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Article

The Chemical Definition of the Essence of Life

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Abstract: Through macroscopic analysis, this study demonstrates that proteins and nucleic acids within living organisms form an “automatically perpetual self-synthesizing cycle”. All components within a lifeform serve to sustain this cyclic synthesis. Thus, the essence of life can be chemically defined as follows: “Life is an automatically perpetual self-synthesizing cycle composed of specific proteins and nucleic acids.” Life has existed on Earth for billions of years. While scientists have extensively mapped the biochemical components and metabolic processes within living systems, the fundamental essence of life remains elusive. Descriptions of life’s chemical composition and phenomena do not equate to understanding its essence. Current scientific definitions of life remain vague. Life is a persistent, repetitive phenomenon of synthesizing identical organic compounds, requiring continuous energy input. This process warrants a precise chemical definition. This paper employs macroscopic analytical reasoning to summarize overarching principles of biochemical reactions, aiming to elucidate the chemical essence of life. For clarity, simple single-celled prokaryotes (e.g., *Escherichia coli*) are selected as representative models.

Keywords: essence of life; dual synthesis reaction

1. Life’s Components Originate from the Environment

Every element within a living organism derives from the natural environment. Cellular proliferation through infinite division represents the transformation of environmental substances into biological components. Thus, intracellular reactions—whether single or multi-step—must exist to convert environmental substances into every constituent of life:

Natural environmental substances → “Component of life” (Reaction formula 1)

This reaction reveals critical biochemical insights: the entire organism acts both as a “product” of environmental transformation and a “catalyst” enabling such transformation. Natural environmental substances cannot spontaneously convert into biological components; instead, pre-existing intracellular components (enzymes and other substances), termed “Conditional Substances” (C1,C2,C3...Cx), mediate this process.

Natural environmental substances → Under the action of “Conditional Substances” (C1,C2,C3...Cx) → “Component of life” (Reaction formula 2)

Importantly, these catalytic components, termed “Conditional Substances” (C1,C2,C3...Cx), are themselves products of Reaction 2. Substituting these into Reaction 2 yields:

Natural environmental substances → ((C1,C2,C3...Cx)-mediated) → (C1,C2,C3...Cx) + Other products (Reaction formula 3)

Reaction 3 demonstrates that Conditional Substances catalyze their own regeneration, doubling their quantity with each cycle. This “automatically perpetual self-synthesizing cycle” underpins the persistent repetition of biochemical processes in life.

2. Identification of Conditional Substances

Conditional Substances are intracellular agents that drive environmental substances into biological components. Enzymes (proteins) are primary constituents, as no biochemical reaction

proceeds without them. Nucleic acids (DNA, RNA) are also critical: DNA replication requires templates, while RNA synthesis depends on DNA and RNA polymerase. Vitamins, lipids, carbohydrates, and small molecules, though essential for metabolism, do not directly catalyze environmental transformations and thus are excluded. Only proteins and nucleic acids qualify as Conditional Substances.

3. Evidence of the “Dual Synthesis Reaction” in Cells

Proteins and nucleic acids form a “Dual Synthesis Reaction” (DSR), wherein their synthesis is catalyzed by their own products. Table 1 summarizes the Conditional Substances required for DSR in cells (including eukaryotes):

Table 1. “Conditional Substances” Required for the Biosynthesis of Proteins and Nucleic Acids [1].

The “conditional substances” required for DNA replication.	The original double-stranded DNA molecule serves as a template, along with many protein factors such as helicase, single-stranded DNA binding protein, topoisomerase, primase, DNA polymerase, and DNA ligase.
The “conditional substances” required for the biosynthesis of mRNA, tRNA, and rRNA.	Using one strand of DNA as a template, RNA polymerase catalyzes the process. Additionally, the following are required: promoters (specific DNA sequences), transcription factors (proteins), terminators (specific DNA sequences), and splicing and modifying enzymes.
The “conditional substances” required for the biosynthesis of protein.	The original template DNA, template mRNA, tRNA which serves as the transporter for amino acids, rRNA which is the site for protein synthesis. Enzymes: aminoacyl-tRNA synthetase, transpeptidase, translocase. Several protein factors: initiation factor [IF], elongation factor [EF], release factor [RF]. Processing and modifying enzymes. There are more than 200 components involved in protein biosynthesis, all of which are nucleic acids and proteins [2].

- DNA replication: Template DNA, helicases, single-strand binding proteins, topoisomerases, primases, DNA polymerases, ligases.

- RNA synthesis: DNA template, RNA polymerases, promoters, transcription factors, terminators, spliceosomes.

- Protein synthesis: DNA/mRNA templates, tRNA, rRNA, aminoacyl-tRNA synthetases, peptidyl transferases, elongation factors.

All listed Conditional Substances are exclusively proteins or nucleic acids. Raw materials (amino acids, nucleotides) and energy sources (ATP, GTP) are environmental derivatives and excluded from Conditional Substances.

4. The Role of Proteins in DSR

Beyond Table 1, all cellular proteins directly or indirectly serve DSR. Enzymes involved in glycolysis, the citric acid cycle [3], or amino acid/nucleotide synthesis supply energy and raw materials [4]. Membrane-forming proteins (e.g., phospholipid synthases) maintain intracellular stability [5], indirectly supporting DSR. Structural proteins (e.g., cytoskeletal fibers) and motility proteins (e.g., flagellin) [6] enhance nutrient acquisition. Critically, every protein and nucleic acid is both a product and catalyst of DSR, perpetuating the cycle.

5. Chemical Definition of Life's Essence

At the molecular level, proteins and nucleic acids form an automatically perpetual cycle:

1. DNA encodes all proteins and RNAs required for DSR [7].
2. Protein synthesis executes DNA's genetic instructions, regenerating enzymes and nucleic acids.
3. Newly synthesized proteins and nucleic acids perpetuate DSR, doubling their population with each cycle.

This cycle sustains all cellular chemistry, driving perpetual synthesis of identical biomolecules—the hallmark of life. Thus, **“Life is an automatically perpetual self-synthesizing cycle composed of specific proteins and nucleic acids.”**

Implications

Understanding life's chemical essence is pivotal for resolving origins-of-life questions and enabling synthetic biology. Artificial life synthesis may be achievable by replicating Conditional Substances listed in Table 1, though such experiments carry significant risks.

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