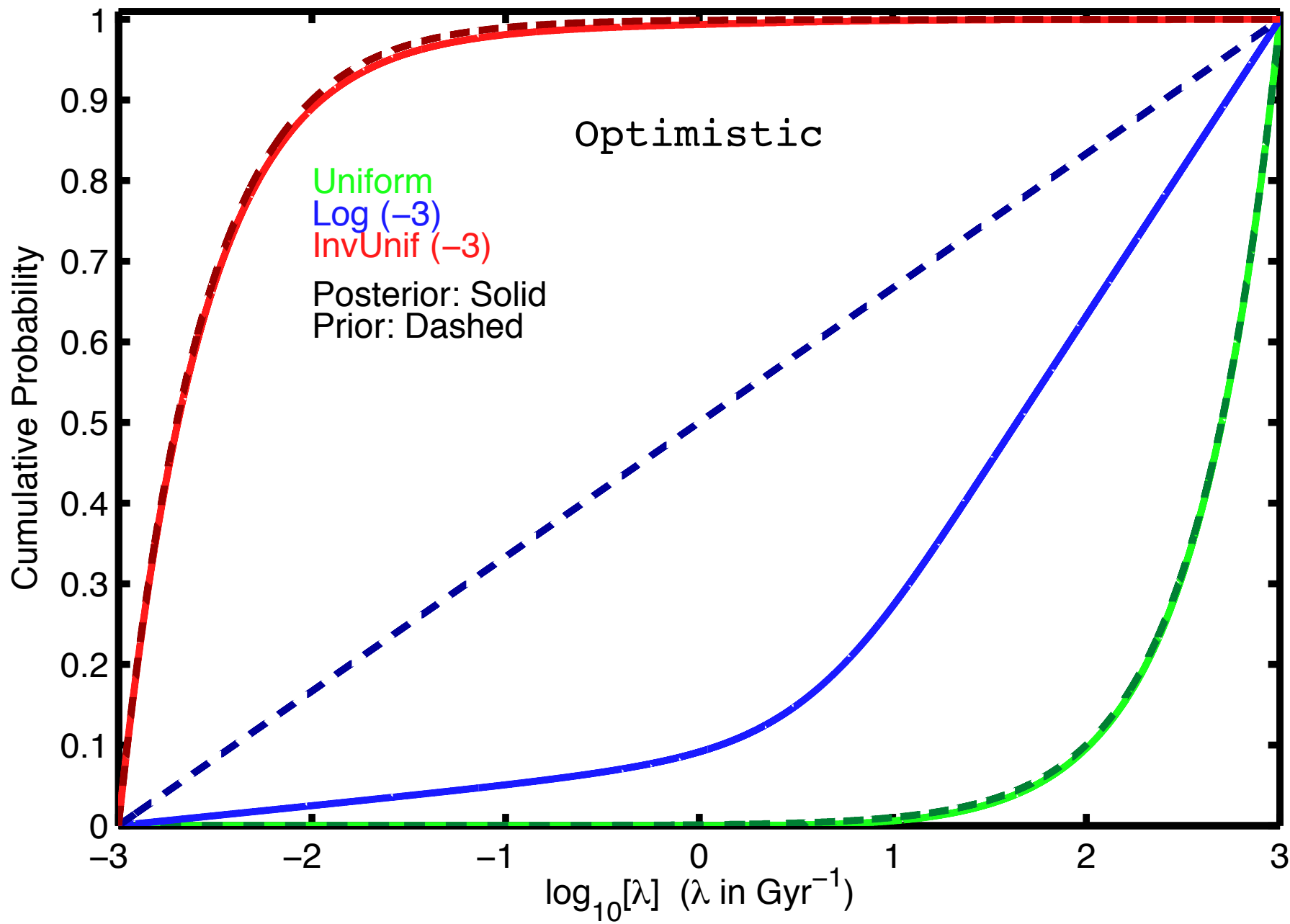
Astronomical

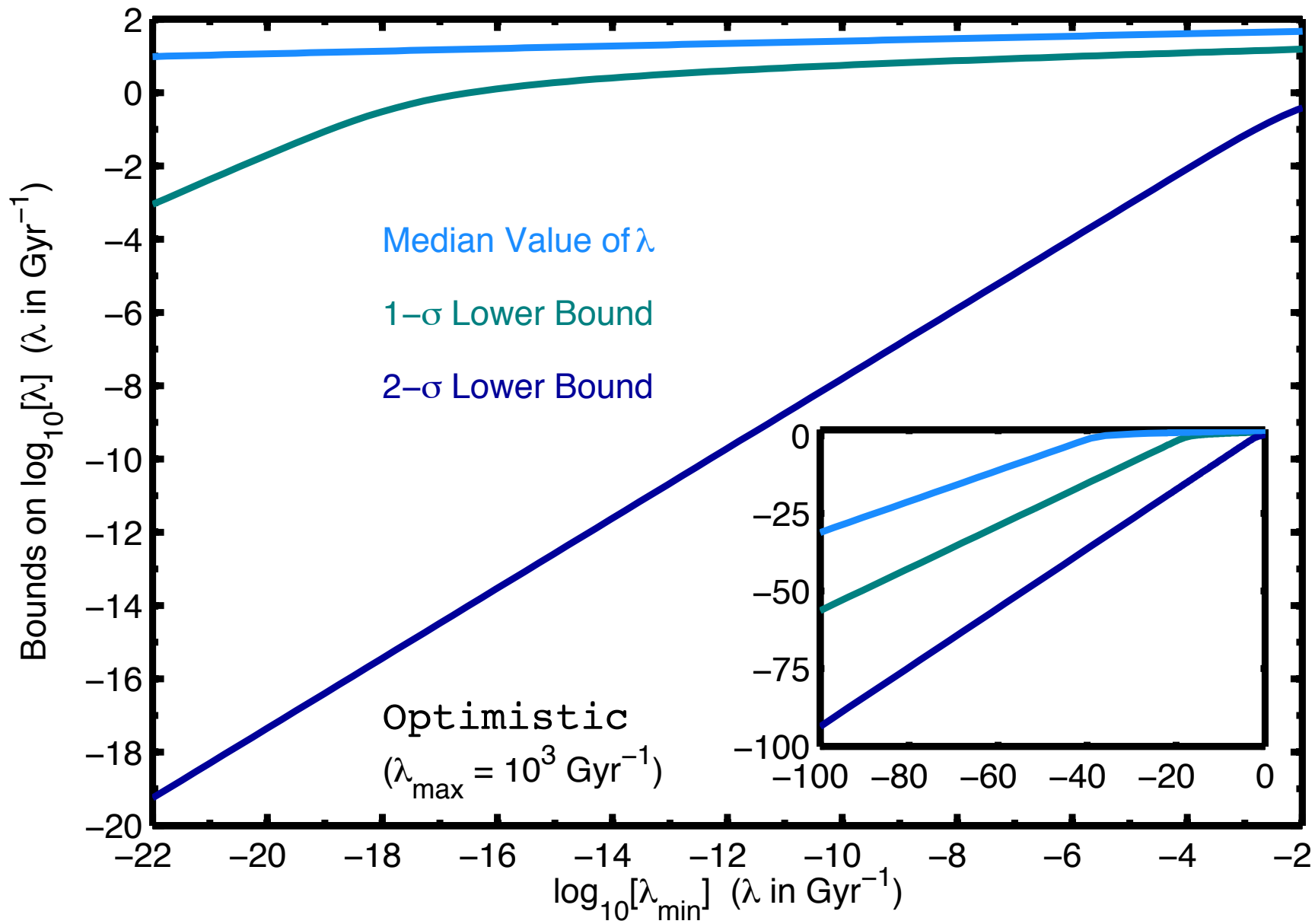
- Fermi-Hart Paradox: no local aliens -> no Galactic colonization
- Universe appears to be a wilderness -> no hyper-advanced distant aliens
- Failure of SETI to date -> no chatty aliens

No aliens at all is a parsimonious explanation.

CHALLENGES TO THE IMPROBABLE LIFE SCENARIO

- Life arose on Earth, but just a selection effect in an infinite universe or multiverse
- Life appeared on Earth very quickly, but this datum provides no meaningful lower limit on the abiogenesis probability (Spiegel & ELT)
- Progress in understanding self-organizing systems and the emergence of complexity: Is decreasing min entropy/complexity analogous to thermodynamics...an inherent physical “direction” of change? Well, maybe...





MERIT RELATIVE TO OTHER AVAILABLE OoL THEORIES

- As good as any other OoL scenario/theory and better than many on purely empirical grounds
- Any possible alternative seems to entail something akin to “intelligent design”, the emergence of life somehow inherent in the basic laws of nature, a universe “made for” life
- Eminently falsifiable

“The first principle is that you must not fool yourself and you are the easiest person to fool.”
— [Richard P. Feynman](#) on science

CONCLUSION

The improbable life scenario should be regarded as a realistic possibility by astrobiologists and OoL researchers.

“I think it's much more interesting to live not knowing than to have answers which might be wrong.” — [Richard P. Feynman](#)

Dark Energy vs OoL Mysteries

- Much First Principles Physics vs Little/No First Principles Biology
- Well Defined DE Experiments/Measurements & Theoretical Issues vs No Clear/Consensus Path Forward Of Any Sort
- A Single Hard Problem vs Multiple Ones
- Quantitative vs Qualitative Challenge
- Both Invite Anthropic Principle Explanations
 - OoL is a bigger/deeper mystery than DE